ATTACHMENT 2 Heat transfer calculations used to develop Attachment 5 and Table A5-1 in the July 12, 2012, License Amendment Request

Component EPN	Noun Name	Design Analysis
1(2)E12-B001A/B	RHR Heat Exchanger	97-201, Rev. A02
0DG01A	0 DG Jacket Water Cooler	97-195, Rev. A01
1(2)DG01A	A DG Jacket Water Cooler	97-195, Rev. A01
1(2)E22-S001	B DG Jacket Water Cooler	97-197, Rev. A04
1(2)VY01A	NW ECCS (A RHR) Pump Cubicle Cooler	97-200, Rev. A05
1(2)VY02A	SW ECCS (HPCS) Pump Cubicle Cooler	97-200, Rev. A05
1(2)VY03A	SE ECCS (B/C RHR) Pump Cubicle Cooler	97-199, Rev. B03
1(2)VY04A	NE ECCS (LPCS/RCIC) Pump Cubicle Cooler	97-198, Rev. A03

Page 1



Design Analysis (Minor Revision) Last Page No. 6 Attachment B, B2 Analysis No.: 1 97-201 Revision: 2 A02 Title: 3 Thermal Model of ComEd/LSCS RHR Heat Exchangers 1(2)RH01A & B EC/ECR No.: 4 Revision: 5 000 388666 LaSalle Station(s): 7 01 & 02 Unit No.: 6 SR Safety/QA Class: * System Code(s): 10 E12, RH Yes 🗌 Is this Design Analysis Safeguards Information? " No 🖾 If yes, see SY-AA-101-106 No 🛛 Does this Design Analysis contain Unverified Assumptions? 12 Yes 🗌 If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: 19 N/A in its entirety. Description of Changes (list affected pages): 14 This revision evaluates a maximum cooling water inlet temperature of 107 °F for the RHR heat exchangers. The previous temperature that was evaluated was 104 °F. Affected pages are Pages 1-3, Attachment A, Pages A1-A2, and Attachment B, Pages B1-B2. Disposition of Changes: 15 See attached pages. The changes made are acceptable. Preparer: 16 Sean Tanton Print Name Alternate Calculations Method of Review: 17 Detailed Review X Testina 🗌 Reviewer: 18 Steve Chon Print Name Review Independent review X Peer review Notes: 19 (For External Analyses Only) N/A External Approver: 20 Print Name Sign Name Date Exelon Reviewer 21 N/A Exelon Approver: 22 DAN SCHMIT





Purpose:

The purpose of this revision is to determine the amount of heat that can be removed via the 1(2)E12-B001A/B heat exchangers for the containment cooling mode (CCM) and to verify that the heat exchangers can remove the design heat load of 41.6 MBTU/hr for the shutdown cooling (SDC) mode with a revised maximum cooling water temperature of 107 °F. The revised design heat load to be used for GL 89-13 surveillance testing will also be determined with this revision.

Assumptions:

There are no assumptions for this revision.

inputs:

- Cooling water temperature = 107 °F (Reference 2)
- Cooling water flow rate = 7400 gpm (Reference 1)
- RHR System water temperature during CCM = 212 °F (Reference 1)
- RHR System water temperature during SDC = 120 °F (Reference 1)
- RHR System flow rate through 1(2)E12-B001A/B = 7200 gpm (Reference 1)
- Fouling factor for 1(2)E12-B001A/B = 0.00185 hr·ft²·°F/BTU (Reference 1)
- 53 tubes plugged (5% tube plugging) (Reference 1)
- RHR Heat Exchanger K factor = 438 (Reference 2)

References:

- 1. Design analysis 97-201, Rev. A, up to and including Rev A01
- 2. EC 388666, Rev. 000
- 3. L-000711, Rev. 004D (See EC 388666)
- 4. EC 382267, Rev. 000
- 5. L-002857, Rev. 001 (See EC 388666)
- 6. L-003352, Rev. 000A (See EC 388666)

Identification of Computer Programs:

The computer program used in this analysis is Proto HX version 4.01. This program has been validated per DTSQA tracking number EX0000103.

Method of Analysis / Numeric Analysis:

As stated in Reference 2, to maintain peak suppression pool temperatures at or below their current analyzed values, the RHR heat exchanger K factor is required to be raised from 417 to 438. This number is used as an input for various analyses. The RHR Heat Exchanger K factor [Btu/sec.°F] is determined as follows:

$$K = \frac{Q}{(T_{SP} - T_{SW}) \times 3600}$$

Where:

Q = heat load (Btu/hr)

T_{SP} = Suppression Pool Temperature (°F)

T_{SW} = Cooling Water Temperature (°F)

3600 = Conversion from hours to seconds

Using this equation, the credited K factor can be used to determine the design heat load to be removed. Using a K factor of 438, a bounding suppression pool temperature of 212 °F, and a cooling water temperature of 107 °F, the design heat load becomes 165,564,000 Btu/hr. Note that Reference 5 performs a sensitivity study of the K factor based on various suppression pool temperatures. It demonstrates that 438 is the appropriate K factor even with varying suppression pool temperatures. Reference 6 shows a peak suppression pool temperature of 197 °F, which would equate to a design heat load lower than that which was calculated with 212 °F. Because 165,564,000 Btu/hr is bounding, it will be used as the acceptance criteria.



To determine the amount of heat that could be transferred with a cooling water temperature of 107 °F, the existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp" from 104 °F to 107 °F for containment cooling mode.



To achieve the required heat transfer rates a change in fouling factor from 0.00185 hr·ft²-°F/BTU to 0.00147 hr·ft²-°F/BTU was necessary. A review of trend data from previous RHR heat exchanger thermal performance evaluations was performed. The most recent thermal performance test data shows a worst case fouling factor of 0.000410 hr·ft²-°F/BTU (Ref. 4), which is well below the new fouling factor of 0.00147 hr·ft²-°F/BTU. The thermal performance testing prior to that shows small changes between each test. The heat exchangers are also cleaned regularly to maintain a very low actual fouling factor. The new fouling factor of 0.00147 hr·ft²-°F/BTU has been accepted by the GL 89-13 program manager.

Results / Conclusions:

The RHR Heat Exchangers can remove the revised design heat load of 165,564,000 Btu/hr with the following CCM conditions:

- 107 °F cooling water temperature
- 7400 gpm cooling water flow
- fouling factor of 0.00147 hr ft².°F/BTU
- 53 tubes plugged
- RHR process temperature of 212 °F (CCM)
- RHR process flow of 7200 gpm

The total heat removed at these conditions is 166,468,480 BTU/hr, which provides 0.5% thermal margin over the design heat load. The model benchmark was shown to conservatively underestimate the heat transfer of the cooler by 1.31% for CCM. Therefore, any positive margin shown in the model would be an underestimate of actual thermal performance, which would show more margin than what is calculated. The previous maximum fouling factor of 0.00185 hr·ft²-°F/BTU has been revised to 0.00147 hr·ft²-°F/BTU. This case is shown in Attachment A.



The RHR Heat Exchangers can remove the design heat load of 41.6 MBTU/hr with the following SDC conditions:

- 107 °F cooling water temperature
- 7400 gpm cooling water flow
- fouling factor of 0.00147 hr·ft²-°F/BTU
- 53 tubes plugged
- RHR process temperature of 121 °F (SDC) (see below)
- RHR process flow of 7200 gpm

The total heat removed at the above listed conditions is 21,770,576 BTU/hr per heat exchanger, which equates to a total of 43,541,152 BTU/hr for two heat exchangers. The operation of 2 heat exchangers for SDC mode is acceptable as it is a non-safety related function of RHR. Operation of two heat exchangers provides 4.7% thermal margin over the design heat load. The model benchmark was shown to conservatively underestimate the heat transfer of the cooler by 0.31% for the SDC mode. Therefore, any positive margin shown in the model would be an underestimate of actual thermal performance, which would show more margin than what is calculated.

Note that the previous process temperature used for the SDC case was 120 °F. Because SDC mode is non-safety related, the basis for the number is outage productivity. This temperature is used to maintain comfortable conditions during refueling outages. Additionally, the change to 121 °F is a change of 0.83% and is considered to be essentially the same. The RHR pumps and seals are rated for a much higher temperature than this (250 °F, Refs. 2 & 3). Because this is considered to be essentially the same, 120 °F should be used for future evaluations of the RHR heat exchangers for the SDC mode. Just as was done for the CCM mode, the previous maximum fouling factor of 0.00185 hr·ft²-°F/BTU has been revised to 0.00147 hr·ft²-°F/BTU. This case is shown in Attachment B

The acceptance criteria to be used in GL 89-13 thermal performance testing is a fouling factor of 0.00147 hr·ft².°F/BTU and a total heat removal of 165,564,000 BTU/hr for CCM. The heat removal of 41.6 MBTU/hr for SDC remains the same.



Attachments:

- A. CCM Data Report for 1(2)E12-B001A/B (2 pgs)
- B. SDC Data Report for 1(2)E12-B001A/B (2 pgs)

PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-1002) Commonwealth Edison

Data Report for E12-B001 - LSCS - RHR Hx.

CCM - tube side = 107 °F, 7400 gpm, shell side = 212 °F, 7200 gpm, 53 tubes plugged, FF = 0.00147

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Mass Fluid Quantity, Tota	l lbm/hr	0.00	0.00
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F	108.80	101.25
Fouling Factor	hr·ft².ºF/BTU	0.00250	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Q (BTU/hr)			41,600,000
Design U (BTU/hr·ft².ºF)			215.00
Outside h Factor (Hoff)			0.563555000
Fixed U (BTU/hr·ft ² ·°F)			0
Fixed Area (ft²)	•		0.00
Performance Factor (% Re	eduction)		0.00
Heat Exchanger Type			TEMA - E
Total Effective Area per U	Jnit (ft²)		11,500.00
Area Factor	` ,		0.996344561
Area Ratio			0.00000
Number of Shells Per Uni	t		1
Shell Minimum Area			4.88000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes			1,010
Tube Length (ft)			55.30
Tube Inside Diameter (in)			0.652
Tube Outside Diameter (i	n)		0.750
Tube Wall K (BTU/hr·ft·°	F)		9.40
Lbc, Central Baffle Spacin	ng (in)		0.000
Lbi, Inlet Baffle Spacing	—		0.000
Lbo, Outlet Baffle Spacin	• •		0.000
Dotl, Tube Circle Diamet			0.000
Bh, Baffle Cut Height (in)			0.000
Ds, Shell Inside Diamter (0.000
Lsb, Diametral difference	• •	d Shell (in)	0.000
Ltb, Diametral difference		• •	0.000
Nss, Number Sealing Stri		Danie (m)	0.000



Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - tube side = 107 °F, 7400 gpm, shell side = 212 °F, 7200 gpm, 53 tubes plugged, FF = 0.00147



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Data		
Data Date Shell Flow (gpm) Shell Temp In (°F)	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F)	7,344.00 6,905.00 107.00	
Shell Temp Out (°F) Tube Flow (gpm) Tube Temp In (°F)	Shell Inlet Temp (°F)	212.00	
Tube Temp Out (°F)	Input Fouling Factor	0.001470	

Fouling Calculation Results

Shell Mass Flow (lbm/hr)

Tube Mass Flow (lbm/hr)

Shell-Side ho (BTU/hr·ft².°F)

Tube-Side hi (BTU/hr·ft².°F)

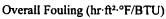
Tube-Side hi (BTU/hr·ft².°F)

Heat Transferred (BTU/hr)

LMTD

LMTD Correction Factor

Effective Area (ft²)



			Overan rounng (m.m. r
Property	Shell-Side	Tube-Side	- '
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)	*	3,454,223.04	Overall Fouling (hr-ft ² .°F/BTU)	0.001470
,		3,673,832.59	Shell-Side ho (BTU/hr·ft².ºF) Tube-Side hi (BTU/hr·ft².ºF)	1,128.7 2,079.4
Heat Transferred (BTU/hr) LMTD		166,468,480.24 58.3	1/Wall Resis (BTU/hr·ft²·°F) LMTD Correction Factor	2,148.1 0.8820
Effective Area (ft²)		10,926.6	U Overall (BTU/hr·ft².°F)	296.3
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.26	7.08	Shell Temp In (°F)	212.0
Reynold's Number	55,935	69,169	Shell Temp Out (°F)	164.0
Prandtl Number	2.0490	3.2991	Tav Shell (°F)	188.0
Bulk Visc (lbm/ft·hr)	0.7909	1.2323	Shell Skin Temp (°F)	172.7
Skin Visc (lbm/ft·hr)	0.8775	1.1347	Tube Temp In (°F)	107.0
Density (lbm/ft³)	60.3957	61.5557	Tube Temp Out (°F)	152.4
Cp (BTU/lbm·°F)	1.0032	0.9990	Tav Tube (°F)	129.7
K (BTU/hr-ft-°F)	0.3872	0.3732	Tube Skin Temp (°F)	139.2



^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved



PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-1002) Commonwealth Edison

Data Report for E12-B001 - LSCS - RHR Hx.

SDC - tube side = 107 °F, 7400 gpm, shell side = 121 °F, 7200 gpm, 53 tubes plugged, FF = 0.00147

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Mass Fluid Quantity, To		0.00	0.00
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F	108.80	101.25
Fouling Factor	hr·ft²·°F/BTU	0.00250	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Q (BTU/hr)			41,600,000
Design U (BTU/hr·ft².ºF)		215.00
Outside h Factor (Hoff)			0.563555000
Fixed U (BTU/hr·ft².ºF)			0
Fixed Area (ft²)	Paduation\		0.00
Performance Factor (%)	Reduction)		0.00
Heat Exchanger Type			TEMA - E
Total Effective Area per	Unit (ft²)		11,500.00
Area Factor			0.996344561
Area Ratio			0.00000
Number of Shells Per U	nit		1
Shell Minimum Area			4.880000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes	5		1,010
Tube Length (ft)			55.30
Tube Inside Diameter (in	•		0.652
Tube Outside Diameter	• •		0.750
Tube Wall K (BTU/hr·ft	:°F)		9.40
Lbc, Central Baffle Space	cing (in)		0.000
Lbi, Inlet Baffle Spacing	g (in)		0.000
Lbo, Outlet Baffle Spaci	ing (in)		0.000
Dotl, Tube Circle Diame			0.000
Bh, Baffle Cut Height (i	n)		0.000
Ds, Shell Inside Diamter	r (in)		0.000
Lsb, Diametral difference		` /	0.000
Ltb, Diametral difference		Baffle (in)	0.000
Nss, Number Sealing St	rips		0.000

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - tube side = 107 °F, 7400 gpm, shell side = 121 °F, 7200 gpm, 53 tubes plugged, FF = 0.00147

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Data		
Data Date Shell Flow (gpm)	Tube Flow (gpm) Shell Flow (gpm)	7,344.00 7,122.00	
Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm)	Tube Inlet Temp (°F) Shell Inlet Temp (°F)	107.00 121.00	
Tube Temp In (°F) Tube Temp Out (°F)	Input Fouling Factor	0.001470	

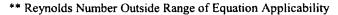
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr-ft2.°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft².°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)
			•

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3,562,777.19	Overall Fouling (hr-ft2-°F/BTU)	0.001470
Tube Mass Flow (lbm/hr)		3,673,832.59	Shell-Side ho (BTU/hr·ft².°F)	965.4
			Tube-Side hi (BTU/hr-ft2.°F)	1,865.5
Heat Transferred (BTU/hr))	21,770,576.54	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		8.0	LMTD Correction Factor	0.8965
Effective Area (ft²)		10,926.6		
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft².ºF)	278.7
Velocity (ft/s)	3.28	7.04	Shell Temp In (°F)	121.0
Reynold's Number	33,234	57,419	Shell Temp Out (°F)	114.9
Prandtl Number	3.7131	4.0454	Tav Shell (°F)	117.9
Bulk Visc (lbm/ft·hr)	1.3730	1.4845	Shell Skin Temp (°F)	115.6
Skin Visc (lbm/ft·hr)	1.4037	1.4643	Tube Temp In (°F)	107.0
Density (lbm/ft³)	61.7433	61.8605	Tube Temp Out (°F)	112.9
Cp (BTU/lbm·°F)	0.9988	0.9988	Tav Tube (°F)	110.0
K (BTU/hr·ft·°F)	0.3693	0.3665	Tube Skin Temp (°F)	111.3



^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved





ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet Page 1 of 1

		La	ast Page No. 1
Analysis No.	97-201		Revision Aol
EC/ECR No.	EC 352363		Revision 0
Title:	Thermal Model of ComEd/LSCS I	RHR Heat Exchangers 1(2)RHR01A & B	
Station(s)	LaSalle	Is this Design Analysis Safeguards?	′es 🗌 No 🏻
Unit No.:	Units 1 and 2	Does this Design Analysis Contain Unverified Assumptions?	′es □ No 🏻
Safety Class	Safety Related		
System Code	E12, RH	ATI/AR#	
is now 163.1 M 0.00185 hr-ft^2 calculation). T evaluations. B Decay Heat Ta GE-NE-A1300	arifies that the required heat remove the service water in the service w	ral capability of an RHR HX for the Containminet temperature of 104 deg. F, a maximuming allowance (ref. Case 3 on page 7 of rev. And as the acceptance criteria in RHR HX thereof, SIL 636 Disposition for LaSalle County Storate Project Task Report 310: Residual Heas Shutdown Cooling Condition (SDC) design the	fouling factor of 00 of this mal performance ation and New at Removal System,
EC 334017 (da of 104 deg-F. Temperature A exchanger efficinlet service wa factor had been was evaluated. deg-F) has not pool temperatu NPSH limit for on a review of for Q2). This is	The Design Considerations Summanalysis: "Design Analysis No. L-00 ciency (expressed as a "K" factor in a ter temperature of 104°F at various n determined, the impact on the Last. As detailed within this design ana increased even with a higher inlets are demonstrated within this design the ECCS pumps of 212°F." The in L-002857: -the credited heat rejections the value of Q used to get a 'K factorialy in the control of the co	ed cooling water temperature to a new maximary states in part for the Post LOCA Suppres (2857, Rev. 0 has been completed to determ a LaSalle's existing Containment Analysis) is suppression pool temperatures. After the lesalle suppression pool temperature responsitysis, the post LOCA peak suppression pool service water temperature of 104°F. The peranalysis is still well below the suppression procreased efficiency implies a higher heat load on capability is 163.1 MBtu/hr for the CCM control of 417. Since we are crediting this heat tould be used as the approved acceptance of	sion Pool ine the RHR heat with an increased neat exchanger K e following a LOCA I temperature (193 ak suppression ool temperature d capability. Based ase (Table 2 value load capability and
	an Schmit	Df. Schmit	11/11/04
· —	Print Name	Sign Name	Date
Reviewer To	erry Martin	len	11 (24/04
	Print Name	Sign Name	Date
Method of Rev	iew	Alternate Calculations	ting
Review Notes:	(D. H1680)	(1)	11 .
Approver	Print Name	Sign Name	11-50-60 Date
(For External Analyses C	Only)	Signivame	Date
Exelon Review	Print Name	Sign Name	Date
Approver N	Print Name	Sign Name	

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 1 of 2

DESIGN ANALYSIS NO.: Calc. # 97-20 Major REV Number: A [] BRAIDWOOD STATION [] BYRON STATION [] CLINTON STATION [] DRESDEN STATION [] DRESDEN STATION [] QUAD CITIES STATION Unit: [] 0 [X] 1 [X] 2 [] 3 TITLE: THERMAL MODEL OF COMED			OR REV Number: ESCRIPTION CODE: SCIPLINE CODE: (STEM CODE: (C	(C011)	PAGE NO. 1 MØ10 M E12, RH s 1(2)RHR01A & B.
[X] Safety Re	olated		nted Quality	[]	ion-Safety Related
		ATTRII	BUTES (C016)	1	·
TYPE Elevation	VALU		TYPE	<u> </u>	VALUE
Software	710 Proto				
COMPONENT EPI	N: (C014 Panel)	DOCUME! サイルトン Type/Sub			esign Analyses References) Input (Y/N)
1E12-B001A	H15	0.0		·····	
1E12-B001A	H15	EE/DCI	P EC# 33401	11.	Υ
2E12-B001A	H15	 ' ,			
2E12-B001B	H15	' ,			
		1			
		1			
		1			
REMARKS: NA					



CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS NO. 97-201	REV: A00	PAGE NO. 2
Revision Summary (including EC's income Service Water inlet temperature and calculate thermal margins for different fouling factor Cooling and Shutdown Cooling condition	culated Unit 1 and 2 RHR H ors and 5% tubes plugged a	eat Exchanger
Electronic Calculation Data Files: ProtoHX 3.	02, e12-b001.phx, 160 KB, 04/19	/2002, 10:36am
(Program Name, Version, File Name extension/s	size/date/hour/min)	
Design impact review completed? [] Ye (If yes, attach impact review sheet)	s [X] N/A, Per EC#: 334017	
Prepared by: Jeff W. VanStrien	1 MW Vartain	/ 5 7-c2 Date
Reviewed by: Brian L. Davenport	1 Bill Sign	15-09-00
- Print Method of Review: [X] Detailed [] Alto	Sign ernate [] Test	Date
	TO THE RESERVE OF THE PARTY OF	
This Design Analysis supersedes: N/A Supplemental Review Required? [] Yes	M1 No	in its entirety.
[] Additional Review [] Special Review		
(A) 医多次性性皮肤 特殊的最大的特别。		
Additional Reviewer or Special Review Team -	Print	Sign Date
Special Review Team: (N/A for Additional Re	view)	
Reviewers: 1) / Print Sign	Date Print	Sign Date
- 3)	1 4)	
Print Sign	Date Print	Sign Date
Supplemental Review Results:		
Approved by: J : T- Centre	De Da	1 5/10/02
- Print	Sign	/ Date
External Design Analysis Review (Attachmen	nt 3 Attached)	
Reviewed by:	í	1
- Print Approved by:	Sign	Date
- Print	Sign) Date
Do any ASSUMPTIONS / ENGINEERING JUDGEM Tracked By: AT#, EC# etc.)		[] Yes [X] No





CALCULATION TABLE OF CONTENTS

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8.0 ATTACHMENTS:	8	
Attachment "A" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Design FF, 5% plugged)	A1 to A5	
Attachment "B" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF)	B1 to B5	
Attachment "C" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF, 5% plugged)	C1 to C5	
Attachment "D" - Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Max. Allowable FF, w\ 5% plugged)	D1 to D5	





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1.0 PURPOSE/OBJECTIVE

The purpose of this minor revision is to revise the thermal model of this heat exchanger for a 104°F Service Water inlet temperature. This assessment will evaluate the adequacy of the RHR Heat Exchangers at both Containment Cooling Mode (CCM) and Shutdown Cooling Conditions (SDC) during a maximum allowable inlet service water temperature of 104°F to ensure that adequate thermal margin still exists.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp." to 104°F and simulated for the following conditions: (Case 1) design fouling factor with 5% of the tubes plugged, (Case 2) twice the 'as-tested' fouling factor and (Case 3) twice the 'as-tested' fouling factor with a 5% tube plugging allowance. The acceptance criteria will be for the thermal margin at Case 3 stated conditions to exceed the LaSalle Design Heat Load of 155,000,000 BTU/hr for Containment Cooling Mode (CCM) and 41,600,000 BTU/hr in Shutdown Cooling Condition (SDC) (Ref. 1, Tables 3-1 & 3-2). If desired, both RHR heat exchangers may be placed in service to provide the maximum cool down rate specified above during the Shutdown Cooling Condition.

Additional conservatism was built into this acceptance criteria by assuming a 5% uncertainty in the Proto-HX heat transfer calculations. The Reference 1 model developed for this heat exchanger demonstrated a correlation to vendor performance specification well within this assumed 5% margin.

A final case will be evaluated which determines the maximum acceptable fouling factor at which the design heat loads can be accommodated including heat transfer model uncertainty.

3.0 ASSUMPTIONS / ENGINEERING JUDGMENTS

The assumptions indicated in section 5.0 of Reference 1 are still valid.

Note: The shell side flow rate specified within reference 1 (8,400 gpm) has been changed to a more conservative number given within Tech. Spec. S.R. 3.5.1.5 as a minimum flow rate of 7,200 gpm. This flow rate was further reduced to account for volumetric flow rate correction required by Proto-Hx software limitations, refer to Table 1.

4.0 DESIGN INPUTS

The design inputs consist of References 1, 2 and 4 listed below.



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5.0 REFERENCES

- 1. Calculation No. 97-201, Rev. A, "Thermal Model of COMED/LSCS RHR Heat Exchangers 1(2)RHR01A & B ".
- 2. NDIT LS-1154, Upgrade 0, "1B RHR Heat Exchanger Test on 10-25-99 Evaluation" and Calculation L-002571, Rev. 0, "1A RHR Heat Exchanger Test performed on 01/10/02".
- 3. EC# 331912, "Assessment of High Lake Temperature Upon the Functionality of the Plant"
- 4. Crane Co. Technical Paper No. 410 "Flow of Fluids", Twenty-Fifth Printing 1991.
- 5. "Standards of the Tubular Exchanger Manufacturers Association" (TEMA), Seventh Edition, 1988



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6.0 CALCULATIONS

The current calculation model is based on a Service Water inlet temperature of 90°F (SDC) and 100°F (CCM). At these temperatures, a design fouling factor of 0.0025 hr*ft²*°F/BTU and a 5% tube plugging allowance, the amount of heat transferred is 163,700,000 BTU/hr compared with a LaSalle Station Containment Cooling Design Heat Load of 155,000,000 BTU/hr for a 5.61% thermal margin. For Shutdown Cooling, the design case temperature, the same fouling factor and tube plugging results in a 41,310,000 BTU/hr heat transfer compared to a Shutdown Cooling Reference Load of 41,600,000 BTU/hr which appears to indicate no thermal margin available (Ref. 1, Tables 6-3 & 6-4).

Thermal margin is calculated by the following method:

Required Heat Load - Calculated Heat Transfer = Thermal Margin

[Equation 1]

To express this as a percent of the required heat load, the following method is used:

$$\frac{ThermalM \arg in}{\text{Re quiredHeatLoad}} \times 100\% = \% ThermalM \arg in$$

[Equation 2]

As detailed in reference 1 Proto-Hx inputs for fluid flow rates need to be adjusted using the ratio of the actual water density and the density of water at 60°F (assumed by Proto-Hx software). The following formula is used for this adjustment and the calculation inputs are tabulated with Table 1.

[Equation 3]

Table 1: Reference Conditions, Proto-Hx Flow Rate Inputs

Parameter	Density (lb/ft ³) Ref. 4	Actual Flow (gpm)	Proto-Hx Input (gpm)
Tube Side, 104 F	61.93	7,400	7,348
Shell-side, 120 F	61.71	7,200	7,124
Shell-side, 212 F	59.81	7,200	6,905
Proto-Hx, 60 F	62.37		





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Case 1

When the service water inlet temperature is increased to 104°F for the same design fouling factor and 5% tube plugging allowance, the amount of heat transferred decreases to 150,800,000 BTU/hr, which appears to have no thermal margin at this elevated temperature and fouling condition for the Containment Cooling required heat load of 155,000,000 BTU/hr. With the RHR system operating in Shutdown Cooling conditions at 104°F service water inlet, design fouling factor, and 5% tube plugging allowance, 21,920,000 BTU/hr is transferred which is below the required heat removal of 41,600,000 BTU/hr and would necessitate the operation of the second RHR heat exchanger thereby providing an ample cooling capacity of 43,840,000 BTU/hr, resulting in a thermal margin of 5.4% (w\ 2 RHR Hx in service) [Attachment A].

Case 2

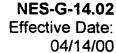
Regular cleaning and testing of these heat exchangers limits the amount of fouling well below the values assumed above. The heat exchanger performance data taken under the G.L. 89-13 program here at LaSalle demonstrates a maximum measured fouling factor of 0.00065 hr*ft²*oF/BTU (Ref. 2). For conservatism, this value was doubled to 0.0013 hr*ft²*oF/BTU and simulated with 104°F service water inlet temperature. The result was a heat transfer rate of 177,900,000 BTU/hr for a thermal margin of 14.8% [Attachment B]. Likewise for Shutdown Cooling condition at this fouling factor and service water condition the resulting heat transfer rate is 25,870,000 BTU/hr. This still necessitates the use of two heat exchangers to remove the design SDC heat load of 41,600,000 BTU/hr. However with two RHR heat exchangers in service the resulting thermal margin is 24.4% [Attachment B].

Case 3

With additional conservatism included by adding a plugging allowance of 53 tubes, 5% of the total, in the heat exchanger and running the model again at the above fouling factor and inlet temperature for a 174,800,000 BTU/hr heat transfer rate, a 12.8% thermal margin above the 155,000,000 BTU/hr Design Containment Cooling Heat Load. As with the previous cases, Shutdown Cooling would require two RHR heat exchangers at 0.0013 hr*ft²*°F/BTU, 104°F inlet temperature and 5% tube plugging allowance. However with 2 heat exchangers in service the resulting heat transfer rate is 50,780,000 BTU/hr (25,390,000 BTU/hr per Hx), resulting in a thermal margin of 22.1% [Attachment C].

The maximum fouling factor was found to be 0.00185 hr*ft²*oF/BTU while maintaining the required heat transfer rate at 104°F inlet temperature and with a 5% plugging allowance [Attachment D]. The resulting heat transfer of 163,100,000 BTU/hr for CCM and 47,380,000 BTU/hr for SDC (w\2 RHR Hx in service) accommodates the design heat loads of 155,000,000 BTU/hr for CCM and 41,600,000 BTU/hr for SDC including analytical model uncertainty.









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This is judged to be a reasonably conservative fouling factor even though it is slightly lower than the typical fouling factor stated in Ref. 5, page 215. The LaSalle lake water quality exceeds the "River Water Fouling Factor" (at a velocity greater than 3 ft/sec) given in this reference. The lake water passes through strainers and is chemically treated to control silt and scale prevention.

7.0 SUMMARY AND CONCLUSIONS

The RHR Heat Exchanger Model has been updated to reflect a maximum lake temperature of 104°F. The model found adequate thermal margin when operated for Containment Cooling Mode and would require two heat exchangers in operation to achieve the Design Heat Rate removal during Shutdown Cooling Mode. The maximum fouling factor was found to be 0.00185 hr*ff²*°F/BTU while maintaining the required heat transfer rate at 104°F inlet temperature and with a 5% plugging allowance. This fouling factor has been determined to be an acceptable benchmark value that can be used in Generic Letter 89-13 testing evaluations of this model heat exchanger.

8.0 ATTACHMENTS:

Attachment "A" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Design FF, 5% plugged)

Attachment "B" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF)

Attachment "C" – Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF, 5% plugged)

Attachment "D" - Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Max. Allowable FF, w\ 5% plugged)

Final Page (Last Page)



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Attachment "A"

Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Design FF, 5% plugged)

Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-5% PLUG, DESIGN FF @ 104 F



		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor		0.00250	0.00000	
Shell Fluid Name			Fresh Water	CASE)
Tube Fluid Name			Fresh Water	~ N=~/
Design Heat Transfer (B	TU/hr)		41,600,000	
Design Heat Trans Coef	f (BTU/hr·ft²	·°F)	215.00	
Emprical Factor for Outs	side h		0.563555000	
Performance Factor (%]	Reduction)		0.00	
Heat Exchanger Type			ТЕМА-Е	
Effective Area (ft^2)			11,500.00	
Area Factor			0.996344561	
Area Ratio				
Number of Shells per Ur	nit		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			Yes	
Total Number of Tubes			1,063 /	
Number of Active Tubes	,		1,010 $\sqrt{}$	
Tube Length (ft)			55.30	
Tube Inside Diameter (in	n)		0.652	
Tube Outside Diameter (•		0.750	
Tube Wall Conductivity		F)	9.40	
Ds, Shell Inside Diamete	er (in)		0.000	
Lbc, Central Baffle Spac			0.000	
Lbi, Inlet Baffle Spacing	• ' '		0.000	
Lbo, Outlet Baffle Spacing	` '		0.000	
Dotl, Tube circle diameter	• , ,		0.000	
Bh, Baffle cut height (in)			0.000	
Lsb, Diametral difference		ffle and Shell (in)	0.000	
Ltb, Diametral difference			0.000	
Nss, Number Sealing Str		or and Darmo (III)	0.000	
,	1		0.000	



PROTO-HX 3.02 by Proto-Power Corporation (SN#663-7371)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM-5% PLUG, DESIGN FF @ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

CASE 1

Test Data	Extrapolation I	Data
Data Date	Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	Shell Flow (gpm)	6,905.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		
	Fouling Calculation Results	

Shell Mass Flow (lbm/hr)		•	U Overall (BTU/hr·ft²-°F)
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².°F)
,			Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft².°F)
LMTD			LMTD Correction Factor
Effective Area (ft²)			
			Overall Fouling (hr-ft2.°F/BTU)
Property	Shell-Side	Tube-Side	

LMTD			LMTD Correction Factor	
Effective Area (ft²)				
			Overall Fouling (hr-ft2.°F	/BTU)
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	Calculation No. 97-201
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Revision No. A00
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Attachment A
Density (lbm/ft³)			Tube Temp Out (°F)	
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. A3 of A5
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)	

	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)	3.454E+6	Overall Fouling (hr-ft ² .°F/BTU)	0.002500
Tube Mass Flow (lbm/hr	·)	3.676E+6	Shell-Side ho (BTU/hr·ft².°F)	1,136.9
			Tube-Side hi (BTU/hr·ft².°F)	2,027.7
Heat Transferred (BTU/h	nr)	1.508E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		65.7	LMTD Correction Factor	0.9268
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft2.°F)	226.6
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.26	7.07	Shell Temp In (°F)	212.0
Reynold's Number	5.677E+04	6.607E+04	Shell Temp Out (°F)	168.5
Prandtl Number	2.02	3.47	Tav Shell (°F)	190.2
Bulk Visc (lbm/ft·hr)	0.78	1.29	Shell Skin Temp (°F)	177.1
Skin Visc (lbm/ft·hr)	0.85	1.20	Tube Temp In (°F)	104.0
Density (lbm/ft3)	60.34	61.64	Tube Temp Out (°F)	145.1
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	124.5
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	133.0

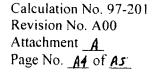
^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-5% PLUG, DESIGN FF (104 F)

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	C 4 5
Outlet Temperature	°F	108.80	101.25	CAR
Fouling Factor		0.00250	0.00000	
Shell Fluid Name			Fresh Water	
Tube Fluid Name			Fresh Water	
Design Heat Transfer (B	TU/hr)		41,600,000	
Design Heat Trans Coef	•	·°F)	215.00	
Emprical Factor for Out		ŕ	0.563555000	
Performance Factor (%)	Reduction)		0.00	
Hart Frankerson Torre		·	TELLA	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2)			11,500.00	
Area Factor Area Ratio			0.996344561	
Alea Rallo				
Number of Shells per Ur	nit		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			Yes	
Total Number of Tubes			1,063	
Number of Active Tubes	•		1,010	
Tube Length (ft)			55.30	
Tube Inside Diameter (ir	n)		0.652	
Tube Outside Diameter (•		0.750	
Tube Wall Conductivity	. ,	F)	9.40	
- AL 11 T 11 T 1		•		
Ds, Shell Inside Diamete			0.000	
Lbc, Central Baffle Spac	•		0.000	
Lbi, Inlet Baffle Spacing			0.000	
Lbo, Outlet Baffle Spaci			0.000	
Dotl, Tube circle diameter	• •		0.000	
Bh, Baffle cut height (in)		CO 1.03 11.71 >	0.000	
Lsb, Diametral difference		` '	0.000	
Ltb, Diametral difference		be and Baffle (in)	0.000	
Nss, Number Sealing Str	nps		0.000	



Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC-5% PLUG, DESIGN FF (104 F)

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

CASE 1

Test Data	Extrapolation I	Data
Data Date	Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	Shell Flow (gpm)	7,124.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		
Fo	ouling Calculation Results	

		U Overall (BTU/hr-ft ^{2,o} F)	
		Shell-Side ho (BTU/hr·ft²	·°F)
		Tube-Side hi (BTU/hr·ft²-	°F)
		1/Wall Resis (BTU/hr-ft2-	°F)
		LMTD Correction Factor	
		Overall Fouling (hr-ft2.°F/	BTU)
Shell-Side	Tube-Side		
		Shell Temp In (°F)	
		Shell Temp Out (°F)	
		Tav Shell (°F)	Calculation N
	Shell-Side	Shell-Side Tube-Side	Shell-Side ho (BTU/hr·ft² Tube-Side hi (BTU/hr·ft²- 1/Wall Resis (BTU/hr·ft²- 1/Wall Resis (BTU/hr·ft²- LMTD Correction Factor Overall Fouling (hr·ft²-°F/ Shell-Side Shell Temp In (°F) Shell Temp Out (°F)

Calculation No. 97-201 Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Revision No. A00 Skin Visc (lbm/ft·hr) Tube Temp In (°F) Attachment A Density (lbm/ft3) Tube Temp Out (°F) Page No. As of As Cp (BTU/lbm.°F) Tav Tube (°F) Tube Skin Temp (°F) K (BTU/hr·ft·°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		3.564E+6	Overall Fouling (hr-ft ² .°F/BTU)	0.002500
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr-ft ² .°F)	962.4
•			Tube-Side hi (BTU/hr·ft².°F)	1,836.6
Heat Transferred (BTU/hr)		2.192E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		9.9	LMTD Correction Factor	0.9348
Effective Area (ft²)		10,926.6		
• •			U Overall (BTU/hr-ft2.°F)	215.9
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.29	7.04	Shell Temp In (°F)	120.0
Reynold's Number	3.292E+04	5.574E+04	Shell Temp Out (°F)	113.8
Prandtl Number	3.75	4.18	Tav Shell (°F)	116.9
Bulk Visc (lbm/ft·hr)	1.39	1.53	Shell Skin Temp (°F)	114.7
Skin Visc (lbm/ft-hr)	1.42	1.51	Tube Temp In (°F)	104.0
Density (lbm/ft³)	61.76	61.90	Tube Temp Out (°F)	110.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	107.0
K (BTU/hr-ft-°F)	0.37	0.37	Tube Skin Temp (°F)	108.3

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



CALCULATION NO. 97-201 REVISION NO. A00

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Attachment "B"

Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF)

CASE 2

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-ALL TUBES 2X TEST FF @ 104 F

Shell and Tube Heat Exchanger Input Parameters

Fluid Quantity, Total gpm 7,446.28 7,396.31 Inlet Temperature °F 120.00 90.00 Outlet Temperature °F 108.80 101.25 Fouling Factor 0.00250			Shell-Side	Tube-Side
Outlet Temperature °F 108.80 101.25 Fouling Factor 0.00250♥ 0.00000 Shell Fluid Name Fresh Water Tube Fluid Name Fresh Water Design Heat Transfer (BTU/hr) 41,600,000 Design Heat Trans Coeff (BTU/hr·ft²-°F) 215.00 Emprical Factor for Outside h 0.563555000 Performance Factor (% Reduction) 0.00 Heat Exchanger Type TEMA-E Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Unside Diameter (in) 0.652 Tube Outside Diameter (in) 0.750	Fluid Quantity, Total	gpm	7,446.28	7,396.31
Shell Fluid Name	Inlet Temperature	°F	120.00	90.00
Shell Fluid Name Fresh Water Tube Fluid Name Fresh Water Design Heat Transfer (BTU/hr) 41,600,000 Design Heat Trans Coeff (BTU/hr·ft².°F) 215.00 Emprical Factor for Outside h 0.563555000 Performance Factor (% Reduction) 0.00 Heat Exchanger Type TEMA-E Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Unside Diameter (in) 0.652 Tube Wall Conductivity (BTU/hr·ft·°F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbc, Central Baffle Spacing (in) 0.000 Lbc, Inlet Baffle Spacing	Outlet Temperature	°F	108.80	101.25
Tube Fluid Name Fresh Water Design Heat Transfer (BTU/hr) 41,600,000 Design Heat Trans Coeff (BTU/hr ft²-°F) 215.00 Emprical Factor for Outside h 0.563555000 Performance Factor (% Reduction) 0.00 Heat Exchanger Type TEMA-E Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Inside Diameter (in) 0.652 Tube Wall Conductivity (BTU/hr ft or F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbi, Inlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Lbo, Outlet Baff	Fouling Factor		0.00250*	0.00000
Design Heat Transfer (BTU/hr) 41,600,000 Design Heat Trans Coeff (BTU/hr·ft².°F) 215.00 Emprical Factor for Outside h 0.563555000 Performance Factor (% Reduction) 0.00 Heat Exchanger Type TEMA-E Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Inside Diameter (in) 0.652 Tube Wall Conductivity (BTU/hr·ft·°F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbi, Inlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Lbo, Diam	Shell Fluid Name		•	Fresh Water
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Performance Factor (% Reduction) 0.00 Heat Exchanger Type TEMA-E Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Inside Diameter (in) 0.652 Tube Outside Diameter (in) 0.750 Tube Wall Conductivity (BTU/hr·ft·°F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbc, Central Baffle Spacing (in) 0.000 Lbi, Inlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Dot, Tube circle diameter (in) 0.000 Bh, Baffle cut height (in) 0.000 Lsb, Diametral difference between B	Design Heat Trans Coeff	(BTU/hr·ft2·	°F)	215.00
Heat Exchanger Type	Emprical Factor for Outs	ide h		0.563555000
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Effective Area (ft^2) 11,500.00 Area Factor 0.996344561 Area Ratio 1 Number of Shells per Unit 1 Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Unside Diameter (in) 0.652 Tube Outside Diameter (in) 0.750 Tube Wall Conductivity (BTU/hr·ft·°F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbc, Central Baffle Spacing (in) 0.000 Lbc, Central Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Dot, Tube circle diameter (in) 0.000 Bh, Baffle cut height (in) 0.000 Lsb, Diametral difference between Baffle and Shell (in) 0.000 Ltb, Diametral difference between Tube and Baffle (in) 0.000 <	Heat Exchanger Type			TEMA-E
Area Factor Area Ratio Number of Shells per Unit Shell Minimum Area \$\text{4.880000000}\$ Shell Velocity (ft/s) \$\text{3.400}\$ Tube Pitch (in) \$\text{1.0000}\$ Tube Pitch Type \$\text{Triangular}\$ Number of Tube Passes \$\text{2}\$ U-Tubes \$\text{Yes}\$ Total Number of Tubes Number of Active Tubes \$\text{1,063}\$ Number of Active Tubes \$\text{1,063}\$ Tube Length (ft) \$\text{5.30}\$ Tube Inside Diameter (in) \$\text{0.652}\$ Tube Outside Diameter (in) \$\text{0.750}\$ Tube Wall Conductivity (BTU/hr·ft·°F) \$\text{0.000}\$ Lbc, Central Baffle Spacing (in) \$\text{0.000}\$ Lbo, Outlet Baffle Spacing (in) \$\text{0.000}\$ Dotl, Tube circle diameter (in) \$\text{0.000}\$ Bh, Baffle cut height (in) \$\text{0.000}\$ Ltb, Diametral difference between Baffle and Shell (in) \$\text{0.000}\$	-			
Number of Shells per Unit Shell Minimum Area 4.880000000 Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes 2 U-Tubes Yes Total Number of Tubes Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Inside Diameter (in) 0.652 Tube Outside Diameter (in) 0.750 Tube Wall Conductivity (BTU/hr·ft·°F) 9.40 Ds, Shell Inside Diameter (in) 0.000 Lbc, Central Baffle Spacing (in) Lbc, Outlet Baffle Spacing (in) 0.000 Lbd, Tube circle diameter (in) 0.000 Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.000 Ltb, Diametral difference between Tube and Baffle (in)	Area Factor			•
Shell Minimum Area Shell Velocity (ft/s) 3.400 Tube Pitch (in) 1.0000 Tube Pitch Type Triangular Number of Tube Passes U-Tubes Total Number of Tubes Number of Active Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Ds, Central Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Dotl, Tube circle diameter (in) Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 1.0000 Tube Vall Conductivity (in) Do000 Lbb, Diametral difference between Tube and Baffle (in) D.0000 Ltb, Diametral difference between Tube and Baffle (in) D.0000	Area Ratio			
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Tube Pitch (in) Tube Pitch Type Triangular Number of Tube Passes U-Tubes Total Number of Tubes Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Ds, Central Baffle Spacing (in) Lbc, Central Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Double, Tube circle diameter (in) Double Conductivity (BTU/hr·ft·°F) Double Conductivity				
Tube Pitch Type Number of Tube Passes U-Tubes Total Number of Tubes Number of Active Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Ds, Shell Inside Diameter (in) Ds, Central Baffle Spacing (in) Lbc, Central Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Double, Tube circle diameter (in) Double Conductivity (Bruden) Double Baffle Spacing (in) Double Conductivity (Bruden) Double Baffle cut height (in) Double Conductivity (Bruden) Double Conductivity (Bruden) Double Baffle cut height (in) Double Conductivity (Bruden) Double Conduct	• • • • • • • • • • • • • • • • • • • •			
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U-Tubes Total Number of Tubes 1,063 Number of Active Tubes 1,063 Tube Length (ft) 55.30 Tube Inside Diameter (in) 0.652 Tube Outside Diameter (in) 0.750 Tube Wall Conductivity (BTU/hr·ft·°F) 9,40 Ds, Shell Inside Diameter (in) 0.000 Lbc, Central Baffle Spacing (in) 0.000 Lbi, Inlet Baffle Spacing (in) 0.000 Lbo, Outlet Baffle Spacing (in) 0.000 Dotl, Tube circle diameter (in) 0.000 Bh, Baffle cut height (in) 0.000 Lsb, Diametral difference between Baffle and Shell (in) 0.000 Ltb, Diametral difference between Tube and Baffle (in) 0.000	Number of Tube Passes			2
Total Number of Tubes Number of Active Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Outside Diameter (in) O.750 Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Dotl, Tube circle diameter (in)				
Number of Active Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Outside Diameter (in) O.750 Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Double, Outlet Baffle Spacing (in) Double, Tube circle diameter (in) Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 1,063 1,063 1,063 1,063 1,063 1,063 1,063 1,063 0.750 0.750 0.000	Total Number of Tubes			
Tube Length (ft) Tube Inside Diameter (in) Tube Outside Diameter (in) Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Dotl, Tube circle diameter (in) Bh, Baffle cut height (in) Ltb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.652 0.750 0.0750 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	Number of Active Tubes			
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Tube Outside Diameter (in) Tube Wall Conductivity (BTU/hr·ft·°F) Ds, Shell Inside Diameter (in) Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Dotl, Tube circle diameter (in) Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.750 0.750 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000 0.000	_ , ,)		
Ds, Shell Inside Diameter (in) Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Dotl, Tube circle diameter (in) Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.000				
Lbc, Central Baffle Spacing (in)0.000Lbi, Inlet Baffle Spacing (in)0.000Lbo, Outlet Baffle Spacing (in)0.000Dotl, Tube circle diameter (in)0.000Bh, Baffle cut height (in)0.000Lsb, Diametral difference between Baffle and Shell (in)0.000Ltb, Diametral difference between Tube and Baffle (in)0.000	Tube Wall Conductivity (BTU/hr·ft·°F	F)	
Lbc, Central Baffle Spacing (in)0.000Lbi, Inlet Baffle Spacing (in)0.000Lbo, Outlet Baffle Spacing (in)0.000Dotl, Tube circle diameter (in)0.000Bh, Baffle cut height (in)0.000Lsb, Diametral difference between Baffle and Shell (in)0.000Ltb, Diametral difference between Tube and Baffle (in)0.000	Ds, Shell Inside Diameter	(in)		0.000
Lbi, Inlet Baffle Spacing (in)0.000Lbo, Outlet Baffle Spacing (in)0.000Dotl, Tube circle diameter (in)0.000Bh, Baffle cut height (in)0.000Lsb, Diametral difference between Baffle and Shell (in)0.000Ltb, Diametral difference between Tube and Baffle (in)0.000	•	` '		
Lbo, Outlet Baffle Spacing (in)0.000Dotl, Tube circle diameter (in)0.000Bh, Baffle cut height (in)0.000Lsb, Diametral difference between Baffle and Shell (in)0.000Ltb, Diametral difference between Tube and Baffle (in)0.000	-	• ,		
Dotl, Tube circle diameter (in) Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.000 0.000				
Bh, Baffle cut height (in) Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.000 0.000	· •	O ()		
Lsb, Diametral difference between Baffle and Shell (in) Ltb, Diametral difference between Tube and Baffle (in) 0.000 0.000	•	` '		
Ltb, Diametral difference between Tube and Baffle (in) 0.000	Lsb, Diametral difference	between Bar	ffle and Shell (in)	
			` /	
			• /	

Calculation No. 97-201 Revision No. A00 Attachment <u>B</u> Page No. <u>G1</u> of <u>B5</u>

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-ALL TUBES 2X TEST FF @ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

* Fouling Was Input by User

Test Data

CASE 2

Extrapolation Data

Extrapolation Data			ation Data	
Data Date			Tube Flow (gpm)	7,348.0
Shell Flow (gpm)			Shell Flow (gpm)	6,905.0
Shell Temp In (°F)			Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.001300 🗶
		Fouling Calculat	ion Results	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F	`\
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft	•
Tube Mass Flow (Iblibili)			Tube-Side hi (BTU/hr-ft²	•
Heat Transferred (BTU/hr	1		1/Wall Resis (BTU/hr·ft²	•
LMTD	,		LMTD Correction Factor	
Effective Area (ft²)			EMT B Conceilon Pacion	l
Directive risea (it)			Overall Fouling (hr-ft2,°F	/BTU)
Property	Shell-Side	Tube-Side		,
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	Calculation No. 97-201
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Revision No. A00
Density (lbm/ft³)			Tube Temp Out (°F)	Attachment B
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. 63 of 85

Extrapolation Calculation Results

Tube Skin Temp (°F)

Shell Mass Flow (lbm/hr)		3.454E+6	Overall Fouling (hr-ft2.0F/BTU)	0.001300
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr-ft2.°F)	1,123.8
			Tube-Side hi (BTU/hr·ft².°F)	1,985.4
Heat Transferred (BTU/hr)		1.779E+8	l/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		58.1	LMTD Correction Factor	0.8618
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr-ft2.°F)	309.1
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.25	6.73	Shell Temp In (°F)	212.0
Reynold's Number	5.533E+04	6.491E+04	Shell Temp Out (°F)	160.6
Prandtl Number	2.07	3.35	Tav Shell (°F)	186.3
Bulk Visc (lbm/ft-hr)	0.80	1.25	Shell Skin Temp (°F)	170.3
Skin Visc (lbm/ft·hr)	0.89	1.14	Tube Temp In (°F)	104.0
Density (lbm/ft³)	60.43	61.58	Tube Temp Out (°F)	152.5
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	128.2
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	138.6

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

CAS6 2

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-ALL TUBES, 2X TEST FF@104 F

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F .	108.80	101.25
Fouling Factor		0.00250	0.00000
Shell Fluid Name		•	Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B	TU/hr)		41,600,000
Design Heat Trans Coef		°F)	215.00
Emprical Factor for Outs			0.563555000
Performance Factor (% l	Reduction)		0.00
Heat Exchanger Type			ТЕМА-Е
Effective Area (ft^2)			11,500.00
Area Factor			0.996344561
Area Ratio			
Number of Shells per Ur	nit		1
Shell Minimum Area			4.880000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
			•
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes			1,063
Tube Length (ft)			55.30
Tube Inside Diameter (in	•		0.652
Tube Outside Diameter (•		0.750
Tube Wall Conductivity	(BTU/hr·ft·°l	()	9.40
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Spac	ing (in)		0.000
Lbi, Inlet Baffle Spacing	(in)		0.000
Lbo, Outlet Baffle Spacing	ng (in)		0.000
Dotl, Tube circle diameter			0.000
Bh, Baffle cut height (in)	•		0.000
Lsb, Diametral difference	e between Ba	ffle and Shell (in)	0.000
Ltb, Diametral difference	between Tul	be and Baffle (in)	0.000
Nss, Number Sealing Str	ips		0.000

Calculation No. 97-201 Revision No. A00 Attachment <u>B</u> Page No. <u>B4</u> of <u>B7</u>

* Fouling Factor input on next page.

Data Date

Shell Flow (gpm)

K (BTU/hr·ft·°F)

Density (lbm/ft3)

Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

Shell Temp In (°F)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-ALL TUBES, 2X TEST FF@104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

➤ Fouling Was Input by User

Test Data

< A562

7,348.0

7,124.0

104.0

111.0

107.5

109.2

Extrapolation Data

Tube Flow (gpm)

Shell Flow (gpm)

Tube Inlet Temp (°F)

Tube Skin Temp (°F)

Tube Temp Out (°F)

Tube Skin Temp (°F)

Tav Tube (°F)

Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)		· · · · · · · · · · · · · · · · · · ·	Input Fouling Factor	0.001300
		Fouling Calculati	ion Results	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².ºF)
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr ft	^{2.} °F)
			Tube-Side hi (BTU/hr-ft2	·°F)
Heat Transferred (BTU/hr)			I/Wall Resis (BTU/hr-ft²-	°F)
LMTD			LMTD Correction Factor	•
Effective Area (ft²)				
			Overall Fouling (hr-ft2.0F	/BTU)
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	C 1 1 1 2 24 07 201
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Calculation No. 97-201
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Revision No. A00
Density (lbm/ft³)			Tube Temp Out (°F)	Attachment _8_
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. <u>85</u> of <u>85</u>

Shell Mass Flow (lbm/hr)		3.564E+6	Overall Fouling (hr-ft ^{2,o} F/BTU)	0.001300
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr·ft².°F)	960.0
			Tube-Side hi (BTU/hr·ft².°F)	1,768.9
Heat Transferred (BTU/hr)	2.587E+7	1/Wall Resis (BTU/hr-ft2.°F)	2,148.1
LMTD		8.8	LMTD Correction Factor	0.8794
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr·ft².°F)	289.2
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.28	6.69	Shell Temp In (°F)	120.0
Reynold's Number	3.274E+04	5.325E+04	Shell Temp Out (°F)	112.7
Prandtl Number	3.78	4.16	Tav Shell (°F)	116.4
Bulk Visc (lbm/ft·hr)	1.39	1.52	Shell Skin Temp (°F)	113.7
Skin Visc (lbm/ft·hr)	1.43	1.50	Tube Temp In (°F)	104.0

61.90

1.00

0.37

Extrapolation Calculation Results



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

61.77

1.00

0.37



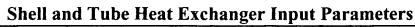


CALCULATION NO. 97-201 REVISION NO. A00 PAGE NO. C1 of C5

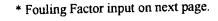
Attachment "C"

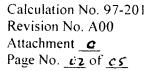
Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ 2X As-Tested FF, 5% plugged)

Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-5% PLUG, 2X TEST FF @ 104 F



		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	-
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor	······································	0.00250	0.00000	_
Shell Fluid Name		r	Fresh Water	CAS
Tube Fluid Name			Fresh Water	- Abi
Design Heat Transfer (B	•		41,600,000	
Design Heat Trans Coeff	`	·°F)	215.00	
Emprical Factor for Outs	side h		0.563555000	
Performance Factor (% F	Reduction)		0.00	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2)			11,500.00	
Area Factor			0.996344561	
Area Ratio		•		
Number of Shells per Un	it		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	•
U-Tubes			Yes	
Total Number of Tubes			1,063	
Number of Active Tubes			1,010	
Tube Length (ft)			55.30	
Tube Inside Diameter (in)		0.652	
Tube Outside Diameter (•		0.750	
Tube Wall Conductivity	•	F)	9.40	
Dr. Chall Inside Diamete	m (im)	•	0.000	
Ds, Shell Inside Diamete	, ,		0.000	
Lbc, Central Baffle Space			0.000	
Lbi, Inlet Baffle Spacing	` '		. 0.000	
Lbo, Outlet Baffle Spacin	•		0.000	
Dotl, Tube circle diamete	` '		0.000	
Bh, Baffle cut height (in)		60 1 01 11 (1)	0.000	
Lsb, Diametral difference			0.000	
Ltb, Diametral difference		be and Baffle (in)	0.000	
Nss, Number Sealing Stri	ıps		0.000	





Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-5% PLUG, 2X TEST FF @ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

* Fouling Was Input by User

CASE 3

Test Data			Extrapolation Data		
Data Date			Tube Flow (gpm)	7,348.0	
Shell Flow (gpm)			Shell Flow (gpm)	6,905.0	
Shell Temp In (°F)			Tube Inlet Temp (°F)	104.0	
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0	
Tube Flow (gpm)					
Tube Temp In (°F)					
Tube Temp Out (°F)			Input Fouling Factor	0.001300 💥	
		Fouling Calculati	on Results		
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)		
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft²		
,			Tube-Side hi (BTU/hr·ft²-		
Heat Transferred (BTU/hi	-)		1/Wall Resis (BTU/hr-ft2.	•	
LMTD			LMTD Correction Factor	•	
Effective Area (ft²)					
` .	Overall Fouling (hr·ft².°F/BTU)		BTU)		
Property	Shell-Side	Tube-Side		,	
Velocity (ft/s)			Shell Temp In (°F)		
Reynold's Number			Shell Temp Out (°F)		
Prandtl Number			Tav Shell (°F)		
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Calculation No. 97-201	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Revision No. A00	
Density (lbm/ft³)			Tube Temp Out (°F)	Attachment e	
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. c) of c5	
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)		

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		3.454E+6	Overall Fouling (hr-ft2.°F/BTU)	0.001300
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr·ft².°F)	1,124.6
			Tube-Side hi (BTU/hr-ft ^{2.} °F)	2,063.8
Heat Transferred (BTU/hr)	1	1.748E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		59.0	LMTD Correction Factor	0.8717
Effective Area (ft²)		10,926.6		
			U Overali (BTU/hr·ft².°F)	311.3
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.25	7.08	Shell Temp In (°F)	212.0
Reynold's Number	5.549E+04	6.806E+04	Shell Temp Out (°F)	161.5
Prandtl Number	2.07	3.36	Tav Shell (°F)	186.8
Bulk Visc (lbm/ft·hr)	0.80	1.25	Shell Skin Temp (°F)	170.4
Skin Visc (lbm/ft·hr)	0.89	1.15	Tube Temp In (°F)	104.0
Density (lbm/ft3)	60.42	61.59	Tube Temp Out (°F)	151.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	127.8
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Temp (°F)	138.0



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-5% PLUG, 2X TEST FF@ 104 F

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor		0.00250🗶	0.00000	CASE3
Shell Fluid Name		,	Fresh Water	•
Tube Fluid Name		•	Fresh Water	
Design Heat Transfer (B7	TU/hr)		41,600,000	
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	215.00	
Emprical Factor for Outsi	de h		0.563555000	
Performance Factor (% R	eduction)		0.00	
Heat Exchanger Type			ТЕМА-Е	
Effective Area (ft^2)			11,500.00	
Area Factor			0.996344561	
Area Ratio				
Number of Shells per Uni	it		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			Yes	
Total Number of Tubes			1,063	
Number of Active Tubes			1,010	
Tube Length (ft)			55.30	
Tube Inside Diameter (in)			0.652	
Tube Outside Diameter (i	,		0.750	
Tube Wall Conductivity (BTU/hr·ft·°	F)	9.40	
Ds, Shell Inside Diameter	(in)		0.000	
Lbc, Central Baffle Spaci	ng (in)		0.000	
Lbi, Inlet Baffle Spacing	(in)		0.000	
Lbo, Outlet Baffle Spacin			0.000	
Dotl, Tube circle diameter	r (in)		0.000	
Bh, Baffle cut height (in)			0.000	
Lsb, Diametral difference		• *	0.000	
Ltb, Diametral difference		be and Baffle (in)	0.000	
Nss, Number Sealing Stri	ps		0.000	



Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-5% PLUG, 2X TEST FF@ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

★ Fouling Was Input by User

CASE 3

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	Shell Flow (gpm)	7,124.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)	• •	
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.001300

Fouling Calculation Results

Shell Mass Flow (lbm/hr)			U Overall (BTU/hr-ft².°F)
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².°F)
			Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft².°F)
LMTD			LMTD Correction Factor
Effective Area (ft²)			
			Overall Fouling (hr ft².°F/BTU)
Property	Shell-Side	Tube-Side	
Valagity (ft/a)		·	Shall Tamp In (OE)

Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	Calculation No. 07 201
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Calculation No. 97-201
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Revision No. A00
Density (lbm/ft³)			Tube Temp Out (°F)	Attachment <u>c</u>
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. <u>cs</u> of <u>Cs</u>
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		3.564E+6	Overall Fouling (hr-ft ^{2,o} F/BTU)	0.001300
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr-ft2.°F)	960.2
, ,			Tube-Side hi (BTU/hr·ft².°F)	1,842.0
Heat Transferred (BTU/hr)		2.539E+7	l/Wall Resis (BTU/hr·ft²-°F)	2,148.1
LMTD		9.0	LMTD Correction Factor	0.8882
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft².°F)	291.4
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.28	7.04	Shell Temp In (°F)	120.0
Reynold's Number	3.277E+04	5.601E+04	Shell Temp Out (°F)	112.9
Prandtl Number	3.77	4.16	Tav Shell (°F)	116.4
Bulk Visc (lbm/ft·hr)	1.39	1.52	Shell Skin Temp (°F)	113.7
Skin Visc (lbm/ft·hr)	1.43	1.50	Tube Temp In (°F)	104.0
Density (lbm/ft3)	61.77	61.90	Tube Temp Out (°F)	110.9
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	107.5
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.37	0.37	Tube Skin Temp (°F)	109.1



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev





Attachment "D"

Proto-Hx Calc. Report for RHR Hx during CCM & SDC (CSCS=104 F @ Max. Allowable FF, w\ 5% plugged)

Calculation Report for E12-B001 - LSCS - RHR Hx. CCM-MAX FF, w\5% PLUG, @ 104 F

Shell and Tube Heat Exchanger Input Parameters

		mger input i ui		
		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor		0.00250	0.00000	_
Shell Fluid Name		r	Fresh Water	
Tube Fluid Name			Fresh Water	
Design Heat Transfer (B'	ΓU/hr)		41,600,000	
Design Heat Trans Coeff	(BTU/hr·ft²·	°F)	215.00	
Emprical Factor for Outs	ide h		0.563555000	
Performance Factor (% R	(eduction)		0.00	
Hart Euchen aus Trace			TEMA	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2) Area Factor			11,500.00 0.996344561	
Area Ratio			0.990344301	
Alea Ratio				
Number of Shells per Un	it		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Namel on a f Tuba Dagga			2	
Number of Tube Passes U-Tubes			2	
Total Number of Tubes			Yes 1,063 7	
Number of Active Tubes			1,010	57 PLUGGED
Tube Length (ft)			55.30	~ A reak GEO
Tube Inside Diameter (in)		0.652	
Tube Outside Diameter (in	•		0.750	
Tube Wall Conductivity	•	7)	9.40	
		,	3.10	
Ds, Shell Inside Diameter	•		0.000	
Lbc, Central Baffle Spaci	O \ ,		0.000	
Lbi, Inlet Baffle Spacing	•		0.000	
Lbo, Outlet Baffle Spacir			0.000	
Dotl, Tube circle diamete	r (in)		0.000	
Bh, Baffle cut height (in)	_		0.000	
Lsb, Diametral difference		, ,	0.000	
Ltb, Diametral difference		e and Baffle (in)	0.000	
Nss, Number Sealing Stri	ps		0.000	



PROTO-HX 3.02 by Proto-Power Corporation (SN#663-7371)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM-MAX FF, w\5% PLUG, @ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

¥ Fouling Was Input by User

Test Data	Extrapolation Data	Extrapolation Data	
Data Date	Tube Flow (gpm)	7,348.0	
Shell Flow (gpm)	Shell Flow (gpm)	6,905.0	
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0	
Tube Flow (gpm)			
Tube Temp In (°F)		_	
Tube Temp Out (°F)	Input Fouling Factor	0.001850	
Foul	ng Calculation Results		
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)		
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)		
,	Tube-Side hi (BTU/hr-ft2.°F)		
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft²-°F)		
LMTD	LMTD Correction Factor		
Effective Area (ft²)			
	Overall Fouling (hr·ft².°F/BTU)		
Property Shell-Side 7	ube-Side		
Velocity (ft/s)	Shell Temp In (°F)		
Reynold's Number	Shell Temp Out (°F)		
Prandtl Number	Tay Shell (°F)		
Bulk Visc (lbm/ft·hr)	Shell Skin Temp (°F)	n No. 97-201	
Skin Visc (lbm/ft·hr)	Tube Temp In (°F) Revision N		
Density (lbm/ft³)	Tube Temp Out (°F) Attachmen		
Cp (BTU/lbm·°F)	Tav Tube (°F) Page No. 1	3 of D 5	
K (BTU/hr·ft·°F)	Tube Skin Temp (°F)		

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		3.454E+6	Overall Fouling (hr-ft ^{2.} °F/BTU)	0.001850	
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr·ft².°F)	1,130.7	
, ,			Tube-Side hi (BTU/hr·ft².°F)	2,046.1	
Heat Transferred (BTU/hr)		1.631E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1	
LMTD		62.2	LMTD Correction Factor	0.9024	
Effective Area (ft2)		10,926.6			
			U Overall (BTU/hr·ft ^{2,9} F)	265.8	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)	3.26	7.08	Shell Temp In (°F)	212.0	
Reynold's Number	5.611E+04	6.709E+04	Shell Temp Out (°F)	164.9	
Prandtl Number	2.04	3.41	Tav Shell (°F)	188.5	
Bulk Visc (lbm/ft·hr)	0.79	1.27	Shell Skin Temp (°F)	173.8	
Skin Visc (lbm/ft·hr)	0.87	1.17	Tube Temp In (°F)	104.0	
Density (lbm/ft³)	60.39	61.61	Tube Temp Out (°F)	148.4	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	126.2	
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	135.5	

^{**} Reynolds Number Outside Range of Equation Applicability



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-MAX FF,w\5% PLUG @ 104 F

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor		0.00250	0.00000	
Shell Fluid Name		·	Fresh Water	
Tube Fluid Name			Fresh Water	
Design Heat Transfer (BT	(U/hr)		41,600,000	
Design Heat Trans Coeff	•	°F)	215.00	
Emprical Factor for Outsi			0.563555000	
Performance Factor (% R	eduction)		0.00	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2)			11,500.00	
Area Factor			0.996344561	
Area Ratio				
Number of Shells per Uni	t		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			Yes	
Total Number of Tubes			1,063 }	71
Number of Active Tubes			1,010J 3 A	१८५६६०
Tube Length (ft)			55.30	
Tube Inside Diameter (in)			0.652	
Tube Outside Diameter (in	•	7)	0.750	
Tube Wall Conductivity (BI U/nr·π·*i	•)	9.40	
Ds, Shell Inside Diameter	, ,		0.000	
Lbc, Central Baffle Spacin	•		0.000	
Lbi, Inlet Baffle Spacing (0.000	
Lbo, Outlet Baffle Spacin	• • •		0.000	
Dotl, Tube circle diameter	(in)		0.000	
Bh, Baffle cut height (in)	hotusan D-	fflo and Chall (in)	0.000	
Lsb, Diametral difference Ltb, Diametral difference		` '	0.000	
Nss, Number Sealing Strip		c and darne (III)	0.000 0.000	
1455, Number Seaming Still	Jo		0.000	

^{*} Fouling Factor input on next page.

Calculation Report for E12-B001 - LSCS - RHR Hx. SDC-MAX FF,w\5% PLUG @ 104 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

≠ Fouling Was Input by User

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	Shell Flow (gpm)	7,124.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)	•	
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.001850
	Fouling Calculation Results	

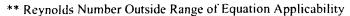
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr ft2.°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.0F/BTU)

Description	Shell-Side	Tube-Side	- · · · · · · · · · · · · · · · · · · ·	· =,
Property	Sileii-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Calculation No. 97-201
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	Revision No. A00
Density (lbm/ft³)			Tube Temp Out (°F)	Attachment D
Cp (BTU/lbm·°F)			Tav Tube (°F)	Page No. 05 of 05
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)	

		 Extrapolation	Calculation	Results
	-		·	

Shell Mass Flow (lbm/hr)		3.564E+6	Overall Fouling (hr-ft2.0F/BTU)	0.001850
Tube Mass Flow (lbm/hr)		3.676E+6	Shell-Side ho (BTU/hr·ft².°F)	961.3
			Tube-Side hi (BTU/hr-ft2.°F)	1,839.3
Heat Transferred (BTU/hr)		2.369E+7	l/Wall Resis (BTU/hr-ft²-°F)	2,148.1
LMTD		9.4	LMTD Correction Factor	0.9140
Effective Area (ft2)		10,926.6		
			U Overall (BTU/hr·ft².ºF)	251.2
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.28	7.04	Shell Temp In (°F)	120.0
Reynold's Number	3.284E+04	5.588E+04	Shell Temp Out (°F)	113.3
Prandtl Number	3.76	4.17	Tav Shell (°F)	116.7
Bulk Visc (lbm/ft·hr)	1.39	1.53	Shell Skin Temp (°F)	114.2
Skin Visc (lbm/ft hr)	1.42	1.50	Tube Temp In (°F)	104.0
Density (lbm/ft³)	61.76	61.90	Tube Temp Out (°F)	110.5
Cp (BTU/lbm °F)	1.00	1.00	Tav Tube (°F)	107.2
K (BTU/hr·ft·°F)	0.37	0.37	Tube Skin Temp (°F)	108.7



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



CLIENT:

Commonwealth Edison / LaSalle County Station

PROJECT:

COMED / LSCS GL 89-13 Program

CALCULATION TITLE:

Thermal Model of COMED / LSCS RHR Heat Exchangers

1(2)RHR01A & B.

CALCULATION NO.:

97-201

FILE NO.:

31-003

COMPUTER CODE & VERSION (if applicable): PROTO-HXTM Version 3.02

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A	<i>5</i> 7 '	D. Physe	S. Ingals 7/16/98	Teller 7/17/28 L. Philpot

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Revision History

Revision	Revision Description
A	Original Issue



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CALCULATION VERIFICATION FORM

REVIEW METHOD: Approach Checked: Logic Checked: Arithmetic Checked: Alternate Method)च्चांच	N/A	EXTENT OF VERIFIC Complete Calculation: Revised areas only:	CATION:
(Attach Brief Summary) Computer Program Used (Attach Listing) Other		N/A I	Other (describe below)	: 🗆
*Errors Detected			*Error Resolution	
Minor editorial			editional + minor nu	merical changes theorporated
*Other Comments				
*Extra References Used */A *(Attach extra sheets if needed)				
CALCULATION FOUND TO BI	E VALID A	ND CONCLUS	SIONS TO BE CORRECT AND) REASONABLE:
IDV Signature:	Sw	HM. Ly	all	Initials:
Printed Name:	560	HM. In	galls	Date: 7/16/98



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A	Proto-Power Calc. 97-201, Rev. A; Vendor Data Sheet & Drawings	5
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С	Proto-Power Calc. 97-201, Rev. A; PROTO-HX™ Calculation Reports and Model Data Sheets	9
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1.0 PURPOSE

The purpose of this calculation is to develop a thermal performance analysis model for the Commonwealth Edison (ComEd) LaSalle Station, Residual Heat Removal Heat Exchanger. This model is to be used for the analysis of heat exchanger thermal performance test data as part of the LaSalle Station heat exchanger testing program.

Once developed, the model is used to evaluate the thermal margin of the heat exchanger at the LaSalle Station Reference Conditions as currently defined in the LaSalle design and licensing basis.

The thermal performance model documented in this calculation has been created and used with PROTO-HX, Version 3.02. The model can be used with previous versions of PROTO-HX and produce identical results as long as the following restrictions are upheld:

- Versions prior to version 3.02 will not calculate a negative fouling factor when calculating the fouling factor based on test data.
- Shell and tube heat exchangers analyzed in Version 3.0 or earlier must have a tube-side Reynolds Number greater than 10,000 (i.e., fully developed turbulent flow).

Current limitations of use for PROTO-HX are established by the limits on fluid properties included within the software. Fluid properties contained within PROTO-HX are currently limited to the following temperature ranges:

• Water (fresh and salt): 32-500°F

2.0 BACKGROUND

LaSalle County Station is in the process of implementing a heat exchanger thermal performance monitoring program in response to the requirements of NRC Generic Letter 89-13 (Reference 8.2). Development of an analytical model in PROTO-HXTM, Version 3.02, will allow timely analysis of data resulting from the test program.

3.0 DESIGN INPUTS

The PROTO-HXTM program was developed and validated in accordance with Proto-Power's Nuclear Software Quality Assurance Program (SQAP). This program meets the requirements of 10CFR50 Appendix B, 10CFR21, and ANSI NQA-1, and was developed in accordance with the guidelines and standards contained in ANSI/IEEE Standard 730/1984 and ANSI NQA-2b-1991. PROTO-HXTM Version 3.02 was verified and approved for use as documented in Reference 8.11.

The design inputs for this calculation consist of the heat exchanger LaSalle Station Reference Condition (Section 3.1), Construction Details (Section 3.2), Performance Details (Section 3.3) provided by the Hx vendor data sheets or design documents as referenced. Construction details give the necessary information for model construction while performance specifications provided



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by the vendor are used to benchmark the models. Section 3.4 discusses the design overall fouling factor used on the vendor data sheets.

3.1. LaSalle Station Reference Condition

Table 3-1 describes the performance requirement of the RHR heat exchanger during Containment Cooling mode of operation.

Table 3-1 Reference Condition - Containment Cooling Mode

Parameter	Value	Reference
Heat Rate (BTU/hr)	155,000,000	8.1
Shell-Side Flow Rate (gpm)	8400	8.1
Shell-Side Inlet Temperature (°F)	212	8.1
Tube-Side Flow Rate (gpm)	7400	8.1
Tube-Side Inlet Temperature (°F)	100	8.1

Table 3-2 describes the performance requirement of the RHR heat exchanger during Shutdown Cooling mode of operation.

Table 3-2 Reference Condition - Shutdown Cooling Mode

Parameter	Value	Reference
Heat Rate (BTU/hr)	41,600,000	8.1
Shell-Side Flow Rate (gpm)	7450	8.1
Shell-Side Inlet Temperature (°F)	120	8.1
Tube-Side Flow Rate (gpm)	7400	8.1
Tube-Side Inlet Temperature (°F)	90	8.1

3.2. Construction Details

The majority of the construction details stay consistent between both the shutdown cooling and containment cooling modes of operation. The values that are specific to a mode of operation or number of available tubes in Table 3-3 are based on the shutdown cooling mode with all tubes available.

Table 3-3 Construction Detail

Parameter	Value	Reference
Heat Exchanger Type	TEMA E / Vertical - AEU	8.6
Total Effective Area per unit (ft ²)	11,500	8.6
Number of Shells per unit	ı	8.6
Tube Passes per shell	2	8.6

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Table 3-3 Construction Detail

Parameter	Value	Reference
U-Tubes (yes or no)	Yes	8.6
Total Number of Tubes	1063	8.6
Tube Length (ft)	55.3	8.6, See below
Tube Inside Diameter (in)	0.652 (18 BWG)	8.6
Tube Outside Diameter (in)	3/4	8.6
Tube Wall Conductivity (BTU/hr-ft-°F)	9.40 (A-249 TP 304L SS)	8.9 (8.6)
Tube Pitch (in)	1	8.6
Pitch Type	Triangle	8.6
Tube Circle Diameter (in)	51.25	8.3

The length of a U-Tube in PROTO-HXTM is twice the straight length of tube plus 30% of the shell diameter (Equation 1). This value is then entered into the PROTO-HXTM data sheet. Based on Reference 8.6 the RHR U-Tube length:

$$U - Tube = 2 \cdot L_{Tube} + 30\% \cdot ID_{Shell}$$

Equation 1

$$L_{Tube} = 50\% \cdot 26.5 \text{ft} + 25\% \cdot 27 \text{ft} + 25\% \cdot 28 \text{ft} = 27 \text{ft}$$

U – Tube=
$$2.27$$
ft+0.30.51.25 in $\frac{1 \text{ft}}{12 \text{in}}$ =55.3 ft

3.3. Performance Details

Table 3-4 shows the performance parameters for the RHR heat exchanger in Containment Cooling mode; whereas, Table 3-5 shows the performance parameters for the RHR heat exchanger in Shutdown Cooling mode. The Shutdown Cooling mode (5% plugged, 53 tubes plugged) performance data was used to create the PROTO-HXTM model.

Table 3-4 Containment Cooling Performance Detail

Parameter	Value	Reference	
Shell Side Fluid Type	Demineralized Water (Fresh)	8.6	
Shell Side Fouling Factor (Design)	0.0005	8.6	
Shell Side Fluid Flow Rate (gpm)	8,400 (4,200,000 lb/hr)	8.6	
Shell Side Inlet Temperature (°F)	212.0	8.6	
Shell Side Outlet Temperature (°F)	All Tubes: 171.6	8.6	
	5% Plugged: 172		
Tube Side Fluid Type	Service Water (Fresh)	8.6	
Tube Side Fouling Factor (Design)	0.002	8.6	

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Table 3-4 Containment Cooling Performance Detail

Parameter	Value	Reference
Tube Side Fluid Flow Rate (gpm)	7,400 (3,700,000 lb/hr)	8.6
Tube Side Inlet Temperature (°F)	100	8.6
Tube Side Outlet Temperature (°F)	All Tubes: 145.9	8.6
	5% Plugged: 145.3	
Design Q - Service (BTU/hr)	All Tubes: 170,000,000	8.6
	5% Plugged: 168,000,000	
Design U - Clean (BTU/hr-ft ² -°F)	All Tubes: 563	8.6
	5% Plugged: 568	
Design U - Service (BTU/hr-ft ² -°F)	All Tubes: 231	8.6
	5% Plugged: 235	
Shell Velocity (ft/sec)	3.82	8.6
Number of Plugged Tubes	All Tubes: 0	8.6
	5% Plugged: 53	

Table 3-5 Shutdown Cooling Performance Detail

Parameter	Value	Reference
Shell Side Fluid Type	Reactor Water (Fresh)	8.6
Shell Side Fouling Factor (Design)	0.0005	8.6
Shell Side Fluid Flow Rate (gpm)	7,450 (3,725,000 lb/hr)	8.6
Shell Side Inlet Temperature (°F)	120.0	8.6
Shell Side Outlet Temperature (°F)	All Tubes: 108.6	8.6
	5% Plugged: 108.8	
Tube Side Fluid Type	Service Water (Fresh)	8.6
Tube Side Fouling Factor (Design)	0.002	8.6
Tube Side Fluid Flow Rate (gpm)	7,400 (3700,000 lb/hr)	8.6
Tube Side Inlet Temperature (°F)	90	8.6
Tube Side Outlet Temperature (°F)	All Tubes: 101.5	8.6
	5% Plugged: 101.25	
Design Q - Service (BTU/hr)	All Tubes: 42,550,000	8.6
	5% Plugged: 41,600,000	
Design U - Clean (BTU/hr-ft ² -°F)	All Tubes: 463	8.6
	5% Plugged: 466	



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Table 3-5 Shutdown Cooling Performance Detail

Parameter	Value	Reference
Design U - Service (BTU/hr-ft ² -°F)	All Tubes: 213	8.6
	5% Plugged: 215	
Shell Velocity (ft/sec)	3.4	8.6
Number of Plugged Tubes	All Tubes: 0	8.6
	5% Plugged: 53	

3.4. VENDOR DESIGN FOULING FACTOR

The PROTO-HX convention for calculating overall fouling factors is to combine the shell-side and tube-side fouling factor using the outside heat transfer surface as the reference area. Equations 2 and 3 show the PROTO-HX method of combining the shell-side and tube-side fouling factors.

$$Area Ratio = \frac{Tube OD}{Tube ID}$$

Equation 2

$$f_{total} = f_{shell} + (Area Ratio) \cdot f_{tube}$$

Equation 3

Table 3-6 shows the results of combining the shell-side and tube-side fouling factors using the area ratio.

Table 3-6 PROTO-HX Design Fouling

Tube ID, in:	0.750
Tube OD, in:	0.652
Area Ratio (OD/ID)	1.150
Tube-side FF	0.002
Shell-side FF	0.0005
Overall FF (Area Ratio)	0.0028006

However, according to the vendor data sheets (Reference 8.6), the design overall fouling factor used by the vendor in the performance analysis presented on the data sheets appears to be approximately 0.0025 verse the 0.0028 calculated in Table 3-6. The fouling factor is calculated from the vendor data sheets by comparing the difference between the service and the clean overall heat transfer coefficients.

$$U = \frac{1}{r(h_i) + r_{\text{tube-side FF}} + r_{\text{wall}} + r_{\text{shell-side FF}} + r(rh_o)}$$
Equation 4

Reference 8.5 discusses that the fouling factor may be calculated directly from the difference between the service and clean overall heat transfer coefficients only when all other parameters remain constant (flow and temperature). Likewise, the total fouling



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factor may be calculated as the sum of the shell-side and tube-side fouling factors (Equation 5).

$$f_{total} = f_{tube-side} + f_{shell-side}$$

Equation 5

Table 3-7 shows that the difference between the service and clean overall heat transfer coefficients is approximately 0.0025. The variations in the fouling factor can be attributed to the round-off error as reported on the vendor data sheets.

Table 3-7 Vendor Data Sheet Fouling Factor

Vendor Data Sheet	U-Service	U-Clean	Fouling (U)
All Tubes - SDC	213	463	0.0025350
5% PLG - SDC	215	466	0.0025052
All Tubes - CCM	231	563	0.0025528
5% PLG - CCM	235	568	0.0024948
		Overall FF=	0.0025

Therefore, the PROTO-HX benchmarking of the RHR model will be performed with an overall fouling factor of 0.0025 versus the standard PROTO-HX method of referencing the fouling resistances to the outside heat transfer area. For PROTO-HX to use the 0.0025 value for fouling it will be entered into the heat exchanger data sheet as a shell-side fouling factor and zero will be entered as the tube-side fouling factor.

The direct addition of the shell-side and tube-side fouling factors will yield a more conservative model then the standard PROTO-HX method of combining the fouling factors. This is because the Hoff calculated at data sheet conditions with a lower overall fouling factor is lower than that calculated with the higher value of overall fouling factor.

4.0 APPROACH

This calculation utilizes plant/vendor fabrication specifications provided in Attachment (A) to develop a thermal performance prediction model for the LSCS RHR Hx. The calculation then benchmarks the models by comparing the heat transfer rate calculated by PROTO-HXTM Version 3.02 with the vendor's specifications for thermal performance under different cooling modes.

4.1. PROTO-HXTM PARAMETER CALCULATION

Minimum Shell Area

The minimum shell area is calculated using either the shell side velocity or shell geometry. The preferred method of calculation is using the shell side velocity. Reference 8.6 gives the shell side velocity to be 3.4 ft/sec at a flow rate of 7396.31 gpm (Section 4.3). Based on this velocity and flow rate the minimum shell side area is 4.880 ft².

Outside H Factor (Hoff)



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The Outside H Factor is a multiplier, with value less then 1.0, used to reduce the ideal shell side film heat transfer coefficient. The Outside H Factor accounts for inefficiency in the heat exchanger. Using the back calculation method, based on the design overall heat transfer coefficient (215 Btu/hr ft² °F), the Outside H Factor was calculated by PROTO-HXTM to be 0.56355.

4.2. PROTO-HXTM EXTRAPOLATION METHOD

All calculations performed for this calculation are based on a constant cold inlet temperature (except where noted). This allows the comparison of the heat transfer, outlet temperatures, log mean temperature difference (LMTD), and heat transfer coefficient. There is no comparison of the heat transfer coefficient in the design case since PROTO-HXTM used the data sheet value of the heat transfer coefficient to calculate the outside heat transfer coefficient.

4.3. PROTO-HX FLOW RATE INPUTS

The vendor data sheets have the actual heat exchanger mass flow rates listed on them. The mass flow must be converted to a volumetric flow rate at 60°F for entry into PROTO-HX.

$$Q_{\text{PHX}} = \frac{7.48 \cdot \dot{m}}{60 \cdot \rho_{60^{\circ} \text{F}}}$$
 Equation 6

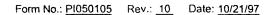
Table 4-1 Vendor Data Sheet: PROTO-HX Flow Rate Inputs

Parameter	Actual Flow (lb/hr)		PROTO-HX Input (gpm)
Tube-side, 90°F	3,700,000		7396.31
Tube-side, 100°F	3,700,000		7396.31
Shell-side, 120°F	3,725,000		7446.28
Shell-side, 212°F	4,200,000		8395.81
Density, 60°F	62.364 lb/ft ³	(8.12)	

Volumetric flow rates are converted to mass flow rates based on a set temperature of 60°F in PROTO-HX. Therefore, the actual PROTO-HX inputs have to be adjusted to give the correct mass flow rate. The PROTO-HX input is adjusted using the ratio of the actual water density and the density of water at 60°F.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60^{\circ}E}}$$

Equation 7



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Table 4-2 Reference Condition: PROTO-HX Flow Rate Inputs

Parameter	Density (l	b/ft ³)	Actual Flow (gpm)	PROTO-HX Input (gpm)
Tube-side, 90°F	62.113	(8.12)	7400	7370.22
Tube-side, 100°F	61.994	(8.12)	7400	7356.08
Shell-side, 120°F	61.712	(8.12)	7450	7372.02
Shell-side, 212°F	59.823	(8.12)	8400	8057.65
PROTO-HX, 60°F	62.364	(8.12)		

5.0 ASSUMPTIONS

- 5.1. For the containment cooling mode of operation with a 212°F shell side inlet temperature all fluid entering the shell is considered to be in the liquid phase. This is consistent with the vendor's analysis of the heat exchanger in Reference 8.6. Therefore, future validation of this assumption is not required.
- 5.2. The vendor data sheet (Reference 8.6) is considered an accurate reflection of the vendor's expectation for the heat exchanger's outside film heat transfer coefficient. Therefore, the benchmarking of the PROTO-HX model to the vendor data sheet will ensure that the PROTO-HX calculated outside film heat transfer coefficient is consistent with the vendor's expectation. Future validation of this assumption is not required.





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6.0 ANALYSIS

6.1. PROTO-HXTM MODEL

Table 6-1 compares the PROTO-HX[™] (P-HX) values to the values shown on the Vendor Data Sheets (V - DS). PROTO-HX output reports can be found in Attachment C.

Table 6-1 PROTO-HX Model Results

	CONTAINMENT COOLING MODE				SHUTDOWN COOLING MODE			
	ALL TUBES		5% PLUGGED		ALL TUBES		5% PLUGGED	
Parameter	P-HX	V-DS	P-HX	V – DS	P-HX	V - DS	P-HX	V - DS
Shell Side Outlet Temp, °F	171.7	171.6	172.7	172	108.6	108.6	108.9	108.8
Tube Side Outlet Temp, °F	146.0	145.9	144.9	145.3	101.5	101.5	101.2	101.25
Heat Transferred, BTU/hr	1.7 E8	1.70 E8	1.658E8	1.68 E8	4.251E7	4.255E7	4.147E7	4.16E7
Heat Transfer Coef, BTU/hr ft ² °F	230.7	231	231.9	235	213.7	213	215	215
Corrected LMTD	64.0	64.1	65.5	65	17.26	17.35	17.6	17.6

Table 6-2 shows the correlation between the manufacture data sheets and the PROTO-HXTM model. PROTO-HX output reports can be found in Attachment C.

Table 6-2 PROTO-HX Model Correlation

Parameter	CONTAINMENT	COOLING MODE	SHUTDOWN COOLING MODE		
	ALL TUBES (%)	53 PLUGS (%)	ALL TUBES (%)	53 PLUGS (%)	
Shell Side Outlet Temp	0.06	0.41	0.00	0.09	
Tube Side Outlet Temp	0.07	-0.27	0.00	-0.05	
Heat Transferred	0.00	-1.31	-0.09	-0.31	
Heat Transfer Coef	-0.13	-1.32	0.33	N/A	
Corrected LMTD	-0.16	0.77	-0.52	0.00	

6.2. FOULING SENSITIVITY

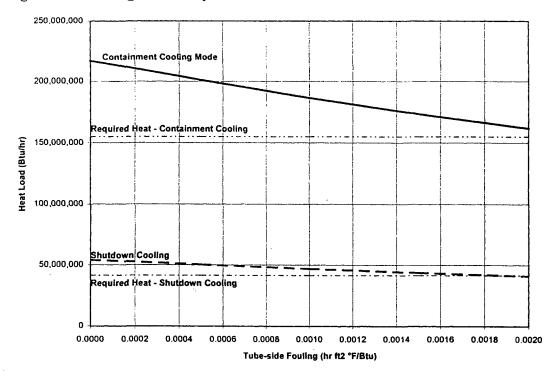
The fouling sensitivity of the jacket water cooler is shown in Figure 6-1. The fouling sensitivity was developed at both sets of Reference Conditions (Table 3-1 and Table 3-2). The tube-side fouling factor was varied from 0.0000 until the required heat load was met by increments of 0.0005 (hr ft² °F/Btu). The shell-side fouling factor is held constant at the design value of 0.0005 (hr ft² °F/Btu). The fouling factors overall fouling factors where entered in PROTO-HX based on the combining of the tube-side and shell-side fouling factors as described in the Heat Exchanger Design Handbook (Reference 8.5). The PROTO-HX Calculation Reports for the fouling sensitivity can be found in Attachment D.



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PROTO-POWER CORPORATION	CALC NO. 97-201	REV A	PAGE 10 OF 12
GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		/DATE 7/16/98 _
	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LSCS GL 89-13 Program		
TITLE Thermal Model of COMED / LaSalle Station RHR Heat Exchangers 1(2)RHR01A & B.			A & B.

Figure 6-1 Fouling Sensitivity



6.3. THERMAL PERFORMANCE MARGIN

The clean thermal margin is assessed by a comparison of the reference condition performance requirements to the heat exchanger performance capability with a zero (0) fouling factor. Using a zero (0) fouling factor shows the maximum available performance of the heat exchanger. Likewise, the service thermal margin is assessed by comparing the reference condition performance requirements to the heat exchanger performance capability with the design fouling factor.

The margin is calculated directly and as a percentage compared to the required heat rate to perform the component's safety function. The PROTO-HX reports can be found in Attachment E.

Equation 8

% Margin=
$$100 \cdot \frac{\text{Margin}}{(\text{Heat Rate})_{\text{required}}}$$

Equation 9



PROTO-POWER CORPORATION	CALC NO. 97-201	REV A	PAGE 11 OF 12	
GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		/DATE 7/16/98 _	
	VERIFIED BY S. Ingalls		JOB NO. 31-003	
CLIENT COMED / LaSalle County Station	PROJECT COMED / LSCS GL 89-13 Program			
Thermal Model of COMED / LaSalle Station RHR Heat Exchangers 1(2)RHR01A & B.				

Table 6-3 Thermal Margin - Containment Cooling Mode

	Service (De:	sign Fouling)	Clean (0 Fouling)	
Parameter	All Tubes	53 Plugs	All Tubes	53 Plugs
Heat Transfer Rate	167,700,000	163,700,000	230,700,000	228,700,000
Required Heat Transfer Rate	155,000,000	155,000,000	155,000,000	155,000,000
Thermal Margin	12,700,000	8,700,000	75,700,000	73,700,000
% Thermal Margin	8.19%	5.61%	48.84%	47.55%

Table 6-4 Thermal Margin - Shutdown Cooling Mode

	Service (De	sign Fouling)	Clean (0 Fouling)	
Parameter	All Tubes	53 Plugs	All Tubes	53 Plugs
Heat Transfer Rate	42,330,000	41,310,000	57,440,000	56,840,000
Required Heat Transfer Rate	41,600,000	41,600,000	41,600,000	41,600,000
Thermal Margin	730,000	-290,000	15,840,000	15,240,000
% Thermal Margin	1.75%	-0.70%	38.08%	36.63%

Table 6-5 Adjusted Tube Plugging for Shutdown Cooling

Parameter	Shutdown Cooling – 38 Plugs
Heat Transfer Rate	41,600,000
Required Heat Transfer Rate	41,600,000
Thermal Margin	0
% Thermal Margin	0.00%

7.0 CONCLUSION

7.1. PROTO-HXTM MODEL

The RHR Hx Model was developed using PROTO-HXTM, Version 3.02. The model was benchmarked and validated using the vendor supplied performance data sheets (Containment Cooling and Shutdown Cooling) for the heat exchangers. Model correlation to the vendor's performance specification for Shutdown Cooling Mode with 53 Plugs was within one percent (-0.31 %). The model correlation with other modes of operation can be found in Table 6-2.

This model should be considered suitable for use in the analysis of thermal performance test data.



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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		/DATE 7/16/98	
	VERIFIED BY S. Ingalls		JOB NO. 31-003	
CLIENT COMED / LaSalle County Station	PROJECT COMED / LSCS GL 89-13 Program			
THE Thermal Model of COMED / LaSalle Station RHR Heat Exchangers 1(2)RHR01A & B.				

7.2. FOULING SENSITIVITY

Given a constant shell-side fouling at the model design value, the sensitivity of the RHR heat exchanger to tube-side fouling effects is shown on Figure 6-1.

7.3. THERMAL PERFORMANCE MARGIN

The available clean thermal margin of the RHR heat exchanger with no tubes plugged in Containment Cooling Mode of operation is 48.84% margin as compared to the Shutdown Cooling Mode of operation margin of 38.08%.

Table 6-3 through Table 6-5 show the thermal margin for the RHR heat exchanger in both the Containment Cooling and Shutdown Cooling modes in service and clean conditions at various tube plugging levels.

For the Shutdown Cooling mode with tubes plugged, the maximum allowable plugs allowed to still meet the required heat load with design fouling is 38 plugs.

8.0 REFERENCES

- 8.1. Process Flow Diagram, Residual Heat Removal System, 731E966AA Sheets 1 & 3 (Attachment B)
- 8.2. NRC Generic Letter 89-13
- 8.3. Struthers Wells Drawing 1-71-04-30971 D2, Revision 1, "2-Pass Tube Layout for 52" I.D. Residual Heat Removal Hx. 52-27U12-6V"
- 8.4. Calculation Acceptance Letter by COMED, Dated 2/6/98 (Attachment D)
- 8.5. Heat Exchanger Design Handbook, Volume 3, Thermal and Hydraulic Design of Heat Exchangers, Hemisphere Publishing Corp., Rev. 1989
- 8.6. Struther Wells Hx Data Sheet (Attachment A)
- 8.7. LSCS Drawing, VPF 3161-4-6, J-2500
- 8.8. LSCS Drawing, VPF 3161-8-2, J-2500
- 8.9. PROTO-HXTM User Manual
- 8.10. LSCS Drawing, T-2792, J-2500
- 8.11. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HX[™] Version 3.02 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision F, dated 2/17/98
- 8.12. Proto-Power Calculation 93-048, "Fluid Properties Fresh Water Range 32°F to 500°F", Rev. A



Attachment A to Proto-Power Calculation 97-201 Revision A

Proto-Power Calc: 97-201

Attachment: A

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SECTION X

18011.4

STRUTHERS WELLS CORPORATION



Heat Exchanger Specification Sheet

	ALL TUBES AVAILAB	LE - SHUT	DOWN OP	ERATING MODE
1			JO	B NO.
2	CUSTOMER GENERAL ELEC	TRIC COMPA		FERENCE NO. 205-AA 668
3	ADDRESS San Jose, Ca	lifornia	<i>FQ</i>	NOWEXCOR NO. (S.W.) 1-71-04-30971
4	PLANT LOCATION La Salle I A	La Salle II	DA	TE 5/19/71
5	SERVICE OF UNIT Residual Heat	t Removal He	S)	EM NO. F12-R001
6	SIZE 52"T.D x 27 Aug.T1. TYPE (SURF./UNIT (EFF.) 11, 790	TEMAL "AEU"	IVERT XXXXXX	XXXXX Channel Down
7	SURF./UNIT (CFF.) 11, 500	SHELLS/UNIT	me* surf./s	HELL (GRES) 11,790
8	* Four (4) Units Read	PERFORMANCE		
9		SHELL S		TUBE SIDE
10	FLUID CIRCULATED	Reactor	Water	Service Water
11	TOTAL FLUID ENTERING #/HR	3,725,000	(7450 GPM)	3700.000 (7400 GPM)
12	VAPOR			
13	LIQUID	3,725,000		3,700,000
14	STEAM			
15	NON-CONDENSABLES			
16	FLUID VAPORIZED OR CONDENSED			
17	STEAM CONDENSED			
18	SPECIFIC GRAVITY			
19	VISCOSITY			
20	MOLECULAR WEIGHT			
21	SPECIFIC HEAT BTU/LB °F			
22	THERMAL CONDUCTIVITY BTU/HR-FT-°F			
23	LATENT HEAT BTU/LB			
24	TEMPERATURE OUT °F	120.0		90.0
25		10.8.6	<u> </u>	
26 27	OPERATING PRESSURE PSIG			• •
28	VELOCITY FT/SEC	- One		Two
29	PRESSURE DROP Max. PSI	3.4 Avg. L		6.7
30	FOULING RESISTANCE (MIN)	8.5		9.0
31		.0005	MTD CORRECT	•002 IED. °F \7.35
32	TRANSFER RATE - SERVICE	213	CLEAN	463
33			ONE SHELL (5.66	Shutdown Mode 5% tubes pl
34	DESIGN PRESSURE PSIG			Pharespan I bue 3/6 mocs p
35	TEST.PRESSURE PSIG			
36	DESIGN TEMPERATURE °F		······	
37	TUBES NO. O.D	. , BWG	MIN. SULS. AVG. NLD. LEN	GTH PITCH
38	SHELL I. D. O.D		SHELL COVER	(INTEG.)(REMOV.)
39	CHANNEL OR BONNET		CHANNEL COVER	
40	TUBESHEET-STATIONARY		TUBESHEET FLOAT	ING .
41 [BAFFLE-CROSS TYPE		FLOATING HEAD CO	OVER
42	BAFFLES-LONG TYPE		IMPINGEMENT PROT	ECTION
43	TUBE SUPPORTS			
44	TUBE TO TUBE SHEET JOINT			
45	GASKETS			
46	CONNECTIONS-SHELL SIDE IN	OUT	RATING	
47	CHANNEL SIDE IN	OUT	RATING	·
48	CORROSION ALLOWANCE-SHELL SIDE	TUBE SID	<u> </u>	
49	CODE REQUIREMENTS		TEMA CLA	ASS
50	REMARKS			
51			~~ ~~~	
52		·		
53			N-a-t	a Power Cala: 97-701
54 L			rrot	o-Power Calc: 97-201

Attachment: A

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SECTION X

STRUTHERS WELLS CORPORATION



Heat Exchanger Specification Sheet

		•	
	FIVE PERCENT TUB	ES PLUGGED - SHUTP	OWN OPERATING MODE
1			8 NO.
2	CUSTOMER GENERAL ELEC	TRIC COMPANY RE	FERENCE NO. 205 - AA 668
3	ADDRESS Son Jose Co	difornia pa	2970541 NO. (S.W.) 1-71-04-30971
4	PLANT LOCATION La Salle I		TE 5/19/71
5	SERVICE OF UNIT Residual Hea	t Removal Heat Exchs. 171	M NO. E12-BOOL
•	SIZE 52" T.D. × 27' AVG. T.L. TYPE (TEMAL "AEU" IVEHT, CORORO	
7	SURF./UNIT IGENSU 11.790		HELL IGROSSI 11,790
	* Four (4) Units Read	PERFORMANCE OF ONE UNIT	THE STATE OF THE S
9	38 1001 (+) Citt's 10-160	SHELL SIDE	TUBE SIDE
10	FLUID CIRCULATED	Reactor Water	Service. Water
11	TOTAL FLUID ENTERING #/HR	3.725.000 (7450 GPM)	3,700,000 (7,400 GPM)
12	VAPOR	1	3.100,000 (1,400 GP-1)
13	Liquip	3.725.000	3.700,000
14	STEAM	3.73,000	3.100,080
15	NON-CONDENSABLES		
16	FLUID VAPORIZED OR CONDENSED		
17	STEAM CONDENSED		
	SPECIFIC GRAVITY		
15			
19	VISCOSITY		
20	MOLECULAR WEIGHT		
21	SPECIFIC HEAT BTU/LB *F		
22	THERMAL CONDUCTIVITY BTU/HR-FT-*F		
23	LATENT HEAT BTU/LB		
24	TEMPERATURE IN *F	120.0	90.0
25	TEMPERATURE OUT *F	108.8	101.25
26	OPERATING PRESSURE PSIG		
27	NO. PASSES PER SHELL	One	Two
28	VELOCITY FT/SEC	3.4 Aug. Long	7.04
29	PRESSURE DROP Max. PSI	8.5	10.0
30	FOULING RESISTANCE (MIN)	.0005	.002
31	HEAT EXCHANGED, BTU/HR 41, 60	MTD CORRECT	ED. °F 17-6
32	TRANSFER RATE - SERVICE 2	CLEAN CLEAN	466
33		CONSTRUCTION OF ONE SHELL	
- 34	DESIGN PRESSURE PSIG	500	150
35	TEST, PRESSURE PSIG	Per Code	Per Code
36	DESIGN TEMPERATURE *F	40 to 480	32 to 480
37	TUBES 304L \$ (A-249) NO.1063 U;0.0	. 3/4" . BWG 18 MARE WLU. LEN	GTH * ** PITCH 1" Triang.
38	SHELL C.S. w/3041/scha. D. 52" RA	SHELL COVER C.S	w/304L3/s Clad(INTEG.)0700000
39	CHANNEL OR BONNET C.S. W/Carbo	mastic Coating CHANNEL COVER	C.S. w/ Carbomastic Coating
40		4 L S/S TUBESHEET FLOAT	
41	BAFFLE-CROSS 304 S/s TYPE Mod.	Split Flow FLOATING HEAD CO	VER
42	BAFFLES-LONG TYPE	IMPINGEMENT PROT	ection Yes
43	TUBE SUPPORTS 304 L 3/3 - LT	Bend Support	
44	TUBE TO TUBE SHEET JOINT Welde		
45		sb.	
46	CONNECTIONS-SHELL SIDE IN 18"	OUT 18" RATING	W.E.
47	CHANNEL SIDE IN 18"	OUT 18" RATING	W.E.
44	CORROSION ALLOWANCE-SHELL SIDE PER SE		
49	CODE REQUIREMENTS Shell Side - Se		
50	REMARKS Performance cond		
51	being plugged ***	Approximately 50% of	
52	111111111111111111111111111111111111111		
53		19th of 28'	straight length and
	THE POLY STEATON IEL	4111 01 10	
[Prote	D-Power Calc: 97-201
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Attachment: A

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SECTION X

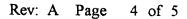
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STRUTHERS WELLS CORPORATION



Heat Exchanger Specification Sheet

	ALL TUBES AVAILA	BLE - CONTA	INMENT C	OOLING MODE
1			70	B NO.
2	CUSTOMER GENERAL ELE		BNY RE	FERENCE NO. 205 - AA 668
3	ADDRESS San Jose C	alifornia	<i>1</i> 600	070000 NO. (s.w.) 1-71-04-30971
4		La Salle II	DA	TE 5/19/71
5	SERVICE OF UNIT Residual Heat	Removal Heat		M NO. E12-BOOL
6	SIZE 52" I.D. x 27 Avg. T.L. TYPE (T	TEMAL "AEU"	(VEHIL) REMESO	Propose Channel Down
j	SIZE 52" I.D. x 27" Avg. T.L. TYPE (7	SHELLS/UNIT C	me* SURF./S	HELL GROSSI 11.790
-8	* Four (4) Units Read	PERFORMANCE		
9		SHELL S	IDE	TUBE SIDE
10	FLUID CIRCULATED	Demin. h	later	Service Water
11	TOTAL FLUID ENTERING #/HR	4,200,000	(8400GPM)	3,700,000 (7400 GPM)
12	VAPOR			
13	LIQUID	4,200,000		3.700,000
14	STEAM			
15	NON-CONDENSABLES			
16	FLUID VAPORIZED OR CONDENSED	<u> </u>		
17	STEAM CONDENSED			
18	SPECIFIC GRAVITY			
19	VISCOSITY			
20	MOLECULAR WEIGHT		·	
21	SPECIFIC HEAT BTU/LB °F			•
22	THERMAL CONDUCTIVITY BTU/HR-FT-°F			
23	LATENT HEAT BTU/LB			
24	TEMPERATURE IN °F	212.c	·	100.0
25	TEMPERATURE OUT *F	171.6	·	145.9
26	OPERATING PRESSURE PSIG			
27 28	NO. PASSES PER SHELL VELOCITY FT/SEC	One		Two
29		•	-ong	6.7
30	PRESSURE DROP MGX. PSI FOULING RESISTANCE (MIN)	ميما	_	9.0
31		.000	MTD CORRECT	•002
32	1/O ₊ .Q	<u>00,000 </u>	CLEAN	563
33				Shutdown Mode 5% tubes
34	DESIGN PRESSURE PSIG		3.2 4.356	Shundaun Place 3/8 fures
35	TEST PRESSURE PSIG			
35	DESIGN TEMPERATURE *F			
37	TUBES NO. O.D.	. BWG	MIN. SMLS. AVG. WLD. LEN	GTH PITCH
38	SHELL I. D. O.D).	SHELL COVER	(INTEG.)(REMOV.)
39	CHANNEL OR BONNET		CHANNEL COVER	
40	TUBESHEET-STATIONARY		TUBESHEET FLOAT	ING
41	BAFFLE-CROSS TYPE		FLOATING HEAD CO	IVER
42	BAFFLES-LONG TYPE		IMPINGEMENT PROT	ECTION
43	TUBE SUPPORTS		·	
44	TUBE TO TUBE SHEET JOINT	<u> </u>		
45	GASKETS	·		· · · · · · · · · · · · · · · · · · ·
46	CONNECTIONS-SHELL SIDE IN	OUT	RATING	
47	CHANNEL SIDE IN	OUT	RATING	
46	CORROSION ALLOWANCE-SHELL SIDE	TUBE SID	E	
48	CODE REQUIREMENTS		TEMA CLA	ASS
50	REMARKS			
51				
⁵² -			Droto	Power Calc: 97-201
53	**************************************	~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~~		Power Calc: 97-201



18011.6

STRUTHERS WELLS CORPORATION



Heat Exchanger Specification Sheet

	FIVE PERCENT TUBE	ES PLUGGE		NMENT COOLING MODE
2	CUSTOMER CENERAL ELE			FERENCE NO. 205 - AA 668
3			HNY	HOMOPPL NO. (3.W.) 1-71-04-30971
4	PLANT LOCATION La Salle I	California & La Salle :		11E 5/19/71
•	SERVICE OF UNIT Residual Heat	P -a sall	<u> </u>	EM NO. F. 12 - BOOL
8	SIZE 63 T D = 37'A T L TYPE (Removal He	A A A A COLL	
,	SURE 52" I.D. # 27 Avo. T.L. TYPE (SURE JUNIT (CROSS) 11, 790			WELL (GROSS) (1.790
	* Four (4) Units Read	PERFORMANCE		BRELL (EFF.) U, AAA
9	A POUR 14) UNITS NEGO	SHELL S		TUBE SIDE
10	FLUID CIRCULATED		later	Service Water
11	TOTAL FLUID ENTERING #/HR	1	(8400 GPM)	3,700,000 (7400 GPM)
12	VAPOR	4,200,000	TOURD RAW	3,700,000 <u>C7400 Gert</u>
13	LIQUID	4,200,000		3,700,000
14	STEAM		 	
15	NON-CONDENSABLES	<u> </u>	·	
16	FLUID VAPORIZED OR CONDENSED			
17	STEAM CONDENSED		····	-
18	SPECIFIC GRAVITY		·	
19	VISCOSITY	· · · · · · · · · · · · · · · · · · ·		
20	MOLECULAR WEIGHT	· · · · · · · · · · · · · · · · · · ·		
21	SPECIFIC HEAT BTU/LB °F			
22	THERMAL CONDUCTIVITY BTU/HR-FT- F			
23	LATENT HEAT BTU/LB			
24	TEMPERATURE IN	212		100
25	TEMPERATURE OUT 4F	172		1.4.5.3
26	OPERATING PRESSURE PSIG			
27	NO. PASSES PER SHELL	One	·	Τωο
28	VELOCITY FT/SEC	3.82 A	va. Long	7.04
29	PRESSURE DROP Max PSI	10.0	ـــــــــــــــــــــــــــــــــــ	10.0
30	FOULING RESISTANCE (MIN)	.000		- 002
31		000,000	MTD CORREC	
32	TRANSFER RATE - SERVICE	235	CLEAN	568
33	DESIGN PRESSURE PSIG	CONSTRUCTION OF	ONE SHELL (See Shutdown Model
34	TEST_PRESSURE PSIG	 		
35 36	DESIGN TEMPERATURE OF	 	***************************************	
37 F	TUBES NO. O.D	. BWG	U.W. SULS. AVG. WLO. LEN	GTH PITCH
18 F	SHELL I.D. O.D		SHELL COVER	(INTEG.)(REMOV.)
39	CHANNEL OR BONNET	`~~```	CHANNEL COVER	
60 T	TUBESHEET-STATIONARY	***************************************	TUBESHEET FLOAT	ING
"	BAFFLE-CROSS TYPE		FLOATING HEAD CO	OVER
12	BAFFLES-LONG TYPE		IMPINGEMENT PROT	ECTION
13 [TUBE SUPPORTS			
4	TUBE TO TUBE SHEET JOINT			
5	GASKETS			
18	CONNECTIONS-SHELL SIDE IN	OUT	RATING	
7	CHANNEL SIDE IN	OUT	RATING	
8 _	CORROSION ALLOWANCE-SHELL SIDE	TUBE SID	Ε	
۰	CODE REQUIREMENTS		TEMA CL	
٥		conditions a	re based	on 53 U-tubes
1	being plugged.			
2				
³			Proto-	Power Calc: 97-201
4 L			11010	

Attachment: A

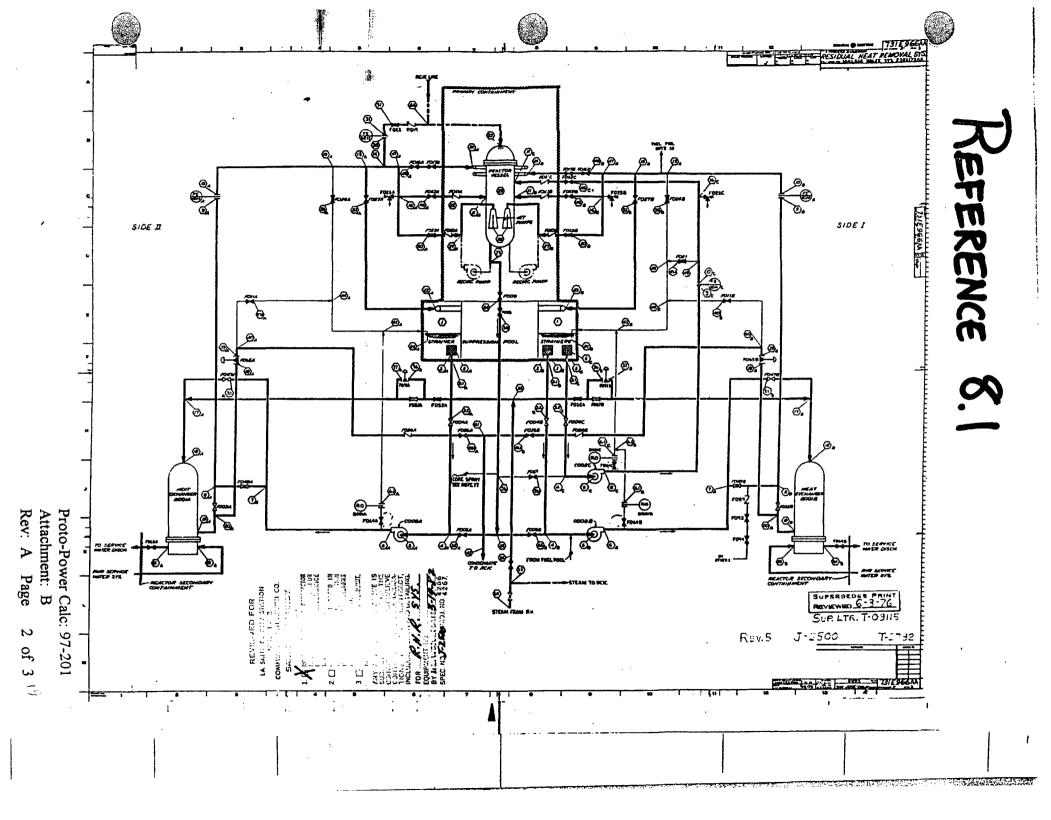
Rev: A Page 5 of 5

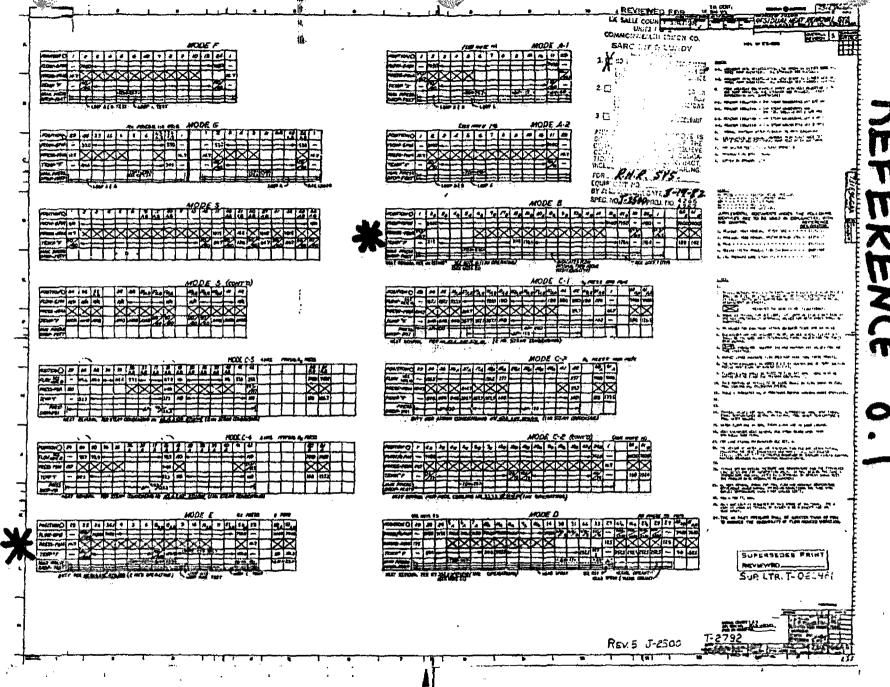
Attachment B to Proto-Power Calculation 97-201 Revision A

Proto-Power Calc: 97-201

Attachment: B

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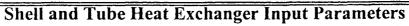
Attachment C to Proto-Power Calculation 97-201 Revision A

Proto-Power Calc: 97-201

Attachment: C

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Calculation Report for E12-B001 - LSCS - RHR Hx. SDC - All Tubes, Vendor Fouling



		inger input i ai		
		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	7,446.28	7,396.31	
Inlet Temperature	°F	120.00	90.00	
Outlet Temperature	°F	108.80	101.25	
Fouling Factor		0.00250	0.00000	
Shell Fluid Name			Fresh Water	
Tube Fluid Name			Fresh Water	
Design Heat Transfer (B	TU/hr)		41,600,000	
Design Heat Trans Coef	f (BTU/hr·ft²	·°F)	215.00	
Emprical Factor for Outs	side h		0.563555000	
Performance Factor (% I	Reduction)		0.00	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2)			11,500.00	
Area Factor			0.996344561	
Area Ratio				
Number of Shells per Ui	nit		1	
Shell Minimum Area			4.880000000	
Shell Velocity (ft/s)			3.400	
Tube Pitch (in)			1.0000	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			Yes	
Total Number of Tubes			1,063 5	_
Number of Active Tubes	S		1,063	_
Tube Length (ft)	_		55.30	
Tube Inside Diameter (in	n)		0.652	
Tube Outside Diameter	•		0.750	
Tube Wall Conductivity	` '	°F)	9.40	
Ds, Shell Inside Diamete	er (in)		0.000	•
Lbc, Central Baffle Space	` '		0.000	
Lbi, Inlet Baffle Spacing	• , ,		0.000	
Lbo, Outlet Baffle Space			0.000	
Dotl, Tube circle diamet	• ,		0.000	
Bh, Baffle cut height (in	• •		0.000	
Lsb, Diametral difference		affle and Shell (in)	0.000	
Ltb, Diametral difference		` '	0.000	
Nss, Number Sealing St			0.000	
, 5	•			

Proto-Power Calc: 97-201

Attachment: C

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Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - All Tubes, Vendor Fouling



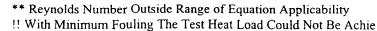
Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I)ata
Data Date	Tube Flow (gpm)	7,396.3
Shell Flow (gpm)	Shell Flow (gpm)	7,446.3
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)	• • •	
Tube Temp In (°F)		
Tube Temp Out (°F)		
Fo	ouling Calculation Results	
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr-ft².°F)	
	Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.0} F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		

` ,			Overall Fouling (hr-ft2.°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp [†] (BTU/lbm-°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		3.725E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500
Tube Mass Flow (lbm/hr)		3.7E+6	Shell-Side ho (BTU/hr·ft²-°F)	977.6
Tube Mass Flow (lottern)		3.72.10	,	
H+TC +(DTH/h-		4.0515.7	Tube-Side hi (BTU/hr ft².ºF)	1,666.6
Heat Transferred (BTU/h	r)	4.251E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		18.5	LMTD Correction Factor	0.9328
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr·ft ² .°F)	213.7
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.43	6.72	Shell Temp In (°F)	120.0
Reynold's Number	3.354E+04	4.729E+04	Shell Temp Out (°F)	108.6
Prandtl Number	3.86	4.77	Tav Shell (°F)	114.3
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.2
Skin Visc (lbm/ft·hr)	1.48	1.67	Tube Temp In (°F)	90.0
Density (lbm/ft3)	61.80	62.05	Tube Temp Out (°F)	101.5
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	95.7
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	98.5
			Proto-Power Calc: 97-201	



Proto-Power Calc: 97-201

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Calculation Report for E12-B001 - LSCS - RHR Hx. SDC - 53 Plugs, Vendor Fouling



Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F	108.80	101.25
Fouling Factor		0.00250	0.00000
Shell Fluid Name	<u> </u>		Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B	TU/hr)		41,600,000
Design Heat Trans Coef	•	°F)	215.00
Emprical Factor for Outs			0.563555000
Performance Factor (% I	Reduction)	•	0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			11,500.00
Area Factor			0.996344561
Area Ratio			
Number of Shells per Ur	nit		1
Shell Minimum Area			4.880000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes	3		1,010
Tube Length (ft)			55.30
Tube Inside Diameter (in	•		0.652
Tube Outside Diameter	` '		0.750
Tube Wall Conductivity	(BTU/hr·ft·°)	F)	9.40
Ds, Shell Inside Diamete	er (in)		0.000
Lbc, Central Baffle Space	ing (in)		0.000
Lbi, Inlet Baffle Spacing	g (in)		0.000
Lbo, Outlet Baffle Spaci	• • •		0.000
Dotl, Tube circle diamet	, ,		0.000
Bh, Baffle cut height (in	,		0.000
Lsb, Diametral difference		` '	0.000
Ltb, Diametral differenc		be and Baffle (in)	0.000
Nss, Number Sealing Str	nps		0.000

Proto-Power Calc: 97-201

Attachment: C

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Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - 53 Plugs, Vendor Fouling

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation D	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,396.3		
Shell Flow (gpm)	Shell Flow (gpm)	7,446.3		
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)				

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft ^{2.o} F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

			Overall Founding (III II - F/D
Property	Shell-Side	Tube-Side	5 .
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp'(BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3.725E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500
Tube Mass Flow (lbm/hr)		3.7E+6	Shell-Side ho (BTU/hr-ft².°F)	978.0
,			Tube-Side hi (BTU/hr-ft2.°F)	1,734.7
Heat Transferred (BTU/hr)		4.147E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		18.8	LMTD Correction Factor	0.9382
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft².°F)	215.0
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3,43	7.07	Shell Temp In (°F)	120.0
Reynold's Number	3.359E+04	4.970E+04	Shell Temp Out (°F)	108.9
Prandtl Number	3.85	4.78	Tav Shell (°F)	114.4
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.3
Skin Visc (lbm/ft·hr)	1.48	1.68	Tube Temp In (°F)	90.0
Density (lbm/ft³)	61.80	62.05	Tube Temp Out (°F)	101.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	95.6
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	98.3

** Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie

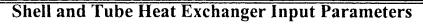
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Proto-Power Calc: 97-201



Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - All Tubes, Vendor Fouling



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F	108.80	101.25
Fouling Factor		0.00250	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B	ΓU/hr)		41,600,000
Design Heat Trans Coeff	(BTU/hr·ft²	°F)	215.00
Emprical Factor for Outs	ide h		0.563555000
Performance Factor (% R	leduction)		0.00
Heat Exchanger Type			ТЕМА-Е
Effective Area (ft^2)			11,500.00
Area Factor			0.996344561
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area			4.880000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes			1,063
Tube Length (ft)			55.30
Tube Inside Diameter (in	3		0.652
Tube Outside Diameter (•		0.750
Tube Wall Conductivity	•	F)	9.40
-	•	,	0.000
Ds, Shell Inside Diamete	` '		0.000
Lbc, Central Baffle Spac	• · ·		0.000
Lbi, Inlet Baffle Spacing			0.000
Lbo, Outlet Baffle Spacin	• ,		0.000
Dotl, Tube circle diameter	• •		0.000
Bh, Baffle cut height (in)		offle and Shall (in)	0.000
Lsb, Diametral difference Ltb, Diametral difference		` '	0.000
Nss, Number Sealing Str		ive and darne (in)	0.000
1400, Indition Deating 311	iha		0.000

Proto-Power Calc: 97-201

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Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - All Tubes, Vendor Fouling



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,396.3	
Shell Flow (gpm)	Shell Flow (gpm)	8,395.8	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)		U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)		Shell-Side ho (BTU/hr·ft².ºF)	
			Tube-Side hi (BTU/hr-ft2-°F)	
Heat Transferred (BTU/h	ır)		1/Wall Resis (BTU/hr-ft ^{2.} °F)	
LMTD			LMTD Correction Factor	
Effective Area (ft²)				
			Overall Fouling (hr·ft².°F/BTU)	
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	
Density (lbm/ft³)			Tube Temp Out (°F)	
Cp ₁ (BTU/lbm·°F)			Tav Tube (°F)	
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)	

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		4.2E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500
Tube Mass Flow (lbm/hr)		3.7E+6	Shell-Side ho (BTU/hr·ft².°F)	1,286.8
,			Tube-Side hi (BTU/hr·ft².°F)	1,944.4
Heat Transferred (BTU/hr	7)	1.7E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		68.8	LMTD Correction Factor	0.9309
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr·ft².°F)	230.7
Property	Shell-Side	Tube-Side	·	
Velocity (ft/s)	3.96	6.76	Shell Temp In (°F)	212.0
Reynold's Number	6.973E+04	6.230E+04	Shell Temp Out (°F)	171.7
Prandtl Number	2.00	3.53	Tav Shell (°F)	191.8
Bulk Visc (lbm/ft·hr)	0.77	1.31	Shell Skin Temp (°F)	179.5
Skin Visc (lbm/ft·hr)	0.84	1.20	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.31	61.67	Tube Temp Out (°F)	146.0
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	123.0
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	132.4



^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

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Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - 53 Plugs, Vendor Fouling



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	7,446.28	7,396.31
Inlet Temperature	°F	120.00	90.00
Outlet Temperature	°F	108.80	101.25
Fouling Factor		0.00250	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B	TU/hr)		41,600,000
Design Heat Trans Coef	•	°F)	215.00
Emprical Factor for Outs			0.563555000
Performance Factor (%)	Reduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			11,500.00
Area Factor			0.996344561
Area Ratio			
Number of Shells per Ur	nit		1
Shell Minimum Area			4.880000000
Shell Velocity (ft/s)			3.400
Tube Pitch (in)			1.0000
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			Yes
Total Number of Tubes			1,063
Number of Active Tubes	}		1,010
Tube Length (ft)			55.30
Tube Inside Diameter (in	1)		0.652
Tube Outside Diameter	· •		0.750
Tube Wall Conductivity	(BTU/hr·ft·°	F)	9.40
Ds, Shell Inside Diamete	er (in)		0.000
Lbc, Central Baffle Space	ing (in)		0.000
Lbi, Inlet Baffle Spacing	; (in)		0.000
Lbo, Outlet Baffle Spaci	ng (in)		0.000
Dotl, Tube circle diamet	` '		0.000
Bh, Baffle cut height (in	*		0.000
Lsb, Diametral difference			0.000
Ltb, Diametral differenc		be and Baffle (in)	0.000
Nss, Number Sealing Str	nps		0.000

Proto-Power Calc: 97-201

Attachment: C

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Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - 53 Plugs, Vendor Fouling



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data	
Data Date	Tube Flow (gpm)	7,396.3
Shell Flow (gpm)	Shell Flow (gpm)	8,395.8
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)	
	Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		

Overall Fouling (hr·ft².°F/BTU)

Property Shell-Side Tube-Side

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results							
Shell Mass Flow (lbm/hr)		4.2E+6	Overall Fouling (hr·ft²-°F/BTU)	0.002500			
Tube Mass Flow (lbm/hr)		3.7E+6	Shell-Side ho (BTU/hr·ft².ºF)	1,287.9			
			Tube-Side hi (BTU/hr-ft²-°F)	2,019.7			
Heat Transferred (BTU/hr)	1.658E+8	1/Wall Resis (BTU/hr·ft²-°F)	2,148.1			
LMTD		69.9	LMTD Correction Factor	0.9365			
Effective Area (ft²)		10,926.6					
			U Overall (BTU/hr·ft².°F)	231.9			
Property	Shell-Side	Tube-Side					
Velocity (ft/s)	3.97	7.12	Shell Temp In (°F)	212.0			
Reynold's Number	6.995E+04	6.523E+04	Shell Temp Out (°F)	172.7			
Prandtl Number	1.99	3.55	Tav Shell (°F)	192.3			
Bulk Visc (lbm/ft·hr)	0.77	1.32	Shell Skin Temp (°F)	179.7			
Skin Visc (lbm/ft·hr)	0.84	1.21	Tube Temp In (°F)	100.0			
Density (lbm/ft³)	60.30	61.67	Tube Temp Out (°F)	144.9			
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	122.4			
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	131.7			

^{**} Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie

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Attachment D to Proto-Power Calculation 97-201 Revision A

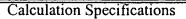
Proto-Power Calc: 97-201

Attachment: D

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Calculation Report for E12-B001 - LSCS - RHR Hx.

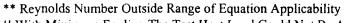
SDC - Tube-side FF = 0.0000



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data			Extrapolation Data		
Data Date			Tube Flow (gpm)	7,370.2	
Shell Flow (gpm)			Shell Flow (gpm)	7,372.0	
Shell Temp In (°F)			Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0	
Tube Flow (gpm)					
Tube Temp In (°F)					
Tube Temp Out (°F)			Input Fouling Factor	0.000500	
		Fouling Calculati	on Results		
Shell Mass Flow (lbm/h	ur)		U Overall (BTU/hr·ft².°F)		
Tube Mass Flow (lbm/h			Shell-Side ho (BTU/hr·ft²-°F)		
•	,		Tube-Side hi (BTU/hr·ft².°F)		
Heat Transferred (BTU)	/hr)		1/Wall Resis (BTU/hr·ft².°F)		
LMTD	•		LMTD Correction Factor		
Effective Area (ft²)					
			Overall Fouling (hr·ft².°F/BTU)		
Property	Shell-Side	Tube-Side			
Velocity (ft/s)			Shell Temp In (°F)		
Reynold's Number			Shell Temp Out (°F)		
Prandtl Number			Tav Shell (°F)		
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)		
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)		
Density (lbm/ft³)			Tube Temp Out (°F)		
Cp (BTU/lbm·°F)			Tav Tube (°F)		
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)		

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr-ft ² -°F/BTU)	0.000500	
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	963.7	
, ,			Tube-Side hi (BTU/hr·ft²-°F)	1,680.3	
Heat Transferred (BTU/hr))	5.4E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1	
LMTD		15.3	LMTD Correction Factor	0.8229	
Effective Area (ft2)		11,500.0			
			U Overall (BTU/hr·ft ² .°F)	372.1	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0	
Reynold's Number	3.268E+04	4.796E+04	Shell Temp Out (°F)	105.3	
Prandtl Number	3.93	4.68	Tav Shell (°F)	112.7	
Bulk Visc (lbm/ft·hr)	1.45	1.70	Shell Skin Temp (°F)	106.7	
Skin Visc (lbm/ft·hr)	1.53	1.63	Tube Temp In (°F)	90.0	
Density (lbm/ft³)	61.82	62.03	Tube Temp Out (°F)	104.7	
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	97.3	
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	101.2	



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-201

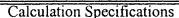
Attachment: D

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Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Tube-side FF = 0.0005



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,370.2	
Shell Flow (gpm)	Shell Flow (gpm)	7,372.0	
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)	Input Fouling Factor	0.001075	

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr-ft2.°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.°F/BTU)

			O · Crain I Caiming (im it	1,01
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	
Density (lbm/ft³)			Tube Temp Out (°F)	
Cp ¹ (BTU/lbm·°F)			Tav Tube (°F)	
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)	

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)	·	3.688E+6	Overall Fouling (hr·ft²-°F/BTU)	0.001075	
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	966.4	
			Tube-Side hi (BTU/hr·ft².°F)	1,674.1	
Heat Transferred (BTU/hr)	5.024E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1	
LMTD		16.4	LMTD Correction Factor	0.8710	
Effective Area (ft²)		11,500.0			
			U Overall (BTU/hr·ft²-°F)	306.5	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0	
Reynold's Number	3.285E+04	4.769E+04	Shell Temp Out (°F)	106.4	
Prandtl Number	3.91	4.71	Tav Shell (°F)	113.2	
Bulk Visc (lbm/ft·hr)	1.44	1.70	Shell Skin Temp (°F)	108.0	
Skin Visc (lbm/ft·hr)	1.51	1.64	Tube Temp In (°F)	90.0	
Density (lbm/ft ³)	61.81	62.03	Tube Temp Out (°F)	103.6	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	96.8	
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F) Proto-Power Calc: 97-2	100.3	

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: D

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Prandtl Number

Density (lbm/ft3)

Cp(BTU/lbm.°F)

K (BTU/hr·ft·°F)

Bulk Visc (lbm/ft·hr)

Skin Visc (lbm/ft·hr)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Tube-side FF = 0.0010

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data			Extrapolation Data		
Data Date		<u> </u>	Tube Flow (gpm)	7,370.2	
Shell Flow (gpm)			Shell Flow (gpm)	7,372.0	
Shell Temp In (°F)			Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0	
Tube Flow (gpm)					
Tube Temp In (°F)					
Tube Temp Out (°F)			Input Fouling Factor	0.001650	
		Fouling Calculati	on Results		
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)		
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².ºF)		
Tube Mass Flow (1611)			Tube-Side hi (BTU/hr-ft²-°F)		
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft²-°F)		
LMTD			LMTD Correction Factor		
Effective Area (ft²)					
` '			Overall Fouling (hr-ft2.0F/BTU)		
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)			Shell Temp In (°F)		
Reynold's Number			Shell Temp Out (°F)	. •	

Tav Shell (°F)

Tav Tube (°F)

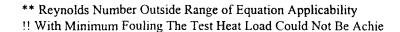
Shell Skin Temp (°F)

Tube Temp In (°F)

Tube Temp Out (°F)

Tube Skin Temp (°F)

	Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr-ft²-°F/BTU)	0.001650		
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	968.7		
			Tube-Side hi (BTU/hr·ft².°F)	1,668.7		
Heat Transferred (BTU/hr)		4.679E+7	1/Wall Resis (BTU/hr-ft ^{2.o} F)	2,148.1		
LMTD		17.3	LMTD Correction Factor	0.9026		
Effective Area (ft²)		11,500.0				
			U Overall (BTU/hr·ft².°F)	260.6		
Property	Shell-Side	Tube-Side				
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0		
Reynold's Number	3.300E+04	4.744E+04	Shell Temp Out (°F)	107.3		
Prandtl Number	3.89	4.74	Tav Shell (°F)	113.6		
Bulk Visc (lbm/ft·hr)	1.43	1.71	Shell Skin Temp (°F)	109.0		
Skin Visc (lbm/ft hr)	1.50	1.66	Tube Temp In (°F)	90.0		
Density (lbm/ft ³)	61.81	62.04	Tube Temp Out (°F)	102.7		
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	96.4		
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	99.5		



Proto-Power Calc: 97-201

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Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Tube-side FF = 0.0015

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Te	est Data		Extrapolation Data	L
Data Date			Tube Flow (gpm)	7,370.2
Shell Flow (gpm)			Shell Flow (gpm)	7,372.0
Shell Temp In (°F)			Tube Inlet Temp (°F)	90.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.002225
		Fouling Calculati	on Results	
Cl. U.M. Flore (U. v. A. v.)			II O II (DTIII 62 OF)	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft²·°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr-ft²-°F)	
Heat Transferred (DTI Mr.	_\		Tube-Side hi (BTU/hr·ft²·°F)	
Heat Transferred (BTU/h	r)		1/Wall Resis (BTU/hr·ft²·°F) LMTD Correction Factor	
LMTD			LM1D Correction Factor	
Effective Area (ft²)			Overall Fouling (hr·ft²-°F/BTU)	
Property	Shell-Side	Tube-Side	Ovolum I duling (in it 17510)	
Velocity (ft/s)	· · · · · · · · · · · · · · · · · · ·		Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	
Density (lbm/ft³)			Tube Temp Out (°F)	
			• ` ` '	

	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft².°F/BTU)	0.002225
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	970.7
,			Tube-Side hi (BTU/hr·ft².°F)	1,663.9
Heat Transferred (BTU/hi	:)	4.369E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		18.1	LMTD Correction Factor	0.9242
Effective Area (ft²)		11,500.0		
, ,			U Overall (BTU/hr·ft².°F)	226.7
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0
Reynold's Number	3.314E+04	4.722E+04	Shell Temp Out (°F)	108.1
Prandtl Number	3.87	4.76	Tav Shell (°F)	114.1
Bulk Visc (lbm/ft·hr)	1.43	1.72	Shell Skin Temp (°F)	109.8
Skin Visc (lbm/ft·hr)	1.49	1.67	Tube Temp In (°F)	90.0
Density (lbm/ft³)	61.80	62.05	Tube Temp Out (°F)	101.9
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	95.9
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F) Proto-Power Calc: 97-201	98.8

^{**} Reynolds Number Outside Range of Equation Applicability

Attachment: D

Tav Tube (°F)
Tube Skin Temp (°F)

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Density (lbm/ft³)

Cp (BTU/lbm.°F)

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Tube-side FF = 0.0020

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data			Extrapolation Data	l
Data Date			Tube Flow (gpm)	7,370.2
Shell Flow (gpm)			Shell Flow (gpm)	7,372.0
Shell Temp In (°F)			Tube Inlet Temp (°F)	90.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.002801
		Fouling Calculati	on Results	
Shell Mass Flow (lbm/hr)		-	U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².°F)	
1 400 11400 110 11 (1011111)			Tube-Side hi (BTU/hr-ft²-°F)	
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft².°F)	
LMTD			LMTD Correction Factor	
Effective Area (ft²)				
,			Overall Fouling (hr-ft2.0F/BTU)	
Property	Shell-Side	Tube-Side	5 (,	
Velocity (ft/s)		.	Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	
_ , ,,,, ,,,, ,				

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft²-°F/BTU)	0.002801	
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².ºF)	972.4	
			Tube-Side hi (BTU/hr-ft2-°F)	1,659.7	
Heat Transferred (BTU/hr	·)	4.092E+7	1/Wall Resis (BTU/hr-ft2-°F)	2,148.1	
LMTD		18.9	LMTD Correction Factor	0.9395	
Effective Area (ft²)		11,500.0			
			U Overall (BTU/hr·ft².°F)	200.5	
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0	
Reynold's Number	3.326E+04	4.703E+04	Shell Temp Out (°F)	108.9	
Prandtl Number	3.85	4.78	Tav Shell (°F)	114.4	
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.6	
Skin Visc (lbm/ft·hr)	1.48	1.68	Tube Temp In (°F)	90.0	
Density (lbm/ft3)	61.80	62.05	Tube Temp Out (°F)	101.1	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	95.6	
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F) Proto-Power Calc: 97-201	98.2	

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

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Tube Temp Out (°F)

Tube Skin Temp (°F)

Tav Tube (°F)

158.4

185.2

165.9

100.0

159.0

129.5

143.1

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Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Tube-side FF = 0.0000

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data		Extrapolation Data	ı	
Data Date		 	Tube Flow (gpm)	7,356.1
Shell Flow (gpm)			Shell Flow (gpm)	8,057.7
Shell Temp In (°F)			Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.000500
		Fouling Calculati	on Results	
Shell Mass Flow (lbm/hr)			LI Oscarali (DTI Idan 62.9F)	
, ,			U Overall (BTU/hr-ft²-°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr-ft²-°F)	
Heat Transferred (DTI I/hr)			Tube-Side hi (BTU/hr·ft².ºF)	
Heat Transferred (BTU/hr) LMTD			1/Wall Resis (BTU/hr·ft²-°F) LMTD Correction Factor	
Effective Area (ft²)			LM 1D Correction Factor	
Effective Alea (it)			Quarall Fouling (hr. 62.9E/DTU)	
Property	Shell-Side	Tube-Side	Overall Fouling (hr·ft²-°F/BTU)	
Velocity (ft/s)		1400 5.40	Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			• ` ` `	
			Tay Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	

Cp [*] (BTU/lbm·°F) K (BTU/hr·ft·°F)			Tav Tube (°F) Tube Skin Temp (°F)	
	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr-ft²-°F/BTU)	0.000500
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr-ft2.°F)	1,227.9
			Tube-Side hi (BTU/hr·ft².°F)	2,006.2
Heat Transferred (BTU/hr)		2.168E+8	1/Wall Resis (BTU/hr-ft ^{2.} °F)	2,148.1
LMTD		55.7	LMTD Correction Factor	0.7971
Effective Area (ft2)		11,500.0		
			U Overall (BTU/hr·ft².°F)	424.9
Property	Shell-Side	Tube-Side	·	
Velocity (ft/s)	3.80	6.74	Shell Temp In (°F)	212.0

6.572E+04

3.31

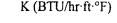
1.23

1.10

61.56

1.00

0.37



Reynold's Number

Bulk Visc (lbm/ft·hr)

Skin Visc (lbm/ft·hr)

Prandtl Number

Density (lbm/ft³)

Cp (BTU/lbm·°F)

Skin Visc (lbm/ft·hr)

Density (lbm/ft³)

6.408E+04

2.09

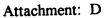
0.81

0.92

60.46

1.00

0.39



Tube Temp In (°F)

Tube Temp Out (°F)

Shell Temp Out (°F)

Shell Skin Temp (°F)

Tube Temp In (°F)

Tube Temp Out (°F)

Tube Skin Temp (°F)

Tav Shell (°F)

Tav Tube (°F)

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Proto-Power Calc: 97-201



^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for E12-B001 - LSCS - RHR Hx.

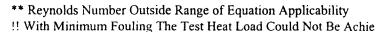
CCM - Tube-side FF = 0.0005

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data		Extrapolation Data	a		
Data Date			Tube Flow (gpm)	7,356.1	
Shell Flow (gpm)			Shell Flow (gpm)	8,057.7	
Shell Temp In (°F)			Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0	
Tube Flow (gpm)					
Tube Temp In (°F)					
Tube Temp Out (°F)			Input Fouling Factor	0.001075	
		Fouling Calculate	ion Results		
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)		
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr-ft2.0F)		
, ,			Tube-Side hi (BTU/hr·ft².°F)		
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft².°F)		
LMTD			LMTD Correction Factor		
Effective Area (ft²)					
			Overall Fouling (hr-ft2-°F/BTU)		
Property	Shell-Side	Tube-Side			
Velocity (ft/s)			Shell Temp In (°F)		
Reynold's Number			Shell Temp Out (°F)		
Prandtl Number			Tav Shell (°F)		
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)		
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)		
Density (lbm/ft³) Tube Temp Out (°F)					
Cp (BTU/lbm.°F)			Tav Tube (°F)		
K (BTU/hr-ft-°F)			Tube Skin Temp (°F)		

	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft²-°F/BTU)	0.001075
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft².°F)	1,236.8
			Tube-Side hi (BTU/hr-ft2.°F)	1,982.3
Heat Transferred (BTU/hr)	2.01E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		59.8	LMTD Correction Factor	0.8568
Effective Area (ft2)		11,500.0		
			U Overall (BTU/hr-ft2-°F)	341.4
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.80	6.73	Shell Temp In (°F)	212.0
Reynold's Number	6.491E+04	6.447E+04	Shell Temp Out (°F)	162.3
Prandtl Number	2.06	3.38	Tav Shell (°F)	187.1
Bulk Visc (lbm/ft·hr)	0.80	1.26	Shell Skin Temp (°F)	170.6
Skin Visc (lbm/ft-hr)	0.89	1.14	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.42	61.59	Tube Temp Out (°F)	154.7
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	127.3
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	139.2



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PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)

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Calculation Report for E12-B001 - LSCS - RHR Hx.

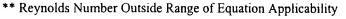
CCM - Tube-side FF = 0.0010



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data		Extrapolation Data	
Data Date	Tube Flow (gpm) 7,35		7,356.1
Shell Flow (gpm)		Shell Flow (gpm)	8,057.7
Shell Temp In (°F)		Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)		Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)		Input Fouling Factor	0.001650
	Fouling Calculati	on Results	
Shell Mass Flow (lbm/hr)		U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)		Shell-Side ho (BTU/hr·ft².°F)	
Tube Mass How (Ibitain)		Tube-Side hi (BTU/hr-ft²-°F)	
Heat Transferred (BTU/hr)		1/Wall Resis (BTU/hr·ft²-°F)	
LMTD		LMTD Correction Factor	
Effective Area (ft²)			
211001110 (11)		Overall Fouling (hr-ft ^{2.o} F/BTU)	
Property Shell-Side	Tube-Side	(IV 1.210)	
Velocity (ft/s)		Shell Temp In (°F)	
Reynold's Number		Shell Temp Out (°F)	
Prandtl Number		Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)		Shell Skin Temp (°F)	
· · · · · · · · · · · · · · · · · · ·		- · ·	
		• • •	
		• • •	
K (BTU/hr·ft·°F)		Tube Skin Temp (°F)	
Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp'(BTU/lbm·°F)		Shell Skin Temp (°F) Tube Temp In (°F) Tube Temp Out (°F) Tav Tube (°F)	

	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr-ft ² .°F/BTU)	0.001650
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr-ft2.°F)	1,244.2
			Tube-Side hi (BTU/hr·ft².°F)	1,961.1
Heat Transferred (BTU/hr	·)	1.865E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		63.5	LMTD Correction Factor	0.8946
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr·ft².°F)	285.2
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.80	6.73	Shell Temp In (°F)	212.0
Reynold's Number	6.568E+04	6.332E+04	Shell Temp Out (°F)	165.9
Prandtl Number	2.04	3.44	Tav Shell (°F)	188.9
Bulk Visc (lbm/ft·hr)	0.79	1.28	Shell Skin Temp (°F)	174.4
Skin Visc (lbm/ft·hr)	0.87	1.17	Tube Temp In (°F)	100.0
Density (lbm/ft ³)	60.37	61.63	Tube Temp Out (°F)	150.7
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	125.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	136.0



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

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Density (lbm/ft³)

Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

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Calculation Report for E12-B001 - LSCS - RHR Hx.

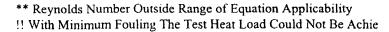
CCM - Tube-side FF = 0.0015

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data Extr		Extrapolation Da	ıta	
Data Date		Tube Flow (gpm)	7,356.1	
Shell Flow (gpm)			Shell Flow (gpm)	8,057.7
Shell Temp In (°F)			Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)			•	
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.002225
		Fouling Calculat	ion Results	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft²-°F)	
1400 11400 1 10 (15112 112)			Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr	·)		1/Wall Resis (BTU/hr·ft².°F)	
LMTD	,		LMTD Correction Factor	
Effective Area (ft²)				
			Overall Fouling (hr·ft²-°F/BTU)	
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number		Shell Temp Out (°F)		
Prandtl Number		Tav Shell (°F)		
Bulk Visc (lbm/ft·hr)		Shell Skin Temp (°F)		
Skin Visc (lbm/ft·hr)		Tube Temp In (°F)		

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft²-°F/BTU)	0.002225-
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft².ºF)	1,250.4
			Tube-Side hi (BTU/hr·ft².°F)	1,942.3
Heat Transferred (BTU/hr))	1.734E+8	1/Wall Resis (BTU/hr-ft2.°F)	2,148.1
LMTD		66.9	LMTD Correction Factor	0.9196
Effective Area (ft2)		11,500.0		
•			U Overall (BTU/hr-ft ^{2.} °F)	244.9
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.80	6.73	Shell Temp In (°F)	212.0
Reynold's Number	6.638E+04	6.230E+04	Shell Temp Out (°F)	169.1
Prandtl Number	2.01	3.50	Tav Shell (°F)	190.6
Bulk Visc (lbm/ft·hr)	0.78	1.30	Shell Skin Temp (°F)	177.4
Skin Visc (lbm/ft·hr)	0.85	1.19	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.34	61.66	Tube Temp Out (°F)	147.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	123.6
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	133.3



Proto-Power Calc: 97-201

Attachment: D

Tube Temp Out (°F)

Tube Skin Temp (°F)

Tav Tube (°F)

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Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Tube-side FF = 0.0020

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Da	nta
Data Date	Tube Flow (gpm)	7,356.1
Shell Flow (gpm)	Shell Flow (gpm)	8,057.7
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.002801
Fo	ouling Calculation Results	
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².ºF)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)	
	Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft ^{2.o} F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		
	Overall Fouling (hr-ft ² .°F/BTU)	

			Overall Fouring (In It 17)
Property	Shell-Side	Tube-Side	- '
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

	Ex	trapolation Calcu	lation Results	
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft².°F/BTU)	0.002801
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft².°F)	1,255.7
			Tube-Side hi (BTU/hr-ft2.0F)	1,925.7
Heat Transferred (BTU/hr)	1.618E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		70.0	LMTD Correction Factor	0.9369
Effective Area (ft2)		11,500.0		
			U Overall (BTU/hr-ft ^{2.0} F)	214.6
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.81	6.72	Shell Temp In (°F)	212.0
Reynold's Number	6.700E+04	6.139E+04	Shell Temp Out (°F)	172.0
Prandtl Number	1.99	3.56	Tav Shell (°F)	192.0
Bulk Visc (lbm/ft·hr)	0.77	1.32	Shell Skin Temp (°F)	180.0
Skin Visc (lbm/ft·hr)	0.83	1.22	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.30	61.68	Tube Temp Out (°F)	144.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	122.0
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	131.0

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: D

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Attachment E to Proto-Power Calculation 97-201 Revision A

Proto-Power Calc: 97-201

Attachment: E

Rev: A Page 1 of 10

K (BTU/hr·ft·°F)

PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Service Margin - All Tubes

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data	
Data Date	Tube Flow (gpm)	7,356.1
Shell Flow (gpm)	Shell Flow (gpm)	8,057.7
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr))	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr))	Shell-Side ho (BTU/hr·ft².°F)
,		Tube-Side hi (BTU/hr·ft²-°F)
Heat Transferred (BTU/h	r)	1/Wall Resis (BTU/hr·ft².°F)
LMTD		LMTD Correction Factor
Effective Area (ft2)		
		Overall Fouling (hr·ft².°F/BTU)
Property	Shell-Side Tube-Side	
Velocity (ft/s)		Shell Temp In (°F)
Reynold's Number		Shell Temp Out (°F)
Prandtl Number		Tav Shell (°F)
Bulk Visc (lbm/ft·hr)		Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)		Tube Temp In (°F)
Density (lbm/ft³)		Tube Temp Out (°F)
Cp (BTU/lbm·°F)		Tav Tube (°F)

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500	
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr-ft².°F)	1,253.0	
			Tube-Side hi (BTU/hr·ft².°F)	1,934.1	
Heat Transferred (BTU/hr)	1.677E+8	1/Wall Resis (BTU/hr·ft²-°F)	2,148.1	
LMTD		68.4	LMTD Correction Factor	0.9286	
Effective Area (ft²)		11,500.0			
			U Overall (BTU/hr·ft².°F)	229.4	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)	3.80	6.73	Shell Temp In (°F)	212.0	
Reynold's Number	6.668E+04	6.185E+04	Shell Temp Out (°F)	170.5	
Prandtl Number	2.00	3.53	Tav Shell (°F)	191.3	
Bulk Visc (lbm/ft·hr)	0.77	1.31	Shell Skin Temp (°F)	178.7	
Skin Visc (lbm/ft·hr)	0.84	1.21	Tube Temp In (°F)	100.0	
Density (lbm/ft3)	60.32	61.67	Tube Temp Out (°F)	145.6	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	122.8	
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc:	97-201 132.2	

^{**} Reynolds Number Outside Range of Equation Applicability

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

Tube Skin Temp (°F)

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Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Service Margin - 53 Plugs

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data	
Data Date	Tube Flow (gpm)	7,356.1	
Shell Flow (gpm)	Shell Flow (gpm)	8,057.7	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)
	Tube-Side hi (BTU/hr·ft²-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp ⁽ (BTU/lbm [°] F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft²-°F)	1,254.1
			Tube-Side hi (BTU/hr-ft².ºF)	2,009.1
Heat Transferred (BTU/hr))	1.637E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		69.5	LMTD Correction Factor	0.9344
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft².°F)	230.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.80	7.08	Shell Temp In (°F)	212.0
Reynold's Number	6.690E+04	6.477E+04	Shell Temp Out (°F)	171.5
Prandtl Number	2.00	3.55	Tav Shell (°F)	191.8
Bulk Visc (lbm/ft·hr)	0.77	1.32	Shell Skin Temp (°F)	179.0
Skin Visc (lbm/ft·hr)	0.84	1.21	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.31	61.68	Tube Temp Out (°F)	144.5
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	122.3
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-20	131.4

^{**} Reynolds Number Outside Range of Equation Applicability

Attachment: E

Overall Fouling (hr-ft2-oF/BTU)

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Clean Margin - All Tubes



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,356.1		
Shell Flow (gpm)	Shell Flow (gpm)	8,057.7		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	212.0		
Tube Flow (gpm)	• , ,			
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.000000		
	Fouling Calculation Posults			

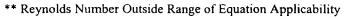
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

Property	Shell-Side	Tube-Side	Overall Fouring (in it
Velocity (ft/s)		· · · · · · · · · · · · · · · · · · ·	Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number	•		Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr·ft².°F/BTU)	0.000000
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft².°F)	1,218.2
,			Tube-Side hi (BTU/hr-ft².ºF)	2,029.2
Heat Transferred (BTU/hr)	2.307E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		52.0	LMTD Correction Factor	0.7148
Effective Area (ft²)		11,500.0		
·			U Overall (BTU/hr·ft ^{2.o} F)	539.6
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.79	6.74	Shell Temp In (°F)	212.0
Reynold's Number	6.335E+04	6.683E+04	Shell Temp Out (°F)	154.9
Prandtl Number	2.12	3.25	Tav Shell (°F)	183.5
Bulk Visc (lbm/ft·hr)	0.82	1.21	Shell Skin Temp (°F)	160.4
Skin Visc (lbm/ft·hr)	0.96	1.06	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.50	61.53	Tube Temp Out (°F)	162.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	131.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-201	147.3



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

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Cp'(BTU/lbm.°F)

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

CCM - Clean Margin - 53 Plugs

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data		Extrapolation Data	ı	
Data Date			Tube Flow (gpm) 7,3	
Shell Flow (gpm)			Shell Flow (gpm)	8,057.7
Shell Temp In (°F)			Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	212.0
Tube Flow (gpm)			-	
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.000000
		Fouling Calculat	ion Results	
Shall Mass Flow (lbm/br)			II Overall (DTII/I 62 9E)	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr-ft²-°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr-ft²-°F)	
II 4 T 4 (DTII/I)			Tube-Side hi (BTU/hr·ft²-°F)	
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr ft².°F)	
LMTD			LMTD Correction Factor	
Effective Area (ft²)			0 11 5 11 (1 00 00 00 00 00	
—	a a	m 1 a:1	Overall Fouling (hr·ft²-°F/BTU)	
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Reynold's Number			Shell Temp Out (°F)	
Prandtl Number			Tav Shell (°F)	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	
Density (lbm/ft³)			Tube Temp Out (°F)	

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		4.031E+6	Overall Fouling (hr-ft²-°F/BTU)	0.000000
Tube Mass Flow (lbm/hr)		3.68E+6	Shell-Side ho (BTU/hr·ft².°F)	1,218.3
			Tube-Side hi (BTU/hr·ft².°F)	2,110.6
Heat Transferred (BTU/hr)	2.287E+8	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		52.5	LMTD Correction Factor	0.7295
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft².°F)	546.0
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.79	7.09	Shell Temp In (°F)	212.0
Reynold's Number	6.345E+04	7.016E+04	Shell Temp Out (°F)	155.4
Prandtl Number	2.11	3.25	Tav Shell (°F)	183.7
Bulk Visc (lbm/ft·hr)	0.81	1.22	Shell Skin Temp (°F)	160.1
Skin Visc (lbm/ft·hr)	0.96	1.07	Tube Temp In (°F)	100.0
Density (lbm/ft ³)	60.49	61.53	Tube Temp Out (°F)	162.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	131.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Tprin Power Calc: 97-2	01 146.8

Tav Tube (°F)

Tube Skin Temp (°F)

Attachment: E

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^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Service Margin - All Tubes

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,370.2	
Shell Flow (gpm)	Shell Flow (gpm)	7,372.0	
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft ²)	

			Overall Fouling (hr-ft2.0F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

	Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500	
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	971.5	
			Tube-Side hi (BTU/hr·ft².°F)	1,661.9	
Heat Transferred (BTU/hr))	4.233E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1	
LMTD		18.5	LMTD Correction Factor	0.9322	
Effective Area (ft2)		11,500.0			
			U Overall (BTU/hr·ft ^{2.o} F)	213.4	
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0	
Reynold's Number	3.320E+04	4.713E+04	Shell Temp Out (°F)	108.5	
Prandtl Number	3.86	4.77	Tav Shell (°F)	114.3	
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.2	
Skin Visc (lbm/ft·hr)	1.48	1.67	Tube Temp In (°F)	90.0	
Density (lbm/ft³)	61.80	62.05	Tube Temp Out (°F)	101.5	
Cp (BTU/lbm.°F)	1.00	1.00	Tay Tube (°F)	95.7	
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F) Proto-Power Calc: 97-	98.5	

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

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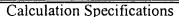


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Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Service Margin - 53 Plugs



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data	
Data Date	Tube Flow (gpm)	7,370.2	
Shell Flow (gpm)	Shell Flow (gpm)	7,372.0	
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0	
Tube Flow (gpm)	• • •		
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².ºF)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.o} F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

			Overall Fouling (hr·ft²-°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)		 	Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp [*] (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft².°F/BTU)	0.002500	
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr-ft2.0F)	971.9	
·			Tube-Side hi (BTU/hr-ft2-°F)	1,729.7	
Heat Transferred (BTU/hr)	4.131E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1	
LMTD		18.8	LMTD Correction Factor	0.9376	
Effective Area (ft²)		10,926.6			
			U Overall (BTU/hr·ft2.°F)	214.6	
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)	3.40	7.05	Shell Temp In (°F)	120.0	
Reynold's Number	3.324E+04	4.952E+04	Shell Temp Out (°F)	108.8	
Prandtl Number	3.86	4.78	Tav Shell (°F)	114.4	
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.2	
Skin Visc (lbm/ft·hr)	1.48	1.68	Tube Temp In (°F)	90.0	
Density (lbm/ft3)	61.80	62.05	Tube Temp Out (°F)	101.2	
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	95.6	
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	98.3	
				• • •	

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-201

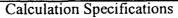
Attachment: E

Rev: A Page 7 of 10



Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC -- Service Margin - 38 Plugs



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data		
Data Date	Tube Flow (gpm)	7,370.2		
Shell Flow (gpm)	Shell Flow (gpm)	7,372.0		
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)				

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
· ,	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	I/Wall Resis (BTU/hr·ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft^{2.°}F/BTU)

Property Shell-Side Tube-Side	
Velocity (ft/s) Shell Ten	np In (°F)
Reynold's Number Shell Ten	np Out (°F)
Prandtl Number Tav Shell	(°F)
Bulk Visc (lbm/ft·hr) Shell Skin	n Temp (°F)
Skin Visc (lbm/ft·hr) Tube Ten	np In (°F)
Density (lbm/ft³) Tube Ten	np Out (°F)
Cp'(BTU/lbm·°F) Tav Tube	(°F)
	n Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft².ºF/BTU)	0.002509
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	971.8
, ,			Tube-Side hi (BTU/hr·ft².°F)	1,709.9
Heat Transferred (BTU/hr)		4.16E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		18.7	LMTD Correction Factor	0.9361
Effective Area (ft2)		11,088.9		
			U Overall (BTU/hr·ft².°F)	214.3
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.40	6.95	Shell Temp In (°F)	120.0
Reynold's Number	3.323E+04	4.882E+04	Shell Temp Out (°F)	108.7
Prandtl Number	3.86	4.78	Tav Shell (°F)	114.4
Bulk Visc (lbm/ft·hr)	1.42	1.73	Shell Skin Temp (°F)	110.2
Skin Visc (lbm/ft·hr)	1.48	1.68	Tube Temp In (°F)	90.0
Density (lbm/ft³)	61.80	62.05	Tube Temp Out (°F)	101.3
Cp (BTU/lbm-°F)	1.00	1.00	Tav Tube (°F)	95.6
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	98.3

** Reynolds Number Outside Range of Equation Applicability

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-201

Attachment: E

Rev: A Page 8 of 10



16:35:32

Commonwealth Edison

Calculation Report for E12-B001 - LSCS - RHR Hx.

SDC - Clean Margin - All Tubes

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	7,370.2
Shell Flow (gpm)	Shell Flow (gpm)	7,372.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)	• • •	
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.000000

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².ºF)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2-°F/BTU)

			Overall Fouling (nr-112-3F/B1)
Property	Shell-Side	Tube-Side	-
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp'(BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr·ft².ºF/BTU)	0.000000
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr-ft2.°F)	960.9
			Tube-Side hi (BTU/hr·ft².°F)	1,686.2
Heat Transferred (BTU/hr)	5.744E+7	1/Wall Resis (BTU/hr·ft²-°F)	2,148.1
LMTD		14.4	LMTD Correction Factor	0.7586
Effective Area (ft²)		11,500.0		
			U Overall (BTU/hr·ft².°F)	457.0
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	3.40	6.70	Shell Temp In (°F)	120.0
Reynold's Number	3.253E+04	4.820E+04	Shell Temp Out (°F)	104.4
Prandtl Number	3.95	4.66	Tav Shell (°F)	112.2
Bulk Visc (lbm/ft hr)	1.45	1.69	Shell Skin Temp (°F)	105.4
Skin Visc (lbm/ft·hr)	1.56	1.61	Tube Temp In (°F)	90.0
Density (lbm/ft³)	61.83	62.02	Tube Temp Out (°F)	105.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	97.8
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F)	102.3

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-201

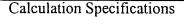
Attachment: E

Rev: A Page 9 of 10



Calculation Report for E12-B001 - LSCS - RHR Hx.



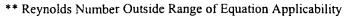


Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data		Extrapolation Data		
Data Date			Tube Flow (gpm)	7,370.2
Shell Flow (gpm)			Shell Flow (gpm)	7,372.0
Shell Temp In (°F)			Tube Inlet Temp (°F)	90.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	120.0
Tube Flow (gpm)			-	
Tube Temp In (°F)				
Tube Temp Out (°F)			Input Fouling Factor	0.000000
		Fouling Calculat	ion Results	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².°F)	
,			Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft².°F)	
LMTD			LMTD Correction Factor	
Effective Area (ft²)				
,			Overall Fouling (hr·ft ^{2.o} F/BTU)	
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	
Revnold's Number			Shell Temp Out (°F)	

Ргорепу	Shell-Side	i ube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm °F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)
			_

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		3.688E+6	Overall Fouling (hr-ft ² .°F/BTU)	0.000000
Tube Mass Flow (lbm/hr)		3.687E+6	Shell-Side ho (BTU/hr·ft².°F)	960.9
•			Tube-Side hi (BTU/hr·ft²-°F)	1,755.7
Heat Transferred (BTU/hr)	5.684E+7	1/Wall Resis (BTU/hr·ft².°F)	2,148.1
LMTD		14.6	LMTD Correction Factor	0.7717
Effective Area (ft²)		10,926.6		
			U Overall (BTU/hr·ft².°F)	462.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	3.40	7.05	Shell Temp In (°F)	120.0
Reynold's Number	3.256E+04	5.068E+04	Shell Temp Out (°F)	104.6
Prandtl Number	3.94	4.66	Tav Shell (°F)	112.3
Bulk Visc (lbm/ft·hr)	1.45	1.69	Shell Skin Temp (°F)	105.3
Skin Visc (lbm/ft·hr)	1.56	1.61	Tube Temp In (°F)	90.0
Density (lbm/ft³)	61.83	62.02	Tube Temp Out (°F)	105.4
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	97.7
K (BTU/hr·ft·°F)	0.37	0.36	Tube Skin Temp (°F) Proto-Power Calc: 9	9 7-20 1



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

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Attachment F to Proto-Power Calculation 97-201 Revision A

Proto-Power Calc: 97-201

Attachment: F

Rev: A Page 1 of 2

PROTO-HXTM Version 3.02 MODEL

LASALLE STATION RESIDUAL HEAT REMOVAL HEAT EXCHANGER.

FILE NAME: E12-B001.PHX

DATE LAST MODIFIED: 7/16/98

TIME LAST MODIFIED: 1:53:18 PM

FILE SIZE: 960 KB

Proto-Power Calc: 97-201

Attachment: F

Rev: A Page 2 of 2



Page 1 Design Analysis (Minor Revision) Last Page No. 4 Attachment A, A2 Analysis No.: 1 97-195 Revision: 2 A01 Title: 3 Thermal Model of ComEd/LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers 388666 EC/ECR No.: 1 Revision: 5 000 Station(s): ' LaSalle Unit No.: 8 01 & 02 Safety/QA Class: 9 SR System Code(s): 10 DG Is this Design Analysis Safeguards Information? " Yes ☐ No 🛛 If yes, see SY-AA-101-106 Does this Design Analysis contain Unverified Assumptions? 12 Yes ☐ No 🖾 If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: " in its entirety. Description of Changes (list affected pages): " This revision evaluates a maximum cooling water inlet temperature of 107 °F. The previous temperature that was evaluated was 104 °F. Affected pages are Pages 1 - 2 and Attachment A, Pages A1-A2 Disposition of Changes: 15 See attached pages. The changes made are acceptable. Preparer: 16 Method of Review: " Alternate Calculations Detailed Review 🔀 Testing [Reviewer: 16 Independent review X Review Notes: 19 (For External Analyses Only) External Approver: 20 Sign Name Exelon Reviewer 21 Sign Name Exelon Approver: 2





Purpose:

The purpose of this revision is to verify that the 0(1)(2)DG01A coolers can remove the design heat load of 8,600,000 BTU/hr with a revised maximum cooling water temperature of 107 °F.

Assumptions:

There are no assumptions for this revision.

Inputs:

- Cooling water temperature = 107 °F (Reference 2)
- Cooling water flow rate = 800 gpm (Reference 1)
- Jacket water temperature for 0(1)(2)DG01A = 190 °F (Reference 1)
- Jacket water flow rate for 0(1)(2)DG01A = 1100 gpm (Reference 1)
- Fouling factor for 0(1)(2)DG01A = 0.0022 hr ft².°F/BTU (Reference 1)
- 9 tubes plugged (5% tube plugging) (Reference 1)

References:

- 1. Design analysis 97-195, Rev. A, up to and including Rev A00
- 2. EC 388666, Rev. 000
- 3. EC 384217, Rev. 000

Identification of Computer Programs:

The computer program used in this analysis is Proto HX version 4.01. This program has been validated per DTSQA tracking number EX0000103.

Method of Analysis / Numeric Analysis:

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp" from 104 °F to 107 °F.



Results / Conclusions:

The 0(1)(2)DG01A coolers can remove the design heat load of 8,600,000 BTU/hr with the following conditions:

- 107 °F cooling water temperature
- 800 gpm cooling water flow
- fouling factor of 0.0022 hr·ft²·°F/BTU
- 9 tubes plugged
- jacket water temperature of 190 °F
- jacket water flow rate of 1100 gpm

The total heat removed at these conditions is 8,727,760 BTU/hr, which provides 1.5% thermal margin over the design heat load. The benchmark of the model was shown to perform within 0.13% of the vendor data sheet, which is bounded by the 1.5% thermal margin. Note that the most recent thermal performance evaluation (Ref. 3) shows a maximum fouling factor of 0.000429 hr·ft²-°F/BTU, which shows that there is actually more margin than what is shown in this analysis. The coolers are cleaned on a regular basis to maintain acceptable fouling factors. The previous maximum fouling factor of 0.0022 hr·ft²-°F/BTU was used, which is the bounding fouling factor. This case is shown in Attachment A.

Attachments:

A. Data Report for 0(1)(2)DG01A (2 pgs)



PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-1002)

Commonwealth Edison

Data Report for DG01A - DG Jacket Water Cooler

0, 1A, 2A DG - 107 °F tube side, 800 gpm, 190 °F shell side, 1100 gpm, FF = 0.0022, 9 tubes plugged

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,099.45	775.61
Mass Fluid Quantity, Tota		0.00	0.00
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor	hr·ft².ºF/BTU	0.00278	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Q (BTU/hr)			8,600,000
Design U (BTU/hr·ft²-°F)			255.20
Outside h Factor (Hoff)			0.780339000
Fixed U (BTU/hr·ft².ºF)			0
Fixed Area (ft²) Performance Factor (% R	aduation)		0.00
renormance ractor (% K	eduction)		0.00
Heat Exchanger Type			TEMA - E
Total Effective Area per U	Jnit (ft²)		471.23
Area Factor			0.981978184
Area Ratio			0.00000
Number of Shells Per Uni	t		1
Shell Minimum Area			0.490000000
Shell Velocity (ft/s)			5.000
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			188
Number of Active Tubes			179
Tube Length (ft)			13.00
Tube Inside Diameter (in)			0.652
Tube Outside Diameter (i	•		0.750
Tube Wall K (BTU/hr·ft·°	r)		112.00
Lbc, Central Baffle Spacin			0.000
Lbi, Inlet Baffle Spacing	•		0.000
Lbo, Outlet Baffle Spacin	-		0.000
Dotl, Tube Circle Diamet			0.000
Bh, Baffle Cut Height (in)			0.000
Ds, Shell Inside Diamter (` '		0.000
Lsb, Diametral difference	between Baffle an	d Shell (in)	0.000
Ltb, Diametral difference		Baffle (in)	0.000
Nss, Number Sealing Stri	ps		0.000



05-01-2012 09:58:37

Calculation Report for DG01A - DG Jacket Water Cooler

0, 1A, 2A DG - 107 °F tube side, 800 gpm, 190 °F shell side, 1100 gpm, FF = 0.0022, 9 tubes plugged



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data	
Data Date Shell Flow (gpm) Shell Temp In (°F)	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F)	793.98 1,064.50 107.00	
Shell Temp Out (°F) Tube Flow (gpm) Tube Temp In (°F)	Shell Inlet Temp (°F) Input Fouling Factor	0.002200	
Tube Temp Out (°F)	mpur rouning rucci	0.002200	

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		532,515.63	Overall Fouling (hr-ft².°F/BTU)	0.002200
Tube Mass Flow (lbm/hr)		397,188.13	Shell-Side ho (BTU/hr·ft².°F)	2,031.5
			Tube-Side hi (BTU/hr·ft².°F)	2,305.6
Heat Transferred (BTU/hr)		8,727,760.47	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		63.8	LMTD Correction Factor	0.9851
Effective Area (ft²)		448.7		
_			U Overall (BTU/hr·ft ^{2,°} F)	309.6
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.99	8.61	Shell Temp In (°F)	190.0
Reynold's Number	82,443	75,787	Shell Temp Out (°F)	173.7
Prandtl Number	2.1391	3.7108	Tav Shell (°F)	181.8
Bulk Visc (lbm/ft·hr)	0.8239	1.3722	Shell Skin Temp (°F)	172.1
Skin Visc (lbm/ft·hr)	0.8810	1.2526	Tube Temp In (°F)	107.0
Density (lbm/ft³)	60.5342	61.7424	Tube Temp Out (°F)	129.0
Cp (BTU/lbm·°F)	1.0024	0.9988	Tav Tube (°F)	118.0
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.3861	0.3694	Tube Skin Temp (°F)	127.9



^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved



CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 1 of 2

DESIGN ANALYSIS NO.: Calc. # 97-195 PAGE NO. 1 Major REV Number: A Minor Rev Number: 00					
[] BRAIDWOOD STATION [] BYRON STATION [] CLINTON STATION [] DRESDEN STATION			DESCRIPTION CODE:(C018)		fisher Mp610
[X] LASALLE CO. [] QUAD CITIES	STATION	DIS	DISCIPLINE CODE: (C011)		M
Unit: [X]0 [X]	1 [X]2 []	3 SY	STEM CODE: (C	011)	DG
TITLE: THERMA GENERATOR JA				N UNIT	0, 1, AND 2 DIESEL
[X] Safety Re	elated	[] Augme	nted Quality	[] Non-Safety Related
		ATTRIE	BUTES (C016)		
TYPE	VALU	E	TYPE		VALUE
Elevation	710	,			
Software	PROTO	-HX			
	·				
COMPONENT EPN: (C014 Panel) DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)				(Design Analyses References)	
EPN	TYPE	Type/Sub	Document N	umber	Input (Y/N)
0DG01A	H15	定/DCF	P EC# 33401	7	Y
1DG01A	H15	/			
2DG01A	H15	1			
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REMARKS: NA					
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CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS NO. 97-195	REV: A00	PAGE NO. 2		
Revision Summary (including EC's incorporated): Updated ProtoHX model for 104°F Service Water inlet temperature and calculated Unit 0, 1, and 2 DG Cooler thermal margins for different fouling factors and 5% tubes plugged.				
Electronic Calculation Data Files: ProtoHX 3.0)2, dg01a.phx, 704 KB, 04/14/20	002, 4:01 pm		
(Program Name, Version, File Name extension/s	ize/date/hour/min)			
Design Impact review completed? [] Yes (If yes, attach impact review sheet)	E [X] N/A, Per EC#: 334017	<u></u>		
Prepared by: Jeff W. VanStrien	1 M. W. Ventin	15/9/02		
- Print	Sign	Daje		
Reviewed by: Brian L. Davenport	Sign	Date		
	mate [] Test	50.5		
This Design Analysis supersedes: N/A		in its entirety.		
Supplemental/Review/Required? > [/] Yes	KANO SP			
Additional Review [[] Special Review				
And the second s		i de la companya di Arte		
Additional Review Por Special Review Team	Leader:	Sign Date		
Special Review Teams (NA for Additional Rev				
Rware 9	/r 2)			
e san	Date Print	Sign Date		
Giù	Date (1) Print (1) (2)	Sign Detail		
Supplemental (Review Results:				
Approved by: IT. Connum /	Son la	15/14/12		
- Print	Sign	Date		
External Design Analysis Review (Attachment	t 3 Attached)			
*				
Reviewed by:/	Sign	Date		
Approved by:	oigi:			
~ Print	Sign	Date		
Do any ASSUMPTIONS / ENGINEERING JUDGEME Tracked By: AT#, EC# etc.)		[] Yes [X] No		
-		_		







CALCULATION TABLE OF CONTENTS

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SECTION:	PAGE NO.	SUB-PAGE NO.
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CALCULATION PAGE

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1.0 PURPOSE/OBJECTIVE

The purpose of this minor revision is to revise the thermal model of the Diesel Generator Coolers (0DG01A, 1DG01A, 2DG01A) for a 104°F Service Water inlet temperature. This assessment will evaluate the adequacy of these heat exchangers during a maximum allowable inlet service water temperature of 104°F. Also an acceptable design fouling factor for use as a benchmark during Generic Letter 89-13 testing evaluations will be determined.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp." from 100°F to 104°F and simulated for the following conditions: (Case 1) design fouling factor, (Case 2) twice the 'as-tested' fouling factor and (Case 3) twice the 'as-tested' fouling factor with a 5% tube plugging allowance. The acceptance criteria will be for the thermal margin at Case 3 conditions to exceed the LaSalle design heat load of 8,600,000 BTU/hr (Ref. 1, Table 3-1). Additional conservatism was built into this acceptance criteria by assuming a 5% uncertainty in the Proto-HX heat transfer calculations. The Reference 1 model developed for this heat exchanger demonstrated a correlation to vendor performance specification well within this assumed 5% margin.

A final case will be evaluated which determines the maximum acceptable fouling factor at which the design heat load can be accommodated including heat transfer model uncertainty.

3.0 ASSUMPTIONS / ENGINEERING JUDGMENTS

The assumptions indicated in section 5.0 of Reference 1 are still valid.

Note: The density of water at 104°F is 61.94 lb/ft³ (per steam tables), this is an insignificant change to the density shown in table 4-1 of Ref. 1 for 100°F, the tube side volumetric flow rate correction made in Ref. 1 is still valid.

4.0 DESIGN INPUTS

The design inputs consist of References 1 and 2 listed below.

5.0 REFERENCES

- 1. Calculation No. 97-195, Rev. A, "Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers".
- 2. Calculation L-002211, Rev. 0, "2DG01A, 2A Emergency Diesel Generator Cooler Thermal Heat Transfer Performance"
- 3. "Standards of the Tubular Exchanger Manufacturers Association" (TEMA), Seventh Edition, 1988.



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6.0 CALCULATIONS

The current calculation model is based on a Service Water inlet temperature of 100°F. At this temperature, a maximum fouling factor of 0.002782 hr*ft²*°F/BTU was calculated within reference 1 while maintaining a heat transfer rate of 8,600,000 BTU/hr (Ref. 1, Table 6-3). This is the LaSalle Station Design Heat Load for 110% power operating conditions. Thus, it presents the appearance that no thermal margin exists at these conditions.

Thermal margin is calculated by the following method:

Required Heat Load - Calculated Heat Transfer = Thermal Margin

[Equation 1]

To express this as a percent of the required heat load, the following method is used:

 $\frac{ThermalM \text{ arg } in}{Re \textit{ quiredHeatLoad}} \times 100\% = \% ThermalM \text{ arg } in$

[Equation 2]

Case 1

When the service water inlet temperature is increased to 104°F for the same fouling factor (0.002782 hr*ft²*oF/BTU), heat transfer reduces to 8,234,000 BTU/hr, which is 4.3% below the design heat load of 8,600,000 BTU/hr for 110% power operating conditions [Attachment A]. With the Diesel Generator operating at 100% power, its design heat load is 7,800,000 BTU/hr resulting in a 5.6% thermal margin at a fouling factor of 0.002782 hr*ft²*oF/BTU.

Case 2

Regular cleaning and testing of these heat exchangers limits the amount of fouling well below the values assumed above. The heat exchanger performance data taken under the G.L. 89-13 program here at LaSalle demonstrates a maximum measured fouling factor of 0.000534 hr*ft²*oF/BTU (Ref. 2, page 9). For conservatism, this value was doubled to 0.001068 hr*ft²*oF/BTU and simulated with 104°F service water inlet temperature. The result was a heat transfer of 12,520,000 BTU/hr for a 45.6% thermal margin at 110% power operating conditions [Attachment B].

Case 3

With additional conservatism included by adding a plugging allowance of 9 tubes, 5% of the total, in the heat exchanger and running the model again at the above fouling factor (0.001068





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hr*ft²*°F/BTU) and inlet temperature (104°F) results in a 12,210,000 BTU/hr heat transfer rate, a 42% thermal margin above the worst case heat load [Attachment C].

A final case was evaluated in which the maximum fouling factor was found to be 0.002200 hr*ft²*oF/BTU for the 110% power operating condition, 104°F inlet temperature and with a 5% plugging allowance [Attachment D]. The resulting heat transferred of 9,032,000 BTU/hr accommodates the design heat load of 8,600,000 BTU/hr including analytical model uncertainty.

This is judged to be a reasonably conservative fouling factor since it is slightly higher than the typical fouling factors stated in Ref. 3, page 215. The LaSalle lake water quality will meet or exceed the "River Water Fouling Factor" (at a velocity greater than 3 ft/sec) given in this reference. The lake water passes through strainers and is chemically treated for silt control and scale prevention.

7.0 SUMMARY AND CONCLUSIONS

The Diesel Generator Jacket Water Cooler Model was found to have adequate thermal margin for a maximum lake temperature of 104°F even when operated at 110% power if fouling is less than 0.002200 hr*ft²*°F/BTU. This fouling factor has been determined to be an acceptable benchmark value that can be used in Generic Letter 89-13 testing evaluations of this model heat exchanger.

8.0 ATTACHMENTS:

Attachment "A" - Proto-Hx Calc. Report for DG01A

(CSCS=104 F @ Design Fouling)

Attachment "B" - Proto-Hx Calc. Report for DG01A

(CSCS=104 F @ 2X Max. Tested FF)

Attachment "C" - Proto-Hx Calc. Report for DG01A

(CSCS=104 F @ 2X Max. Tested FF, w\ 5% plugged)

Attachment "D" - Proto-Hx Calc. Report for DG01A

(CSCS=104 F @ Max. Allowable FF, w\ 5% plugged)

Final Page



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Attachment "A"

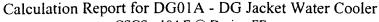
Proto-Hx Calc. Report for DG01A (CSCS=104 F @ Design Fouling)

Calculation Report for DG01A - DG Jacket Water Cooler CSCS= 104 F @ Design FF



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,099.45	775.61
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor		0.00278	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B)	TU/hr)		8,600,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	255.20
Emprical Factor for Outsi	de h		0.780339000
Performance Factor (% R	eduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)		•	471.23
Area Factor			0.981978184
Area Ratio			
Number of Shells per Uni	+		1
Shell Minimum Area			0.490000000
Shell Velocity (ft/s)			5.000
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			188
Number of Active Tubes			188
Tube Length (ft)			13.00
Tube Inside Diameter (in)			0.652
Tube Outside Diameter (i	n)		0.750
Tube Wall Conductivity (BTU/hr·ft·°	F)	112.00
Ds, Shell Inside Diameter	(in)		0.000
Lbc, Central Baffle Spacing	` '		0.000
Lbi, Inlet Baffle Spacing			0.000
Lbo, Outlet Baffle Spacin	•		0.000
Dotl, Tube circle diameter	O		0.000
Bh, Baffle cut height (in)	• /		0.000
Lsb, Diametral difference	between Ba	iffle and Shell (in)	0.000
Ltb, Diametral difference		` '	0.000
Nss, Number Sealing Strip		()	0.000





CSCS= 104 F @ Design FF



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².ºF)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
,	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².ºF)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp
Revnold's Number			Shell Temp

p In (°F) p Out (°F) Reynold's Numb Tav Shell (°F) Prandtl Number Shell Skin Temp (°F) Bulk Visc (lbm/ft·hr) Tube Temp In (°F) Skin Visc (lbm/ft·hr) Tube Temp Out (°F) Density (lbm/ft3) Tav Tube (°F) Cp (BTU/lbm.°F) Tube Skin Temp (°F) K (BTU/hr·ft·°F)

Calculation No. 97-195 Revision No. A00 Attachment A Page No. A3 of A3

Overall Fouling (hr-ft2-0F/BTII)

Extrapolation	Calculation	Results
		271

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft2-°F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².°F)	2,035.7
, ,			Tube-Side hi (BTU/hr-ft2.°F)	2,177.8
Heat Transferred (BTU/hr)	•	8.234E+6	1/Wall Resis (BTU/hr-ft2.°F)	25,594.8
LMTD		67.9	LMTD Correction Factor	0.9884
Effective Area (ft²)		471.2	·	
• •			U Overall (BTU/hr-ft2.°F)	260.4
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.99	8.21	Shell Temp In (°F)	190.0
Reynold's Number	8.270E+04	6.978E+04	Shell Temp Out (°F)	174.6
Prandtl Number	2.13	3.86	Tav Shell (°F)	182.3
Bulk Visc (lbm/ft-hr)	0.82	1.42	Shell Skin Temp (°F)	173.6
Skin Visc (lbm/ft·hr)	0.87	1.30	Tube Temp In (°F)	104.0
Density (lbm/ft3)	60.52	61.80	Tube Temp Out (°F)	124.7
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	114.4
K (BTU/hr-ft-*F)	0.39	0.37	Tube Skin Temp (°F)	123.7



^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



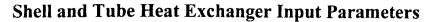
CALCULATION NO. 97-195
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Attachment "B"

Proto-Hx Calc. Report for DG01A (CSCS=104 F @ 2X Max. Tested FF)

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler CSCS = 104 F @ 2X NDIT FF



			Shell-Side	Tuka Cida
Fluid Quantity, Total	mm.		1,099.45	Tube-Side 775.61
Inlet Temperature	gpm °F		190.00	
Outlet Temperature	°F		174.40	100.00 122.20
Fouling Factor	1	*	0.00278	0.00000
		*	0.00278	
Shell Fluid Name				Fresh Water
Tube Fluid Name	*** * ** *			Fresh Water
Design Heat Transfer (B	•			8,600,000
Design Heat Trans Coeff	•	"·°F)		255.20
Emprical Factor for Outs				0.780339000
Performance Factor (% R	leduction)			0.00
Heat Exchanger Type				TEMA-E
Effective Area (ft^2)				471.23
Area Factor				0.981978184
Area Ratio				
Number of Shells per Un	it			1
Shell Minimum Area				0.490000000
Shell Velocity (ft/s)				5.000
Tube Pitch (in)				0.7500
Tube Pitch Type				Triangular
• •				Triumguian
Number of Tube Passes				2
U-Tubes				No
Total Number of Tubes				188
Number of Active Tubes				188
Tube Length (ft)				13.00
Tube Inside Diameter (in)				0.652
Tube Outside Diameter (i	•			0.750
Tube Wall Conductivity (BTU/hr·ft·°	F)		112.00
Ds, Shell Inside Diameter	(in)			0.000
Lbc, Central Baffle Spacin	ng (in)			0.000
Lbi, Inlet Baffle Spacing ((in)			0.000
Lbo, Outlet Baffle Spacin	g (in)			0.000
Dotl, Tube circle diameter	(in)			0.000
Bh, Baffle cut height (in)	•			0.000
Lsb, Diametral difference	between Ba	ffle a	nd Shell (in)	0.000
Ltb, Diametral difference			` /	0.000
Nss, Number Sealing Strip	os		.)	0.000

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Attachment B
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Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

K (BTU/hr-ft-°F)

133.9

Extrapolation Data

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 104 F @ 2X NDIT FF

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

★ Fouling Was Input by User

Test Data

Data Date			Tube Flow (gpm)		795.3
Shell Flow (gpm)			Shell Flow (gpm)		1,064.5
Shell Temp In (°F)			Tube Inlet Temp (°F)		104.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)		190.0
Tube Flow (gpm)					
Tube Temp In (°F)					
Tube Temp Out (°F)			★ Input Fouling Factor		0.001068
		Fouling Calculation	on Results		
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft²-°	F)	
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·1	ft².°F)	
,			Tube-Side hi (BTU/hr·fi	t2.0F)	
Heat Transferred (BTU/hr)			I/Wall Resis (BTU/hr-ft	^{2.} °F)	
LMTD			LMTD Correction Factor	or	
Effective Area (ft²)					
			Overall Fouling (hr-ft ^{2.0}	F/BT(J)
Property	Shell-Side	Tube-Side			
Velocity (ft/s)			Shell Temp In (°F)	ı	Calculation No. 97-195
Reynold's Number			Shell Temp Out (°F)		Revision No. A00
Prandtl Number			Tav Shell (°F)		Attachment B
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)		Page No. B3 of B7
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)		9-1.0. 13 01 B1
Density (lbm/ft³)			Tube Temp Out (°F)		

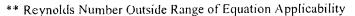
Tav Tube (°F)

Tube Skin Temp (°F)

Tube Skin Temp (°F)

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft²-°F/BTU)	0.001068	
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².ºF)	2,006.8	
			Tube-Side hi (BTU/hr-ft².°F)	2,250.9	
Heat Transferred (BTU/hr)		1.252E+7 /	1/Wall Resis (BTU/hr-ft2-°F)	25,594.8	
LMTD		58.4	LMTD Correction Factor	0.9628	
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft ^{2.} °F)	472.5	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)	4.98	8.22	Shell Temp In (°F)	190.0	
Reynold's Number	8.047E+04	7.349E+04	Shell Temp Out (°F)	166.5	
Prandtl Number	2.19	3.64	Tav Shell (°F)	178.3	
Bulk Visc (lbm/ft·hr)	0.84	1.35	Shell Skin Temp (°F)	164.5	
Skin Visc (lbm/ft hr)	0.93	1.19	Tube Temp In (°F)	104.0	
Density (lbm/ft³)	60.61	61.72	Tube Temp Out (°F)	135.5	
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	119.8	
• •					

0.37



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

0.39



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Attachment "C"

Proto-Hx Calc. Report for DG01A (CSCS=104 F @ 2X Max. Tested FF & 5% plugged)

E-FORM

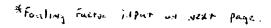
Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler CSCS=104 F@2X NDIT FF, 5% plugged

Shell and Tube Heat Exchanger Input Parameters

		S	Shell-Side	Tube-Side
Fluid Quantity, Total	gpm		1,099.45	775.61
Inlet Temperature	°F		190.00	100.00
Outlet Temperature	°F		174.40	122.20
Fouling Factor		X	0.00278	0.00000
Shell Fluid Name				Fresh Water
Tube Fluid Name				Fresh Water
Design Heat Transfer (B)	ΓU/hr)			8,600,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)		255.20
Emprical Factor for Outs	ide h			0.780339000
Performance Factor (% R	eduction)			0.00
Heat Exchanger Type				TEMA-E
Effective Area (ft^2)				471.23
Area Factor				0.981978184
Area Ratio				
Number of Shells per Uni	it			1
Shell Minimum Area				0.490000000
Shell Velocity (ft/s)				5.000
Tube Pitch (in)				0.7500
Tube Pitch Type				Triangular
Number of Tube Passes				2
U-Tubes				No
Total Number of Tubes				188
Number of Active Tubes				179
Tube Length (ft)				13.00
Tube Inside Diameter (in))			0.652
Tube Outside Diameter (i	n)			0.750
Tube Wall Conductivity (BTU/hr·ft·°l	F)		112.00
Ds, Shell Inside Diameter	(in)			0.000
Lbc, Central Baffle Spacin	ng (in)			0.000
Lbi, Inlet Baffle Spacing	(in)			. 0.000
Lbo, Outlet Baffle Spacin	g (in)			0.000
Dotl, Tube circle diameter	r (in)			0.000
Bh, Baffle cut height (in)				0.000
Lsb, Diametral difference	between Ba	ffle a	and Shell (in)	0.000
Ltb, Diametral difference			` ,	0.000
Nss, Number Sealing Strip	ps			0.000

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Attachment _C
Page No. C2 of C3



Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler CSCS=104 F@2X NDIT FF, 5% plugged

Calculation Specifications

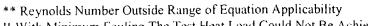
Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

* Fouling Was Input by User

		Data
Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.001068
Fouling Calculation	n Results	
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)	
,	Tube-Side hi (BTU/hr-ft2.°F)	
Heat Transferred (BTU/hr)	I/Wall Resis (BTU/hr·ft²-°F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		
	Overall Fouling (hr-ft2.0F/BTU)
Property Shell-Side Tube-Side		
Velocity (ft/s)	Shell Temp In (°F)	Calculation No. 97-195
Reynold's Number	Shell Temp Out (°F)	Revision No. A00
Prandtl Number	Tav Shell (°F)	Attachment C
Bulk Visc (lbm/ft·hr)	Shell Skin Temp (°F)	Page No. C3 of C3
Skin Visc (lbm/ft hr)	Tube Temp In (°F)	- ago 110. <u>C3</u> 01 <u>C3</u>
Density (lbm/ft³)	Tube Temp Out (°F)	
Cp (BTU/lbm·°F)	Tav Tube (°F)	
K (BTU/hr·ft·°F)	Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft2.0F/BTU)	0.001068
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr-ft ^{2.} °F)	2,007.6
•	2.00		Tube-Side hi (BTU/hr·ft².°F)	2,335.8
Heat Transferred (BTU/hr)	- V***	1.221E+7	1/Wall Resis (BTU/hr ft2.°F)	25,594.8
LMTD		59.1	LMTD Correction Factor	0.9655
Effective Area (ft²)		448.7		
•			U Overall (BTU/hr-ft2.°F)	476.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.98	8.63	Shell Temp In (°F)	190.0
Reynold's Number	8.063E+04	7.690E+04	Shell Temp Out (°F)	167.1
Prandtl Number	2.19	3.66	Tav Shell (°F)	178.6
Bulk Visc (lbm/ft·hr)	0.84	1.36	Shell Skin Temp (°F)	164.5
Skin Visc (lbm/ft·hr)	0.93	1.19	Tube Temp In (°F)	104.0
Density (lbm/ft ³)	60.61	61.72	Tube Temp Out (°F)	134.7
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	119.4
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Temp (°F)	133.3



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



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Attachment "D"

Attachment "D" - Proto-Hx Calc. Report for DG01A (CSCS=104 F @ Max. Allowable FF, w\ 5% plugged)

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler CSCS=104 F@Max. FF, 5% plugged



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,099.45	775.61
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor		★ 0.00278	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (BT	`U/hr)		8,600,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	255.20
Emprical Factor for Outsi	de h		0.780339000
Performance Factor (% Re	eduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			471.23
Area Factor			0.981978184
Area Ratio			
Number of Shells per Uni	t		1
Shell Minimum Area			0.490000000
Shell Velocity (ft/s)			5.000
Tube Pitch (in)	0.7500		
Tube Pitch Type	Triangular		
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			188
Number of Active Tubes			179
Tube Length (ft)			13.00
Tube Inside Diameter (in)			0.652
Tube Outside Diameter (in	1)		0.750
Tube Wall Conductivity (BTU/hr·ft·°l	F)	112.00
Ds, Shell Inside Diameter	(in)		0.000
Lbc, Central Baffle Spacin			0.000
Lbi, Inlet Baffle Spacing (in)		0.000
Lbo, Outlet Baffle Spacing			0.000
Dotl, Tube circle diameter			0.000
Bh, Baffle cut height (in)	,		0.000
Lsb, Diametral difference	between Ba	ffle and Shell (
Ltb, Diametral difference			•
Nss, Number Sealing Strip		`	0.000

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Revision No. A00
Attachment <u>0</u>
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Cp (BTU/lbm-°F)

K (BTU/hr·ft·°F)

Extrapolation Data

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler CSCS=104 F@Max. FF, 5% plugged

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

* Fouling Was Input by User

Test Data

Data Date			Tube Flow (gpm)	795.3
Shell Flow (gpm)			Shell Flow (gpm)	1,064.5
Shell Temp In (°F)			Tube Inlet Temp (°F)	104.0
Shell Temp Out (°F)			Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)			★ Input Fouling Factor	0.002200
		Fouling Calculati	on Results	
			II O II (DIELIA OZON)	
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)	~
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr-ft²-	,
			Tube-Side hi (BTU/hr·ft².º	*
Heat Transferred (BTU/hr)	l		1/Wall Resis (BTU/hr-ft2.0	F)
LMTD			LMTD Correction Factor	
Effective Area (ft²)				
			Overall Fouling (hr-ft ^{2.} °F/I	BTU)
Property	Shell-Side	Tube-Side		
Velocity (ft/s)			Shell Temp In (°F)	Calculation No. 97-195
Reynold's Number			Shell Temp Out (°F)	Revision No. A00
Prandtl Number			Tav Shell (°F)	Attachment D
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Page No. D3 of D3
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)	9
Density (lbm/ft³)			Tube Temp Out (°F)	
Designity (solid to)			10mp Out (1)	

Tav Tube (°F)

Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².ºF/BTU)	0.002200
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr-ft2-°F)	2,029.5
			Tube-Side hi (BTU/hr·ft².°F)	2,279.5
Heat Transferred (BTU/hr	r)	9.032E+6 /	l/Wall Resis (BTU/hr-ft2.°F)	25,594.8
LMTD		66.1	LMTD Correction Factor	0.9852
Effective Area (ft2)		448.7		
			U Overall (BTU/hr·ft².°F)	309.0
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.99	8.62	Shell Temp In (°F)	190.0
Reynold's Number	8.228E+04	7.401E+04	Shell Temp Out (°F)	173.1
Prandtl Number	2.14	3.82	Tav Shell (°F)	181.5
Bulk Visc (lbm/ft·hr)	0.83	1.41	Shell Skin Temp (°F)	171.5 /
Skin Visc (lbm/ft·hr)	0.89	1.28	Tube Temp In (°F)	104.0
Density (lbm/ft3)	60.54	61.78	Tube Temp Out (°F)	126.7
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	115.4
K (BTU/hr·ft·°F)	. 0.39	0.37	Tube Skin Temp (°F)	125.7

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

PROTO-POWER CORPORATION CALCULATION TITLE SHEET

CLIENT:

Commonwealth Edison / LaSalle County Station

PROJECT:

COMED / LaSalle Station GL 89-13 Program

CALCULATION TITLE:

Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2

Diesel Generator Jacket Water Coolers

CALCULATION NO.:

97-195

FILE NO.:

31-003

COMPUTER CODE & VERSION (if applicable): PROTO-HX ver 3.02

REV	TOTAL NO. OF PAGES	ORIGINATOR/DATE	VERIFIER/DATE	APPROVAL/DATE
A	73	D. Phyfe	S. Ingalls	L. Philpot 430/9

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Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers				

Revision History

Revision	Revision Description
A	Original Issue



Form No.: PI050102 Rev.: 10 Date: 10/21/97

Ref.: <u>P&I 5-1</u>

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Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers				

CALCULATION VERIFICATION FORM

REVIEW METHOD:	,		EXTENT OF VERIFICA	ATION:	
Approach Checked: Logic Checked: Arithmetic Checked: Alternate Method	াব্যব্র	N/A	Complete Calculation: Revised areas only:		
(Attach Brief Summary) Computer Program Used (Attach Listing) Other		N/A 🖸	Other (describe below):		
*Errors Detected	_	_ ,	*Error Resolution		
Minor Editional		 	Cornected		
				· · · · · · · · · · · · · · · · · · ·	
*Other Comments					
*Extra References Used					
*(Attach extra sheets if needed)					<u> </u>
CALCULATION FOUND TO BE	VALID A	ND CONCLUS	SIONS TO BE CORRECT AND 1	REASONABL	E:
IDV Signature:	Sign	HM. L	nels	Initials:	Lul
		, , _ , _ , _ , _ , _ , _ , _ , _	· · · · · · · · · · · · · · · · · · ·	_	_ ✓ Ø



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TITLE Thermal Model of COMED / LaSalle St	ation Unit 0, 1, and 2 Diesel	Generator J	Jacket Water Coolers

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A	Proto-Power Calc. 97-195, Rev. A;	3			
	Vendor Supplied Hx. Information				
В	Proto-Power Calc. 97-195, Rev. A;	3			
	Sargent & Lundy Specification J-2544				
С	Proto-Power Calc. 97-195, Rev. A;	7			
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D	Proto-Power Calc. 97-195, Rev. A;	5			
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	PROTO-HX™ Calculation Reports for Fouling Sensitivity				
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1. PURPOSE

The purpose of this calculation is to develop a thermal performance analysis model for the Commonwealth Edison (ComEd) LaSalle Station, Standby Diesel Generator heat exchanger. This model is to be used for the analysis of heat exchanger thermal performance test data as part of the LaSalle Station heat exchanger testing program.

Once developed, the model is used to evaluate the thermal margin of the heat exchanger at the LaSalle Station Reference Conditions as currently defined in the LaSalle design and licensing basis.

The thermal performance model documented in this calculation has been created and used with PROTO-HX, Version 3.02. The model can be used with previous versions of PROTO-HX and produce identical results as long as the following restrictions are upheld:

- Versions prior to version 3.02 will not calculate a negative fouling factor when calculating the fouling factor based on test data.
- Shell and tube heat exchangers analyzed in Version 3.0 or earlier must have a tube-side Reynolds Number greater than 10,000 (i.e., fully developed turbulent flow).

Current limitations of use for PROTO-HX are established by the limits on fluid properties included within the software. Fluid properties contained within PROTO-HX are currently limited to the following temperature ranges:

• Water (fresh and salt): 32-500°F

2. BACKGROUND

LaSalle Station is in the process of implementing a heat exchanger thermal performance monitoring program in response to the requirements of NRC Generic Letter 89-13 (Reference 8.2). Development of an analytical model in PROTO-HXTM, Version 3.02, will allow timely analysis of data resulting from the test program.

3. DESIGN INPUTS

The PROTO-HXTM program was developed and validated in accordance with Proto-Power's Nuclear Software Quality Assurance Program (SQAP). This program meets the requirements of 10CFR50 Appendix B, 10CFR21, and ANSI NQA-1, and was developed in accordance with the guidelines and standards contained in ANSI/IEEE Standard 730/1984 and ANSI NQA-2b-1991. PROTO-HXTM Version 3.02 was verified and approved for use as documented in Reference 8.10.

The design inputs for this calculation consist of the heat exchanger design basis requirement (Section 3.1), construction details (Section 3.2), and performance specifications (Section 3.3) provided by the Hx manufacturer data sheets or design documents as referenced. Construction

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details give the necessary information for model construction while performance specifications provided by the manufacturer are used to benchmark the model.

Thermal performance of the Standby diesel generator heat exchanger is assessed in this calculation at the LaSalle Station Reference Conditions of Section 3.1 with all tubes active at 100% and 110% of rated load. No tube plugging margin is considered.

3.1. LASALLE STATION REFERENCE CONDITIONS

Table 3-1 describes the performance requirement of the jacket water cooler. These conditions ensure that the engine operating temperature range will not be exceeded.

Table 3-1 LaSalle Station Reference Conditions

Parameter	Value	Reference
Heat Load at 100% power/110% power (BTU/hr)	7,800,000 / 8,600,000	8.1, 8.4
Shell-Side Flow Rate (gpm)	1,100	8.4
Shell-Side Inlet Temperature (°F)	190	8.4
Tube-Side Flow Rate (gpm)	800	8.1, 8.4
Tube-Side Inlet Temperature (°F)	100	8.1

3.2. CONSTRUCTION DETAILS

Table 3-2 Construction Details

Parameter	Value	Reference
Heat Exchanger Type	AEW	8.11
Total Effective Area per unit (ft²)	479	8.11
Number of Shells per unit	1	8.11
Shell Velocity (ft/sec)	5	8.11
Tube Passes per shell	2	8.11
U-Tubes (yes or no)	No	8.11
Total Number of Tubes	188	8.11
Tube Length (ft)	13	8.11
Tube Inside Diameter (in)	0.652 (18 BWG)	8.11
Tube Outside Diameter (in)	0.750	8.11
Stationary Tubesheet Thickness (in)	0.938	8.3
Floating Tubesheet Thickness (in)	1.875	8.3
Tube Wall Conductivity (BTU/hr-ft-°F)	112 (Arsenical Cooper)	8.9, (8.11)
Tube Pitch (in)	0.750	8.11

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Table 3-2 Construction Details

Parameter	Value	Reference
Pitch Type	Triangle	8.11

The vendor data sheet shows the effective area as 479 ft², however, based on the outside tube diameter and tube length, this value is a gross area (A_{yr}) approximation:

$$A_{gr} = (number of tubes) \cdot (L_{tube}) \cdot (tube outside circ.)$$
 Equation 1

$$A_{gr} = 188 \cdot 13 \, \text{ft} \cdot \pi \cdot \left(\frac{0.750 \, \text{in}}{12 \, \text{in/ft}} \right) = 479.878 \, \text{ft}^2$$

The effective area (A_{eff}) can be approximated as follows:

$$A_{eff} = (number of tubes) \cdot (L_{tube} - T_{fixed} - T_{floating}) \cdot (tube outside circ.)$$
 Equation 2

$$A_{eff} = 188 \cdot \left(13 \, \text{ft} - \frac{\left(0.938 \, \text{in} + 1.875 \, \text{in} \right)}{12 \, \text{in} / \text{ft}} \right) \cdot \pi \cdot \left(\frac{0.750 \, \text{in}}{12 \, \text{in} / \text{ft}} \right) = 471.2251 \, \text{ft}^2$$

where:

A_{er} – Heat Exchanger Gross Area, ft²

A_{eff} – Heat Exchanger Effective Area, ft²

L_{tube} - Tube Length, ft

T_{fixed} - Fixed End Tubesheet Thickness, ft (0.938" per Reference 8.3)

T_{floating} - Floating End Tubesheet Thickness, ft (1.875" per Reference 8.3)

The data sheet value for the effective area will be used in the model benchmarking process. However, for PROTO-HXTM runs of the Standby heat exchanger model the above calculated effective area will be used.

3.3. Performance Details

Table 3-3 Performance Details

Parameter	Value	Reference
Shell Side Fluid Type	Jacket Water (Fresh)	8.11
Total Fouling Factor (Design)	0.00285	8.11
Shell Side Fluid Flow Rate (lb/hr)	550,000	8.11
Shell Side Inlet Temperature (°F)	190	8.11
Shell Side Outlet Temperature (°F)	174.4	8.11
Tube Side Fluid Type	Service Water (Fresh)	8.1/8.7

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Table 3-3 Performance Details

Parameter	Value	Reference
Tube Side Fluid Flow Rate (lb/hr)	388,000	8.11
Tube Side Inlet Temperature (°F)	100	8.11
Tube Side Outlet Temperature (°F)	122.2	8.11
Hx. Design Q - Scrvice (BTU/hr)	8,600,000	8.11
Hx. Design U - Service (BTU/hr-ft²-°F)	255.2	8.11

4. APPROACH

This calculation utilizes plant/vendor fabrication specifications provided in Attachment (A) to develop a thermal performance prediction model for the LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers. The calculation then benchmarks the model by comparing the heat transfer rate calculated by PROTO-HXTM Version 3.02 with the manufacturer's specifications for thermal performance.

4.1. PROTO-HXTM PARAMETER CALCULATION

Minimum Shell Area

The minimum shell area is calculated using either the shell side velocity or a shell geometry. The preferred method of calculation is using the shell side velocity. Reference 8.11 gives the shell side velocity to be 5 ft/sec at a flow rate of 1100 gpm. Based on this velocity and flow rate the minimum shell side area is calculated by PROTO-HXTM to be 0.490 ft².

Outside H Factor (Hoff)

The Outside H Factor is a multiplier, with value less then 1.0, used to reduce the ideal shell side film heat transfer coefficient. The Outside H Factor accounts for inefficiency in the heat exchanger. Using the back calculation method, based on the design overall heat transfer coefficient, the Outside H Factor was calculated by PROTO-HXTM to be 0.780.

4.2. PROTO-HXTM FLOW RATE INPUTS

Volumetric flow rates are converted to mass flow rates based on a set temperature of 60°F in PROTO-HXTM. Therefore, the actual PROTO-HXTM inputs have to be adjusted to give the correct mass flow rate. The PROTO-HXTM input is adjusted using the ratio of the actual water density and the density of water at 60°F.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60^{\circ}F}}$$

Equation 3

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Table 4-1 PROTO-HX™ Flow Rate Inputs

Parameter	Density (lb/ft³)	Actual Flow (gpm)	PROTO-HX™ It	iput (gpm)
Tube-side, 100°F	61.994 (8.12)	800	795.25	e Artista Maria
Shell-side, 190°F	60.349 (8.12)	1,100	1,064.495	
PROTO-HX™, 60°F	62.364 (8.12)			

4.3. PROTO-HXTM EXTRAPOLATION METHOD

All calculations performed for this calculation are based on a constant cold inlet temperature. This allows the comparison of the heat transfer, outlet temperatures, log mean temperature difference (LMTD), and overall heat transfer coefficient. There is no comparison of the overall heat transfer coefficient in the design case since PROTO-HXTM used the data sheet value of the overall heat transfer coefficient to calculate the shell side film heat transfer coefficient.

5. ASSUMPTIONS

5.1. The vendor data sheet (Reference 8.11) is considered an accurate reflection of the vendor's expectation for the heat exchanger's outside film heat transfer coefficient. Therefore, the benchmarking of the PROTO-HXTM model to the vendor data sheet will ensure that the PROTO-HXTM calculated outside film heat transfer coefficient is consistent with the vendor's expectation. The PROTO-HXTM model is benchmarked with the vendor data sheet effective area. However, calculations performed with the model use the effective area determined in Section 3.2. Future validation of this assumption is not required.

6. ANALYSIS

6.1. PROTO-HXTM MODEL

Table 6-1 shows the PROTO-HXTM benchmarking of the Jacket Water Cooler for the Standby Diesel Generator. The PROTO-HXTM reports can be found in Attachment E.

Table 6-1 Model Benchmark Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft ²	479	479	0.00 %
Shell Side Outlet Temp, °F	174.4	174.4	0.00 %
Tube Side Outlet Temp, °F	122.2	122.2	0.00 %
Heat Transferred, BTU/hr	8,589,000	8,600,000	-0.13 %
Corrected LMTD	70.3	70.2	0.14 %

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Table 6-2 shows the PROTO-HX[™] results for the heat exchanger design conditions using the corrected effective area, Section 3.2. The PROTO-HX[™] reports can be found in Attachment E.

Table 6-2 Model Design Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft ²	471.2	479	-1.63 %
Shell Side Outlet Temp, °F	174.6	174.4	0.11 %
Tube Side Outlet Temp, °F	121.9	122.2	-0.25 %
Heat Transferred, BTU/hr	8,481,000	8,600,000	-1.38 %
Corrected LMTD	70.5	70.2	0.43 %

All PROTO-HXTM calculations performed with the Standby Jacket Water Cooler model will use the effective area of 471.23 ft². This change is made to the PROTO-HXTM heat exchanger data sheet as shown in Attachment E.

6.2. HEAT EXCHANGER FOULING FACTOR LIMIT

In order for the jacket water cooler to meet the Reference Conditions (Table 3-1) the fouling must be limited from the values listed on the vendor's data sheet (Reference 8.11). The overall fouling factor limit was determined by iterating on the overall fouling factor, a PROTO-HXTM input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HXTM runs for the limited fouling factor case, see Attachment E.

Table 6-3 Fouling Factor Limit

Parameter	Design Fouling	Limited Fouling
Overall Fouling Factor	0.00285	0.002782
Overall Heat Transfer Coefficient	255.2	259.7
Heat Transfer Rate	8,484,000	8,600,000
Required Heat Transfer Rate	8,600,000	8,600,000
Thermal Margin	-116,000	0.0
% Thermal Margin	1.35 %	0.00 %

The limitations on the fouling factor are placed on the tube-side fouling factor, since the tube-side is the most controllable via periodic tube-side cleaning. To be consistent with the HPCS Diesel the shell-side fouling factor will be set to 0.0005 hr ft² °F/Btu for this analysis. The tube-side fouling factor is calculated from the overall fouling found from the PROTO-HXTM iteration process.

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The area ratio is used to convert the overall fouling factor to a tube-side and shell-side fouling factor

$$f_{total} = f_{shell} + (Area Ratio) \cdot f_{tube}$$

Equation 4

Area Ratio =
$$\frac{\text{Tube OD}}{\text{Tube ID}}$$

Equation 5

Area Ratio =
$$\frac{0.750 \,\text{in}}{0.652 \,\text{in}} = 1.150$$

From the vendor datasheet the design overall fouling factor is

$$f_{Total} = 0.002850^{\text{hr ft}^2 \circ F} /_{\text{Btu}}$$

From the PROTO - HX iteration the adjusted overall fouling factor is found:

$$f_{adjusted} = 0.002782 \, \text{hr ft}^2 \, \text{°F} / \text{Btu}$$

From the new overall fouling factor the new tube - side fouling factor is calculated:

$$f_{\text{tube}} = \frac{\left(f_{\text{adjusted}} - f_{\text{shell}}\right)}{\text{Area Ratio}} = \frac{\left(0.002782 - 0.0005\right)^{\text{hr ft}^2 \circ \text{F}}}{1.150} = 0.001984^{\text{hr ft}^2 \circ \text{F}}$$

The PROTO-HX[™] heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

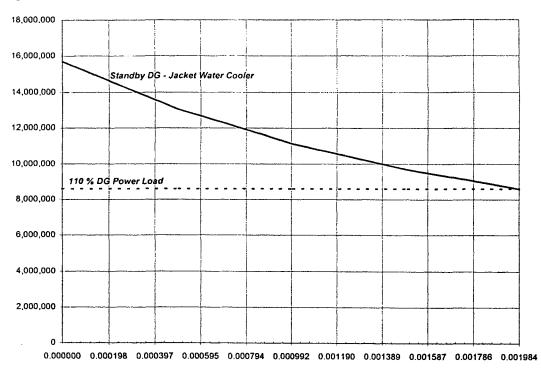
Attachment E includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HXTM data sheet.

6.3. FOULING SENSITIVITY

The fouling sensitivity of the jacket water cooler is shown in Figure 6-1. The fouling sensitivity was developed at 800 gpm CSCS flow, 100°F CSCS inlet temperature, 1100 gpm jacket water flow, and 190°F jacket water inlet temperature. The tube-side fouling factor was varied from 0.0000 to 0.001984 (hr ft² °F/Btu) by increments of 0.0005 (hr ft² °F/Btu). As in Section 6.2, the shell-side fouling factor is held constant at 0.0005 (hr ft² °F/Btu). The PROTO-HXTM Calculation Reports for the fouling sensitivity can be found in Attachment F.

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Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

Figure 6-1



6.4. THERMAL MARGIN ASSESSMENT

The clean thermal margin is assessed by a comparison of the reference condition performance requirements to the heat exchanger performance capability with a zero (0) fouling factor. Using a zero (0) fouling factor shows the maximum available performance of the heat exchanger. Likewise, the service thermal margin is assessed by comparing the reference condition performance requirements to the heat exchanger performance capability with the design fouling factor.

The margin is calculated directly and as a percentage compared to the required heat rate to perform the component's safety function. The PROTO-HXTM reports can be found in Attachment E.

$$margin = Heat \, Rate - Heat \, Rate_{required}$$

Equation 6

$$\% margin = 100 \cdot \left(\frac{margin}{Heat Rate_{required}} \right)$$

Equation 7

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Table 6-4 Thermal Margin

Parameter	Service (Design Fouling)	Clean (0 Fouling)
Overall Heat Transfer Coefficient	259.7	955.9
Heat Transfer Rate	8,600,000	18,850,000
Required Heat Transfer Rate	8,600,000	8,600,000
Thermal Margin	0.0	10,250,000
% Thermal Margin	0.00 %	119.19 %

6.5. MINIMUM SERVICE WATER FLOW RATE

The minimum service water flow rate for the adjusted design fouling condition is calculated with the shell-side inlet temperature at 190°F and a flow rate of 1,100 gpm. Iterating using the service water flow rate and inlet temperature, the minimum acceptable flow rate is found for each inlet temperature (Attachment G). The heat load for each iteration must be equal to or slightly above the required heat load of 7,800,000 BTU/hr and 8,600,000 BTU/hr, the diesel heat load at 100% and 110% power, respectively (Reference 8.1). Figure 6-2 shows the results of this iteration process.

The results of the model iterations are summarized in Table 6-5 and Table 6-6 along with Figure 6-2. Density corrections of the PROTO-HXTM flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.12.

Table 6-5 Minimum CSCS Flow Rate at 100% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HX TM Input Flow Rate (gpm)	Density Corrected Flow Rate (gpm)
35	62.41903	161.1	161.0
40	62.42184	169.8	169.6
50	62.40595	190.5	190.3
60	62.36445	217.5	217.5
70	62.30034	254.2	254.5
80	62.21603	307.0	307.7
90	62.11349	389.3	390.9
100	61.99437	534.5	537.7

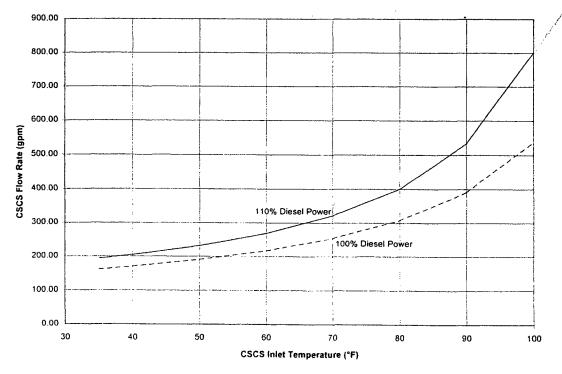
Form No.: P1050105 Rev.: 10 Date: 10/21/97

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Table 6-6 Minimum CSCS Flow Rate at 110% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HX TM Input Flow Rate (gpm)	Density Corrected Flow Rate (gpm)
35	62.41903	193.5	193.3
40	62.42184	204.8	204.6
50	62.40595	232.2	232.1
60	62.36445	269.1	269.1
70	62.30034	321.0	321.3
80	62.21603	399.3	400.3
90	62.11349	530.9	533.1
100	61.99437	795.3	800.0

Figure 6-2 Minimum Service Water Flow



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7. CONCLUSION

7.1. PROTO-HXTM MODEL

The Standby Jacket Water Cooler model was developed using PROTO-HXTM, Version 3.02. The model was benchmarked to the vendor data sheet. The benchmark model correlation to the vendor data sheet is -0.13 %. The benchmark model is for reference only based on the non-conservative approximation of heat exchanger effective area as discussed in Section 3.2 and Assumption 5.1. Calculations performed with the Standby Jacket Water Cooler model are to use the effective area developed in Section 3.2.

This model should be considered suitable for use in the analysis of thermal performance test data.

The model database is saved under file name dg01a.phx, with a file size of 640 KB, and a file date and time of 6/29/98 at 1:50:34 PM. The saved database is set up to run the Reference Conditions with design fouling factor selected, the design fouling factor is a shell-side fouling of 0.002782. The database file is included as Attachment H.

7.2. HEAT EXCHANGER FOULING FACTOR LIMIT

For the Standby Diesel Generator Jacket Water Cooler to provide adequate heat removal at the specified LaSalle Station Reference Conditions the overall fouling factor must be equal to or less than 0.002782 hr ft² °F/Btu. This overall fouling factor is entered in the model as the shell-side design fouling factor.

7.3. FOULING SENSITIVITY

Given a constant shell-side fouling at the model design value, the sensitivity of the jacket water cooler to tube-side fouling effects is shown on Figure 6-1.

7.4. THERMAL MARGIN ASSESSMENT

Assuming the adjusted heat exchanger effective area and maximum overall fouling factor, the clean and service available thermal margins are 119.19 % and 0.00 % respectively.

7.5. MINIMUM SERVICE WATER FLOW RATE

As shown in Figure 6-2 the service water flow can be throttled down to account for lower service water inlet temperature conditions. The heat exchanger can remove the design heat load for the diesel at 100% (7,800,000 BTU/hr) and 110% (8,600,000 BTU/hr) rated power, by reducing service water flow rates as the service water temperature decreases.



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8. REFERENCES

- 8.1. LaSalle Station UFSAR, Sections: 9.2.1.1.1, 9.5.5.1.1 (Attachment D)
- 8.2. NRC Generic Letter 89-13
- 8.3. The National Board of Boiler and Pressure Vessel Inspectors, Form N-1 Manufacturers' Data Report for nuclear Vessels (Attachment C)
- 8.4. LaSalle Station FSAR Q40.92 (Attachment D)
- 8.5. Stewart & Stevens Vendor Manual, VM J-152 through VM J-157
- 8.6. LaSalle Station Drawing, D-22079
- 8.7. Sargent and Lundy Specification J-2544 (Selected Pages, Attachment B)
- 8.8. Not used
- 8.9. Standard of the Tubular Exchanger Manufacturers Association
- 8.10. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HX[™] Version 3.02 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision F, dated 2/17/98
- 8.11. American Standard Heat Exchanger Data Sheet for the LaSalle Station Standby Diesel Generator Jacket Water Coolers. (Attachment A)
- 8.12. Proto-Power Calculation 93-048, "Fluid Properties Fresh Water Range 32°F to 500°F", Rev. A

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JUN -5 1999

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Attachment B to Proto-Power Calculation 97-195 Revision A

Proto-Power Calc: 97-195

Attachment: B

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REFERENCE 8.7

include a shell and tube heat exchanger which will be supplied with cooling water from the Purchaser's cooling water system.

- b. The closed cooling water system pump shall be of the centrifugal type and shall be driven by the engine.
- c. The shell and the tube heat exchanger shall be of the capacity required for 110 percent of rated power with a fouling factor of 0.0005 on shell side and .002 on the tube side. The heat exchanger shall be in accordance with the requirements of ITEM A, TEMA (Tube Exchanger Manufacturers' Association) Class C and the ASME Code Section III. The type bundle shall be removable without removing shell from its mounting. The tubes shall be 5/8 inch minimum and be of admiralty metal.
- d. The circulating water system shall be provided with controls which will sense and maintain optimum jacket water temperature.
- e. Cooling water supply for the heat exchangers will be at a maximum inlet temperature of 100°F and a minimum of 32°F. The coolers shall be designed for a 150 psig water working pressure and tested at a hydraulic pressure of 225 psig.

F. Starting System

- a. Each engine shall be equipped with an independent pneumatic starting system complete with all valves, integral piping, controls, etc.
- b. The reliability of the starting system is paramount and no compromise of the starting capability shall be made with other basic requirements of the equipment design. Any special devices or auxiliaries required to insure successful starting shall be provided, except any equipment of an experimental type will be unacceptable. Contractor shall describe in his proposal what occurances are possible to preclude successful starting, and what remedies would be necessary that are not already provided for in the equipment design.
- c. The compressed air starting system shall consist of two redundant sets of equipment, each completely independent of the other for successful operation. A cross-connecting line with a normally closed valve shall be provided between sets. The accumulator furnished with each set of equipment shall have the capacity for a minimum of three normal cranking cycles in rapid succession without the use of its air compressor. Each accumulator shall be furnished with a shut-off cock, pressure gauge drain valve, safety valve, and sensing element for low pressure alarm.

 Proto-Power Calc: 97-195

Attachment: B

Proposal Technical Data for Diesel Engine-Generator Sets, Cont. La Salle County Station - Units 1 and 2

CP

REFERENCE 8.7

Name of Bidder: Stewart & Stevenson Services, Inc.

(Insert all data in these columns)

ENGINE-GENERATOR DATA, Cont.	(Insert all	data in these	columns)
	BASE	BID	ALTERNATE 1
		DIESEL GEN.	DIESEL GEN.
	DIESEL GEN.O	1A AND 2A	O, 1A AND 2A
(Contractor to furnish complete information for starting system furnished)		·	
nation for starting system furnished)	•		
E. Engine Cooling System:			
a. Cooling system capacity.(gal)	545		
b. Pipe size for cooling water			
connections(in)	8		
c. Heat exchanger dimensions:			
(1) Length(in)	179.5		
(2) Diam(in)	16"		
(3) Height(in)	19.5"		
d. Quantity of cooling water			
at rated load, required at			
80°F(gal/min)	550		
at 95°F(gal/min)	750		
at 100°F(gal/min)	840		
at 100 r(gar/min)			
e. Tube material	Arsenical Copper (SB1	11)	
f. Diameter and thickness of	oopper (obj		
tubes(in)	3/4" x 18 BWG		
g. Total tube cooling surface			
(ft ²)	479		
h. Water box material	Carbon		
water box material	Steel		
	Weights:		
	3050 lbs Dry		
	4350 lbs Wet		
	i l		

PTD-15

Proto-Power Calc: 97-195

Attachment: B

Rev: A Page 3 of 3

Attachment C to **Proto-Power Calculation** 97-195 **Revision A**

Form No.: <u>Pl050104</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

Proto-Power Calc: 97-195

Attachment: C

Rev: A Page l of 7 Ref.: <u>P&I 5-1</u>

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS. As required by the Provisions of the ASME Code Rules.

1. Manufactured by AMERICAN STANDARD HEAT TRANSPER DIVISION - BUFFALO, NEW YORK 1	4240
(Mune sirt endisse of married (mail	
2. Manufactured for STEWART - STEVENSON SERVICES; HOUSTON, I	
3. Type HORIZ. Kind Heat Exch. Vessel No. 8-20005-PI-1 Nat'l Rd. No. Yr. E	الماد النوا
(Meter on Ages) (The France party party)	
3a. Applicable ASME Code: Section III, Edition 1974 Addenda date WINTER 1974, Care N	o
Class3	
tems 4-8 incl. to be completed for single wall vessels, jackets of jacketed vessels, u. shells of heat exchangers.	
	2.43
SMUS. 5TL Nominal 275 Cotrosion 663 16.000 15 4. Shellt Material SP 106-B T.S. 60,000 Thickness 21 in. Allowance in Dia. 11. in Length 11	
S. Seamer Lone SML'S H.T. NO R.T. NONE Efficiency	<u> </u>
Girth II.T R.T No. of Courses	1
6. Heeds (a) Material T.S (b) Material T.S	
	to Press.
	or Conc
(a)	
(b)	
If removable, bolts used(Material, Spec. No., T.S., Size, Number) Other factoning (Describe or attach	sketch)
(Describe so ogen & weld, bar, etc. If har give dimensione, describe or shotch)	
Drop Veight Presumeric	
Charpy Impactfield Hydrostatic or Test B. Design Pressure 150 psi at 3.00 "F at temp, of "F. Gentination Pressure	~~~
Floating. Material NUMIT SBITIDIA II. 250 in Thickness 438 in Attachment BO (Kind & Spec. No.) Floating. Material NUMIT SBITIDIA IS A DOO in Thickness 1:875 in Attachment BO (Kind & Spec. No.) ARS. COPPER	
, Tubest Material SB 111 0.D. 74 in. Thickness. 8 or gage Number 188 Type ST	RAK
ems 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.	· · · · · · · · · · · · · · · · · · ·
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CHANNEL: SMLE OFL. CHANNEL: SMLE OFL. GEORGIAN STATE OF THE CONTROL OF THE CONT	_ (t
Scamer Long SMLS H.T. NO R.T. NONE Efficiency (Yes of No)	
	0_
Girth No. of Courses No.	0
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# o. STL.	
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FORM N-1 (back) Control of the Property of the	
trong below to be completed for all vessels where applicable.	
13. Befety Valve Outlets: Number Size Lucation	·
SHELLIN COLT 2 10"-150" ASA PIPE FIG. SA 106.B 307	WELDE!
TUBEINGOUT 2 8"-150#ASA PIPEGRG. SAIRGB 277	unbet
17. Inspection Manholes, No. Size Location	
18. Supports: Shitt NO. Lugs Legs ()ther CRADLES Attached WELDED (Where it 19. Remarks: JACKET WATER COOLER	TO SHEL
(Brief description of service for which vessel was designed)	
CERTIFICATION OF DESIGN Design information on file and IERICAN STD. HEAT STANS. DIV. BUFFALO NY. Birror analysis report on file at NOL AFPLICABLE TO SECTION III CLISS & VESSE Design specifications cartified by P. J. MAZZA. Prof. Eng. State LLL Reg. No. 6 Stress analysis report cartified by MOT PAPHICABLE. Prof. Eng. State Reg. No.	2-21850
We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rule tion of the ASME Lode, Section III. AMERICAN STANDARD HEAT Date The Signed TRANSPER DIVISION Dy K. R. Warner - Hanage (Manufacturer)	
(Manufacturer) R. R. War Der - Hanage Certificate of authorization Expires August L. 1978 Certificate of Authorization No.	-
CERTIFICATE OF SHOP INSPECTION VESSEL MADE NAMERICAN STANDARD HEAT TRANSPER DIVISION Buffalo, New York L, the undersigned, helding a valid assemblation issued by the National Board of Refer and Pressure Vessel Inspection and/ or Pressure of New York and employed by Limbermons Hitual Casualty Co. 'Chicago,'	or the State
have inspected the pressure vessel described in this Manufacturer's Data Report on	ha praesure
Date	
CERTIFICATE OF FIELD ASSEMBLY INSPECTION 1, the undersigned, holding a velid committation tasted by the National Board of Barles and Pressure Vessel Inspectors and/or Province of	er the State
have compared the statements in this Manufacturer's Data Paper, with the described pressure vessel and state that parts re- data liams, not included in the certificate of shop insp- heen inspected by me ambilist to the best of a 3 housings and belief the manufacturer has constructed and essembled this pr- sel in accordance with the ASME Code, Section lif. The described vessel was inspected and subjected to a hydrostatic Presumatic Test of	vellos have teede ves- teet and/or
vessel described in this Monifacturer's Data Report, Furthermore, neither the Inspector not his employer shall be Hable in	

Printed in H.S.A. (7/71)

This form (E34) is obtainable from the ASME, 345 E. 47th St., New York, N.Y. 10017

Proto-Power Calc: 97-195

Attachment: C

Notional Board, State, Province and No.

3 of 7 Rev: A Page

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS. An required by the Provisions of the ASME Code Rules.

Class 3 A-B Incl. to be completed for single wall vessels, jackers of jackers vessels, or shells of heat exchangers. SCHUTS. 5TH. SCHUTS. 5	(Kame and sidiles of Manufactures)	-
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excificate of authorization Expires <u>August</u>	4. 1978	Certificate of Authorization N	0. 1164
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VEHEL HADE WANERICAN STANDARD REAT	TRANSFER DIVISIO	H at Buffalo, New York	
i, the undersigned, helding a valid completion traure or Province of New YORK and employed by L	webermens Kutual	Casualty Co. Chicage	o, Tilinois
have inspected the pressure vessel described in this M	anufacturer's Data Report on	Lebury AG	19.26, 404
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J. A. Thomas	Commissions	NB 7710 National Board, State, Province an	
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Proto-Power Calc: 97-195
Attachment: C

Rev. A Page 5 of 7

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS. An required by the Provisions of the ASME Code Rules.

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	(Brief desci	igition of service for	which vessel was designed)		
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Inted _a lii U.S.A. (7/71)		This form (£58)	is obtainable from the ASSIB	toto-Power Calc: Stackment: C	97-195 Grk, N.Y. 1001
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Attachment D to Proto-Power Calculation 97-195 Revision A

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Reference 8.1

LSCS-UFSAR

9.2 WATER SYSTEMS

The auxiliary water systems for the LaSalle County Station are as follows:

- a. CSCS equipment cooling water system,
- b. station service water system,
- c. reactor building closed cooling water system,
- d. demineralized water makeup system,
- e. potable and sanitary water system,
- f. ultimate heat sink,
- g. cycled condensate system and refueling water storage facilities,
- h. turbine building closed cooling water system (TBCCWS),
- i. primary containment chilled water system,
- j. station heat recovery system,
- k. suppression pool cleanup system, and
- 1. chemical feed system.

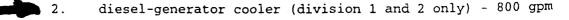
9.2.1 CSCS Equipment Cooling Water System

The function of the core standby cooling system-equipment cooling water system (CSCS-ECWS) is to circulate lake water from the ultimate heat sink for cooling of the residual heat removal (RHR) heat exchangers, diesel-generator coolers, CSCS cubicle area cooling coils, RHR pump seal coolers, and low-pressure core spray (LPCS) pump motor cooling coils. This system also provides a source of emergency makeup water for fuel pool cooling and also provides containment flooding water for post-accident recovery. This CSCS-ECWS system is equivalent in purpose to the essential service water cooling systems at other stations.

9.2.1.1 <u>Design Bases</u>

9.2.1.1.1 Safety Design Bases

- a. The system is sized based on the following minimum equipment cooling water flow requirements:
 - 1. RHR heat exchanger 7400 gpm



3. diesel-generator cooler (division 3) - 650 gpm

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REV. 12 - MARCH 1998

REFERENCE S.I

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9.5.4.5 Instrumentation and Controls

Fuel levels in each day tank and storage tank are indicated locally, and storage tank levels are also indicated at each storage tank filling station. Control room alarms annunciate high or low levels in each day tank and low level in each storage tank. All day tank level instruments and diesel-generator transfer pump controls are Seismic Category I and Class IE. A local pressure indicator is connected to the discharge of each transfer pump to monitor pump discharge head. A local differential pressure indicator is connected across the transfer pump suction strainer to identify a clogged strainer.

Each diesel engine gauge panel includes local gauges for monitoring the following diesel-generator skid-mounted system fuel oil parameters: fuel oil temperature, fuel pump suction strainer inlet and outlet pressure (Divisions 1 and 2 diesel generators only), fuel pump discharge pressure, fuel filter inlet pressure, and fuel filter outlet pressures (for the Division 3 diesel generators, filter inlet and outlet pressure gauges are mounted on the engine and not on the gauge panel). In addition, pressure switches are installed in the skid-mounted systems to annunciate high fuel filter differential pressure for the Divisions 1 and 2 diesel generators and low fuel pump discharge pressure for the Division 3 diesel generators. The entire skid-mounted fuel oil system, including instrumentation, is supplied by the engine manufacturer as a part of the diesel engine.

Each diesel-generator fuel transfer pump is started and stopped automatically by day tank level control switches. The diesel fire pump fuel transfer pump is started manually; however, it is automatically shut down by day tank high level. Elapsed time instrumentation monitors diesel-generator transfer pump running time and, when the diesel engine is operating, pump shutdown time. This instrumentation actuates control room alarm lights if pump running time is excessive or shutdown time is too short to permit remote detection of possible fuel oil leaks at the day tank or diesel generator.

9.5.5 Diesel-Generator Cooling Water System

The function of the diesel-generator cooling water system is to transfer the heat rejected from the engine water jacket, the lube oil cooler and the engine air aftercooler to the CSCS equipment cooling water system (CSCS-ECWS).

9.5.5.1 Design Bases

9.5.5.1.1 Safety Design Bases

Cooling capacity of this system is based on a diesel-generator output of 2860 kW with an environmental temperature of 122° F maximum and a minimum and maximum lake water temperature of 32° F and 100° F, respectively. Total heat transfer by this system is

REFERENCE D. 1

LSCS-UFSAR



approximately 7.8 x 10° Btu/hr per diesel-generator set at rated engine capacity. The diesel cooling water heat exchangers are sized based on operation of 110% of rated load.

High water temperature is alarmed at 200° F and the engine is automatically shut down if the cooling water temperature at the engine outlet exceeds 208° F in order to prevent engine damage due to overheating. This shutdown control is in effect only when the engine is started manually and bypassed when the diesel generator is started automatically during an emergency.

Heaters are installed in the cooling water piping below the lube oil cooler to maintain the engine water and lube oil in a warm standby condition while the engine is not operating; thus increasing the starting reliability of the diesel generator. Natural convection is employed to circulate the warm engine water through the lube oil cooler during standby.

Each system is designed based on Seismic Category I requirements and is protected from tornadoes, missiles, and flooding.

9.5.5.1.2 Power Generation Design Bases

The diesel-generator cooling water system is not required during power generation. Consequently, it possesses no power generation design bases.



Each diesel-generator cooling water system is a separate, independent closed loop system supplied with the diesel generator and located entirely on the diesel-generator skid. It consists of two parallel engine driven centrifugal circulating pumps, a low-pressure expansion tank, an AMOT temperature regulating valve, a lube oil cooler, and the engine cooling water heat exchanger. The expansion tank is fitted with a 7 psig relief cap which also will relieve vacuum. Engine coolant is demineralized water treated with chromate, borate-nitrite, or silicate-nitrite type corrosion inhibitors in accordance with the engine manufacturer's recommendations.

During operation, cooling water at a flow of 1100 gpm per dieselgenerator set is circulated by the engine driven pumps through the diesel engine cooling water passages to the lube oil cooler, through the temperature regulating valve, and then to the engine cooling water heat exchanger. See Figure 9.5-5 for additional details.

The engine cooling water heat exchanger is a two-pass shell and tube type heat exchanger having admiralty tubes with a carbon steel water box and shell. Engine cooling water is circulated through the shell side while strained lake water is pumped through the tube side by the CSCS-ECWS (Subsection 9.2.1). Design pressure and temperature is 150 psig and 300° F for both



REFERENCE 9.4

LSCS-FSAR

AMENDMENT 29 JANUARY 1978

QUESTION 040.92

"In response to Question 040.16 you have provided in section 9.5.5.1.1 a total diesel generator cooling water heat rate of approximately 6.15 million Btu/hr. This heat is rejected in the heat exchanger interfacing with CSCS equipment cooling water system when the diesel generator is operating at rated capacity. Also, in section 9.5.5.2 you mention that the cooling waterflow rate in the diesel engine is 1,100 gpm. It is not clear whether these heat and flow rates are for the total five diesel generators or for a single diesel generator. Please provide the heat and flow rates for each of the five diesel generators. In addition, also provide the design temperature differential((°F) for each diesel engine cooling water when operating at rated capacity."

RESPONSE

The design conditions for each diesel-generator cooling water system are:

Shell side flow	1100 gpm
Design shell side inlet temperature	190° F
Shell side outlet temperature	175° F
Tube side design flow	800 gpm
Tube side inlet temperature	100° F
Tube side outlet temperature	122° F
Heat exchanger design heat removal	8.6 x 10 ⁶ btu/hr
Diesel-generator set cooling requirement	7.8 x 10 ⁶ btu/hr

(The value of 6.15 x 10^6 btu/hr heat removal specified in Subsection 9.5.5.1.1 has been corrected to read 7.8 x 10^6 btu/hr in accordance with the above data).

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Attachment E to Proto-Power Calculation 97-195 Revision A

Proto-Power Calc: 97-195

Attachment: E

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Calculation Report for DG01A - DG Jacket Water Cooler Vendor Data Sheet - BENCHMARK

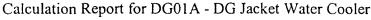
Shell and Tube Heat Exchanger Input Parameters

_			0 1		
			Shell-Side	Tube-Side	
	Fluid Quantity, Total	gpm	1,099.45	775.61	
	Inlet Temperature	°F	190.00	100.00	VENDOR DATA
	Outlet Temperature	°F	174.40	122.20	CUEFT GIVES
	Fouling Factor		0.00285	0.00000	TOTAL FOULING
	Shell Fluid Name			Fresh Water	THEREFORE SHELL SIDE TOTAL
	Tube Fluid Name			Fresh Water	SHELL-SIDE TOTAL SHELL-SIDE TOTAL 13 SET TO TOTAL 13 SET TO TOTAL 13 SET TO TOTAL 13 SET TO TOTAL 14 SET TO TOTAL 15 SET TO TOTAL 16 SET TO TOTAL 17 SET TO TOTAL 18 SET TOT
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	Design Heat Trans Coeff	f (BTU/hr·ft²·	°F)	255.20	TUBE-SINE P.
	Emprical Factor for Outs	side h		0.780339000	13561
	Performance Factor (% I	Reduction)		0.00	
	Heat Exchanger Type Effective Area (ft^2) Area Factor		ROTO-HX CA VALUE (OBE) CONDITIONS	NCHMARK 1479 ON	DATA SHEET AREA (EFFECTIVE)
	Area Ratio				
	> 1 COL 11 TT	•.			
	Number of Shells per Ur	lit		l 0.400000000	
	Shell Valority (19/2)			0.490000000	
	Shell Velocity (ft/s)			5.000	
	Tube Pitch (in) Tube Pitch Type			0.7500	
	Tube Filen Type			Triangular	
	Number of Tube Passes			2	
	U-Tubes			No	
	Total Number of Tubes			188	
	Number of Active Tubes	3		188	
	Tube Length (ft)			13.00	
	Tube Inside Diameter (in	,		0.652	
	Tube Outside Diameter (• •		0.750	
	Tube Wall Conductivity	(BTU/hr·ft·°l	·)	112.00	
	Ds, Shell Inside Diamete	er (in)		0.000	
	Lbc, Central Baffle Space	ing (in)		0.000	
	Lbi, Inlet Baffle Spacing	; (in)		0.000	
	Lbo, Outlet Baffle Spaci	ng (in)		0.000	
	Dotl, Tube circle diamet	er (in)		0.000	
	Bh, Baffle cut height (in)		0.000	
	Lsb, Diametral difference		` /	0.000	
	Ltb, Diametral difference		be and Baffle (in)	0.000	
	Nss, Number Sealing Str	rips		0.000	

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Vendor Data Sheet - BENCHMARK

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	775.6	
Shell Flow (gpm)	Shell Flow (gpm)	1,099.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)

Tube Mass Flow (lbm/hr)

U Overall (BTU/hr·ft².°F)

Shell-Side ho (BTU/hr·ft².°F)

Tube-Side hi (BTU/hr·ft².°F)

Heat Transferred (BTU/hr)

LMTD

LMTD Correction Factor

Effective Area (ft²)

Overall Fouling (hr·ft².ºF/BTU)

Property Shell-Side Tube-Side

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Tav Shell (°F) Prandtl Number Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Tube Temp Out (°F) Density (lbm/ft3) Cp (BTU/lbm.ºF) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.5E+5	Overall Fouling (hr·ft²-°F/BTU)	0.002850
Tube Mass Flow (lbm/hr)	COMPARER	3.88E+5	Shell-Side ho (BTU/hr-ft2-°F)	2,075.6
	COMPAROD		Tube-Side hi (BTU/hr·ft².°F)	2,100.5
Heat Transferred (BTU/hr)	TO VENDOK DATA SHEE	7 8.589E+6	1/Wall Resis (BTU/hr·ft ^{2.o} F)	25,594.8
LMTD	DHIM	71.1	LMTD Correction Factor	0.9886
Effective Area (ft²)		479.0		
			U Overall (BTU/hr·ft².°F)	255.2
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.15	8.00	Shell Temp In (°F)	190.0
Reynold's Number	8.537E+04	6.589E+04	Shell Temp Out (°F)	174.4
Prandtl Number	2.13	4.00	Tav Shell (°F)	182.2
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	173.5
Skin Visc (lbm/ft·hr)	0.87	1.33	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	122.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	111.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	121.0

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

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Proto-Power Calc: 97-195



Calculation Report for DG01A - DG Jacket Water Cooler Vendor Design Condition - Adj. Area

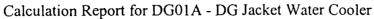
Shell and Tube Heat Exchanger Input Parameters

	Shell-Side	Tube-Side	
Fluid Quantity, Total gpm	1,099.45	775.61	
Inlet Temperature °F	190.00	100.00	VENDOR DATA SHEET
Outlet Temperature °F	174.40	122.20	PATA SHEET
Fouling Factor	0.00285	0.00000	VALUES
Shell Fluid Name		Fresh Water	
Tube Fluid Name		Fresh Water	
Design Heat Transfer (BTU/hr)		8,600,000	
Design Heat Trans Coeff (BTU/hr-ft2-	°F)	255.20	
Emprical Factor for Outside h		0.780339000	
Performance Factor (% Reduction)		0.00	CALCULATED
Heat Exchanger Type		TEMA-E	IN SECTION 3.7
Effective Area (ft^2)		471.23	1142
Area Factor		0.981978184	
Area Ratio			
Number of Challe nor Unit		1	
Number of Shells per Unit Shell Minimum Area		0.490000000	
Shell Velocity (ft/s)		5.000	
Tube Pitch (in)		0.7500	
Tube Pitch Type		Triangular	
Number of Tube Passes		2	
U-Tubes		No	
Total Number of Tubes		188	
Number of Active Tubes		188	
Tube Length (ft)		13.00	
Tube Inside Diameter (in)		0.652	
Tube Outside Diameter (in)		0.750	
Tube Wall Conductivity (BTU/hr-ft-°	F)	112.00	
Ds, Shell Inside Diameter (in)		0.000	
Lbc, Central Baffle Spacing (in)		0.000	
Lbi, Inlet Baffle Spacing (in)		0.000	
Lbo, Outlet Baffle Spacing (in)		0.000	
Dotl, Tube circle diameter (in)		0.000	
Bh, Baffle cut height (in)		0.000	
Lsb, Diametral difference between Ba	` /	0.000	
Ltb, Diametral difference between Tu	be and Baffle (in)	0.000	
Nss, Number Sealing Strips		0.000	

Proto-Power Calc: 97-195

Attachment: E

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Vendor Design Condition - Adj. Area

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	775.6	
Shell Flow (gpm)	Shell Flow (gpm)	1,099.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
,	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor

Effective Area (ft²)

			Overall Fouling (hr-ft ² -°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm.°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		5.5E+5	Overall Fouling (hr-ft²-°F/BTU)	0.002850	
Tube Mass Flow (lbm/hr)		3.88E+5	Shell-Side ho (BTU/hr·ft².°F)	2,076.0	
,			Tube-Side hi (BTU/hr·ft².°F)	2,099.0	
Heat Transferred (BTU/hr)	8.481E+6	1/Wall Resis (BTU/hr·ft².°F)	25,594.8	
LMTD	,	71.3	LMTD Correction Factor	0.9889	
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft².°F)	255.2	
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)	5.15	8.00	Shell Temp In (°F)	190.0	
Reynold's Number	8.543E+04	6.580E+04	Shell Temp Out (°F)	174.6	
Prandti Number	2.13	4.00	Tav Shell (°F)	182.3	
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	173.5	
Skin Visc (lbm/ft hr)	0.87	1.34	Tube Temp In (°F)	100.0	
Density (lbm/ft3)	60.52	61.85	Tube Temp Out (°F)	121.9	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.9	
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-195	120.9	

^{**} Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

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Calculation Report for DG01A - DG Jacket Water Cooler Adj. Area - LSCS Ref. Conditions

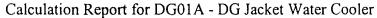
Shell and Tube Heat Exchanger Input Parameters

			
		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,099.45	775.61
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor		0.00285	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B)	ΓU/hr)		8,600,000
Design Heat Trans Coeff	(BTU/hr·ft²·	°F)	255.20
Emprical Factor for Outsi	ide h		0.780339000
Performance Factor (% R	eduction)		0.00
Heat Exchanger Type			тема-е
Effective Area (ft ²)			471.23
Area Factor			0.981978184
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area	16		0.490000000
Shell Velocity (ft/s)			5.000
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
			•
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			188
Number of Active Tubes			188
Tube Length (ft)	`		13.00
Tube Inside Diameter (in	•		0.652
Tube Outside Diameter (i	•	r-\	0.750
Tube Wall Conductivity	(BIO/nr·iti·°	r)	112.00
Ds, Shell Inside Diameter	r (in)		0.000
Lbc, Central Baffle Spaci	• ,		0.000
Lbi, Inlet Baffle Spacing	` '		0.000
Lbo, Outlet Baffle Spacir	ng (in)		0.000
Dotl, Tube circle diamete	` '		0.000
Bh, Baffle cut height (in)			0.000
Lsb, Diametral difference		` '	0.000
Ltb, Diametral difference		be and Baffle (in)	0.000
Nss, Number Sealing Stri	ps		0.000

Proto-Power Calc: 97-195

Attachment: E

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Adj. Area - LSCS Ref. Conditions

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

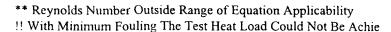
Fouling Calculation Results

U Overall (BTU/hr·ft2.°F) Shell Mass Flow (lbm/hr) Shell-Side ho (BTU/hr·ft2.°F) Tube Mass Flow (lbm/hr) Tube-Side hi (BTU/hr·ft².°F) 1/Wall Resis (BTU/hr·ft2.°F) Heat Transferred (BTU/hr) LMTD Correction Factor **LMTD** Effective Area (ft²)

Overall Fouling (hr-ft2.0F/BTU) Shell-Side Tube-Side Property Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr) Heat Transferred (BTU/hr) LMTD	LESS THAN REF. COND. REQUIRED HEATRATE	8.484E+6 71.3	Shell-Side ho (BTU/hr·ft²-°F) Tube-Side hi (BTU/hr·ft²-°F)	002850 2,034.1 2,138.0 5,594.8 0.9889
Effective Area (ft²)	•••	471.2		
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft².°F)	255.2
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	190.0
Reynold's Number	8.257E+04	6.728E+04	Shell Temp Out (°F)	174.1
Prandtl Number	2.14	4.01	Tav Shell (°F)	182.1
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	173.1
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	121.4
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.7
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Tepproto-Power Calc: 97-195	120.5



Attachment: E

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INPUT MODE USEDIN FOLLOWING CALCULATION

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler Reference Condition - Fouling Limit

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	1,099.45	775.61	
Inlet Temperature	°F	190.00	100.00	٠
Outlet Temperature	°F	174.40	122.20	FOULING INPUT MI
Fouling Factor		0.00285	0.00000	USEDIN
Shell Fluid Name			Fresh Water	FOLLOWING
Tube Fluid Name			Fresh Water	CALCULAT
Design Heat Transfer (B	ΓU/hr)		8,600,000	
Design Heat Trans Coeff	(BTU/hr·ft²·	°F)	255.20	
Emprical Factor for Outs	ide h		0.780339000	
Performance Factor (% R	leduction)		0.00	
Heat Exchanger Type			TEMA-E	
Effective Area (ft^2)			471.23	
Area Factor			0.981978184	
Area Ratio				
Number of Shells per Un	it		1	
Shell Minimum Area			0.490000000	
Shell Velocity (ft/s)			5.000	
Tube Pitch (in)			0.7500	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			No	
Total Number of Tubes			188	
Number of Active Tubes			188	
Tube Length (ft)			13.00	
Tube Inside Diameter (in)		0.652	
Tube Outside Diameter (in)		0.750	
Tube Wall Conductivity	(BTU/hr·ft·°	F)	112.00	
Ds, Shell Inside Diamete	r (in)		0.000	
Lbc, Central Baffle Space	ing (in)		0.000	
Lbi, Inlet Baffle Spacing	(in)		0.000	
Lbo, Outlet Baffle Spacin	ng (in)		0.000	
Dotl, Tube circle diamete	er (in)		0.000	
Bh, Baffle cut height (in)			0.000	
Lsb, Diametral difference	e between Ba	iffle and Shell (in)	0.000	
Ltb, Diametral difference	between Tu	be and Baffle (in)	0.000	
Nss, Number Sealing Str	ips		0.000	

Proto-Power Calc: 97-195

Attachment: E

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Calculation Report for DG01A - DG Jacket Water Cooler

Reference Condition - Fouling Limit

Calculation Specifications

Constant Inlet Temperature Method Was Used

Extrapolation Was to User Specified Conditions

Fouling Was Input by User | ITERATION USING FOULING

UNTIL REF. CONDITION HEAT RATE

IS REACHED

Test Data Extrapolation Data

Tube Flow (gpm) Data Date 795.3 Shell Flow (gpm) Shell Flow (gpm) 1,064.5 Tube Inlet Temp (°F) Shell Temp In (°F) 100.0 Shell Temp Out (°F) Shell Inlet Temp (°F) 190.0 Tube Flow (gpm) Tube Temp In (°F) Tube Temp Out (°F) Input Fouling Factor 0.002782

Fouling Calculation Results

Shell Mass Flow (lbm/hr)

Tube Mass Flow (lbm/hr)

Shell-Side ho (BTU/hr·ft²-°F)

Tube-Side hi (BTU/hr·ft²-°F)

Tube-Side hi (BTU/hr·ft²-°F)

Heat Transferred (BTU/hr)

LMTD

LMTD Correction Factor

Effective Area (ft²)

Overall Fouling (hr·ft²-°F/BTU)
Property Shell-Side Tube-Side

Velocity (ft/s)Shell Temp In (°F)Reynold's NumberShell Temp Out (°F)Prandtl NumberTav Shell (°F)Bulk Visc (lbm/ft·hr)Shell Skin Temp (°F)Skin Visc (lbm/ft·hr)Tube Temp In (°F)Density (lbm/ft³)Tube Temp Out (°F)

Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

Tav Tube (°F)

Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)	Derco FN(F.	5.325E+5 3.978E+5	_ · · · · · · · · · · · · · · · · · · ·	02782
Heat Transferred (BTU/hr)	REFERENCE HEAT RATE	8.6E+6	1/U/all Davis (DTI I/I 62 OF)	,140.0 ,594.8
LMTD		71.1	' INFRACE	.9885
Effective Area (ft²)		471.2		250 7
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft².°F)	259.7
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	6.738E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	4.01	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	172.9
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)	100.0
Density (lbm/ft ³)	60.53	61.85	Tube Temp Out (°F)	121.6

1.00

0.37

Tav Tube (°F)

Cp (BTU/lbm·°F)

K (BTU/hr-ft-°F)

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

1.00

0.39

Attachment: E

Tube Skin Temp(°F) Proto-Power Calc: 97-195 120.8

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110.8

^{**} Reynolds Number Outside Range of Equation Applicability

Calculation Report for DG01A - DG Jacket Water Cooler
**** FINAL MODEL ****

Shell and Tube Heat Exchanger Input Parameters

	Shell-Side	Tube-Side	
Fluid Quantity, Total gpm	1,099.45	775.61	
Inlet Temperature °F	190.00	EDUCED 100.00	
Outlet Temperature °F	174.40	12000 12220	
Fouling Factor	0.00278 F	Fresh Water	
Shell Fluid Name	<i>\(\xi\)</i>	Fresh Water	_
Tube Fluid Name		Fresh Water	
Design Heat Transfer (BTU/hr)		8,600,000	
Design Heat Trans Coeff (BTU/hr·ft²-c	°F)	255.20	
Emprical Factor for Outside h		0.780339000	aasa
Performance Factor (% Reduction)		0.00	" (TET) HREAT
Heat Exchanger Type		TEMA-E	ADTUSTED AREA SECTION 3.2
Effective Area (ft^2)		471.23	SÉCTIO.
Area Factor		0.981978184	
Area Ratio			
Number of Challeness I Init		1	
Number of Shells per Unit Shell Minimum Area		0.490000000	•
Shell Velocity (ft/s)		5.000	
Tube Pitch (in)		0.7500	
Tube Pitch Type		Triangular	
••		_	
Number of Tube Passes		2	·
U-Tubes		No	
Total Number of Tubes Number of Active Tubes		188	
Tube Length (ft)		188 13.00	
Tube Inside Diameter (in)		0.652	
Tube Outside Diameter (in)		0.750	
Tube Wall Conductivity (BTU/hr·ft·°F	7)	112.00	
• ,	,	112.00	
Ds, Shell Inside Diameter (in)		0.000	
Lbc, Central Baffle Spacing (in)		0.000	
Lbi, Inlet Baffle Spacing (in)		0.000	
Lbo, Outlet Baffle Spacing (in)		0.000	
Dotl, Tube circle diameter (in)		0.000	
Bh, Baffle cut height (in)	fflo and Chall (in)	0.000	
Lsb, Diametral difference between Ba Ltb, Diametral difference between Tul	` ,		
Nss, Number Sealing Strips	be and dame (in)	0.000	
1400, 14dinoer bearing burps		0.000	

Proto-Power Calc: 97-195

Attachment: E

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Data Date

Shell Flow (gpm)

190.0

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

**** FINAL MODEL ****

Calculation Specifications

Constant Inlet Temperature Method Was Used

Extrapolation Was to User Specified Conditions

Design Fouling Factors Were Used

ADJUSTED FOULING NOW DESIGN FOULING FACTOR IN PROTO-HY MODEL

Test Data	Extrapolation Data		
	Tube Flow (gpm)	795.3	
	Shell Flow (gpm)	1,064.5	
	Tube Inlet Temp (°F)	100.0	

Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm) Tube Temp In (°F) Tube Temp Out (°F)

T - - 4 Da4-

Fouling Calculation Results

U Overall (BTU/hr·ft2.0F) Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr) Shell-Side ho (BTU/hr·ft2.°F) Tube-Side hi (BTU/hr·ft2.°F) Heat Transferred (BTU/hr) 1/Wall Resis (BTU/hr·ft².°F) LMTD Correction Factor

LMTD

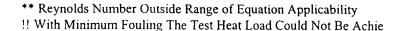
Effective Area (ft²)

Overall Fouling (hr·ft2.0F/BTU)

Shell Inlet Temp (°F)

Shell-Side Property Tube-Side Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Shell Skin Temp (°F) Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm-°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft2-°F/BT	U) [0.002782
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft2.°F)		2,033.3
			Tube-Side hi (BTU/hr·ft².°F)	ADJUSTED	2,140.0
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft ² .°F)	FOULING	
LMTD		71.1	LMTD Correction Factor	PUALITO	0.9885
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft².°F)		259.7
Property	Shell-Side	Tube-Side		5	
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	-19 of	190.0
Reynold's Number	8.251E+04	6.738E+04	Shell Temp Out (°F)	76	173.9
Prandtl Number	2.14	4.01	Tav Shell (°F)		181.9
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	Calc: E	172.9
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)		100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	We nt:	121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	or me	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	o-Power chment: A Pa	120.8





Calculation Report for DG01A - DG Jacket Water Cooler FINAL MODEL- CLEAN (0 Fouling)

Shell and Tube Heat Exchanger Input Parameters

		CI11 C:-J-	T.J. Cid.
		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,099.45	775.61
Inlet Temperature	°F °F	190.00	100.00
Outlet Temperature	- 4	174.40	122.20
Fouling Factor		0.00278	0.00000
Shell Fluid Name			Fresh Water
Tube Fluid Name	*********		Fresh Water
Design Heat Transfer (B'	•	077)	8,600,000
Design Heat Trans Coeff	•	°F)	255.20
Emprical Factor for Outs			0.780339000
Performance Factor (% F	(leduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			471.23
Area Factor			0.981978184
Area Ratio			
	•		
Number of Shells per Un	1 t		1
Shell Minimum Area			0.490000000
Shell Velocity (ft/s)			5.000
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			188
Number of Active Tubes			188
Tube Length (ft)			13.00
Tube Inside Diameter (in)		0.652
Tube Outside Diameter (in)		0.750
Tube Wall Conductivity	(BTU/hr·ft·°	F)	112.00
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Spac	• /		0.000
Lbi, Inlet Baffle Spacing	• . ,		0.000
Lbo, Outlet Baffle Spacing	` '		0.000
Dotl, Tube circle diameter			0.000
Bh, Baffle cut height (in)	• /		0.000
Lsb, Diametral difference		affle and Shell (in)	0.000
Ltb, Diametral difference		` '	0.000
Nss, Number Sealing Str		unu Dunio (m)	0.000
.,	r -		0.000

Proto-Power Calc: 97-195

Attachment: E

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Calculation Report for DG01A - DG Jacket Water Cooler FINAL MODEL- CLEAN (0 Fouling)

Calculation Specifications

Constant Inlet Temperature Method Was Used

Extrapolation Was to User Specified Conditions

Fouling Was Input by User FOR "CLEAN"

Hx. Analysis.

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.000000

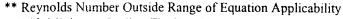
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².ºF)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2-0F/BTU)

Shell-Side Tube-Side Property Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Tav Shell (°F) Prandtl Number Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BT	U)	0.000000
Tube Mass Flow (lbm/hr)	CLEAN HEAT	3.978E+5	Shell-Side ho (BTU/hr·ft².ºF)		1,957.5
	CLEAN HEAT RATE		Tube-Side hi (BTU/hr-ft2-°F)	"CLEAN"	2,318.4
Heat Transferred (BTU/hr)	• •	1.885E+7	1/Wall Resis (BTU/hr·ft².°F)		25,594.8
LMTD		48.3	LMTD Correction Factor		0.8656
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft ^{2.°} F)		955.9
Property	Shell-Side	Tube-Side		5 13	
Velocity (ft/s)	4.97	8.22	Shell Temp In (°F)	-19: of	190.0
Reynold's Number	7.721E+04	7.626E+04	Shell Temp Out (°F)	97- 3 o	154.6
Prandtl Number	2.29	3.50	Tav Shell (°F)		172.3
Bulk Visc (lbm/ft·hr)	0.88	1.30	Shell Skin Temp (°F)	alc:	148.6
Skin Visc (lbm/ft·hr)	1.05	1.07	Tube Temp In (°F)	ОШ %	100.0
Density (lbm/ft³)	60.74	61.65	Tube Temp Out (°F)	er it: Pa	147.4
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	oto-Power tachment: v: A Pa	123.7
K (BTU/hr-ft-°F)	0.38	0.37	Tube Skin Temp (°F)	A H	146.8
				oto tac	



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie



Attachment F to Proto-Power Calculation 97-195 Revision A

Proto-Power Calc: 97-195

Attachment: F

Rev: A Page 1 of 6

Calculation Report for DG01A - DG Jacket Water Cooler

Tube-side Fouling = 0.0000

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)	Input Fouling Factor	0.000500	

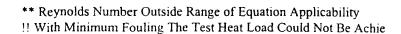
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr-ft ^{2.o} F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.0F/BTU)

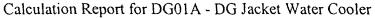
Property	Shell-Side	Tube-Side	3 \
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)	•		Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.0} F/BTU)	0.000500
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².°F)	1,983.9
·			Tube-Side hi (BTU/hr-ft².ºF)	2,261.9
Heat Transferred (BTU/hr)		1.57E+7	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		55.4	LMTD Correction Factor	0.9332
Effective Area (ft²)		471.2		
			U Overall (BTU/hr·ft ² .°F)	644.5
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.98	8.22	Shell Temp In (°F)	190.0
Reynold's Number	7.883E+04	7.349E+04	Shell Temp Out (°F)	160.6
Prandtl Number	2.24	3.64	Tav Shell (°F)	175.3
Bulk Visc (lbm/ft-hr)	0.86	1.35	Shell Skin Temp (°F)	157.2
Skin Visc (lbm/ft·hr)	0.98	1.15	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.68	61.72	Tube Temp Out (°F)	139.5
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	119.8
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin TemProto-Power Calc: 9'	



Attachment: F

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Tube-side Fouling = 0.0005

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.001075

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr-ft2.°F)
· ·	Tube-Side hi (BTU/hr·ft²-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.°F/BTU)

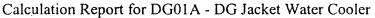
Property	Shell-Side	Tube-Side	3 (
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft-hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU) 0.0	001075
Tube Mass Flow (lbm/hr)		3.978E+5	/	2,003.3
, ,			· · · · · · · · · · · · · · · · · · ·	2,216.1
Heat Transferred (BTU/hr)		1.304E+7	,	5,594.8
LMTD		61.3	` ,	0.9633
Effective Area (ft2)		471.2		
			U Overall (BTU/hr-ft2.°F)	469.0
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.98	8.21	Shell Temp In (°F)	190.0
Reynold's Number	8.020E+04	7.118E+04	Shell Temp Out (°F)	165.6
Prandtl Number	2.20	3.77	Tav Shell (°F)	177.8
Bulk Visc (lbm/ft·hr)	0.85	1.39	Shell Skin Temp (°F)	163.4
Skin Visc (lbm/ft·hr)	0.94	1.21	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.62	61.77	Tube Temp Out (°F)	132.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	116.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Ter Proffo-Power Calc: 97-195	131.4

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: F
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Tube-side Fouling = 0.0010



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.001650		
F 1	in a Calaulatian Danulta			

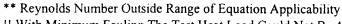
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
` ,	•
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²·°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

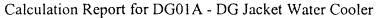
Overall Fouling (hr·ft²-°F/BTU) Property Shell-Side Tube-Side

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Shell Mass Flow.(lbm/hr)		5.325E+5	Overall Fouling (hr-ft2.0F/B'			0.001650
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr-ft2.0I			2,016.5
			Tube-Side hi (BTU/hr·ft².ºF	•		2,183.2
Heat Transferred (BTU/hr)		1.112E+7	1/Wall Resis (BTU/hr-ft2.°F)		25,594.8
LMTD		65.5	LMTD Correction Factor			0.9770
Effective Area (ft²)		471.2				
			U Overall (BTU/hr·ft ² .°F)			368.8
Property	Shell-Side	Tube-Side		5	9	
Velocity (ft/s)	4.98	8.20	Shell Temp In (°F)	-19	of	190.0
Reynold's Number	8.120E+04	6.953E+04	Shell Temp Out (°F)	97	4	169.2
Prandtl Number	2.17	3.87	Tav Shell (°F)		7	179.6
Bulk Visc (lbm/ft·hr)	0.84	1.43	Shell Skin Temp (°F)	Calc:	- 43	167.6
Skin Visc (lbm/ft·hr)	0.91	1.27	Tube Temp In (°F)		age	100.0
Density (lbm/ft³)	60.58	61.80	Tube Temp Out (°F)	Proto-Power	Attachment: Rev: A Pa	128.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	Ó	ne 1	114.0
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	<u> </u>	rg v	126.7



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie



Tube-side Fouling = 0.0015

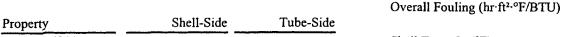
Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Data
Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)	•	
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.002225

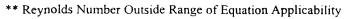
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
,	` ,
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	



Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Shell Skin Temp (°F) Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

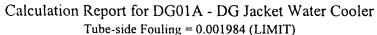
<u> </u>						
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft²-°F/B]	ΓU)		0.002225
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft²-°F			2,026.2
			Tube-Side hi (BTU/hr·ft².°F)	•		2,158.6
Heat Transferred (BTU/h	r)	9.683E+6	1/Wall Resis (BTU/hr·ft²·°F)	·)		25,594.8
LMTD		68.7	LMTD Correction Factor			0.9842
Effective Area (ft²)		471.2				
			U Overall (BTU/hr·ft2.°F)			303.9
Property	Shell-Side	Tube-Side			. ~	
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	95	_	190.0
Reynold's Number	8.194E+04	6.830E+04	Shell Temp Out (°F)	7-1	of	171.9
Prandtl Number	2.15	3.95	Tav Shell (°F)	. 97	ν,	180.9
Bulk Visc (lbm/ft·hr)	0.83	1.45	Shell Skin Temp (°F)	alc:		170.6
Skin Visc (lbm/ft·hr)	0.89	1.31	Tube Temp In (°F)	ပိ	F 50	100.0
Density (lbm/ft³)	60.55	61.83	Tube Temp Out (°F)	ē		124.4
Cp (BTU/lbm-°F)	1.00	1.00	Tav Tube (°F)	^] [112.2
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	-Power	hment: A Pa	123.3



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Pro Atta Rev

Commonwealth Edison



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation :	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.002782		

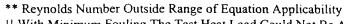
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².ºF)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
· ·	Tube-Side hi (BTU/hr-ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft2.°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft²-°F/BTU)
roperty Shell-Side Tube-Side

Tube-Side Property Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2,o} F/BT	 (U)		0.002782
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².ºF	,		2,033.3
·			Tube-Side hi (BTU/hr·ft².°F)	,)		2,140.0
Heat Transferred (BTU/h	τ)	8.6E+6	1/Wall Resis (BTU/hr-ft2.°F)			25,594.8
LMTD		71.1	LMTD Correction Factor			0.9885
Effective Area (ft²)		471.2				
			U Overall (BTU/hr·ft².°F)			259.7
Property	Shell-Side	Tube-Side		2	9	
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	195	_	190.0
Reynold's Number	8.251E+04	6.738E+04	Shell Temp Out (°F)		of	173.9
Prandtl Number	2.14	4.01	Tav Shell (°F)	: 97		181.9
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	alc:		172.9
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)	Ü	F ge	100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	er er		121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	∧	E	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	to-Power	achment:	120.8
			• • •	2	ွဗ္ဗ	



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie



Attachment G to Proto-Power Calculation 97-195 Revision A

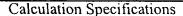
Proto-Power Calc: 97-195

Attachment: G

Rev: A Page 1 of 17

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 35°F



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data		
Data Date	Tube Flow (gpm)	193.5		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	35.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)				

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft²-°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)		· · · · · · · · · · · · · · · · · · ·	Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.o} F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		9.68E+4	Shell-Side ho (BTU/hr·ft².°F)	2,032.2
•			Tube-Side hi (BTU/hr·ft²-°F)	599.1
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		98.1	LMTD Correction Factor	0.9740
Effective Area (ft²)		471.2		
			U Overall (BTU/hr·ft2.°F)	191.1
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.99	1.98	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	1.155E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	5.90	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	2.09	Shell Skin Temp (°F)	172.3
Skin Visc (lbm/ft·hr)	0.88	1.39	Tube Temp In (°F)	35.0
Density (lbm/ft ³)	60.53	62.22	Tube Temp Out (°F)	123.9
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	79.4
K (BTU/hr·ft·°F)	0.39	0.35	Tube Skin Temp (°F)	117.0

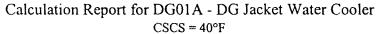
** Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-195

Attachment: G

Rev: A Page 2 of 17







Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Extrapolation I	Extrapolation Data		
Tube Flow (gpm)	204.8		
Shell Flow (gpm)	1,064.5		
Tube Inlet Temp (°F)	40.0		
Shell Inlet Temp (°F)	190.0		
	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².ºF)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.0F/BTU)

			Overall Fouring (III It)
Property	Shell-Side	. Tube-Side	
Velocity (ft/s)	٠.		Shell Temp In (°F)
Reynold's Number	. •		Shell Temp Out (°F)
Prandtl Number	e de la companya de		Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² -°F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		1.024E+5	Shell-Side ho (BTU/hr-ft ^{2.} °F)	2,032.3
			Tube-Side hi (BTU/hr·ft².ºF)	634.9
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		96.0	LMTD Correction Factor	0.9744
Effective Area (ft²)		471.2		
			U Overall (BTU/hr·ft²-°F)	195.1
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.99	2.10	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	1.261E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	5.70	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	2.02	Shell Skin Temp (°F)	172.3
Skin Visc (lbm/ft·hr)	0.88	1.38	Tube Temp In (°F)	40.0
Density (lbm/ft³)	60.53	62.20	Tube Temp Out (°F)	124.0
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	82.0
K (BTU/hr·ft.°F)	0.39	0.36	Tube Skin Temp (°F)	117.3

** Reynolds Number Outside Range of Equation Applicability

| With Minimum Fouling The Test Heat Load Could Not Revenue.

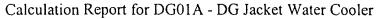
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-195

Attachment: G

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Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	232.2	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	50.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

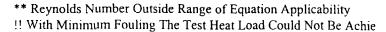
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.0F/BTU)

Property	Shell-Side	Tube-Side	•
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

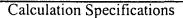
	Extrapolation Calculation Results			
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		1.162E+5	Shell-Side ho (BTU/hr-ft2.°F)	2,032.5
			Tube-Side hi (BTU/hr·ft².°F)	719.6
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft2.°F)	25,594.8
LMTD		91.9	LMTD Correction Factor	0.9756
Effective Area (ft2)		471.2		
			U Overall (BTU/hr·ft².°F)	203.6
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.99	2.38	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	1.520E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	5.33	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.91	Shell Skin Temp (°F)	172.4
Skin Visc (lbm/ft·hr)	0.88	1.37	Tube Temp In (°F)	50.0
Density (lbm/ft3)	60.53	62.15	Tube Temp Out (°F)	124.1
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	87.0
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	117.9
	Protó-Power Calc: 97-195			



Attachment: G
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Calculation Report for DG01A - DG Jacket Water Cooler





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

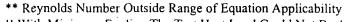
Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	269.1	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	60.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft ^{2.} °F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

			Overall Fouling (hr·ft²-°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

	Extrapolation Calculation Results			
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		1.346E+5	Shell-Side ho (BTU/hr-ft2.0F)	2,032.7
			Tube-Side hi (BTU/hr·ft².°F)	828.7
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft²-°F)	25,594.8
LMTD		87.8	LMTD Correction Factor	0.9770
Effective Area (ft²)		471.2		
			U Overall (BTU/hr·ft².°F)	212.7
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.99	2.76	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	1.865E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	5.00	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.80	Shell Skin Temp (°F)	172.5
Skin Visc (lbm/ft·hr)	0.88	1.37	Tube Temp In (°F)	60.0
Density (lbm/ft³)	60.53	62.09	Tube Temp Out (°F)	123.9
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	92.0
K (BTU/hr ft °F)	0.39	0.36	Tube Skin Temp (°F)	118.5
	Proto-Power Calc: 97-195			



!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: G

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Calculation Report for DG01A - DG Jacket Water Cooler

 $CSCS = 70^{\circ}F$

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	321.0	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	70.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².ºF)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft².°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².ºF/BTU)	0.002782
Tube Mass Flow (lbm/hr)		1.606E+5	Shell-Side ho (BTU/hr-ft2.°F)	2,032.8
			Tube-Side hi (BTU/hr·ft²-°F)	975.6
Heat Transferred (BTU/hr	.)	8.6E+6	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		83.7	LMTD Correction Factor	0.9790
Effective Area (ft²)		471.2		
			U Overall (BTU/hr·ft².°F)	222.6
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	4.99	3.30	Shell Temp In (°F)	190.0
Reynold's Number	8.251E+04	2.348E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	4.71	Tav Shell (°F)	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.71	Shell Skin Temp (°F)	172.6
Skin Visc (lbm/ft·hr)	0.88	1.36	Tube Temp In (°F)	70.0
Density (lbm/ft3)	60.53	62.03	Tube Temp Out (°F)	123.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	96.8
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	119.2
			Proto-Power Calc	

^{**} Reynolds Number Outside Range of Equation Applicability

Attachment: G

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for DG01A - DG Jacket Water Cooler





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

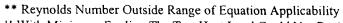
Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	399.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	80.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

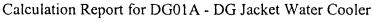
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².ºF)
			Tube-Side hi (BTU/hr·ft2.°F)
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr·ft²-°F)
LMTD			LMTD Correction Factor
Effective Area (ft²)			
			Overall Fouling (hr·ft².ºF/BTU)
Property	Shell-Side	Tube-Side	
V-1'4. (G/-)			OL -11 (P I. (OP)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft²-°F/BTU)	0.002782
Tube Mass Flow (lbm/hr)		1.997E+5	Shell-Side ho (BTU/hr·ft².°F)	2,033.0
			Tube-Side hi (BTU/hr·ft2.°F)	1,186.3
Heat Transferred (BTU/hr)		8.6E+6	1/Wall Resis (BTU/hr·ft².°F)	25,594.8
LMTD		79.6	LMTD Correction Factor	0.9814
Effective Area (ft²)		471.2		
			U Overall (BTU/hr-ft2.°F)	233.5
Property	Shell-Side	Tube-Side		5
Velocity (ft/s)	4.99	4.11	Shell Temp In (°F)	0
Reynold's Number	8.251E+04	3.075E+04	Shell Temp Out (°F)	Jo 190.0
Prandtl Number	2.14	4.45	Tav Shell (°F)	6 181.9
Bulk Visc (lbm/ft·hr)	0.82	1.62	Shell Skin Temp (°F)	172.7 172.7
Skin Visc (lbm/ft·hr)	0.88	1.35	Tube Temp In (°F)	- cu av.v
Density (lbm/ft3)	60.53	61.97	Tube Temp Out (°F)	a ∷ a 123.1
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	101.5
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	전 된 전 119.8
				Proto-Power Attachment: Rev. A Pa 153.1 101.5 119.8
** Reynolds Number Outsi	_			Proto-Power Attachment: Rev. A Pa 15371 81611 Page 15371 Page 1537



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie







Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data		
Data Date	Tube Flow (gpm)	530.9		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)				

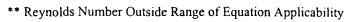
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr ft².ºF)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

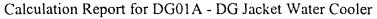
Overall Fouling (hr.ft2.°F/BTU)

			Overan rouning (m.11-1-17/B10
Property	Shell-Side	Tube-Side	<u> </u>
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results						
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)		0.	.002782
Tube Mass Flow (lbm/hr)		2.656E+5	Shell-Side ho (BTU/hr·ft².ºF)			2,033.2
			Tube-Side hi (BTU/hr·ft².°F)			1,519.8
Heat Transferred (BTU/hr)	8.6E+6	1/Wall Resis (BTU/hr-ft2.°F)		2	5,594.8
LMTD		75.4	LMTD Correction Factor			0.9845
Effective Area (ft²)		471.2				
			U Overall (BTU/hr-ft2.°F)			245.7
Property	Shell-Side	Tube-Side			17	
Velocity (ft/s)	4.99	5.47	Shell Temp In (°F)	95		190.0
Reynold's Number	8.251E+04	4.293E+04	Shell Temp Out (°F)	7	of	173.9
Prandtl Number	2.14	4.22	Tav Shell (°F)	97	90	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.54	Shell Skin Temp (°F)	alc:		172.8
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)	ပ္မ	ပ္ စ္က	90.0
Density (lbm/ft³)	60.53	61.91	Tube Temp Out (°F)		<u> </u>	122.4
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	Ž	ent:	106.2
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	o-Power	chment: A Pa	120.3



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie







Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

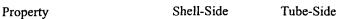
Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	795.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Overall Fouling (hr·ft²-°F/BTU)

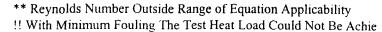
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Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	



Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

	Ех	ctrapolation Calcu	llation Results			
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² .°F/BTU)		0.	002782
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².°F)			2,033.3
			Tube-Side hi (BTU/hr·ft2.°F)			2,140.0
Heat Transferred (BTU/hr	:)	8.6E+6	1/Wall Resis (BTU/hr-ft2-°F)		2	5,594.8
LMTD		71.1	LMTD Correction Factor			0.9885
Effective Area (ft²)		471.2				
			U Overall (BTU/hr·ft².°F)			259.7
Property	Shell-Side	Tube-Side		10	17	
Velocity (ft/s)	4.99	8.20	Shell Temp In (°F)	Calc: 97-195	ot	190.0
Reynold's Number	8.251E+04	6.738E+04	Shell Temp Out (°F)	7-	0	173.9
Prandtl Number	2.14	4.01	Tav Shell (°F)	6.	6	181.9
Bulk Visc (lbm/ft·hr)	0.82	1.47	Shell Skin Temp (°F)	ac		172.9
Skin Visc (lbm/ft·hr)	0.88	1.34	Tube Temp In (°F)	Ü	ට සී	100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	Æ.	ıt: G Page	121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	8	jer	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	o-Power	chment: : A Pa	120.8





Calculation Report for DG01A - DG Jacket Water Cooler





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	161.1	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	35.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

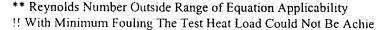
Overall Fouling (hr·ft2.°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft².ºF)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property Shell-Side Tube-Side

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results								
	E)	drapolation Calcu	nation Results					
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft²-°F/BTU)		0	.002782		
Tube Mass Flow (lbm/hr)		8.059E+4 Shell-Side ho (BTU/hr·ft².°F)			2,037.1			
			Tube-Side hi (BTU/hr·ft².°F)			531.4		
Heat Transferred (BTU/hr	·)	7.8E+6	1/Wall Resis (BTU/hr·ft2.°F)		2	25,594.8		
LMTD		93.3	LMTD Correction Factor			0.9713		
Effective Area (ft²)		471.2						
			U Overall (BTU/hr·ft².°F)			182.6		
Property	Shell-Side	Tube-Side	,	10	17			
Velocity (ft/s)	4.99	1.65	Shell Temp In (°F)	97-195		190.0		
Reynold's Number	8.292E+04	1.010E+04	Shell Temp Out (°F)	7-	of	175.4		
Prandtl Number	2.13	5.59	Tav Shell (°F)	9.	10	182.7		
Bulk Visc (lbm/ft·hr)	0.82	1.99	Shell Skin Temp (°F)	Calc: G	_	173.8		
Skin Visc (lbm/ft-hr)	0.87	1.31	Tube Temp In (°F)	Ü	ge	35.0		
Density (lbm/ft3)	60.52	62.18	Tube Temp Out (°F)	it ë	~	131.8		
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	en S	_	83.4		
K (BTU/hr-ft-°F)	0.39	0.36	Tube Skin Temp (°F)	to-Power	 A	122.7		





Calculation Report for DG01A - DG Jacket Water Cooler





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data	
Data Date	Tube Flow (gpm)	169.8	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	40.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Overall Fouling (hr-ft2-°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Shell-Side Tube-Side Property Velocity (ft/s) Shell Temp In (°F) Shell Temp Out (°F) Reynold's Number Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

	Ex	trapolation Calcu	lation Results			
hell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².ºF/BTU)		0.	002782
ube Mass Flow (lbm/hr)		8.492E+4	Shell-Side ho (BTU/hr·ft².ºF)			2,037.2
			Tube-Side hi (BTU/hr·ft²-°F)			561.0
leat Transferred (BTU/hr))	7.8E+6	1/Wall Resis (BTU/hr-ft2.°F)		2	5,594.8
MTD		91.4	LMTD Correction Factor			0.9716
Effective Area (ft2)		471.2				
			U Overall (BTU/hr·ft².°F)			186.5
roperty	Shell-Side	Tube-Side		\$	17	
elocity (ft/s)	4.99	1.74	Shell Temp In (°F)	0		190.0
leynold's Number	8.292E+04	1.097E+04	Shell Temp Out (°F)	7-1	of	175.4
randtl Number	2.13	5.40	Tav Shell (°F)	9	11	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.93	Shell Skin Temp (°F)	Calc: 97	-	173.8
kin Visc (lbm/ft·hr)	0.87	1.31	Tube Temp In (°F)	ÜÜ	g e	40.0
Density (lbm/ft³)	60.52	62.16	Tube Temp Out (°F)	٠ ټ	~	131.9
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	Proto-Power	Attacimiem. Rev: A Pa	86.0
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	ابم	∄ ∀	122.9

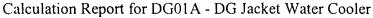


^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie



Tube Temp Out (°F)

Commonwealth Edison







Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	190.5	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	50.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			

Fouling Calculation Results

Overall Fouling (hr-ft2-°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft ^{2.o} F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft2.0F)
LMTD	LMTD Correction Factor

Effective Area (ft²)

Shell-Side Property Tube-Side

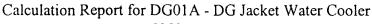
Velocity (ft/s) Shell Temp In (°F) Shell Temp Out (°F) Reynold's Number Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation	Calculation	Results

				
Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)		5.325E+5 9.527E+4	Overall Fouling (hr·ft²-°F/BTU) Shell-Side ho (BTU/hr·ft²-°F)	0.002782 2,037.4
Heat Transferred (BTU/hr)	1	7.8E+6	Tube-Side hi (BTU/hr·ft².ºF) 1/Wall Resis (BTU/hr·ft².ºF)	629.9 25,594.8
Effective Area (ft²)		87.5 471.2	LMTD Correction Factor	0.9726
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft².°F)	194.6
Velocity (ft/s)	4.99	1.96	Shell Temp In (°F)	of 1
Reynold's Number Prandtl Number	8.292E+04 2.13	1.305E+04 5.06	Shell Temp Out (°F)	6 7 103.7
Bulk Visc (lbm/ft-hr)	0.82	1.82	Tav Shell (°F) Shell Skin Temp (°F)	7 182.7 173.9 173.9
Skin Visc (lbm/ft·hr)	0.87	1.30	Tube Temp In (°F)	<u> </u>
Density (lbm/ft³) Cp (BTU/lbm·°F)	60.52 1.00	62.10 1.00	Tube Temp Out (°F) Tav Tube (°F)	Page 131.9
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	of-C ehme 91.0
** Reynolds Number Outs				Proto-Power Attachment: Rev. A Pa 131.6 10.0 10.0 10.0 10.0 10.0 10.0 10.0 1



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie







Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	217.5	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	60.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft2.°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

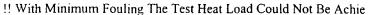
Overall Fouling (hr-ft2.°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm.°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

	Ex	trapolation Calcu	lation Results		
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)		0.002782
Tube Mass Flow (lbm/hr)		1.088E+5	Shell-Side ho (BTU/hr·ft².°F) Tube-Side hi (BTU/hr·ft².°F)		2,037.6 716.3
Heat Transferred (BTU/hr)	7.8E+6	1/Wall Resis (BTU/hr·ft ^{2.o} F)		25,594.8
LMTD		83.6	LMTD Correction Factor		0.9739
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft ^{2.o} F)	_	203.3
Property	Shell-Side	Tube-Side)5 17	
Velocity (ft/s)	4.99	2.24	Shell Temp In (°F)	-19. of	190.0
Reynold's Number	8.292E+04	1.575E+04	Shell Temp Out (°F)	7	175.4
Prandtl Number	2.13	4.76	Tav Shell (°F)		182.7
Bulk Visc (lbm/ft·hr)	0.82	1.72	Shell Skin Temp (°F)	Calc: G	174.0
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)	. 4	60.0
Density (lbm/ft ³)	60.52	62.05	Tube Temp Out (°F)	w iii y	131.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	Po Ime A	95.9
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)		124.2
** Reynolds Number Out	side Range of Equat	ion Applicability		Proto-Power Attachment: Rev: A Pa	







Calculation Report for DG01A - DG Jacket Water Cooler

 $CSCS = 70^{\circ}F$

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	254.2	
Sheil Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	70.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Overall Fouling (hr-ft2-0F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2.ºF)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².ºF)
LMTD	LMTD Correction Factor
Effective Area (ft ²)	

Droparty	Shell-Side	Tube-Side
Property	Blich-Bide	Tube-bide

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Tav Shell (°F) Prandtl Number Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft2.0F/BTU)		0.	002782
Tube Mass Flow (lbm/hr)		1.272E+5	Shell-Side ho (BTU/hr·ft².°F)			2,037.8
			Tube-Side hi (BTU/hr·ft²-°F)			829.2
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft ^{2.} °F)		2	5,594.8
LMTD		79.7	LMTD Correction Factor			0.9757
Effective Area (ft²)		471.2				
			U Overall (BTU/hr-ft2.°F)			212.8
Property	Shell-Side	Tube-Side	•	S	17	
Velocity (ft/s)	4.99	2.62	Shell Temp In (°F)	-195	ot	190.0
Reynold's Number	8.292E+04	1.940E+04	Shell Temp Out (°F)	97-	0	175.4
Prandtl Number	2.13	4.50	Tav Shell (°F)	27	14	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.63	Shell Skin Temp (°F)	Calc: G		174.1
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)		ge	70.0
Density (lbm/ft³)	60.52	61.99	Tube Temp Out (°F)	.t: √e	Page	131.4
Cp (BTU/lbm.°F)	1.00	1.00	Tav Tube (°F)	ું જે		100.7
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	Proto-Power Attachment:	A	124.9
			,	otc	<u>;</u>	
** Reynolds Number Outside	de Range of Equat	ion Applicability		Prc Att	Ş	

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 80°F



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Data
Data Date	Tube Flow (gpm)	307.0
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	80.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

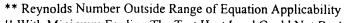
Fouling Calculation Results

Overall Fouling (hr-ft2.°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr-ft ² -°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft²-°F)
LMTD	LMTD Correction Factor
Effective Area (ft ²)	

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number	· ·		Shell Temp Out (°F)
Prandtl Number	• • •		Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results						
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft²-°F/BT	J)		0.002782
Tube Mass Flow (lbm/hr)		1.536E+5	Shell-Side ho (BTU/hr·ft².ºF)	,		2,038.0
			Tube-Side hi (BTU/hr·ft².°F)			984.2
Heat Transferred (BTU/hr)	7.8E+6	1/Wall Resis (BTU/hr·ft².ºF)			25,594.8
LMTD		75.8	LMTD Correction Factor			0.9779
Effective Area (ft²)		471.2				
			U Overall (BTU/hr-ft2.°F)			223.2
Property	Shell-Side	Tube-Side			_	
Velocity (ft/s)	4.99	3.16	Shell Temp In (°F)	95	17	190.0
Reynold's Number	8.292E+04	2.462E+04	Shell Temp Out (°F)	Ŧ	of	175.4
Prandtl Number	2.13	4.26	Tav Shell (°F)	97-1	_	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.56	Shell Skin Temp (°F)	ပ	15	174.2
Skin Visc (lbm/ft·hr)	0.87	1.28	Tube Temp In (°F)	Calc:	5 9	80.0
Density (lbm/ft3)	60.52	61.92	Tube Temp Out (°F)	_	- ≌	130.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	×e	P	105.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	to-Power	connent: : A Pa	125.6



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie







Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	389.3	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

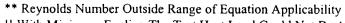
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU) Shell-Side

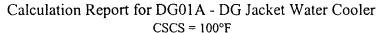
Property Tube-Side Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft-hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

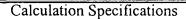
Extrapolation	Calculation Results
25.111. up o 1uti o 11	Cuitainon ittourits

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)			0.002782
Tube Mass Flow (lbm/hr)		1.947E+5	Shell-Side ho (BTU/hr·ft².°F)			2,038.2
			Tube-Side hi (BTU/hr·ft².°F)			1,213.3
Heat Transferred (BTU/hr	·)	7.8E+6	1/Wall Resis (BTU/hr-ft2.°F)			25,594.8
LMTD		71.9	LMTD Correction Factor			0.9808
Effective Area (ft²)		471.2				
			U Overall (BTU/hr-ft2.°F)			234.8
Property	Shell-Side	Tube-Side		Ś	17	
Velocity (ft/s)	4.99	4.01	Shell Temp In (°F)	.19	of	190.0
Reynold's Number	8.292E+04	3.273E+04	Shell Temp Out (°F)	97.	_	175.4
Prandtl Number	2.13	4.04	Tav Shell (°F)		16	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.48	Shell Skin Temp (°F)	alc:		174.3
Skin Visc (lbm/ft hr)	0.87	1.27	Tube Temp In (°F)	Č C	Page	90.0
Density (lbm/ft ³)	60.52	61.86	Tube Temp Out (°F)	z č	പ്പ	130.1
Cp (BTU/lbm-°F)	1.00	1.00	Tav Tube (°F)	(5) E	,	110.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	4.	K	126.2
** Reynolds Number Out	side Range of Equat	ion Applicability		Proto-Power	Rev.	



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Extrapolation Data		
Data Date	Tube Flow (gpm)	534.5		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)				

Fouling Calculation Results

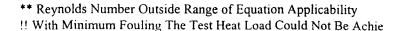
Overall Fouling (hr-ft2-°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².ºF)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property Shell-Side Tube-Side

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results					
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² .°F/B	TU)	0.002782
Tube Mass Flow (lbm/hr)		2.674E+5	Shell-Side ho (BTU/hr·ft².º)		2,038.4
			Tube-Side hi (BTU/hr-ft2.°F	·)	1,592.6
Heat Transferred (BTU/hr)	7.8E+6	1/Wall Resis (BTU/hr-ft2-°F	r)	25,594.8
LMTD		67.8	LMTD Correction Factor		0.9844
Effective Area (ft²)		471.2			
			U Overall (BTU/hr·ft ^{2.} °F)	_	247.9
Property	Shell-Side	Tube-Side		95	
Velocity (ft/s)	4.99	5.52	Shell Temp In (°F)	-15 of	190.0
Reynold's Number	8.292E+04	4.701E+04	Shell Temp Out (°F)	7	175.4
Prandtl Number	2.13	3.85	Tav Shell (°F)		182.7
Bulk Visc (lbm/ft hr)	0.82	1.42	Shell Skin Temp (°F)	Calc: G	174.4
Skin Visc (lbm/ft·hr)	0.87	1.27	Tube Temp In (°F)	ı X	100.0
Density (lbm/ft3)	60.52	61.79	Tube Temp Out (°F)	Pitte	129.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	o o u	114.6
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	to-Power schment: : A Pa	126.8





Attachment H to Proto-Power Calculation 97-195 Revision A

Proto-Power Calc: 97-195

Attachment: H

Rev: A Page 1 of 2



PROTO-HXTM Version 3.02 MODEL

LASALLE STATION STANDBY DIESEL GENERATOR HEAT EXCHANGER.

FILE NAME: DG01A.PHX

DATE LAST MODIFIED: 6/29/98

TIME LAST MODIFIED: 1:50:34 PM

FILE SIZE: 640 KB

Proto-Power Calc: 97-195

Attachment: H

Rev: A Page 2 of 2

ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Page 1 Design Analysis (Minor Revision) Last Page No. 6 Attachment B, B2 Analysis No.: 1 97-197 Revision: 2 A04 Title: 3 Thermal Model of ComEd/LaSalle Station HPCS Diesel Generator Jacket Water Coolers Revision: 5 EC/ECR No.: 4 388666 000 Station(s): 7 LaSalle 01 & 02 Unit No.: 8 Safety/QA Class: 9 SR System Code(s): 10 HP, DG, E22 Is this Design Analysis Safeguards Information? " Yes 🗌 No 🔯 If yes, see SY-AA-101-106 Does this Design Analysis contain Unverified Assumptions? 12 No 🖂 Yes 🗌 If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: 13 in its entirety. Description of Changes (list affected pages): " This revision evaluates a maximum cooling water inlet temperature of 107 °F. The previous temperature that was evaluated was 104 °F. Affected pages are Pages 1 - 3, Attachment A, Pages A1-A2, and Attachment B, Pages B1-B2 Disposition of Changes: 15 See attached pages. The changes made are acceptable. Preparer: 16 rint Name Method of Review: 17 Detailed Review X Alternate Calculations Testing 🔲 Reviewer: 18 Review Independent review X Peer review Notes: 19 (For External Analyses Only) External Approver: 20 Date Sign Name Exelon Reviewer 21 Exelon Approver: 22 DAN SCHMIT





Purpose:

The purpose of this revision is to verify that the 1(2)E22-S001 coolers can remove the design heat load of 7,800,000 BTU/hr with a revised maximum cooling water temperature of 107 °F.

Assumptions:

There are no assumptions for this revision.

Inputs:

- Cooling water temperature = 107 °F (Reference 2)
- Cooling water flow rate = 650 gpm* (References 1, 3, and 4)
- Jacket water temperature for 1(2)E22-S001 = 190 °F (Reference 1)
- Jacket water flow rate for 1(2)E22-S001 = 1100 gpm (Reference 1)
- Fouling factor for 1(2)E22-S001 = 0.00223 hr ft² °F/BTU** (Reference 1, 3, and 4)
- 4 tubes plugged (1% tube plugging) (Reference 1)

*The flow rate for this cooler was reduced to 550 gpm for both units per References 3 and 4. An additional case is run with this flow rate and a CSCS temperature of 107 °F.

**The fouling factor for this cooler was increased to 0.00196 hr ft².°F/BTU per References 3 and 4. An additional case is run with this fouling factor and a CSCS temperature of 107 °F.

References:

- 1. Design analysis 97-197, Rev. A, up to and including Rev A03
- 2. EC 388666, Rev. 000
- 3. EC 370853, Rev. 000
- 4. EC 384525, Rev. 000
- 5. EC 382117, Rev. 000

Identification of Computer Programs:

The computer program used in this analysis is Proto HX version 4.01. This program has been validated per DTSQA tracking number EX0000103.

Method of Analysis / Numeric Analysis:

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp" from 104 °F to 107 °F.

Results / Conclusions:

The 1(2)E22-S001 coolers can remove the design heat load of 7,800,000 BTU/hr with the following conditions:

- 107 °F cooling water temperature
- 650 gpm and 550 gpm cooling water flow
- fouling factor of 0.00223 hr-ft²-°F/BTU and 0.00196 hr-ft²-°F/BTU
- 4 tubes plugged
- jacket water temperature of 190 °F
- jacket water flow rate of 1100 gpm

The total heat removed at 650 gpm with a fouling factor of 0.00223 hr·ft².°F/BTU is 7,916,590 BTU/hr, which provides 1.5% thermal margin over the design heat load. The total heat removed at 550 gpm with a fouling factor of 0.00196 hr·ft².°F/BTU is 7,936,128 BTU/hr, which provides 1.7% thermal margin over the design heat load. The model benchmark was shown to conservatively underestimate the heat transfer of the cooler by 2.68%. Therefore, any positive margin shown in the model would be an underestimate of actual thermal performance, which would show more margin than what is calculated. Additionally, the most recent thermal performance evaluation (Ref. 5) shows a maximum fouling factor of 0.000447 hr·ft².°F/BTU, which also shows that additional margin exists. The calculated thermal margin of 1.5% and 1.7% for the two cases is acceptable. The maximum fouling factor of 0.00196 hr·ft².°F/BTU shall be used for acceptance criteria in thermal performance evaluations after ECs 370853 and 384525 have been implemented on Units 1 & 2, respectively. The two cases are shown in Attachments A and B.





Attachments:

A. Data Report for 1(2)E22-S001 at 650 gpm with FF = 0.00223 hr·ft²·°F/BTU (2 pgs)

B. Data Report for 1(2)E22-S001 at 550 gpm with FF = 0.00196 hr·ft²·°F/BTU (2 pgs)





PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-1002)

Commonwealth Edison

Data Report for DG01B - LSCS - HPCS DG Hx.

1B, 2B DG - 107 °F tube side, 650 gpm, 190 °F shell side, 1100 gpm, FF = 0.00223, 4 tubes plugged

Shell and Tube Heat Exchanger Input Parameters

	Shell-Side	Tube-Side
Fluid Quantity, Total gpm	1,064.46	795.25
Mass Fluid Quantity, Total lbm/hr	0.00	0.00
Inlet Temperature °F	190.00	100.00
Outlet Temperature °F	175.00	121.00
Fouling Factor hr-ft ^{2.o} F/BTU	0.00050	0.00193
Shell Fluid Name Tube Fluid Name Design Q (BTU/hr) Design U (BTU/hr·ft²·°F) Outside h Factor (Hoff) Fixed U (BTU/hr·ft²·°F) Fixed Area (ft²) Performance Factor (% Reduction)		Fresh Water Fresh Water 8,505,000 241.70 0.633693000 0 0.00
Heat Exchanger Type Total Effective Area per Unit (ft²) Area Factor Area Ratio		TEMA - E 468.17 0.973212339 0.00000
Number of Shells Per Unit Shell Minimum Area Shell Velocity (ft/s) Tube Pitch (in) Tube Pitch Type		1 0.438000000 5.600 0.7500 Triangular
Number of Tube Passes U-Tubes Total Number of Tubes Number of Active Tubes Tube Length (ft) Tube Inside Diameter (in) Tube Outside Diameter (in) Tube Wall K (BTU/hr·ft·°F)		2 No 420 416 7.00 0.541 0.625 58.00
Lbc, Central Baffle Spacing (in) Lbi, Inlet Baffle Spacing (in) Lbo, Outlet Baffle Spacing (in) Dotl, Tube Circle Diameter Bh, Baffle Cut Height (in) Ds, Shell Inside Diameter (in) Lsb, Diametral difference between Baffle and Ltb, Diametral difference between Tube and I Nss, Number Sealing Strips	` '	0.000 19.688 19.688 0.000 0.000 0.000 0.000 0.000



Calculation Report for DG01B - LSCS - HPCS DG Hx.

1B, 2B DG - 107 °F tube side, 650 gpm, 190 °F shell side, 1100 gpm, FF = 0.00223, 4 tubes plugged



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date Shell Flow (gpm)	Tube Flow (gpm) Shell Flow (gpm)	645.10 1,064.50		
Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm)	Tube Inlet Temp (°F) Shell Inlet Temp (°F)	107.00 190.00		
Tube Temp In (°F) Tube Temp Out (°F)	Input Fouling Factor	0.002230		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)

Tube Mass Flow (lbm/hr)

U Overall (BTU/hr·ft²-°F)

Shell-Side ho (BTU/hr·ft²-°F)

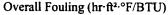
Tube-Side hi (BTU/hr·ft²-°F)

Heat Transferred (BTU/hr)

LMTD

LMTD Correction Factor

Effective Area (ft²)



			overall Jaming (in it
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr-ft-°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		532,515.63	Overall Fouling (hr-ft²-°F/BTU)	0.002230
Tube Mass Flow (lbm/hr)		322,710.98	Shell-Side ho (BTU/hr·ft².°F)	1,891.2
Heat Transferred (BTU/hr)		7,916,590.94	Tube-Side hi (BTU/hr·ft².°F)	1,408.2
LMTD		63.2	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
		· ·	LMTD Correction Factor	0.9847
Effective Area (ft²)		463.7	II O II (DTII/L., Q1 OP)	274.4
Property	Shell-Side	Tube-Side	U Overali (BTU/hr·ft².°F)	274.4
Velocity (ft/s)	5.58	4.37	Shell Temp In (°F)	190.0
Reynold's Number	77,252	32,323	Shell Temp Out (°F)	175.2
Prandtl Number	2.1276	3.6616	Tav Shell (°F)	182.6
Bulk Visc (lbm/ft·hr)	0.8197	1.3556	Shell Skin Temp (°F)	173.4
Skin Visc (lbm/ft·hr)	0.8730	1.1913	Tube Temp In (°F)	107.0
Density (lbm/ft³)	60.5172	61.7228	Tube Temp Out (°F)	131.6
Cp (BTU/lbm·°F)	1.0025	0.9988	Tav Tube (°F)	119.3
K (BTU/hr·ft·°F)	0.3862	0.3698	Tube Skin Temp (°F)	133.5



^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved

PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-1002) Commonwealth Edison

Data Report for DG01B - LSCS - HPCS DG Hx.

1B, 2B DG - 107 °F tube side, 550 gpm, 190 °F shell side, 1100 gpm, FF = 0.00196, 4 tubes plugged

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Mass Fluid Quantity, To		0.00	0.00
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor	hr·ft²·°F/BTU	0.00050	0.00193
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Q (BTU/hr)			8,505,000
Design U (BTU/hr·ft².º)	*		241.70
Outside h Factor (Hoff)			0.633693000
Fixed U (BTU/hr·ft².ºF))		0
Fixed Area (ft²) Performance Factor (%	Reduction)		0.00
1 criointance 1 actor (70	Reduction)		0.00
Heat Exchanger Type			TEMA - E
Total Effective Area pe	r Unit (ft²)		468.17
Area Factor			0.973212339
Area Ratio			0.00000
Number of Shells Per U	Jnit		1
Shell Minimum Area			0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes	3		2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tube	es		416
Tube Length (ft)	: \		7.00
Tube Inside Diameter (· ·		0.541
Tube Outside Diameter			0.625
Tube Wall K (BTU/hr·1	π··r)		58.00
Lbc, Central Baffle Spa	• •		0.000
Lbi, Inlet Baffle Spacin	- ` '		19.688
Lbo, Outlet Baffle Space	- · ·		19.688
Dotl, Tube Circle Diam			0.000
Bh, Baffle Cut Height (•		0.000
Ds, Shell Inside Diamte	• •		0.000
Lsb, Diametral differen		7 7	0.000
Ltb, Diametral differen		Baffle (in)	0.000
Nss, Number Sealing S	trips		0.000



Calculation Report for DG01B - LSCS - HPCS DG Hx.

1B, 2B DG - 107 °F tube side, 550 gpm, 190 °F shell side, 1100 gpm, FF = 0.00196, 4 tubes plugged

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date Shell Flow (gpm) Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm)	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F) Shell Inlet Temp (°F)	545.90 1,064.50 107.00 190.00		
Tube Temp In (°F) Tube Temp Out (°F)	Input Fouling Factor	0.001960		

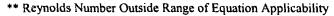
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft ² .°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Sheli Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		532,515.63	Overall Fouling (hr·ft².°F/BTU)	0.001960
Tube Mass Flow (lbm/hr)		273,086.22	Shell-Side ho (BTU/hr·ft².°F)	1,890.9
			Tube-Side hi (BTU/hr·ft².°F)	1,248.7
Heat Transferred (BTU/hr)		7,936,128.27	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		60.7	LMTD Correction Factor	0.9802
Effective Area (ft²)		463.7		
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft ^{2.} °F)	287.5
Velocity (ft/s)	5.58	3.70	Shell Temp In (°F)	190.0
Reynold's Number	77,243	27,941	Shell Temp Out (°F)	175.1
Prandtl Number	2.1278	3.5771	Tav Shell (°F)	182.6
Bulk Visc (lbm/ft·hr)	0.8198	1.3270	Shell Skin Temp (°F)	173.3
Skin Visc (lbm/ft·hr)	0.8737	1.1487	Tube Temp In (°F)	107.0
Density (lbm/ft³)	60.5176	61.6875	Tube Temp Out (°F)	136.1
Cp (BTU/lbm·°F)	1.0025	0.9988	Tav Tube (°F)	121.5
K (BTU/hr·ft·°F)	0.3862	0.3705	Tube Skin Temp (°F)	137.8



^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved







ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Page 1 Design Analysis (Minor Revision) Last Page No. 6 1 97-197 Revision: 2 Analysis No.: 1 A03 Title: 3 Thermal Model of ComEd / LaSalle Station HPCS Diesel Generator Jacket Water Coolers Revision: 5 EC/ECR No.: 1 EC 384525 000 Station(s): 7 LaSalle Unit No.: 8 02 SR Safety/QA Class: 9 System Code(s): 10 HP, E22, DG Is this Design Analysis Safeguards Information? " Yes 🗍 No 🛛 If yes, see SY-AA-101-106 Does this Design Analysis contain Unverified Assumptions? 12 No 🔯 Yes If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: 13 in its entirety. Description of Changes (list affected pages): " EC 384525 revised the flows in Division 3 of the Unit 2 CSCS. This revision makes the changes made in Revision A02 applicable to both Units. Disposition of Changes: 15 As shown in Attachment A of Revision A02, the changes made are acceptable. The revised flows in combination with the reduced fouling factor allow the heat exchanger to remove the design basis heat load. System engineering has agreed to accept more stringent criteria for the cleanliness of the 2E22-S001 cooler. Preparer: 16 Sean Tanton Print Name **Alternate Calculations** Method of Review: 17 Detailed Review X Testing 🔲 Reviewer: 18 Matthew Cosenza Print Name Review Independent review 🛛 Peer review Notes: 19 (For External Analyses Only) N/A N/A N/A External Approver: 20 Print Name Date Sion Name Exelon Reviewer 21 N/A N/A N/A Print Name Sion Name



Exelon Approver: 22

Dan Schmit



ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Page 1

Design Analysis (Mino	r Revision)	Last	Page No. 6 Attachme	ent A, pg A2
Analysis No.: 1 97-	197	Revision: 2	A02	:
Title: 3 The	rmal Model of ComEd / LaS	alle Station HPCS [Diesel Generator Jack	et Water Coolers
EC/ECR No.: 4 370	853	Revision: 5	000	
Station(s): '	LaSalle			
Unit No.: 8	01			
Safety/QA Class: °	SR			
System Code(s): 10	HP, E22, DG			
Is this Design Analysis	Safeguards Information?	Yes 🗌	No 🛛 If yes, see	SY-AA-101-106
Does this Design Analysi	is contain Unverified Assump	otions? ' ² Yes 🗌	No 🛛 If yes, ATI//	AR#: N/A
This Design Analysis	SUPERCEDES: 13 N/A			in its entirety.
	s (list affected pages): 14			
100 gpm will be diverted C002 pump, while the o	vision 3 of Unit 1 of the CSC I from the 1E22-S001 cooler ther 50 gpm will be given to d can remove the required a	r. Of this 100 gpm, the 1VY02A cooler.	50 gpm will be returne . This revision determ	ed to the 1E22-
This revision only applie revision.	es to Unit 1. The flows show	n for Unit 2 remain	valid and are not impa	acted by this
0.00196 hr*ft ² *°F/BTU. plugged, and a fouling fa	at a sufficient heat transfer ra By inputting 546.26 gpm tub actor of 0.00196 hr*ft ² *°F/BT	be flow, 104 °F tube TU the resulting hea	side inlet water tempe t transfer rate is appro	rature, 4 tubes oximately
has agreed to accept m	n maintains the 5% margin a ore stringent criteria for the e acceptable and can remov	cleanliness of the 11	E22-S001 cooler. The	
Preparer: 16	Sean Tanton	_ Sean	Vauton Sign Name	5/24/11
Method of Review: 17	Detailed Review ⊠ A	Iternate Calculatio	ns 🔲 Testing 🗌	
Reviewer: 18	Matthew Cosenza	Mest		05/24/2011
	Print Name		Sign Name	Date
Review Notes: 19	Independent review 🛛	Peer review 🗌		
(For External Analyses Only)				B.F./ A
External Approver: 20	N/A Print Name		, N/A Sign Name	- N/A Date
Exelon Reviewer 21	N/A .	•	N/A	N/A
Exelon Approver: 22	Print Name Dan Schmit	DASU	Sign Name	6/1/11



Purpose:

To recover margin in Division 3 of Unit 1 of the CSCS, EC 370853 revises the flows of the 1E22-S001 cooler. 100 gpm will be diverted from the 1E22-S001 cooler. Of this 100 gpm, 50 gpm will be returned to the 1E22-C002 pump, while the other 50 gpm will be given to the 1VY02A cooler. This minor revision documents the change in flow. These flow revisions were selected by system engineering and are specified in reference 2.

This revision only applies to Unit 1. A later EC and revision to this calculation will incorporate the changes on Unit 2.

Inputs:

Tubeside flow¹ = 550 gpm (Ref. 2) Plugging allowance = 1% (4 tubes) (Ref. 1) Tubeside inlet water temperature = 104 °F (Ref. 1) Overall fouling factor² = 0.00223 hr*ft²*°F/BTU (Ref. 1) Design heat load³ = 7.8E+06 BTU/hr (Ref. 1)

- ¹ Note that since Proto HX assumes a water density at 60 °F, the impact on the required mass flow due to the density change at a CSCS water temperature of 104 °F was evaluated and the actual flow input in Proto-HX was 546.26 gpm.
- ² A fouling factor of 0.00223 hr*ft²*°F/BTU was used as a starting point for iterations to achieve the design heat transfer + 5% margin. The fouling factor that resulted in the desired margin (5%, see note 3) was 0.00196 hr*ft²*°F/BTU
- ³ The design heat load for the Division 3 jacket water coolers is 7.8E+06 BTU/hr, however, the desired heat load is ≥ 8.189E+06 BTU/hr to maintain 5% thermal margin at 100% operating conditions. The 5% margin accounts for uncertainty in the Proto HX heat transfer calculations. (Ref. 1)



There are no assumptions associated with this revision.

References:

- 97-197, Rev. A, up to and including Revs A00 through A01, Thermal Model of ComEd / LaSalle Station HPCS Diesel Generator Jacket Water Coolers
- 2. AT 595380-11-13, CSCS HIT team Use values provided by System Engineering to determine the new Div 3 accident penalty

Identification of Computer Programs:

The computer program used in this analysis is Proto HX version 4.01. This program has been validated per DTSQA tracking number EX0000103.

Method of Analysis / Numerical Analysis:

The existing heat exchanger model will be revised by changing the input of the "Tube Flow" from 646.1 gpm to 546.26 gpm. Iterations are made by adjusting the fouling factor to achieve the desired heat transfer rate. The results are detailed below.

Results / Conclusion:

Attachment A shows that a sufficient heat transfer rate can be achieved by reducing the fouling factor to 0.00196 hr*ft²*°F/BTU. By inputting 546.26 gpm tube flow, 104 °F tubeside inlet water temperature, 4 tubes plugged, and a fouling factor of 0.00196 hr*ft²*°F/BTU the resulting heat transfer rate is approximately 8.21E+06 BTU/hr, which maintains the 5% margin above the design heat transfer rate.

Attachments:

A. Proto HX Calculation Report (2 pages)



Calculation Report for DG01B - LSCS - HPCS DG Hx. 546.26 gpm Tube Flow, 104 F Tube Temp, FF = 0.00196, 4 Tubes Plugged



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date Shell Flow (gpm) Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm)	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F) Shell Inlet Temp (°F)	546.26 1,064.50 104.00 190.00		
Tube Temp In (°F) Tube Temp Out (°F)	Input Fouling Factor	0.001960		

Fouling Calculation Results

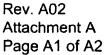
Overall Fouling (hr-ft2.°F/BTU)

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft2.°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property Shell-Side Tube-Side Shell Temp In (°F) Velocity (ft/s) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft³) Tube Temp Out (°F) Cp (BTU/lbm·°F) Tav Tube (°F) K (BTU/hr-ft-°F) Tube Skin Temp (°F)

Extrapolation Calculation Results						
Shell Mass Flow (lbm/hr)		532,515.63	Overall Fouling (hr-ft².°F/BTU)	0.001960		
Tube Mass Flow (lbm/hr)		273,266.31	Shell-Side ho (BTU/hr-ft²,°F)	1,889.2		
Heat Transferred (BTU/hr LMTD	r)	8,206,590.75 63.0 463.7	Tube-Side hi (BTU/hr·ft².°F) 1/Wall Resis (BTU/hr·ft².°F) LMTD Correction Factor	1,235.3 15,431.0 0.9803		
Effective Area (ft²)	CF-11 C:4-		U Overall (BTU/hr·ft².°F)	286.6		
Property	Shell-Side	Tube-Side				
Velocity (ft/s)	5.58	3.70	Shell Temp In (°F)	190.0		
Reynold's Number	77,111	27,306	Shell Temp Out (°F)	174.6		
Prandtl Number	2.1317	3.6710	Tav Shell (°F)	182.3		
Bulk Visc (lbm/ft·hr)	0.8212	1.3588	Shell Skin Temp (°F)	172.7		
Skin Visc (lbm/ft·hr)	0.8772	1.1663	Tube Temp In (°F)	104.0		
Density (lbm/ft³)	60.5233	61.7266	Tube Temp Out (°F)	134.1		
Cp (BTU/lbm·°F)	1.0025	0.9988	Tav Tube (°F)	119.0		
K (BTU/hr-ft-°F)	0.3862	0.3697	Tube Skin Temp (°F) 97-197	136.0		

^{**} Reynolds Number Outside Range of Equation Applicability





^{!!} With Zero Fouling The Test Heat Load Could Not Be Achieved

PROTO-HX 4.00 by Proto-Power Corporation (SN#PHX-0000)

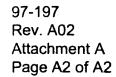
Commonwealth Edison

Data Report for DG01B - LSCS - HPCS DG Hx.

546.26 gpm Tube Flow, 104 F Tube Temp, FF = 0.00196, 4 Tubes Plugged

Shell and Tube Heat Exchanger Input Parameters

	Shell-Side	Tube-Side
Fluid Quantity, Total gpr	- , - ·	795.25
Mass Fluid Quantity, Total lbm/h		0.00
mice remperature	F 190.00	100.00
Outlet Temperature	175.00	121.00
Fouling Factor hr-ft ² .°F/BTU	J 0.00050	0.00193
Shell Fluid Name		Fresh Water
Tube Fluid Name		Fresh Water
Design Q (BTU/hr)		8,505,000
Design U (BTU/hr·ft ² .°F)		241.70
Outside h Factor (Hoff)		0.633693000
Fixed U (BTU/hr·ft².ºF)		0
Fixed Area (ft²)		0.00
Performance Factor (% Reduction)		0.00
Heat Exchanger Type		TEMA - E
Total Effective Area per Unit (ft²)		468.17
Area Factor		0.973212339
Area Ratio		0.0000
Number of Shells Per Unit		1
Shell Minimum Area		0.438000000
Shell Velocity (ft/s)		5.600
Tube Pitch (in)		0.7500
Tube Pitch Type		Triangular
Number of Tube Passes		2
U-Tubes		No
Total Number of Tubes		420
Number of Active Tubes		416
Tube Length (ft)		7.00
Tube Inside Diameter (in)		0.541
Tube Outside Diameter (in)		0.625
Tube Wall K (BTU/hr·ft·°F)		58.00
Lbc, Central Baffle Spacing (in)		0.000
Lbi, Inlet Baffle Spacing (in)		19.688
Lbo, Outlet Baffle Spacing (in)		19.688
Dotl, Tube Circle Diameter		0.000
Bh, Baffle Cut Height (in)		0.000
Ds, Shell Inside Diamter (in)		0.000
Lsb, Diametral difference between Baff	le and Shell (in)	0.000
Ltb, Diametral difference between Tube	` '	0.000
Nss, Number Sealing Strips		0.000





ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Design Analysis (I	Minor Revision)	Last Page No.	⁶ Attach. B Pg. 4/5
Analysis No.: ¹	97-197	Revision: 2 A01	
Title: 3	Thermal Model of COMED	/ LaSalle Station 1B(2B) Diesel Ge	enerator Jacket Water Coolers
EC/ECR No.: 1	EC 366846	Revision: 5 0	
Station(s): 7	LaSalle		
Unit No.: *	1 and 2		
Safety/QA Class: 5	SR		
System Code(s): 1	E22		
ls this Design Ana	lysis Safeguards Informat	ion? "Yes 🗌 No 🛛	If yes, see SY-AA-101-106
Does this Design Ar	alysis contain Unverified As	sumptions? ¹² Yes 🗌 No 🛛	If yes, ATI/AR#:
This Design Analy	sis SUPERCEDES: 13 NA	<u></u>	in its entirety.
Revised pg. Added Reference Replaced pg. Section 9.5. Added new Verified no UFSAR cl (UFSAR Section 9.2. Disposition of Characteristic This revision updates additional reference ff 628211 and associated Based on diesel general manufacturer, is the section balance data for the I Specification J-2544 conditions is 2284 kW calculation.	5.1.1 from pending approved URef. 8.12 (pg. PTD-7 from Spectange to the 650 gpm minimum 1.1.1 a. 3) has occurred over tire anges: 15 an included UFSAR section refer the basis of the heat load from the basis of the heat loa	prence 8.12 to Table 3-1 page 12 of 12 of Rev. A Rev. A, UFSAR Section 9.5.5.1.1 Rev. FSAR Change LUCR-0082 for Rev. 17 iffication J-2544 Amd. 2) to Attachment cooling water flow value shown on Attachment ference with the latest approved UFSA m the DG cooler. This revision also act by the System Manager, the Div. 3 die ne same rated output as the Div. 1 and the supplier (see Ref. 8.12 in Attachmenergy absorbed by the cooling water w/hr, as stated in the UFSAR and used	of the UFSAR It B as page 4 Itachment B pg. 2/5 of Rev. A Itachment B pg. 1/5 of Rev. A Itahment B pg. 1/5 of Rev. A Itachment B pg. 1/5 of Rev. A Itachment
Method of Review	Print Name : ¹7 Detailed Review ⊠	Sign Name	Testing
Reviewer: 18	Sean Tanto	1 0	8/9/07
Review Notes: 19	Print Name Independent review	Sign Name	bate
(For External Analyses Only) External Approve			
Exelon Reviewer		Sign Name	Date
Exelon Approver:	22 Bill Hilton	Sigh Marne/	8-10-07
	Print Name	Sign Name	Date

PROTO-POWER CORPORATION	CALC NO. 97-197	REV A OI	PAGE 2 OF 12	
GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/26/98	
	VERIFIED BY S. Ingalls		JOB NO. 31-003	
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program			
THE Thermal Model of COMED / LaSalle Station 1B(2B) Diesel Generator Jacket Water Coolers.				

the necessary information for model construction while performance specifications provided by the vendor are used to benchmark the model.

Thermal performance of the HPCS diesel generator heat exchanger is assessed in this calculation at the LaSalle Station Reference Conditions of Section 3.1 with all tubes active and 100% of rated load. No tube plugging margin or load conditions beyond 100% are considered.

3.1. LASALLE STATION REFERENCE CONDITIONS

Table 3-1 describes the performance requirement of the jacket water cooler. These conditions ensure that the engine operating temperature range will not be exceeded.

Table 3-1 LaSalle Station Reference Conditions

Parameter	Value	Reference	
Heat Load at 100% power (BTU/hr)	7,800,000	8.1, 8.4, 8.12	
Shell-Side Flow Rate (gpm)	1,100	8.4	
Shell-Side Inlet Temperature (°F)	190	8.4	
Tube-Side Flow Rate (gpm)	650	8.1	
Maximum Tube-Side Inlet Temperature (°F)	100	8.1	

3.2. Construction Details

Table 3-2 Vendor Construction Detail

Parameter	Value	Reference 8.7, 8.8	
Heat Exchanger Type	TEMA - E		
Number of Shells per unit	1	8.7	
Total Effective Area per unit (ft²)	482	8.6, See Below	
Shell Velocity (ft/sec)	5.6	8.6	
Baffle Thickness (in)	3/8 (min)	8.8	
Fixed Tubesheet Thickness (in)	1	8.8	
Floating Tubesheet Thickness (in)	1-1/4	8.8	
Tube Passes per shell	2	8.7	
U-Tubes (yes or no)	No	8.7	
Total Number of Tubes	420	8.6, 8.8	
Tube Length (ft)	7	8.6	
Tube Inside Diameter (in)	0.541 (19 BWG)	8.6	
Tube Outside Diameter (in)	5/8	8.6	

PROTO-POWER CORPORATION	CALC NO. 97-197	REV A OJ	PAGE 12 OF 12
GROTON, CONNECTICUT	ORIGINATOR D. Physe		DATE 6/26/98
	VERIFIED BY S. Ingalls	·	^{3OB NO.} 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
THE Thermal Model of COMED / LaSalle	Station 1B(2B) Diesel Gene	rator Jacket W	ater Coolers.

8.0 REFERENCES

- 8.1. LaSalle Station UFSAR, Sections: 9.2.1 and 9.5.5.1.1 (Attachment B)
- 8.2. NRC Generic Letter 89-13
- 8.3. GE Purchase Specification 211872RO-SW9 Item 4.3.6.1
- 8.4. LaSalle Station FSAR Q40.92 (Attachment B)
- 8.5. Stewart & Stevens Vendor Manual, VM J-152 through VM J-157
- 8.6. O & M Manufacturing Hx Data Sheet (Attachment A)
- 8.7. LaSalle Station Drawing, VPF 3411-080(1)-1, J-2500 (Attachment A)
- 8.8. LaSalle Station Drawing, VPF 3411-080(2)-1, J-2500 (Attachment A)
- 8.9. Standard of the Tubular Exchanger Manufacturers Association
- 8.10. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HXTM Version 3.02 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision F, dated 2/17/98
- 8.11. Proto-Power Calculation 93-048, "Fluid Properties Fresh Water Range 32°F to 500°F", Rev. A
- 8.12 Proposal Technical Data for Diesel Engine-Generator Sets from Specification J-2544 Amd. 2, pg. PTD-7



Calc. 97-197 R. AOI Attach. B Pg. 3/5

LSCS-UFSAR

excessive or shutdown time is too short to permit remote detection of possible fuel oil leaks at the day tank or diesel generator.

9.5.5 Diesel-Generator Cooling Water System

The function of the diesel-generator cooling water system is to transfer the heat rejected from the engine water jacket, the lube oil cooler and the engine air aftercooler to the CSCS equipment cooling water system (CSCS-ECWS).

9.5.5.1 Design Bases

9.5.5.1.1 Safety Design Bases

Cooling capacity of this system is based on a diesel generator output of 2860 kW with an environmental temperature of 122° F maximum and a minimum and maximum lake water temperature of 32° F and (102) F, respectively. Total heat transfer by this system is approximately 7.8 x 106 Btu/hr per diesel-generator set at rated engine capacity. The Division I and II diesel cooling water heat exchangers are sized based on operation of 110% of rated load. The Division III diesel cooling water heat exchangers are sized based on operation of 100% of rated load.

High water temperature is alarmed at 200° F and the engine is automatically shut down if the cooling water temperature at the engine outlet exceeds 208° F in order to prevent engine damage due to overheating. This shutdown control is in effect only when the engine is started manually and bypassed when the diesel generator is started automatically during an emergency.

Heaters are installed in the cooling water piping below the lube oil cooler to maintain the engine water and lube oil in a warm standby condition while the engine is not operating; thus increasing the starting reliability of the diesel generator. Natural convection is employed to circulate the warm engine water through the lube oil cooler during standby.

Each system is designed based on Seismic Category I requirements and is protected from tornadoes, missiles, and flooding.

9.5.5.1.2 Power Generation Design Bases

The diesel-generator cooling water system is not required during power generation. Consequently, it possesses no power generation design bases.

9.5.5.2 System Description

Each diesel-generator cooling water system is a separate, independent closed loop system supplied with the diesel generator and located entirely on the diesel-generator skid. It consists of two parallel engine driven centrifugal circulating pumps, a lowpressure expansion tank, an AMOT temperature regulating valve, a

REV. 15, APRIL 2004

Approved pending
UFSAR Change LUCK-0082.

Proposal Technical Data for Diesel Engine-Generator Sets, Cont. J-2544 Amd. 2, 01-27-78

La Salle County Station - Units 1 and 2

Name of Bidder: Steward & Stevenson Services, Inc.

CHATNE CENEDA	TOP DATA Cont	(Insert al	l data in thes	e columns)	_
ENGINE-GENERA	TOR DATA, Cont.	BASI	E BID	ALTERNATE 1	_
k.	WK ² value of all rotating	DIESEL CEN. O	DIESEL GEN. 1A AND 2A	DIESEL GEN. O, 1A AND 24	1
_	parts(1b-ft ²)	34,690			
	Is base frame stress re- lieved after fabrication but before machining	no			
m.	Vibration Dampers:				
	(1) Type	None require	d or recommen	ded	
	(2) Number	N/A			
n.	Full load speed(r/min)	900			
0.	Diesel Heat Balance at rated load and design ambient temperature:		·		
	(1) Diesel shaft output(kW)	* 2,600			
	(2) Energy absorbed by cooling water(kW)	2,284 × 3.	414 × 10 3 Bts.	EW = 7.8×10	
	(3) Energy dissipated in exhaust gases(kW)	2,689	700		
	(4) Energy lost to ambient by radiation and convection(kW)	260			
р.	Environmental Data:				
	(1) Maximum ambient temperature for continuous operation(°F)	104°		Amd .	
	(2) Minimum ambient temperature for continuous operation(°F)	30 °		Amd.	•
	(3) Generator losses to ambient at rated load and design ambient.(kW)	98			

PTD-7

Calc. 97-197 R. AOI Attach.B Pg. 4/5

125

		LASALLE CALCUL	ATION		
	EDITORIAL	- COMMENT T	O CAL	CULATION	
Affecting Calculation No.: (77-197	Rev: A00	POLS	Reference	Page No. / of
The use of this fo	orm shall be limited to	document corrections o	f editorial	nature. Return to	Sylvia Venecia
Prepared by:	Discar- Comment	Sign			Date
Reviewed by:	Print	Sign	<u> </u>		Date
Approved by:					Jac
	Print	Sign	1	I	Date
\ ~~	Street, Al, ned Log, i	BI I CI as hidd are hi solfeld no need ceen			
The state of the s					

when these comments are incorporate	ted, return this form wit	h the revised	d calculation.	
Incorporated on Calc Rev.	By:		Date:	

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 1 of 2

DESIGN ANALYSIS NO.: Calc. # 97-197 PAGE NO. 1 Major REV Number: A Minor Rev Number: 00						
[] BRAIDWOOD STATION [] BYRON STATION [] CLINTON STATION			DESCRIPTION CODE:(C018)		Дivinod Mød 10	
[] DRESDEN STATION [X] LASALLE CO. STATION [] QUAD CITIES STATION			SCIPLINE CODE:	M		
Unit: [] 0 [X]	[X]2 []	₃ SY	SYSTEM CODE: (C011) E22			
TITLE: THERMAL MODEL OF COMED/LASALLE STATION UNIT 1 AND 2 HPCS DIESEL GENERATOR COOLERS						
[X] Safety Related [] Augmented Quality [] Non-Safety Related] Non-Safety Related	
ATTRIBUTES (C016)						
TYPE	VALUE		TYPE		VALUE	
Elevation	710' 0"					
Software	PROTO)-HX				
COMPONENT EPI	COMPONENT EPN: (C014 Panel) DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)					
EPN	TYPE	y ype/Sub	Document N	umber	Input (Y/N)	
1E22-S001	H15	DEC/DCF	P EC# 33401	7	Y	
2E22-S001	H15	1				
		1				
	····	/				
		/				
		/				
REMARKS: NA						

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS NO. 97-197	REV: A00	PAGE NO. 2			
Revision Summary (including EC's incorporated): Updated Proto-HX model for 104°F Service Water inlet temperature and calculated Unit 1 and 2 HPCS DG Cooler thermal margins for different fouling factors and 1% tubes plugged.					
Electronic Calculation Data Files: ProtoHX 3.02, dg01b.phx, 19	92 KB, 04/14/2	2002, 5:04pm			
(Program Name, Version, File Name extension/size/date/hour/mir	n)				
Design impact review completed? [] Yes [X] N/A, Per EC#: 334017 (If yes, attach impact review sheet)					
Prepared by: Jeff W. VanStrien / Www. VanStrien	Laftan.	159-02			
- Print Reviewed by: Brian L. Davenport /	Sign	Date / Color			
- Print	Sign	Date			
Method of Review: [X] Detailed [] Alternate [] Tes	st				
This Design Analysis supersedes: N/A		in its entirety.			
Supplemental Review Required? [4] Yes: [X] No					
[] Additional Review [] Special Review Team	252	No. of the second			
Additional Reviewer or Special Review Team Leader:					
Special/Review Teams (N/A for Additional Review)					
Reviewers: (1) Productive Constitution (1) Constitution (
Print Sign Date	Print :	Sign Cate			
(a) (b) (c) (d) (d) (d) (d) (d) (d) (d) (d) (d) (d	Print	Sign Date			
Supplemental Review Results:					
Approved by: 5 T. Connu Print Si)(1 5/14/22 Date			
External Design Analysis Review (Attachment 3 Attached)					
Reviewed by:/	-				
Approved by:/	ign 	Date /			
	ign	Date			
Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later Tracked By: AT#, EC# etc.)		[] Yes [X] No			





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DESIGN ANALYSIS APPROVAL / REVISION SUMMARY	2	
TABLE OF CONTENTS	3	
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2.0 METHODOLOGY AND ACCEPTANCE CRITERIA	4	
3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS	4	
4.0 DESIGN INPUT	4	
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6.0 CALCULATIONS	5	
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Attachment "A" – Proto-Hx Calc. Report for DG01B (CSCS=104 F @ Design Fouling)	A1 to A3	
Attachment "B" – Proto-Hx Calc. Report for DG01B (CSCS=104 F @ 2X Max. Tested FF)	B1 to B3	
Attachment "C" – Proto-Hx Calc. Report for DG01B (CSCS=104 F @ 2X Max. Tested FF, w\ 1% plugged)	C1 to C3	





NES-G-14.02 Effective Date: 04/14/00

CALCULATION PAGE

CALCULATION NO. 97-197

REV. NO. A00

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1.0 PURPOSE/OBJECTIVE

The purpose of this minor revision is to revise the thermal model of this heat exchanger for a 104°F Service Water inlet temperature. This assessment will evaluate the adequacy of HPCS Diesel Generator Coolers during a maximum allowable inlet service water temperature of 104°F to ensure adequate thermal margin still exist. Also an acceptable design fouling factor for use as a benchmark during Generic Letter 89-13 testing evaluations will be determined.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp." from 100°F to 104°F and simulated for the following conditions: (Case 1) design fouling factor, (Case 2) twice the 'as-tested' fouling factor and (Case 3) twice the 'as-tested' fouling factor with 1% of the tubes plugged. The acceptance criteria will be for the thermal margin during Case 3 conditions to exceed the LaSalle design heat load of 7,800,000 BTU/hr at 100% rated power output (Ref. 1, Table 3-1). Additional conservatism is built into this acceptance criteria by assuming a 5% uncertainty in the Proto-HX heat transfer calculations. The Reference 1 model developed for this heat exchanger demonstrated a correlation to vendor performance specification well within this assumed 5% margin.

3.0 ASSUMPTIONS / ENGINEERING JUDGMENTS

The assumptions indicated in section 5.0 of Reference 1 are still valid.

Note: The density of water at 104°F is 61.94 lb/ft³ (per steam tables), this is an insignificant change to the density shown in table 4-1 of Ref. 1 for 100°F, the tube side volumetric flow rate correction made in Ref. 1 is still valid.

4.0 DESIGN INPUTS

The design inputs consist of References 1 and 2 listed below.

5.0 REFERENCES

- 1. Calculation No. 97-197, Rev. A, "Thermal Model of COMED / LaSalle Station HPCS Diesel Generator Jacket Water Coolers".
- 2. Calculations L-002399, Rev. 0 (Unit 2) & L-002684, Rev. 0 (Unit 1), "1 & 2E22-S001 HPCS Diesel Generator Cooler Thermal Heat Transfer Performance"
- 3. "Standards of the Tubular Exchanger Manufacturers Association" (TEMA), Seventh Edition, 1988.



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6.0 CALCULATIONS

The current calculation model is based on a Service Water inlet temperature of 100°F. At this temperature and with a fouling factor of 0.002732 hr*ft²*°F/BTU, the amount of heat transferred is 7,801,000 BTU/hr compared with a LaSalle Station design heat load of 7,800,000 BTU/hr at 100% rated power output resulting in a 0.01% thermal margin (Ref. 1, Table 6-3). The cooler appears to have little thermal margin.

Thermal margin is calculated by the following method:

Required Heat Load - Calculated Heat Transfer = Thermal Margin

[Equation 1]

To express this as a percent of the required heat load, the following method is used:

 $\frac{ThermalM \text{ arg in}}{\text{Re quiredHeatLoad}} \times 100\% = \%ThermalM \text{ arg in}$

[Equation 2]

Case 1

When the service water inlet temperature is increased to 104°F for the same fouling factor (0.002732 hr*ft²*°F/BTU), the heat transfer reduces to 7,474,000 BTU/hr, which is 4.2% below the required load of 7,800,000 BTU/hr for 100% power operating conditions [Attachment A].

Case 2

Regular cleaning and testing of these heat exchangers limits the amount of fouling well below the values assumed above. The heat exchanger performance data taken under the G.L. 89-13 program here at LaSalle demonstrates a maximum measured fouling factor of 0.001117 hr*ft²*oF/BTU (Ref. 2). For conservatism, this value was doubled to 0.00223 hr*ft²*oF/BTU and simulated with 104°F service water inlet temperature. The result was a heat transfer of 8,237,000 BTU/hr for a 5.6% thermal margin at 100% power operating conditions [Attachment B].



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Case 3

When additional conservatism was included by adding a plugging allowance of 4 tubes, 1% of the total, in the heat exchanger and running the model again at the above fouling factor (0.00223 hr*ft²*°F/BTU) and inlet temperature (104°F) for a 8,189,000 BTU/hr heat transfer rate, representing a 5% thermal margin at 100% power operating conditions [Attachment C].

This is judged to be a reasonably conservative fouling factor since it is slightly higher than the typical fouling factors stated in Ref. 3, page 215. The LaSalle lake water quality will meet or exceed the "River Water Fouling Factor" (at a velocity greater than 3 ft/sec) given in this reference. The lake water passes through strainers and is chemically treated for silt control and scale prevention.

7.0 SUMMARY AND CONCLUSIONS

The Diesel Generator Water Cooler Model was found to have adequate thermal margin for a maximum lake temperature of 104°F when operated at 100% rated power output with a fouling factor of less than or equal to 0.00223 hr*ft²*°F/BTU and a plugging allowance of 1% (4 tubes). This fouling factor has been determined to be an acceptable benchmark value that can be used in Generic Letter 89-13 testing evaluations of this model heat exchanger.

8.0 ATTACHMENTS:

Attachment "A" – Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ Design Fouling)

Attachment "B" – Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ 2X Max. Tested FF)

Attachment "C" – Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ 2X Max. Tested FF, w\ 1% plugged)

Final Page (Last Page)



CALCULATION NO. 97-197 REVISION NO. A00 PAGE NO. A1 of A3

Attachment "A"

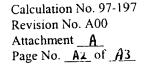
Proto-Hx Calc. Report for DG01B (CSCS=104 F @ Design Fouling)

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS = 104 F @ Design Fouling



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor		0.00050	0.00193
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B			8,505,000
Design Heat Trans Coef	•	°F)	241.70
Emprical Factor for Outs			0.633693000
Performance Factor (% I	Reduction)		0.00
Heat Exchanger Type			ТЕМА-Е
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Un	.;+		1
Shell Minimum Area	ш		1 0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
			1.101160101
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			420
Tube Length (ft)	`		7.00
Tube Inside Diameter (in	•		0.541
Tube Outside Diameter (•	25	0.625
Tube Wall Conductivity	(D 1 O/III-11 F	')	58.00
Ds, Shell Inside Diameter	r (in)		0.000
Lbc, Central Baffle Space	ng (in)		0.000
Lbi, Inlet Baffle Spacing	(in)		19.688
Lbo, Outlet Baffle Spacin	ıg (in)		19.688
Dotl, Tube circle diamete	r (in)		0.000
Bh, Baffle cut height (in)			0.000
Lsb, Diametral difference		7 /	0.000
Ltb, Diametral difference		e and Baffle (in)	0.000
Nss, Number Sealing Stri	ps		0.000



Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

129,2

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS = 104 F @ Design Fouling

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data			Extrapolation Data		
Data Date Shell Flow (gpm)			Tube Flow (gpm) Shell Flow (gpm)	646.1 1,064.5	
Shell Temp In (°F)			Tube Inlet Temp (°F)	104.0	
Shell Temp Out (°F)			Shell Inlet Temp (°F)	190,0	
Tube Flow (gpm)			• , ,	150.0	
Tube Temp In (°F)					
Tube Temp Out (°F)					
		Fouling Calculat	tion Results		
Shall Mass Flow (lbm/br)			IIO II (DOWN II CO		
Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)			U Overall (BTU/hr-ft²-c		
I doe Mass 1 low (lolletti)			Shell-Side ho (BTU/hr		
Heat Transferred (BTU/hr	`		Tube-Side hi (BTU/hr·ft²-°F)		
LMTD	,		1/Wall Resis (BTU/hr·ft²-°F) LMTD Correction Factor		
Effective Area (ft²)			LIMI D Correction Fact	or	
` ,			Overall Fouling (hr-ft2.0	PF/BTU)	
Property	Shell-Side	Tube-Side			
Velocity (ft/s)			Shell Temp In (°F)	Calculation No. 07 107	
Reynold's Number		Shell Temp Out (°F)	Calculation No. 97-197 Revision No. A00		
Prandtl Number		Tav Shell (°F)	Attachment A		
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Page No. A3 of A3	
Skin Visc (lbm/ft·hr)	Skin Visc (lbm/ft·hr)			. 45 110. <u>N3</u> 01 <u>#3</u>	
Density (lbm/ft³)			Tube Temp In (°F) Tube Temp Out (°F)		
C (DOTTINE OF)			• • •		

	E	xtrapolation Calc	ulation Results	
Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)		5.325E+5 3.232E+5	Overall Fouling (hr·ft².°F/BTU) Shell-Side ho (BTU/hr·ft².°F) Tube-Side hi (BTU/hr·ft².°F)	0.002732 1,894.1 1,372.6
Heat Transferred (BTU/h	r)	7.474E+6	1/Wall Resis (BTU/hr ft²:°F)	15,431.0
LMTD		67.3	LMTD Correction Factor	0.9880
Effective Area (ft²)		468.2		213 000
Property	Shell-Side	Tube-Side	U Overall (BTU/hr·ft².°F)	240.0
Velocity (ft/s)	5.58	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.746E+04	3.095E+04	Shell Temp Out (°F)	176.0
Prandtl Number	2.12	3.81	Tav Shell (°F)	183.0
Bulk Visc (lbm/ft·hr)	0.82	1.41	Shell Skin Temp (°F)	174.5
Skin Visc (lbm/ft·hr)	0.87	1.24	Tube Temp In (°F)	104.0
Density (Ibm/ft³)	60.51	61.78	Tube Temp Out (°F)	127.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	115.6
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	129.2

Tav Tube (°F)

Tube Skin Temp (°F)

Tube Skin Temp (°F)

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



REVISION NO. A00

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Attachment "B"

Proto-Hx Calc. Report for DG01B (CSCS=104 F @ 2X Max. Tested FF)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS = 104 F @ 2X NDIT FF

Shell and Tube Heat Exchanger Input Parameters

Shell-Side	Tube-Side
Fluid Quantity, Total gpm 1,064.46	795.25
Inlet Temperature °F 190.00	100.00
Outlet Temperature °F 175.00	121.00
Fouling Factor \star 0.00050	0.00193
Shell Fluid Name	Fresh Water
Tube Fluid Name	Fresh Water
Design Heat Transfer (BTU/hr)	8,505,000
Design Heat Trans Coeff (BTU/hr·ft²-°F)	241.70
Emprical Factor for Outside h	0.633693000
Performance Factor (% Reduction)	0.00
Heat Exchanger Type	ТЕМА-Е
Effective Area (ft^2)	468.17
Area Factor	0.973212339
Area Ratio	0.3 (0.2.2.3.5)
Number of Shells per Unit	1
Shell Minimum Area	0.439000000
Shell Velocity (ft/s)	0.438000000
Tube Pitch (in)	5.600 0.7500
Tube Pitch Type	
Tube Then Type	Triangular
Number of Tube Passes	2
U-Tubes	No
Total Number of Tubes	420
Number of Active Tubes	420
Tube Length (ft)	7.00
Tube Inside Diameter (in)	0.541
Tube Outside Diameter (in)	0.625
Tube Wall Conductivity (BTU/hr·ft·°F)	58.00
Ds, Shell Inside Diameter (in)	0.000
Lbc, Central Baffle Spacing (in)	0.000
Lbi, Inlet Baffle Spacing (in)	19.688
Lbo, Outlet Baffle Spacing (in)	19.688
Dotl, Tube circle diameter (in)	0.000
Bh, Baffle cut height (in)	0.000
Lsb, Diametral difference between Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Calculation No. 97-197
Revision No. A00
Attachment B
Page No. B2 of B3

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS = 104 F @ 2X NDIT FF

Calculation Specifications

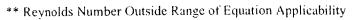
Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

★ Fouling Was Input by User

Test Data	Extrapolation Data	
Data Date	Tube Flow (gpm) 6	646.1
Shell Flow (gpm)	Shell Flow (gpm) 1,0	064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	04.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	90.0
Tube Flow (gpm)	-	
Tube Temp In (°F)		
Tube Temp Out (°F)	✓ Input Fouling Factor 0.002	2230
Fouling Calc	culation Results	
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)	
Tube Mass Tion (10112111)	Tube-Side hi (BTU/hr·ft².°F)	
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		
Eliconi vo i mod (1-)	Overall Fouling (hr-ft ² .°F/BTU)	
Property Shell-Side Tube-Side	9 ` ,	
Velocity (ft/s)	Shell Temp In (°F) Colorlation No. 97	107
Reynold's Number	Shell Temp Out (°F) Calculation No. 97 Revision No. A00	-17/
Prandtl Number	Tav Shell (°F) Attachment \(\beta \)	
Bulk Visc (lbm/ft·hr)	Shell Skin Temp (°F) Page No. 63 of	ΩZ
Skin Visc (lbm/ft·hr)	Tube Temp In (°F)	<u>0</u>
Density (lbm/ft³)	Tube Temp Out (°F)	
Cp (BTU/lbm·°F)	Tav Tube (°F)	
K (BTU/hr·ft·°F)	Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft ^{2.} °F/BTU)	0.002230
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr-ft².°F)	1,889.3
			Tube-Side hi (BTU/hr-ft2-°F)	1,383.0
Heat Transferred (BTU/hr)		8.237E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		65.4	LMTD Correction Factor	0.9845
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft ² .°F)	273.3
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.709E+04	3.130E+04	Shell Temp Out (°F)	174.6
Prandtl Number	2.13	3.76	Tav Shell (°F)	182.3
Bulk Visc (lbm/ft/hr)	0.82	1.39	Shell Skin Temp (°F)	172.8
Skin Visc (lbm/ft·hr)	0.88	1.21	Tube Temp In (°F)	104.0
Density (lbm/ft3)	60.52	61.76	Tube Temp Out (°F)	129.5
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	116.8
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Temp (°F)	131.7



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev



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Attachment "C"

Proto-Hx Calc. Report for DG01B (CSCS=104 F @ 2X Max. Tested FF, w\ 1% plugged)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx. CSCS=104 F@ 2X NDIT FF, 1% plug



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor	*	0.00050	0.00193
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (BT	U/hr)		8,505,000
Design Heat Trans Coeff	(BTU/hr·ft²·	°F)	241.70
Emprical Factor for Outsi	de h		0.633693000
Performance Factor (% Re	eduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Uni	t		1
Shell Minimum Area			0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			416
Tube Length (ft)			7.00
Tube Inside Diameter (in)			0.541
Tube Outside Diameter (ir			0.625
Tube Wall Conductivity (1	BTU/hr·ft·°F)	58.00
Ds, Shell Inside Diameter	(in)		0.000
Lbc, Central Baffle Spacir	ıg (in)		0.000
Lbi, Inlet Baffle Spacing (in)		19.688
Lbo, Outlet Baffle Spacing			19.688
Dotl, Tube circle diameter			0.000
Bh, Baffle cut height (in)			0.000
Lsb, Diametral difference	between Baf	fle and Shell (in)	0.000
Ltb, Diametral difference l	oetween Tub	e and Baffle (in)	0.000
Nss, Number Sealing Strip	s		0.000

Calculation No. 97-197 Revision No. A00 Attachment <u>C</u> Page No. <u>C2</u> of <u>C3</u>

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=104 F@ 2X NDIT FF, 1% plug

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

⋆ Fouling Was Input by User

Test Data	Extrapolation	Data		
Data Date	Tube Flow (gpm)	646.1		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	104.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)		0.002230		
F	ouling Calculation Results			
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft²-°F)			
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)			
,	Tube-Side hi (BTU/hr·ft².°F)			
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.o} F)	1/Wall Resis (BTU/hr·ft²-°F)		
LMTD	LMTD Correction Factor			

Effective Area (ft²)			Overall Fouling (hr·ft²-°F/BTU)		
Property	Shell-Side	Tube-Side	o rotum rouning (in it		
Velocity (ft/s)			Shell Temp In (°F)	Calculation No. 97-197	
Reynold's Number			Shell Temp Out (°F)	Revision No. A00	
Prandtl Number			Tav Shell (°F)	Attachment C	
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)	Page No. C3 of C3	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)		
Density (lbm/ft³)			Tube Temp Out (°F)		
Cp (BTU/lbm·°F)			Tav Tube (°F)		
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)		

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.} °F/BTU)	0.002230
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft²-°F)	1,889.4
•			Tube-Side hi (BTU/hr·ft²-°F)	1,393.0
Heat Transferred (BTU/hr))	8.189E+6	1/Wall Resis (BTU/hr-ft2.°F)	15,431.0
LMTD		65.5	LMTD Correction Factor	0.9848
Effective Area (ft²)		463.7		
` ,		• •	U Overall (BTU/hr·ft².°F)	273.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	4.38	Shell Temp In (°F)	190.0
Reynold's Number	7.712E+04	3.158E+04	Shell Temp Out (°F)	174.7
Prandtl Number	2.13	3.76	Tav Shell (°F)	182.3
Bulk Visc (lbm/ft·hr)	0.82	1.39	Shell Skin Temp (°F)	172.8
Skin Visc (lbm/ft/hr)	0.88	1.21	Tube Temp In (°F)	104.0
Density (lbm/ft³)	60.52	61.76	Tube Temp Out (°F)	129.4
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	116.7
K (BTU/hr-ft-°F)	0.39	0.37	Tube Skin Temp (°F)	131.6

^{**} Reynolds Number Outside Range of Equation Applicability

^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achiev

PROTO-POWER CORPORATION CALCULATION TITLE SHEET

CLIENT:

Commonwealth Edison / LaSalle County Station

PROJECT:

COMED / LaSalle Station GL 89-13 Program

CALCULATION TITLE:

Thermal Model of COMED / LaSalle Station HPCS Diesel Generator

Jacket Water Coolers.

CALCULATION NO.:

97-197

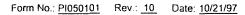
FILE NO.:

31-003

COMPUTER CODE & VERSION (if applicable): PROTO-HX™ ver 3.02

		<u> </u>		
REV	TOTAL NO. OF PAGES	ORIGINATOR/DATE	VERIFIER/DATE	APPROVAL/DATE
A	58	DWD GALGE D. Physe	S. Ingalls	TESSIFING 6/30/98
1				

Page I of V



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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/26/98
	VERIFIED BY S. Ingalls		^{JOB NO.} 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
TITLE Thermal Model of COMED / LaSalle Station HPCS Diesel Generator Jacket Water Coolers.			

Revision History

Revision	Revision Description
A	Original Issue



Form No.: P1050102 Rev.: 10 Date: 10/21/97

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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/26/98	
	VERIFIED BY S. Ingalls		^{JOB NO.} 31-003	
CLIENT COMED / LaSalle County Station PROJECT COMED / LaSalle Station GL 89-13 Program				
THE Thermal Model of COMED / LaSalle	Station HPCS Diesel Gene	erator Jacket W	ater Coolers.	

CALCULATION VERIFICATION FORM

REVIEW METHOD: Approach Checked: Logic Checked: Arithmetic Checked: Alternate Method (Attach Brief Summary) Computer Program Used (Attach Listing) Other		N/A	EXTENT OF VERIFICATION: Complete Calculation: Revised areas only: Other (describe below):	
*Errors Detected			*Error Resolution	
Editorial Comments		·····	Sections Revised as Necessary	
References Need to be updated	- Density	Reference Added	References updated/Added	
Postotix Density effects real	to be acc	aunted for	Section Added to discuss p and PROTOHIX Runs re-n	
*Other Comments None				
*Extra References Used				
*(Attach extra sheets if needed)				
CALCULATION FOUND TO BE	VALID A	ND CONCLUSIO	ONS TO BE CORRECT AND REASONABLE:	
IDV Signature: Suff M. Jugall Initials: Jugally				
Printed Name:	5	cott M. Ing	Date: 6/26/98	



PROTO-POWER CORPORATION	CALC NO. 97-197	REV A	PAGE IV OF V
GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/26/98
	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
Thermal Model of COMED / LaSalle Station HPCS Diesel Generator Jacket Water Coolers.			

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CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
Thermal Model of COMED / LaSalle Station HPCS Diesel Generator Jacket Water Coolers.			

LIST OF ATTACHMENTS

<u>Attachment</u>	Subject Matter	Total Pages
A	Proto-Power Calc. 97-197, Rev. A; Vendor Data Sheet & Drawings	4
В	Proto-Power Calc. 97-197, Rev. A; LaSalle Station UFSAR Section: 9.5.5.1.1, and FSAR Q40.92	5
С	Proto-Power Calc. 97-197, Rev. A; PROTO-HX™ HPCS Model Development Calculation Reports	13
D	Proto-Power Calc. 97-197, Rev. A; PROTO-HX™ Calculation Reports for Fouling Sensitivity	7
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न	Proto-Power Calc. 97-197, Rev. A; PROTO-HX [™] Version 3.02 Model	2 (and disk)

Number of Attachment Pages: 41

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	VERIFIED BY S. Ingalls		JOB NO. 31-003	
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program			
Thermal Model of COMED / LaSalle Station 1B(2B) Diesel Generator Jacket Water Coolers.				

1.0 PURPOSE

The purpose of this calculation is to develop a thermal performance analysis model for the Commonwealth Edison (ComEd) LaSalle Station, High Pressure Core Spray (HPCS) Diesel Generator heat exchanger. This model is to be used for the analysis of heat exchanger thermal performance test data as part of the LaSalle Station heat exchanger testing program.

Once developed, the model is used to evaluate the thermal margin of the heat exchanger at the LaSalle Station Reference Conditions as currently defined in the LaSalle design and licensing basis.

The thermal performance model documented in this calculation has been created and used with PROTO-HX, Version 3.02. The model can be used with previous versions of PROTO-HX and produce identical results as long as the following restrictions are upheld:

- Versions prior to version 3.02 will not calculate a negative fouling factor when calculating the fouling factor based on test data.
- Shell and tube heat exchangers analyzed in Version 3.0 or earlier must have a tube-side Reynolds Number greater than 10,000 (i.e., fully developed turbulent flow).

Current limitations of use for PROTO-HX are established by the limits on fluid properties included within the software. Fluid properties contained within PROTO-HX are currently limited to the following temperature ranges:

• Water (fresh and salt): 32-500°F

2.0 BACKGROUND

LaSalle Station is in the process of implementing a heat exchanger thermal performance monitoring program in response to the requirements of NRC Generic Letter 89-13 (Reference 8.2). Development of an analytical model in PROTO-HXTM, Version 3.02, will allow timely analysis of data resulting from the test program.

3.0 DESIGN INPUTS

The PROTO-HXTM program was developed and validated in accordance with Proto-Power's Nuclear Software Quality Assurance Program (SQAP). This program meets the requirements of 10CFR50 Appendix B, 10CFR21, and ANSI NQA-1, and was developed in accordance with the guidelines and standards contained in ANSI/IEEE Standard 730/1984 and ANSI NQA-2b-1991. PROTO-HXTM Version 3.02 was verified and approved for use as documented in Reference 8.10.

The design inputs for this calculation consist of the LaSalle Station Reference Condition (Section 3.1), Construction Details (Section 3.2), and Performance Details (Section 3.3) provided by the heat exchanger vendor data sheets or design documents as referenced. Construction details give

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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/26/98	
	VERIFIED BY S. Ingalls		JOB NO. 31-003	
CLIENT COMED / LaSalle County Station	IENT COMED / LaSalle County Station PROJECT COMED / LaSalle Station GL 89-13 Program			
Thermal Model of COMED / LaSalle Station 1B(2B) Diesel Generator Jacket Water Coolers.				

the necessary information for model construction while performance specifications provided by the vendor are used to benchmark the model.

Thermal performance of the HPCS diesel generator heat exchanger is assessed in this calculation at the LaSalle Station Reference Conditions of Section 3.1 with all tubes active and 100% of rated load. No tube plugging margin or load conditions beyond 100% are considered.

3.1. LASALLE STATION REFERENCE CONDITIONS

Table 3-1 describes the performance requirement of the jacket water cooler. These conditions ensure that the engine operating temperature range will not be exceeded.

Table 3-1 LaSalle Station Reference Conditions

Parameter	Value	Reference
Heat Load at,100% power (BTU/hr)	7,800,000	8.1, 8.4
Shell-Side Flow Rate (gpm)	1,100	8.4
Shell-Side Inlet Temperature (°F)	190	8.4
Tube-Side Flow Rate (gpm)	650	8.1
Maximum Tube-Side Inlet Temperature (°F)	100	8.1

3.2. CONSTRUCTION DETAILS

Table 3-2 Vendor Construction Detail

Parameter	Value	Reference
Heat Exchanger Type	TEMA - E	8.7, 8.8
Number of Shells per unit	ı	8.7
Total Effective Area per unit (ft²)	482	8.6, See Below
Shell Velocity (ft/sec)	5.6	8.6
Baffle Thickness (in)	3/8 (min)	8.8
Fixed Tubesheet Thickness (in)	1	8.8
Floating Tubesheet Thickness (in)	1-1/4	8.8
Tube Passes per shell	2	8.7
U-Tubes (yes or no)	No	8.7
Total Number of Tubes	420	8.6, 8.8
Tube Length (ft)	7	8.6
Tube Inside Diameter (in)	0.541 (19 BWG)	8.6
Tube Outside Diameter (in)	5/8	8.6

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Table 3-2 Vendor Construction Detail

Parameter	Value	Reference
Tube Wall Conductivity (BTU/hr-ft-°F)	58 (Admiralty Naval Brass)	8.6, 8.9
Tube Pitch (in)	3/4	8.6
Pitch Type	Triangle	8.8

The vendor data sheet shows the effective area as 482 ft^2 , however, based on the outside tube diameter and tube length, this value is a gross area (A_{gr}) approximation:

$$A_{gr} = (number of tubes) \cdot (L_{tube}) \cdot (tube outside circ.)$$
 Equation 1

$$A_{gr} = 420 \cdot 7 \text{ ft} \cdot \pi \cdot \left(\frac{0.625 \text{ in}}{12 \text{ in/ft}}\right) = 481.056 \text{ ft}^2$$

The effective area (Aeff) can be approximated as follows:

$$A_{eff} = (\text{number of tubes}) \cdot (L_{\text{tube}} - T_{\text{fixed}} - T_{\text{floating}}) \cdot (\text{tube outside circ.})$$
 Equation 2

$$A_{eff} = 420 \cdot \left(7 \text{ ft} - \frac{(1.\text{in} + 1.25 \text{ in})}{12^{\frac{\text{in}}{12}}} \right) \cdot \pi \cdot \left(\frac{0.625 \text{ in}}{12^{\frac{\text{in}}{12}}} \right) = 468.171 \text{ ft}^2$$

where:

Agr - Heat Exchanger Gross Area, ft²

A_{eff} - Heat Exchanger Effective Area, ft²

L_{tube} - Tube Length, ft

T_{fixed} - Fixed End Tubesheet Thickness, ft (1" per Reference 8.8)

T_{floating} - Floating End Tubesheet Thickness, ft (1.25" per Reference 8.8)

The data sheet value for the effective area will be used in the model benchmarking process. However, for PROTO-HXTM runs of the HPCS heat exchanger model the above calculated effective area will be used.

3.3. PERFORMANCE DETAILS

Table 3-3 Vendor Performance Detail

Parameter	Value	Reference
Shell Side Fluid Type	Water (Fresh)	8.6
Shell Side Fouling Factor (Design)	0.0005	8.6
Shell Side Fluid Flow Rate (gpm)	1100	8.6

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Table 3-3 Vendor Performance Detail

Parameter	Value	Reference
Shell Side Inlet Temperature (°F)	190	8.6
Shell Side Outlet Temperature (°F)	175	8.6
Tube Side Fluid Type	Raw Water (Fresh)	8.6
Tube Side Fouling Factor (Design)	0.002	8.6
Tube Side Fluid Flow Rate (gpm)	800	8.6
Tube Side Inlet Temperature (°F)	100	8.6
Tube Side Outlet Temperature (°F)	121	8.6
Hx. Design Q - Service (BTU/hr)	8,505,000	8.6
Hx. Design U – Service (BTU/hr-ft²-°F)	241.7	8.6
Corrected LMTD	73	8.6

4.0 APPROACH

This calculation utilizes plant/vendor fabrication specifications provided in Attachment A to develop a thermal performance prediction model for the LaSalle Station HPCS Diesel Generator Jacket Water Coolers. The calculation then benchmarks the model by comparing the heat transfer rate calculated by PROTO-HXTM Version 3.02 with the vendor's specifications for thermal performance.

4.1. PROTO-HXTM PARAMETER CALCULATION

Minimum Shell Area

The minimum shell area is calculated using either the shell side velocity or a shell geometry. The preferred method of calculation is using the shell side velocity. Reference 8.6 gives the shell side velocity to be 5.6 ft/sec at a flow of 1100 gpm. Based on this velocity and flow rate the minimum shell side area is calculated by PROTO-HXTM to be 0.438 ft².

Outside H Factor (Hoff)

The Outside H Factor is a multiplier, with value less then 1.0, used to reduce the ideal shell-side film heat transfer coefficient. The Outside H Factor accounts for inefficiency in the heat exchanger. Using the back calculation method based on the design overall heat transfer coefficient, the Outside H Factor was calculated by PROTO-HXTM to be 0.616913. Values of the Outside H Factor in the range of 0.6 are considered to be representative of a "well designed" heat exchanger.

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4.2. PROTO-HXTM FLOW RATE INPUTS

When the volumetric flow rates are entered into PROTO-HXTM they are converted to mass flow rates based on a set temperature of 60°F. Therefore, the actual PROTO-HXTM inputs have to be adjusted to give the correct mass flow rate. The PROTO-HXTM input is adjusted using the ratio of the actual water density and the density of water at 60°F.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60^{\circ}F}}$$

Equation 3

Table 4-1 PROTO-HX™ Flow Rate Inputs

Parameter	Density (l	b/ft³)	Actual Flow (gpm)	PROTO-HX™ Input (gpm)
Tube-side, 100°F	61.994	(8.11)	800	795.25
	61.994	(8.11)	650	646.14
Shell-side, 190°F	60.349	(8.11)	1,100	1,064.495
PROTO-HX™, 60°F	62.364	(8.11)		

4.3. PROTO-HXTM EXTRAPOLATION METHOD

All calculations performed for this calculation are based on a constant cold inlet temperature. This allows the comparison of the heat transfer, outlet temperatures, log mean temperature difference (LMTD), and overall heat transfer coefficient. There is no comparison of the overall heat transfer coefficient in the design case since PROTO-HXTM used the data sheet value of the overall heat transfer coefficient to calculate the outside film heat transfer coefficient.

5.0 ASSUMPTIONS

5.1. The vendor data sheet (Reference 8.6) is considered to be an accurate reflection of the vendor's expectation for the heat exchanger's outside film heat transfer coefficient. Therefore, the benchmarking of the PROTO-HXTM model to the vendor data sheet will ensure that the PROTO-HXTM calculated outside film heat transfer coefficient is consistent with the vendor's expectation. The PROTO-HXTM model is benchmarked with the vendor data sheet effective area. However calculations performed with the model use the effective area determined in Section 3.2. Future validation of this assumption is not required.



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6.0 ANALYSIS

6.1. PROTO-HXTM MODEL

Table 6-1 shows the PROTO-HXTM benchmarking of the Jacket Water Cooler for the HPCS Diesel Generator. The PROTO-HXTM reports can be found in Attachment C.

Table 6-1 Model Benchmark Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft ²	482	482	0.00 %
Shell Side Outlet Temp, °F	174.5	175	-0.29 %
Tube Side Outlet Temp, °F	120.8	121	-0.17 %
Heat Transferred, BTU/hr	8,277,000	8,505,000	-2.68 %
Corrected LMTD	71.0	73	-2.74 %

Table 6-2 shows the PROTO-HXTM results for the heat exchanger design conditions using the corrected effective area, Section 3.2. The PROTO-HXTM reports can be found in Attachment C.

Table 6-2 Model Design Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft ²	468.17	482	-2.87 %
Shell Side Outlet Temp, °F	174.8	175	0.11 %
Tube Side Outlet Temp, °F	120.4	121	-0.50 %
Heat Transferred, BTU/hr	8,089,000	8,505,000	-4.89 %
Corrected LMTD	71.5	73	-2.05 %

All PROTO-HXTM calculations performed with the HPCS Jacket Water Cooler model will use the effective area of 468.17 ft². This change is made to the PROTO-HXTM heat exchanger data sheet as shown in Attachment C.

6.2. HEAT EXCHANGER FOULING FACTOR LIMIT

In order for the jacket water cooler to meet the Reference Conditions (Table 3-1) the fouling must be limited from the values listed on the vendor's data sheet (Reference 8.6). The overall fouling factor limit was determined by iterating on the overall fouling factor, a PROTO-HXTM input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HXTM runs for the limited fouling factor case, see Attachment C.



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Table 6-3 Fouling Factor Limit

Parameter	Design Fouling	Limited Fouling
Tube-side Fouling Factor	0.002	0.001932
Shell-side Fouling Factor	0.0005	0.0005
Total Fouling Factor	0.002811	0.002732
Overall Heat Transfer Coefficient	234.7	239.2
Heat Transfer Rate	7,718,000	7,801,000
Required Heat Transfer Rate	7,800,000	7,800,000
Thermal Margin	-82,000	1,000
% Thermal Margin	-1.05 %	0.01 %

The limitations on the fouling factor are placed on the tube-side fouling factor, since the tube-side is the most controllable via periodic tube-side cleaning. The tube-side fouling factor is calculated from the overall fouling found from the PROTO-HXTM iteration process. The area ratio is used to convert the overall fouling factor to a tube-side and shell-side fouling factor

$$f_{total} = f_{shell} + (Area Ratio) \cdot f_{tube}$$
 Equation 4

$$Area Ratio = \frac{Tube OD}{Tube ID}$$
 Equation 5

Area Ratio =
$$\frac{0.625 \, \text{in}}{0.541 \, \text{in}} = 1.15527$$

From the vendor datasheet the design overall fouling factor is calculated

$$f_{shell} = 0.0005^{\text{hr ft}^2 \text{ °F}} /_{\text{Btu}} \quad \text{and} \quad f_{tube} = 0.002^{\text{hr ft}^2 \text{ °F}} /_{\text{Btu}}$$

$$f_{total} = 0.0005^{\text{hr ft}^2 \text{ °F}} /_{\text{Btu}} + 1.15527 \cdot 0.002^{\text{hr ft}^2 \text{ °F}} /_{\text{Btu}} = 0.002811^{\text{hr ft}^2 \text{ °F}} /_{\text{Btu}}$$

From the PROTO - HX iteration the adjusted overall fouling factor is found:

$$f_{adjusted} = 0.002732 \, {}^{hr \, ft}^2 \, {}^oF / _{Btu}$$



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From the new overall fouling factor the new tube - side fouling factor is calculated:

$$f_{\text{tube}} = \frac{\left(f_{\text{adjusted}} - f_{\text{shell}}\right)}{\text{Area Ratio}} = \frac{\left(0.002732 - 0.0005\right)^{\text{hr ft}^2 \circ \text{F}}}{1.15527} = 0.001932^{\text{hr ft}^2 \circ \text{F}}$$

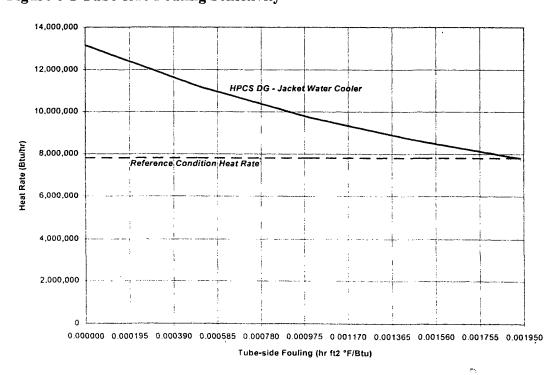
The PROTO-HX[™] heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

Attachment C includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HXTM data sheet.

6.3. FOULING SENSITIVITY

The fouling sensitivity of the jacket water cooler is shown in Figure 6-1. The fouling sensitivity was developed at 650 gpm CSCS flow, 100°F CSCS inlet temperature, 1100 gpm jacket water flow, and 190°F jacket water inlet temperature. The tube-side fouling factor was varied from 0.0000 to 0.001932 (hr ft² °F/Btu) by increments of 0.0005 (hr ft² °F/Btu). The shell-side fouling factor is held constant at the design value of 0.0005 (hr ft² °F/Btu). The PROTO-HXTM Calculation Reports for the fouling sensitivity can be found in Attachment D

Figure 6-1 Tube-side Fouling Sensitivity



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6.4. THERMAL MARGIN ASSESSMENT

The clean thermal margin is assessed by a comparison of the reference condition performance requirement (Table 3-1) to the heat exchanger performance capability with a zero (0) fouling factor. Using a zero (0) fouling factor shows the maximum available performance of the heat exchanger. Likewise the service thermal margin is assessed by comparing the reference condition performance requirement (Table 3-1) to the heat exchanger performance capability with the design fouling factor.

The margin is calculated directly and as a percentage compared to the required heat rate to perform the component's safety function. The PROTO-HXTM reports can be found in Attachment C.

 $margin = Heat Rate - Heat Rate_{required}$

Equation 6

$$\% \text{ margin} = 100 \cdot \left(\frac{\text{margin}}{\text{Heat Rate}_{\text{required}}} \right)$$

Equation 7

Table 6-4 Thermal Margin

Parameter	Service (Design Fouling)	Clean (0 Fouling)
Overall Heat Transfer Coefficient	239.2	713.2
Heat Transfer Rate	7,801,000	15,420,000
Required Heat Transfer Rate	7,800,000	7,800,000
Thermal Margin	1,000	7,620,000
% Thermal Margin	0.01 %	97.69 %

6.5. MINIMUM SERVICE WATER FLOW RATE

The minimum service water flow rate for the adjusted design fouling condition is calculated with the shell-side inlet temperature at 190°F and a flow rate of 1,100 gpm. Iterating using the service water flow rate and inlet temperature, the minimum acceptable flow rate is found for each inlet temperature (Attachment E). The heat load for each iteration must be equal to or slightly above the required heat load of 7,800,000 BTU/hr, the diesel heat load at 100% power (reference 8.1).

The results of the model iterations are summarized in Table 6-5 and Figure 6-2. Density corrections of the PROTO-HXTM flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.11.

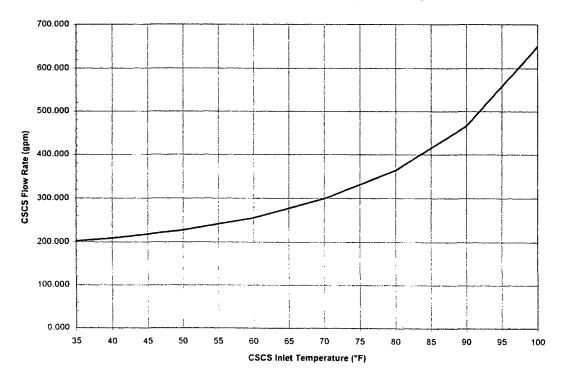


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Table 6-5 Minimum Required CSCS Flow Rate

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HXTM Input Flow Rate (gpm)	Density Corrected Flow Rate (gpm)
35	62.41903	202.4	202.2
40	62.42184	209.1	208.9
50	62.40595	227.4	227.2
60	62.36445	255.0	255.0
70	62.30034	298.7	299.0
80	62.21603	362.9	363.8
90	62.11349	464.2	466.1
100	61.99437	646.1	650.0

Figure 6-2 Minimum CSCS Flow at Adjusted Design Fouling



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7.0 CONCLUSION

7.1. PROTO-HXTM MODEL

The HPCS Jacket Water Cooler model was developed using PROTO-HXTM, Version 3.02. The model was benchmarked to the vendor data sheet. The benchmark model correlation to the vendor data sheet heat rate is 2.68 %. The benchmark model is for reference only based on the non-conservative approximation of heat exchanger effective area as discussed in Section 3.2 and Assumption 5.1. Calculations performed with the HPCS Jacket Water Cooler model are to use the effective area developed in Section 3.2.

This model should be considered suitable for use in the analysis of thermal performance test data.

The model database is saved under file name dg01b.phx, with a file size of 864 KB, and a file date and time of 6/26/98 at 11:25:36 AM. The saved database is set up to run the Reference Conditions with design fouling factor selected, the design fouling factor is a shell-side fouling of 0.002782. The database file is included as Attachment F.

7.2. HEAT EXCHANGER FOULING FACTOR LIMIT

For the HPCS Diesel Generator Jacket Water Cooler to provide adequate heat removal at the specified LaSalle Station Reference Conditions the overall fouling factor must be equal to or less than 0.002732 hr ft² °F/Btu. This overall fouling factor is broken down into a 0.001932 and 0.0005 hr ft² °F/Btu for the tube-side and shell-side fouling factors respectively and entered in the model as the design fouling factors.

7.3. FOULING SENSITIVITY

Given a constant shell-side fouling at the model design value, the sensitivity of the jacket water cooler to tube-side fouling effects is shown on Figure 6-1.

7.4. THERMAL MARGIN ASSESSMENT

The clean and service available thermal margins are 97.69 % and 0.01 % respectively.

7.5. MINIMUM SERVICE WATER FLOW RATE

As shown in Figure 6-2 the service water flow can be throttled down to account for lower service water inlet temperature conditions. The heat exchanger can remove the design heat load for the diesel at 100% rated power, 7,800,000 BTU/hr, by reducing service water flow rates as the service water temperature decreases.

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8.0 REFERENCES

- 8.1. LaSalle Station UFSAR, Sections: 9.2.1 and 9.5.5.1.1 (Attachment B)
- 8.2. NRC Generic Letter 89-13
- 8.3. GE Purchase Specification 211872RO-SW9 Item 4.3.6.1
- 8.4. LaSalle Station FSAR Q40.92 (Attachment B)
- 8.5. Stewart & Stevens Vendor Manual, VM J-152 through VM J-157
- 8.6. O & M Manufacturing Hx Data Sheet (Attachment A)
- 8.7. LaSalle Station Drawing, VPF 3411-080(1)-1, J-2500 (Attachment A)
- 8.8. LaSalle Station Drawing, VPF 3411-080(2)-1, J-2500 (Attachment A)
- 8.9. Standard of the Tubular Exchanger Manufacturers Association
- 8.10. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HXTM Version 3.02 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision F, dated 2/17/98
- 8.11. Proto-Power Calculation 93-048, "Fluid Properties Fresh Water Range 32°F to 500°F", Rev. A



Attachment A to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

Attachment: A

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REFERENCE 8.6

O & H MANUFACTURING COMPANY Houston, Texas

RECEIVED OCT 11 1974

EXCHANGER SPECIFICATION SHEET

ENCINEERING DEPT.

CUSTOMER	Stewart & Stevenson Services	REFERENCE NO. F-64546-50583
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9/26/74: Copy to Mr. Bill Phillips, Mr. Bob Evans 10/10/74: Original to Mr. W. C. Philipp

Form #103

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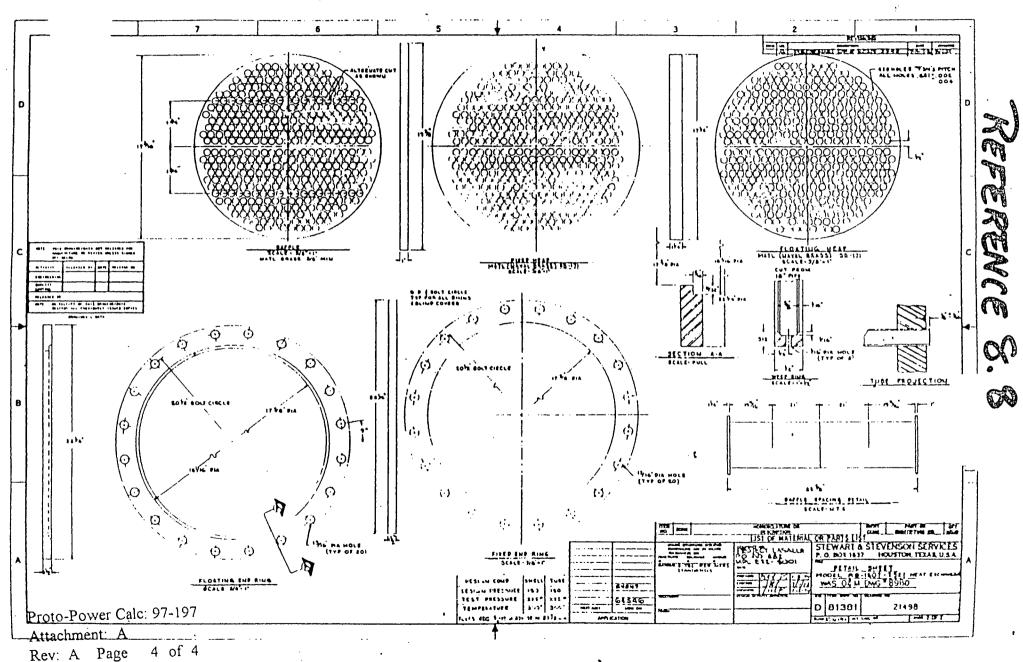
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Attachment B to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

Attachment: B

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Reference 8.1

LSCS-UFSAR

9.2 WATER SYSTEMS

The auxiliary water systems for the LaSalle County Station are as follows:

- a. CSCS equipment cooling water system,
- b. station service water system,
- c. reactor building closed cooling water system,
- d. demineralized water makeup system,
- e. potable and sanitary water system,
- f. ultimate heat sink,
- g. cycled condensate system and refueling water storage facilities,
- h. turbine building closed cooling water system (TBCCWS),
- i. primary containment chilled water system,
- j. station heat recovery system,
- k. suppression pool cleanup system, and
- 1. chemical feed system.

9.2.1 CSCS Equipment Cooling Water System

The function of the core standby cooling system-equipment cooling water system (CSCS-ECWS) is to circulate lake water from the ultimate heat sink for cooling of the residual heat removal (RHR) heat exchangers, diesel-generator coolers, CSCS cubicle area cooling coils, RHR pump seal coolers, and low-pressure core spray (LPCS) pump motor cooling coils. This system also provides a source of emergency makeup water for fuel pool cooling and also provides containment flooding water for post-accident recovery. This CSCS-ECWS system is equivalent in purpose to the essential service water cooling systems at other stations.

9.2.1.1 <u>Design Bases</u>

9.2.1.1.1 Safety Design Bases

- a. The system is sized based on the following minimum equipment cooling water flow requirements:
 - 1. RHR heat exchanger 7400 gpm
 - diesel-generator cooler (division 1 and 2 only) 800 gpm

3. diesel-generator cooler (division 3) - 650 gpm

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Attachment: B

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KEFERENCE 8.1

LSCS-UFSAR

9.5.4.5 Instrumentation and Controls

Fuel levels in each day tank and storage tank are indicated locally, and storage tank levels are also indicated at each storage tank filling station. Control room alarms annunciate high or low levels in each day tank and low level in each storage tank. All day tank level instruments and diesel-generator transfer pump controls are Seismic Category I and Class IE. A local pressure indicator is connected to the discharge of each transfer pump to monitor pump discharge head. A local differential pressure indicator is connected across the transfer pump suction strainer to identify a clogged strainer.

Each diesel engine gauge panel includes local gauges for monitoring the following diesel-generator skid-mounted system fuel oil parameters: fuel oil temperature, fuel pump suction strainer inlet and outlet pressure (Divisions 1 and 2 diesel generators only), fuel pump discharge pressure, fuel filter inlet pressure, and fuel filter outlet pressures (for the Division 3 diesel generators, filter inlet and outlet pressure gauges are mounted on the engine and not on the gauge panel). In addition, pressure switches are installed in the skid-mounted systems to annunciate high fuel filter differential pressure for the Divisions 1 and 2 diesel generators and low fuel pump discharge pressure for the Division 3 diesel generators. The entire skid-mounted fuel oil system, including instrumentation, is supplied by the engine manufacturer as a part of the diesel engine.

Each diesel-generator fuel transfer pump is started and stopped automatically by day tank level control switches. The diesel fire pump fuel transfer pump is started manually; however, it is automatically shut down by day tank high level. Elapsed time instrumentation monitors diesel-generator transfer pump running time and, when the diesel engine is operating, pump shutdown time. This instrumentation actuates control room alarm lights if pump running time is excessive or shutdown time is too short to permit remote detection of possible fuel oil leaks at the day tank or diesel generator.

9.5.5 <u>Diesel-Generator Cooling Water System</u>

The function of the diesel-generator cooling water system is to transfer the heat rejected from the engine water jacket, the lube oil cooler and the engine air aftercooler to the CSCS equipment cooling water system (CSCS-ECWS).

9.5.5.1 <u>Design Bases</u>

9.5.5.1.1 Safety Design Bases



Cooling capacity of this system is based on a diesel-generator output of 2860 kW with an environmental temperature of 122° F maximum and a minimum and maximum lake water temperature of 32° F and 100° F, respectively. Total heat transfer by this system is

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LSCS-UFSAR



approximately 7.8 x 10° Btu/hr per diesel-generator set at rated engine capacity. The diesel cooling water heat exchangers are sized based on operation of 110% of rated load.

High water temperature is alarmed at 200° F and the engine is automatically shut down if the cooling water temperature at the engine outlet exceeds 208° F in order to prevent engine damage due to overheating. This shutdown control is in effect only when the engine is started manually and bypassed when the diesel generator is started automatically during an emergency.

Heaters are installed in the cooling water piping below the lube oil cooler to maintain the engine water and lube oil in a warm standby condition while the engine is not operating; thus increasing the starting reliability of the diesel generator. Natural convection is employed to circulate the warm engine water through the lube oil cooler during standby.

Each system is designed based on Seismic Category I requirements and is protected from tornadoes, missiles, and flooding.

9.5.5.1.2 Power Generation Design Bases

The diesel-generator cooling water system is not required during power generation. Consequently, it possesses no power generation design bases.



Each diesel-generator cooling water system is a separate, independent closed loop system supplied with the diesel generator and located entirely on the diesel-generator skid. It consists of two parallel engine driven centrifugal circulating pumps, a low-pressure expansion tank, an AMOT temperature regulating valve, a lube oil cooler, and the engine cooling water heat exchanger. The expansion tank is fitted with a 7 psig relief cap which also will relieve vacuum. Engine coolant is demineralized water treated with chromate, borate-nitrite, or silicate-nitrite type corrosion inhibitors in accordance with the engine manufacturer's recommendations.

During operation, cooling water at a flow of 1100 gpm per dieselgenerator set is circulated by the engine driven pumps through the diesel engine cooling water passages to the lube oil cooler, through the temperature regulating valve, and then to the engine cooling water heat exchanger. See Figure 9.5-5 for additional details.

The engine cooling water heat exchanger is a two-pass shell and tube type heat exchanger having admiralty tubes with a carbon steel water box and shell. Engine cooling water is circulated through the shell side while strained lake water is pumped through the tube side by the CSCS-ECWS (Subsection 9.2.1). Design pressure and temperature is 150 psig and 300° F for both



REFERENCE 8.4

LSCS-FSAR

AMENDMENT 29 JANUARY 1978

QUESTION 040.92

"In response to Question 040.16 you have provided in section 9.5.5.1.1 a total diesel generator cooling water heat rate of approximately 6.15 million Btu/hr. This heat is rejected in the heat exchanger interfacing with CSCS equipment cooling water system when the diesel generator is operating at rated capacity. Also, in section 9.5.5.2 you mention that the cooling waterflow rate in the diesel engine is 1,100 gpm. It is not clear whether these heat and flow rates are for the total five diesel generators or for a single diesel generator. Please provide the heat and flow rates for each of the five diesel generators. In addition, also provide the design temperature differential((°F) for each diesel engine cooling water when operating at rated capacity."

RESPONSE

The design conditions for each diesel-generator cooling water system are:

Shell si	de flow	1100 gpm
Design s temperat	hell side inlet ure	190° F
Shell si temperat	de outlet ure	175° F
Tube sid	le design flow	800 gpm
Tube sid temperat		100° F
Tube sid	de outlet cure	122° F
Heat exc heat rem	changer design noval	8.6 x 10 ⁶ btu/hr
	generator set requirement	7.8 x 10 ⁶ btu/hr

(The value of 6.15 x 10^6 btu/hr heat removal specified in Subsection 9.5.5.1.1 has been corrected to read 7.8 x 10^6 btu/hr in accordance with the above data).

040.92 - 1

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Attachment C to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

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Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Vendor Data - BENCHMARK

Shell and Tube Heat Exchanger Input Parameters

		anger Input Lar		
		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	1,064.46	795.25	
Inlet Temperature	°F	190.00	100.00	VENDOR
Outlet Temperature	°F	175.00	121.00 _	- MA SHELL
Fouling Factor		0.00050	0.00200	VALUES
Shell Fluid Name			Fresh Water	
Tube Fluid Name			Fresh Water	
Design Heat Transfer (BT	U/hr)		8,505,000	
Design Heat Trans Coeff (BTU/hr·ft	² .°F)	241.70	
Emprical Factor for Outsid	ie h		0.633693000	
Performance Factor (% Re	duction)		0.00	VENDOR
Hard Paul and Trans		PROTO-HX CALCUL	ATED	DATA SHEE
Heat Exchanger Type		@BENCHMARK CONDI	TIONS IEMA-E	VALUE
Effective Area (ft^2)	•		482.00	11100
Area Factor			1.001961568	
Area Ratio			•	
Number of Shells per Unit			1	
Shell Minimum Area			0.438000000	
Shell Velocity (ft/s)			5.600	
Tube Pitch (in)			0.7500	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			No	
Total Number of Tubes			420	
Number of Active Tubes			420	
Tube Length (ft)			7.00	
Tube Inside Diameter (in)			0.541	
Tube Outside Diameter (ir	1)		0.625	
Tube Wall Conductivity (I	•	°F)	58.00	
De Shall Incide Diameter	(in)		0.000	
Ds, Shell Inside Diameter Lbc, Central Baffle Spacir			0.000	
Lbi, Inlet Baffle Spacing (- \ /		0.000	
	•		19.688	
Lbo, Outlet Baffle Spacing	- ` '		19.688	
Dotl, Tube circle diameter Bh, Baffle cut height (in)	(111)		0.000	
• • • • • • • • • • • • • • • • • • • •	hatiyaan D	officend Shall Gar	0.000	
Lsb, Diametral difference			0.000	
Ltb, Diametral difference	between 1	ude and Battle (in)	0.000	

Nss, Number Sealing Strips

Proto-Power Calc: 97-197

0.000

Attachment: C

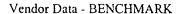
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Tube Temp Out (°F)

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

CC .	~ .
lact	Data

Extrapolation Data

Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)	-	
Tube Temp In (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr-ft ^{2.o} F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr-ft2.0F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

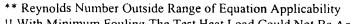
Overall Fouling (hr·ft².°F/BTU)

Tube Skin Temp (°F)

Shell-Side Tube-Side Property Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft2.°F/BTU)	0.002811
Tube Mass Flow (lbm/hr)	COMPARE	3.978E+5	Shell-Side ho (BTU/hr·ft².ºF)	1,889.7
	TO VENDOR		Tube-Side hi (BTU/hr·ft².°F)	1,576.5
Heat Transferred (BTU/hr)	DATA SHEET	8.277E+6	1/Wall Resis (BTU/hr·ft2.°F)	15,431.0
LMTD	UNITIO	71.8	LMTD Correction Factor	0.9895
Effective Area (ft²)		482.0		
			U Overall (BTU/hr·ft².°F)	241.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	5.33	Shell Temp In (°F)	190.0
Reynold's Number	7.707E+04	3.620E+04	Shell Temp Out (°F)	174.5
Prandtl Number	2.13	4.03	Tav Shell (°F)	182.2
Bulk Visc (lbm/ft·hr)	0.82	1.48	Shell Skin Temp (°F)	173.1
Skin Visc (lbm/ft hr)	0.88	1.31	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.53	61.85	Tube Temp Out (°F)	120.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	123.1



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

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Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Design Conditions - Adjusted Eff. Area

Shell and Tube Heat Exchanger Input Parameters

				<u></u>
		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	1,064.46	795.25	•
Inlet Temperature	°F	190.00	100.00	
Outlet Temperature	٥F	175.00	121.00	
Fouling Factor		0.00050	0.00200	
Shell Fluid Name		The state of the s	Fresh Water	-
Tube Fluid Name			Fresh Water	
Design Heat Transfer (B'	TU/hr)		8,505,000	
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	241.70	
Emprical Factor for Outs	ide h		0.633693000	
Performance Factor (% F	Reduction)		0.00	CALCULATED
Heat Eveloneen Time			тема-е	IN SECTION 3
Heat Exchanger Type Effective Area (ft^2)			468.17	/ IN Sec. 101.
Area Factor			0.973212339	1
Area Ratio			0.773212337	
Area Natio				
Number of Shells per Un	iit		1	
Shell Minimum Area			0.438000000	
Shell Velocity (ft/s)			5.600	
Tube Pitch (in)			0.7500	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			No	
Total Number of Tubes			420	
Number of Active Tubes	L		420	
Tube Length (ft)			7.00	
Tube Inside Diameter (ir	n)		0.541	
Tube Outside Diameter ((in)		0.625	
Tube Wall Conductivity	(BTU/hr·ft·°	F)	58.00	
Ds, Shell Inside Diamete	er (in)		0.000	
Lbc, Central Baffle Space			0.000	
Lbi, Inlet Baffle Spacing	•		19.688	
Lbo, Outlet Baffle Spaci			19.688	
Dotl, Tube circle diamet			0.000	
Bh, Baffle cut height (in	• •		0.000	
Lsb, Diametral difference		affle and Shell (in)	0.000	
Ltb, Diametral differenc		• •	0.000	
Nss, Number Sealing Str		, ,	0.000	
	•			

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K (BTU/hr·ft·°F)

and the same

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Design Conditions - Adjusted Eff. Area

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation I	Data
Data Date	Tube Flow (gpm)	795.3
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)	·	
Tube Temp Out (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr-ft ^{2.} °F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.o} F)
LMTD	LMTD Correction Factor

Effective Area (ft²)

Shell-Side Property Tube-Side Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Shell Skin Temp (°F) Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.} °F/BTU)	0.002811
Tube Mass Flow (lbm/hr)		3.978E+5	Shell-Side ho (BTU/hr·ft².°F)	1,890.3
			Tube-Side hi (BTU/hr·ft².°F)	1,574.7
Heat Transferred (BTU/hr)		8.089E+6	1/Wall Resis (BTU/hr-ft2.°F)	15,431.0
LMTD		72.2	LMTD Correction Factor	0.9901
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	241.7
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	5.33	Shell Temp In (°F)	190.0
Reynold's Number	7.717E+04	3.612E+04	Shell Temp Out (°F)	174.8
Prandtl Number	2.13	4.04	Tav Shell (°F)	182.4
Bulk Visc (lbm/ft·hr)	0.82	1.48	Shell Skin Temp (°F)	173.2
Skin Visc (lbm/ft·hr)	0.87	1.31	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.52	61.86	Tube Temp Out (°F)	120.4
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.2
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	123.0

** Reynolds Number Outside Range of Equation Applicability

With Minimum Fouling The Test Heat Load Could Not Be Achie

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Overall Fouling (hr·ft²-°F/BTU)

Tube Skin Temp (°F)

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Calculation Report for DG01B - LSCS - HPCS DG Hx.

LSCS Reference Cond. Vendor Fouling

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,100.00	800.00
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor		0.00050	0.00200
Shell Fluid Name		The state of the s	Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B)	ΓU/hr)		8,505,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	241.70
Emprical Factor for Outs	ide h		0.616913000
Performance Factor (% R	Reduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area			0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			420
Tube Length (ft)			7.00
Tube Inside Diameter (in	.)		0.541
Tube Outside Diameter (in)		0.625
Tube Wall Conductivity	(BTU/hr·ft·°	F)	58.00
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Spac	ing (in)		0.000
Lbi, Inlet Baffle Spacing	(in)		19.688
Lbo, Outlet Baffle Spacin	ng (in)		19.688
Dotl, Tube circle diameter	er (in)		0.000
Bh, Baffle cut height (in)			0.000
Lsb, Diametral difference		, ,	0.000
Ltb, Diametral difference		ibe and Baffle (in)	0.000
Nss, Number Sealing Str	ips		0.000

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Tube Temp Out (°F)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

LSCS Reference Cond. Vendor Fouling

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

T	est	Data

Extrapolation Data

Overall Fouling (hr·ft2.°F/BTU)

	L	
Data Date	Tube Flow (gpm)	650.0
Shell Flow (gpm)	Shell Flow (gpm)	1,100.0
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.} °F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Property Shell-Side Tube-Side

Troperty	onen-blae	r doc-bide	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)
			• • •

Extrapolation Calculation Results

LAWER THAT	√ 5.503E+5	Overall Fouling (hr-ft2-°F/BTU)	0.002811
ISTS REE	3.252E+5	Shell-Side ho (BTU/hr·ft².°F)	1,880.7
LUCU NET!		Tube-Side hi (BTU/hr·ft².°F)	1,354.4
DEDUIRED.	7.718E+6	1/Wall Resis (BTU/hr-ft ² .°F)	15,431.0
Vere	71.0 468.2	LMTD Correction Factor	0.9890
		U Overall (BTU/hr·ft².°F)	234.7
Shell-Side	Tube-Side		
5.77	4.36	Shell Temp In (°F)	190.0
8.005E+04	3.003E+04	Shell Temp Out (°F)	176.0
2.12	3.96	Tav Shell (°F)	183.0
0.82	1.46	Shell Skin Temp (°F)	174.1
0.87	1.27	Tube Temp In (°F)	100.0
60.51	61.83	Tube Temp Out (°F)	123.8
1.00	1.00	Tav Tube (°F)	111.9
0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 9	97-197
	Shell-Side 5.77 8.005E+04 2.12 0.82 0.87 60.51 1.00	Shell-Side Tube-Side 5.77 4.36 8.005E+04 3.003E+04 2.12 3.96 0.82 1.46 0.87 1.27 60.51 61.83 1.00 1.00	Shell-Side ho (BTU/hr·ft²-°F)

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

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Calculation Report for DG01B - LSCS - HPCS DG Hx. Reduced FF to meet LSCS Ref. Cond.

Shell and Tube Heat Exchanger Input Parameters

	Shell-Side	Tube-Side	
Fluid Quantity, Total gpm	1,064.46	795.25	
Inlet Temperature °F	190.00	100.00	VENDOR VALUES
Outlet Temperature °F	175.00	121.00	NOT USED IN
Fouling Factor	0.00050	0.00200	FULLOWING
Shell Fluid Name		Fresh Water	_ (400 - 211
Tube Fluid Name		Fresh Water	
Design Heat Transfer (BTU/hr)		8,505,000	
Design Heat Trans Coeff (BTU/hr-ft	^{2.0} F)	241.70	
Emprical Factor for Outside h		0.633693000	
Performance Factor (% Reduction)		0.00	
Heat Exchanger Type		тема-е	
Effective Area (ft^2)		468.17	
Area Factor		0.973212339	
Area Ratio			
Number of Shells per Unit		1	
Shell Minimum Area		0.438000000	
Shell Velocity (ft/s)		5.600	
Tube Pitch (in)		0.7500	
Tube Pitch Type		Triangular	
Number of Tube Passes		2	
U-Tubes		No	
Total Number of Tubes		420	
Number of Active Tubes		420	
Tube Length (ft)		7.00	
Tube Inside Diameter (in)		0.541	
Tube Outside Diameter (in)		0.625	
Tube Wall Conductivity (BTU/hr ft	°F)	58.00	
Ds, Shell Inside Diameter (in)		0.000	
Lbc, Central Baffle Spacing (in)		0.000	
Lbi, Inlet Baffle Spacing (in)		19.688	
Lbo, Outlet Baffle Spacing (in)		19.688	
Dotl, Tube circle diameter (in)		0.000	
Bh, Baffle cut height (in)		0.000	
Lsb, Diametral difference between I	• • •	0.000	
Ltb, Diametral difference between T	ube and Battle (in)	0.000	
Nss, Number Sealing Strips		0.000	

Proto-Power Calc: 97-197

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Calculation Report for DG01B - LSCS - HPCS DG Hx.

Reduced FF to meet LSCS Ref. Cond.

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

Fouling Was Input by User

- FOULING FACTOR REDUCED

UNTIL REFERENCE HEAT RATE WAS REACHED.

Test Data	Extrapolation 1	Data
Data Date Shell Flow (gpm) Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm)	Tube Flow (gpm) Shell Flow (gpm) Tube Inlet Temp (°F) Shell Inlet Temp (°F)	646.1 1,064.5 100.0 190.0
Tube Temp In (°F) Tube Temp Out (°F)	Input Fouling Factor	0.002732

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
·	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft².°F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm.°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr) Tube Mass Flow (lbm/hr)	MEETS _	5.325E+5 3.232E+5	Shell-Side ho (BTU/hr·ft²-°F)	1,892.1
Heat Transferred (BTU/hr) LMTD Effective Area (ft²)	REFERENCE HEAT RATE	7.801E+6 70.5 468.2	Tube-Side hi (BTU/hr·ft²-°F) ANJUSTED 1/Wall Resis (BTU/hr·ft²-°F) OVERAU LMTD Correction Factor FOULNES FACTOR	1,349.8 15,431.0 0.9881
D4	etall eda	T C:1-	U Overall (BTU/hr·ft².°F)	239.2
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	4.33	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	2.991E+04	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	3.95	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.45	Shell Skin Temp (°F)	173.8
Skin Visc (lbm/ft·hr)	0.87	1.27	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.52	61.83	Tube Temp Out (°F)	124.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	112.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	126.5
,			Proto-Power Calc: 97-19) 7

^{**} Reynolds Number Outside Range of Equation Applicability

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for DG01B - LSCS - HPCS DG Hx. LSCS Ref. Condition - FINAL MODEL

Shell and Tube Heat Exchanger Input Parameters

		Shell-Side	Tube-Side	
Fluid Quantity, Total	gpm	1,064.46	795.25	
Inlet Temperature	°F	190.00	100.00	REDUCED
Outlet Temperature	°F	175.00	121.00	TUBE-SIDE
Fouling Factor		0.00050	0.00193	FOULING SECTION 6.
Shell Fluid Name			Fresh Water	36410
Tube Fluid Name			Fresh Water	
Design Heat Transfer (B)	ΓU/hr)		8,505,000	
Design Heat Trans Coeff	(BTU/hr-ft ²	·°F)	241.70	
Emprical Factor for Outs	ide h		0.633693000	
Performance Factor (% R	eduction)		0.00	TED
Hast Euchanaar Trus			TEMAE	ADJUSTUS
Heat Exchanger Type			TEMA-E 468.17	ADJUSTED AREA SECTION 3
Effective Area (ft^2) Area Factor			0.973212339	SECIL
Area Ratio			0.973212339	
Alca Ratio				
Number of Shells per Un	it		1	
Shell Minimum Area			0.438000000	
Shell Velocity (ft/s)			5.600	
Tube Pitch (in)			0.7500	
Tube Pitch Type			Triangular	
Number of Tube Passes			2	
U-Tubes			No	
Total Number of Tubes			420	
Number of Active Tubes			420	
Tube Length (ft)			7.00	
Tube Inside Diameter (in)		0.541	
Tube Outside Diameter (•		0.625	
Tube Wall Conductivity	(BTU/hr·ft·°	F)	58.00	
Da Shall Incida Diagrata	- (i)		0.000	
Ds, Shell Inside Diamete	• •		0.000	
Lbc, Central Baffle Space	• • •		0.000	
Lbi, Inlet Baffle Spacing Lbo, Outlet Baffle Spacin	` '		19.688	
Dotl, Tube circle diamete	• ,		19.688 0.000	
Bh, Baffle cut height (in)	` '		0.000	
Lsb, Diametral difference		affle and Shell (in)	0.000	
Ltb, Diametral difference		` '	0.000	
Nss, Number Sealing Str		.oc and Darrie (III)	0.000	
	. ۲.		0.000	

Proto-Power Calc: 97-197

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Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

LSCS Ref. Condition - FINAL MODEL

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

Design Fouling Factors Were Used

-DESIGN FOULING FACTOR INCLUDES REDUCERTUBE-SWE FOULING.

Test	Data

Test Data	Extrapolation Data		
	Tube Flow (gpm)	646.1	
	Shell Flow (gpm)	1,064.5	
	Tube Inlet Temp (°F)	100.0	

Shell Inlet Temp (°F)

Overall Fouling (hr-ft2-oF/BTU)

Shell Temp In (°F) Shell Temp Out (°F) Tube Flow (gpm) Tube Temp In (°F) Tube Temp Out (°F)

Data Date Shell Flow (gpm)

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft²-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
IMTD	I MTD Correction Factor

Effective Area (ft²)

Shell-Side Tube-Side Property

Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

	Extrapolati	on Ca	alculation	Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft²-°F/BTU) 0.002732
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F) 1.892.1
			Tube-Side hi (BTU/hr-ft ² .°F) DESIGN 1,349.8
Heat Transferred (BTU/hr)	7.801E+6	1/Wall Resis (BTU/hr·ft².ºF) /ADJUSTEU 15.431.0
LMTD		70.5	LMTD Correction Factor OUERALL 0.9881
Effective Area (ft2)		468.2	CONTRACT
			U Overall (BTU/hr-ft².°F) FOULING FACTOR 239.2
Property	Shell-Side	Tube-Side	pno.
Velocity (ft/s)	5.58	4.33	Shell Temp In (°F) 190.0
Reynold's Number	7.731E+04	2.991E+04	Shell Temp Out (°F) 175.4
Prandtl Number	2.13	3.95	Tav Shell (°F) 182.7
Bulk Visc (lbm/ft·hr)	0.82	1.45	Shell Skin Temp (°F) 173.8
Skin Visc (lbm/ft·hr)	0.87	1.27	Tube Temp In (°F) 100.0
Density (lbm/ft³)	60.52	61.83	Tube Temp Out (°F) 124.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F) 112.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) 126.5

^{**} Reynolds Number Outside Range of Equation Applicability

Proto-Power Calc: 97-197

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for DG01B - LSCS - HPCS DG Hx.
CLEAN - FINAL MODEL



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor		0.00050	0.00193
Shell Fluid Name	The second secon		Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B)	ΓU/hr)		8,505,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	241.70
Emprical Factor for Outs	ide h		0.633693000
Performance Factor (% R	leduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area			0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			420
Tube Length (ft)			7.00
Tube Inside Diameter (in	•		0.541
Tube Outside Diameter (•		0.625
Tube Wall Conductivity	(BTU/hr·ft·	°F)	58.00
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Spac	•		0.000
Lbi, Inlet Baffle Spacing	` '		19.688
Lbo, Outlet Baffle Spacing	• ,		19.688
Dotl, Tube circle diameter			0.000
Bh, Baffle cut height (in)		00 101 H (1)	0.000
Lsb, Diametral difference		` '	0.000
Ltb, Diametral difference		ube and Battle (in)	0.000
Nss, Number Sealing Str	ıps		0.000

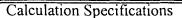
Proto-Power Calc: 97-197

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Calculation Report for DG01B - LSCS - HPCS DG Hx.

CLEAN - FINAL MODEL



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions

Fouling Was Input by User

- OFOULING FOR "CLEAN" Hx ANALYSIS - MAXIMUM HEAT RATE

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	646.1	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)	•		
Tube Temp In (°F)			
Tube Temp Out (°F)	Input Fouling Factor	0.000000	

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.o} F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft ³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results

				,
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² .°F/BTU)	0.000000
Tube Mass Flow (lbm/hr)	MAXIMUM	3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,839.7
	MAXIMUM HEAT RATE		Tube-Side hi (BTU/hr·ft².°F)	1,455.3
Heat Transferred (BTU/hr)	HEALIN	1.542E+7	1/Wall Resis (BTU/hr·ft²-°F)	15,431.0
LMTD		51.1	LMTD Correction Factor	0.9039
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	713.2
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.57	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.363E+04	3.347E+04	Shell Temp Out (°F)	161.1
Prandtl Number	2.24	3.49	Tav Shell (°F)	175.5
Bulk Visc (lbm/ft·hr)	0.86	1.30	Shell Skin Temp (°F)	155.5
Skin Visc (lbm/ft·hr)	1.00	1.01	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.67	61.65	Tube Temp Out (°F)	147.8
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	123.9
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	153.1
			Proto-Power Calc:	7/-19/

^{**} Reynolds Number Outside Range of Equation Applicability

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment D to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

Attachment: D

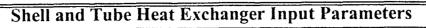
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PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG ${\sf Hx}$.

LSCS Ref. Condition - FINAL MODEL



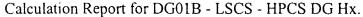
		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor		0.00050	0.00193
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B7	TU/hr)		8,505,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	241.70
Emprical Factor for Outsi	de h		0.633693000
Performance Factor (% R	eduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area	-		0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			420
Tube Length (ft)			7.00
Tube Inside Diameter (in)		0.541
Tube Outside Diameter (in)		0.625
Tube Wall Conductivity	(BTU/hr·ft·	°F)	58.00
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Space	ing (in)		0.000
Lbi, Inlet Baffle Spacing	(in)		19.688
Lbo, Outlet Baffle Spacin	ng (in)		19.688
Dotl, Tube circle diamete	er (in)		0.000
Bh, Baffle cut height (in)	· · ·		0.000
Lsb, Diametral difference	e between B	affle and Shell (in)	0.000
Ltb, Diametral difference	e between T	ube and Baffle (in)	0.000
Nss, Number Sealing Str	ips		0.000

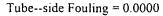
Proto-Power Calc: 97-197

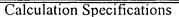
Attachment: D

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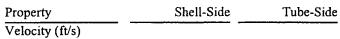






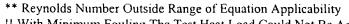
Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation Data	
Data Date	Tube Flow (gpm)	646.1
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)	Input Fouling Factor	0.000500
Fo	uling Calculation Results	
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft²·°F)	
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)	
,	Tube-Side hi (BTU/hr·ft²-°F)	
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft²-°F)	
LMTD	LMTD Correction Factor	
Effective Area (ft²)		
,	Overall Fouling (hr·ft².°F/BTU)	

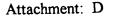


Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft²-°F/BTU)	0.000500
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,856.7
			Tube-Side hi (BTU/hr·ft².°F)	1,423.4
Heat Transferred (BTU/hr	·)	1.316E+7	1/Wall Resis (BTU/hr-ft2.°F)	15,431.0
LMTD		56.9	LMTD Correction Factor	0.9458
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	522.2
Property	Shell-Side	Tube-Side	•	
Velocity (ft/s)	5.57	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.471E+04	3.240E+04	Shell Temp Out (°F)	165.3
Prandtl Number	2.20	3.62	Tav Shell (°F)	177.7
Bulk Visc (lbm/ft·hr)	0.85	1.34	Shell Skin Temp (°F)	161.6
Skin Visc (lbm/ft·hr)	0.95	1.09	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.63	61.71	Tube Temp Out (°F)	140.8
Cp (BTU/lbm °F)	00.1	1.00	Tav Tube (°F)	120.4
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-19	144.7



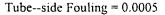
^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

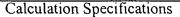


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Calculation Report for DG01B - LSCS - HPCS DG Hx.



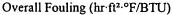


Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date	Tube Flow (gpm)	646.1		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)			
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.001078		
	Fouling Calculation Pagulta			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft²-°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft ² .°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	



			Overall Fouling (hr-ft2.0F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	.001078
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,870.2
			Tube-Side hi (BTU/hr·ft².°F)	1,396.4
Heat Transferred (BTU/hr)		1.12E+7	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		61.9	LMTD Correction Factor	0.9675
Effective Area (ft²)		468.2		
			U Overall (BTU/hr-ft2.°F)	399.2
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.57	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.566E+04	3.148E+04	Shell Temp Out (°F)	169.0
Prandtl Number	2.18	3.74	Tav Shell (°F)	179.5
Bulk Visc (lbm/ft·hr)	0.84	1.38	Shell Skin Temp (°F)	166.2
Skin Visc (lbm/ft·hr)	0.92	1.15	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.59	61.75	Tube Temp Out (°F)	134.7
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	117.3
K (BTU/hr ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-197	137.9

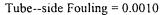
^{**} Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: D

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Calculation Report for DG01B - LSCS - HPCS DG Hx.



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date	Tube Flow (gpm)	646.1		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.001655		
	Fouling Calculation Results			

rounng	Calculat	ion Ke	suits

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr-ft2-°F)
LMTD	LMTD Correction Factor
Effective Area (ft ²)	

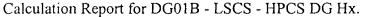
			Overall Fouling (hr-ft ^{2.} °F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

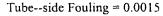
Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² .°F/BTU)	0.001655
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,879.8
			Tube-Side hi (BTU/hr·ft²-°F)	1,376.2
Heat Transferred (BTU/hr)	9.727E+6	1/Wall Resis (BTU/hr-ft2.°F)	15,431.0
LMTD		65.6	LMTD Correction Factor	0.9784
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	323.5
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	4.34	Shell Temp In (°F)	190.0
Reynold's Number	7.637E+04	3.080E+04	Shell Temp Out (°F)	171.8
Prandtl Number	2.15	3.83	Tav Shell (°F)	180.9
Bulk Visc (lbm/ft·hr)	0.83	1.41	Shell Skin Temp (°F)	169.6
Skin Visc (lbm/ft·hr)	0.90	1.20	Tube Temp In (°F)	0.001
Density (lbm/ft3)	60.56	61.79	Tube Temp Out (°F)	130.1
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	115.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-197	132.9

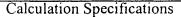
** Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie Attachment: D

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Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Extrapolation Data	
ow (gpm)	646.1
ow (gpm)	1,064.5
let Temp (°F)	100.0
let Temp (°F)	190.0
ouling Factor	0.002233
: =	ouling Factor

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft ^{2.} °F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

U)

			Overall Fouling (hr-ft ² .°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)		· · · · · · · · · · · · · · · · · · ·	Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

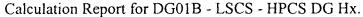
Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².ºF/BTU)	0.002233
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft²-°F)	1,887.1
			Tube-Side hi (BTU/hr-ft2.0F)	1,360.6
Heat Transferred (BTU/hr)	8.59E+6	1/Wall Resis (BTU/hr·ft ^{2.o} F)	15,431.0
LMTD		68.5	LMTD Correction Factor	0.9847
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	272.0
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	4.33	Shell Temp In (°F)	190.0
Reynold's Number	7.692E+04	3.027E+04	Shell Temp Out (°F)	173.9
Prandtl Number	2.14	3.90	Tav Shell (°F)	182.0
Bulk Visc (lbm/ft·hr)	0.82	1.44	Shell Skin Temp (°F)	172.1
Skin Visc (lbm/ft·hr)	0.88	1.24	Tube Temp In (°F)	100.0
Density (lbm/ft3)	60.53	61.81	Tube Temp Out (°F)	126.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	113.3
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-197	129.2

^{**} Reynolds Number Outside Range of Equation Applicability !! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: D

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Tube--side Fouling = 0.001932 (LIMIT)



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data	Extrapolation	Extrapolation Data		
Data Date	Tube Flow (gpm)	646.1		
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5		
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0		
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0		
Tube Flow (gpm)				
Tube Temp In (°F)				
Tube Temp Out (°F)	Input Fouling Factor	0.002732		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft²-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr·ft2.°F/BTU)

Property	Shell-Side	Tube-Side	2 (
Velocity (ft/s)		·····	Shell Temp In (°F)
Reynold's Number		.7	Shell Temp Out (°F)
Prandtl Number		à	Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft3)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft²-°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,892.1
, ,			Tube-Side hi (BTU/hr·ft²-°F)	1,349.8
Heat Transferred (BTU/hr)		7.801E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		70.5	LMTD Correction Factor	0.9881
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	239.2
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	4.33	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	2.991E+04	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	3.95	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft-hr)	0.82	1.45	Shell Skin Temp (°F)	173.8
Skin Visc (lbm/ft·hr)	0.87	1.27	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.52	61.83	Tube Temp Out (°F)	124.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	112.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) ower Calc: 97-197	126.5

^{**} Reynolds Number Outside Range of Equation Applicability

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: D

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Attachment E to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

Attachment: E

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Calculation Report for DG01B - LSCS - HPCS DG Hx. LSCS Ref. Condition - FINAL MODEL



		Shell-Side	Tube-Side
Fluid Quantity, Total	gpm	1,064.46	795.25
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	175.00	121.00
Fouling Factor		0.00050	0.00193
Shell Fluid Name			Fresh Water
Tube Fluid Name			Fresh Water
Design Heat Transfer (B'	ΓU/hr)		8,505,000
Design Heat Trans Coeff	(BTU/hr·ft²	·°F)	241.70
Emprical Factor for Outs			0.633693000
Performance Factor (% R	Reduction)		0.00
Heat Exchanger Type			TEMA-E
Effective Area (ft^2)			468.17
Area Factor			0.973212339
Area Ratio			
Number of Shells per Un	it		1
Shell Minimum Area			0.438000000
Shell Velocity (ft/s)			5.600
Tube Pitch (in)			0.7500
Tube Pitch Type			Triangular
Number of Tube Passes			2
U-Tubes			No
Total Number of Tubes			420
Number of Active Tubes			420
Tube Length (ft)			7.00
Tube Inside Diameter (in	1)		0.541
Tube Outside Diameter (in)		0.625
Tube Wall Conductivity	(BTU/hr·ft·°	(F)	58.00
Ds, Shell Inside Diamete	r (in)		0.000
Lbc, Central Baffle Spac	` '		0.000
Lbi, Inlet Baffle Spacing	(in)		19.688
Lbo, Outlet Baffle Spacin	ng (in)		19.688
Dotl, Tube circle diamete	er (in)		0.000
Bh, Baffle cut height (in))		0.000
Lsb, Diametral difference		` '	0.000
Ltb, Diametral difference		ube and Baffle (in)	0.000
Nss, Number Sealing Str	ips		0.000

Proto-Power Calc: 97-197

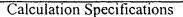
Attachment: E

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Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=35°F



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	202.4	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	35.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

Property	Shell-Side	Tube-Side	Overall Fouring (in it i
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number	***		Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft²-°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		1.012E+5	Shell-Side ho (BTU/hr-ft².°F)	1,891.5
, ,			Tube-Side hi (BTU/hr·ft².°F)	393.5
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr-ft2.°F)	15,431.0
LMTD		106.1	LMTD Correction Factor	0.9829
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	159.7
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	1.35	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	6.041E+03	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	6.41	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	2.25	Shell Skin Temp (°F)	173.5
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)	35.0
Density (lbm/ft3)	60.52	62,27	Tube Temp Out (°F)	112.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	73.5
K (BTU/hr·ft·°F)	0.39	0.35	Tube Skin Temp (°F)	124.7

** Reynolds Number Outside Range of Equation Applicability

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-197

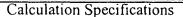
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Calculation Report for DG01B - LSCS - HPCS DG Hx.





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test	Data
------	------

Extrapolation Data

Data Date	Tube Flow (gpm)	209.1
Shell Flow (gpn1)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	40.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft²·°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

·			Overall Fouling (hr-ft2.°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² -°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		1.046E+5	Shell-Side ho (BTU/hr·ft².°F)	1,891.5
			Tube-Side hi (BTU/hr·ft².°F)	425.1
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft ^{2.°} F)	15,431.0
LMTD		102.5	LMTD Correction Factor	0.9822
Effective Area (ft2)		468.2		
			U Overall (BTU/hr·ft2.0F)	165.5
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	1.39	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	6.552E+03	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	6.08	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	2.15	Shell Skin Temp (°F)	173.5
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)	40.0
Density (lbm/ft³)	60.52	62.24	Tube Temp Out (°F)	114.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	77.3
K (BTU/hr·ft·°F)	0.39	0.35	Tube Skin Temp (°F)	124.7

^{**} Reynolds Number Outside Range of Equation Applicability

Proto-Power Calc: 97-197

Attachment: E

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^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=50°F



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

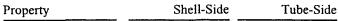
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	COL	1/	α	a

Extrapolation Data

Data Date	Tube Flow (gpm)	227.4
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	50.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

Fouling Calculation Results

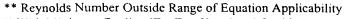
Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft²-°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	
	Overall Fouling (hr-ft ² .°F/BTU)



Velocity (ft/s) Shell Temp In (°F) Reynold's Number Shell Temp Out (°F) Prandtl Number Tav Shell (°F) Bulk Visc (lbm/ft·hr) Shell Skin Temp (°F) Skin Visc (lbm/ft·hr) Tube Temp In (°F) Density (lbm/ft3) Tube Temp Out (°F) Cp (BTU/lbm.°F) Tav Tube (°F) K (BTU/hr·ft·°F) Tube Skin Temp (°F)

Extrapolation Calculation Results	;
	=

Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ² .°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		1.138E+5	Shell-Side ho (BTU/hr-ft2.0F)	1,891.5
			Tube-Side hi (BTU/hr·ft².°F)	497.6
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		95.9	LMTD Correction Factor	0.9813
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft ² .°F)	177.1
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	1.52	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	7.772E+03	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	5.52	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.97	Shell Skin Temp (°F)	173.5
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)	50.0
Density (lbm/ft3)	60.52	62.17	Tube Temp Out (°F)	118.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	84.3
K (BTU/hr-ft-°F)	0.39	0.36	Tube Skin Temp (°F)	124.8
			_ ' '	



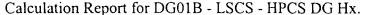
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-197

Attachment: E

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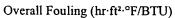
Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	255.0	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	60.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)	•		
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft2.°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft ^{2.o} F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	



Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm.°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.} °F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		1.276E+5	Shell-Side ho (BTU/hr-ft ^{2.0} F)	1,891.6
			Tube-Side hi (BTU/hr-ft2-°F)	583.3
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		90.1	LMTD Correction Factor	0.9812
Effective Area (ft2)		468.2		
			U Overall (BTU/hr·ft².°F)	188.5
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	1.70	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	9.385E+03	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	5.09	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.83	Shell Skin Temp (°F)	173.5
Skin Visc (lbm/ft·hr)	0.87	1.29	Tube Temp In (°F)	60.0
Density (lbm/ft ³)	60.52	62.11	Tube Temp Out (°F)	121.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	90.6
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	125.0

^{**} Reynolds Number Outside Range of Equation Applicability

Proto-Power Calc: 97-197

Attachment: E

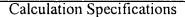
Rev: A Page 6 of 10



^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=70°F



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

~ .	r
Test	Data:

Extrapolation Data

Data Date	Tube Flow (gpm)	298.7
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5
Shell Temp In (°F)	Tube Inlet Temp (°F)	70.0
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0
Tube Flow (gpm)		
Tube Temp In (°F)		
Tube Temp Out (°F)		

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft².°F)
	Tube-Side hi (BTU/hr·ft²-°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².ºF)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

•			Overall Fouling (hr-ft2.°F/BTU)
Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

Extrapolation Calculation Results

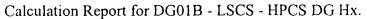
CI II M FI (II(I)		£ 225E+5	O 115 11 (1 63 05 07 77 7)	0.000000
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		1.494E+5	Shell-Side ho (BTU/hr·ft².°F)	1,891.7
			Tube-Side hi (BTU/hr-ft2-°F)	680.9
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		85.2	LMTD Correction Factor	0.9821
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	199.1
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	2.00	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	1.170E+04	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	4.75	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.72	Shell Skin Temp (°F)	173.6
Skin Visc (lbm/ft·hr)	0.87	1.28	Tube Temp In (°F)	70.0
Density (lbm/ft3)	60.52	62.04	Tube Temp Out (°F)	122.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	96.1
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	125.4
			Proto-Power Calc: 97-19	7

^{**} Reynolds Number Outside Range of Equation Applicability
!! With Minimum Fouling The Test Heat Load Could Not Be Achie

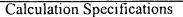
Attachment: E

Rev: A Page 7 of 10









Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	362.9	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	80.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

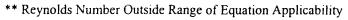
Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr-ft2.°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	

Overall Fouling (hr-ft2.0F/BTU)

Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)

	Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	0.002732	
Tube Mass Flow (lbm/hr)		1.815E+5	Shell-Side ho (BTU/hr·ft².°F)	1,891.8	
, ,			Tube-Side hi (BTU/hr-ft2.0F)	814.6	
Heat Transferred (BTU/hr)		7.8E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0	
LMTD		80.4	LMTD Correction Factor	0.9835	
Effective Area (ft2)		468.2			
			U Overall (BTU/hr-ft ² .°F)	210.8	
Property	Shell-Side	Tube-Side	,		
Velocity (ft/s)	5.58	2.43	Shell Temp In (°F)	190.0	
Reynold's Number	7.731E+04	1.507E+04	Shell Temp Out (°F)	175.4	
Prandtl Number	2.13	4.45	Tav Shell (°F)	182.7	
Bulk Visc (lbm/ft·hr)	0.82	1.62	Shell Skin Temp (°F)	173.6	
Skin Visc (lbm/ft·hr)	0.87	1.28	Tube Temp In (°F)	80.0	
Density (lbm/ft³)	60.52	61.98	Tube Temp Out (°F)	123.0	
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	101.5	
K (BTU/hr·ft·°F)	0.39	0.36	Tube Skin Temp (°F)	125.8	
				7 100	



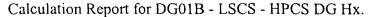
^{!!} With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-197

Attachment: E

Rev: A Page 8 of 10









Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	464.2	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	90.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)	• • •		
Tube Temp In (°F)			
Tube Temp Out (°F)			

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)	Shell-Side ho (BTU/hr·ft²-°F)
	Tube-Side hi (BTU/hr·ft².°F)
Heat Transferred (BTU/hr)	1/Wall Resis (BTU/hr·ft².°F)
LMTD	LMTD Correction Factor
Effective Area (ft²)	



Property	Shell-Side	Tube-Side	
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)			Shell Skin Temp (°F)
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft³)			Tube Temp Out (°F)
Cp (BTU/lbm·°F)			Tav Tube (°F)
K (BTU/hr·ft·°F)			Tube Skin Temp (°F)
			• • •

	Extrapolation Calculation Results			
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr-ft ^{2.o} F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		2.322E+5	Shell-Side ho (BTU/hr-ft²-°F)	1,892.0
			Tube-Side hi (BTU/hr-ft2.°F)	1,014.2
Heat Transferred (BTU/hr	:)	7.8E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		75.5	LMTD Correction Factor	0.9855
Effective Area (ft²)		468.2		
			U Overall (BTU/hr·ft².°F)	224.0
Property	Shell-Side	Tube-Side		
Velocity (ft/s)	5.58	3.11	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	2.037E+04	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	4.19	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.53	Shell Skin Temp (°F)	173.7
Skin Visc (lbm/ft·hr)	0.87	1.27	Tube Temp In (°F)	90.0
Density (lbm/ft3)	60.52	61.90	Tube Temp Out (°F)	123.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	106.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F) Proto-Power Calc: 97-1	97 126.2

^{**} Reynolds Number Outside Range of Equation Applicability

!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Attachment: E

Rev: A Page 9 of 10



Cp (BTU/lbm·°F)

K (BTU/hr·ft·°F)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data	Extrapolation Data		
Data Date	Tube Flow (gpm)	646.1	
Shell Flow (gpm)	Shell Flow (gpm)	1,064.5	
Shell Temp In (°F)	Tube Inlet Temp (°F)	100.0	
Shell Temp Out (°F)	Shell Inlet Temp (°F)	190.0	
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)			

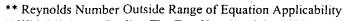
Fouling Calculation Results

			·
Shell Mass Flow (lbm/hr)			U Overall (BTU/hr·ft².°F)
Tube Mass Flow (lbm/hr)			Shell-Side ho (BTU/hr·ft².°F)
,			Tube-Side hi (BTU/hr-ft2.°F)
Heat Transferred (BTU/hr)			1/Wall Resis (BTU/hr-ft2.°F)
LMTD			LMTD Correction Factor
Effective Area (ft²)			
` ,			Overall Fouling (hr-ft2.0F/BTU)
Property	Shell-Side	Tube-Side	•
Velocity (ft/s)			Shell Temp In (°F)
Reynold's Number			Shell Temp Out (°F)
Prandtl Number			Tav Shell (°F)
Bulk Visc (lbm/ft·hr)		Shell Skin Temp (°F)	
Skin Visc (lbm/ft·hr)			Tube Temp In (°F)
Density (lbm/ft ³)			Tube Temp Out (°F)

Extrapolation Calculation Results				
Shell Mass Flow (lbm/hr)		5.325E+5	Overall Fouling (hr·ft².°F/BTU)	0.002732
Tube Mass Flow (lbm/hr)		3.232E+5	Shell-Side ho (BTU/hr·ft².°F)	1,892.1
•			Tube-Side hi (BTU/hr·ft²-°F)	1,349.8
Heat Transferred (BTU/hr)	7.801E+6	1/Wall Resis (BTU/hr·ft².°F)	15,431.0
LMTD		70.5	LMTD Correction Factor	0.9881
Effective Area (ft2)		468.2		
			U Overall (BTU/hr·ft².°F)	239.2
Property	Shell-Side	Tube-Side	,	
Velocity (ft/s)	5.58	4.33	Shell Temp In (°F)	190.0
Reynold's Number	7.731E+04	2.991E+04	Shell Temp Out (°F)	175.4
Prandtl Number	2.13	3.95	Tav Shell (°F)	182.7
Bulk Visc (lbm/ft·hr)	0.82	1.45	Shell Skin Temp (°F)	173.8
Skin Visc (lbm/ft hr)	0.87	1.27	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.52	61.83	Tube Temp Out (°F)	124.2
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	112.1
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	126.5

Tav Tube (°F)

Tube Skin Temp (°F)



!! With Minimum Fouling The Test Heat Load Could Not Be Achie

Proto-Power Calc: 97-197

Attachment: E

Rev: A Page 10 of 10

Attachment F to Proto-Power Calculation 97-197 Revision A

Proto-Power Calc: 97-197

Attachment: F

Rev: A Page 1 of 2



PROTO-HXTM Version 3.02 MODEL

LASALLE STATION HPCS DIESEL GENERATOR HEAT EXCHANGER.

FILE NAME: DG01B.PHX

DATE LAST MODIFIED: 6/26/98

TIME LAST MODIFIED: 11:25:36 AM

FILE SIZE: 864 KB

Proto-Power Calc: 97-197

Attachment: F

Rev: A Page 2 of 2

Page 1



ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision) Last Page No. 6 Attachment C, C8 Analysis No.: 1 97-200 Revision: 2 A05 VY Cooler Thermal Performance Model - 1(2)VY01A and 1(2)VY02A Title: 3 Revision: 5 EC/ECR No.: 1 388666 000 Station(s): 7 LaSalle Unit No.: 8 01 & 02 Safety/QA Class: 9 SR VY System Code(s): 10 is this Design Analysis Safeguards Information? " Yes 🗍 No 🛛 If yes, see SY-AA-101-106 Does this Design Analysis contain Unverified Assumptions? 12 Yes 🗌 No 🖂 If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: 13 N/A in its entirety. Description of Changes (list affected pages): " This revision evaluates a maximum cooling water inlet temperature of 107 °F. The previous temperature that was evaluated was 104 °F. This revision also raises the maximum room temperature of the Southwest corner room to 153 °F. Affected pages are Pages 1 - 3 and Attachment A, Pages A1-A8, Attachment B, Pages B1-B8, and Attachment C, Pages C1-C8. Disposition of Changes: 15 See attached pages. The changes made are acceptable. Sean Tanton Preparer: " Method of Review: " Detailed Review X Alternate Calculations Reviewer: 18 Review Independent review X Peer review Notes: 19 (For External Analyses Only) External Approver: 20 Sign Name Date Exelon Reviewer 21 Exelon Approver: 22 CHMIT





Purpose:

The purpose of this revision is to verify that the 1(2)VY01A and 1(2)VY02A coolers can remove the design heat load of 517,239 and 646,235 BTU/hr, respectively with a revised maximum cooling water temperature of 107 °F.

Assumptions:

There are no assumptions for this revision.

Inputs:

- Cooling water temperature = 107 °F (Reference 2)
- Air temperature for 1(2)VY01A = 148 °F (Reference 1)
- Air temperature for 1(2)VY02A = 153 °F*
- Water flow rate for 1(2)VY01A = 75 gpm (Reference 1)
- Water flow rate for 1(2)VY02A = 108 gpm (References 1, 3, and 4)**
- Air Flow rate for 1(2)VY01A = 17,100 cfm (Reference 1)
- Air Flow rate for 1(2)VY02A = 18,000 cfm (Reference 1)
- Fouling factor for both coolers = 0.02832467 hr ft².°F/BTU (design fouling factor) (Reference 1)
- 1 tube plugged for both coolers (5% tube plugging) (Reference 1)

*153 °F was chosen to achieve the desired heat transfer rate for the VY02 room cooler. As long as the heat transfer rate of at least 646,235 BTU/hr is achieved, the room will stay ≤ 153 °F. This temperature will be reflected in the EQ binders associated with the components in this room.

**Note that an additional 50 gpm was allocated to the 1(2)VY02A coolers per ECs 370853 and 384525. The results of the run with a 158 gpm flow rate on the water side is shown in Attachment C.



References:

- 1. Design analysis 97-200, Rev. A, up to and including Revs A00 through A04
- 2. EC 388666, Rev. 000
- 3. EC 370853, Rev. 000
- 4. EC 384525, Rev. 000

Identification of Computer Programs:

The computer program used in this analysis is Proto HX version 4.01. This program has been validated per DTSQA tracking number EX0000103.

Method of Analysis / Numeric Analysis:

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp" from 104 °F to 107 °F. Because the fan for the 1(2)VY01A and 1(2)VY02A coolers is at the exit of the cooler, the inlet air flow for the front cooler is iterated until the flow rate at the exit of the last row of the back cooler is approximately 17,100 cfm for the 1(2)VY01A cooler and 18,000 cfm for the 1(2)VY02A cooler. The iteration process is detailed in section 6.7 of revision A. The air flow values can be found on pages A8, B8, and C8 for each of the three cases considered.

Results / Conclusions:

The 1(2)VY01A coolers can remove the design heat load of 517,239 BTU/hr with the following conditions:

- 107 °F cooling water temperature
- 148 °F air temperature
- design fouling factor of 0.02832467 hr ft².°F/BTU
- 1 tube plugged
- air flow rate of 17,100 cfm
- water flow rate of 75 gpm



The total heat removed at these conditions is 560,505 BTU/hr, which provides 8.4% thermal margin over the design heat load. This thermal margin is enough to account for the 4.9% model uncertainty shown in Attachment J and is acceptable. Note that a maximum fouling factor was not calculated as was done in previous revisions because it is not practical to set up test conditions that would allow accurate measurement of the fouling factor



for these heat exchangers. The bounding fouling factor is the design fouling factor of 0.02832467 hr-ft².°F/BTU. This case is shown in Attachment A.

The 1(2)VY02A coolers can remove the design heat load of 646,235 BTU/hr with the following conditions:

- 107 °F cooling water temperature
- 153 °F air temperature
- design fouling factor of 0.02832467 hr-ft².°F/BTU
- 1 tube plugged
- air flow rate of 18,000 cfm
- water flow rate of 108 gpm

The total heat removed at these conditions is 681,320 BTU/hr, which provides 5.4% thermal margin over the design heat load. This thermal margin is enough to account for the 4.9% model uncertainty shown in Attachment J and is acceptable. Note that a maximum fouling factor was not calculated as was done in previous revisions because it is not practical to set up test conditions that would allow accurate measurement of the fouling factor for these heat exchangers. The bounding fouling factor is the design fouling factor of 0.02832467 hr-ft².°F/BTU. This case is shown in Attachment B.

Additionally, a case was run for the 1(2)VY02A coolers with a water flow rate of 158 gpm. All other input parameters listed above remained the same. The total heat removed at these conditions is 701,741 BTU/hr, which provides 8.6% thermal margin over the design heat load. This case is shown in Attachment C. As stated above, this cooling water flow is to be implemented with ECs 370853 and 384525 for Units 1 & 2, respectively. If this flow is to be used as the minimum equipment cooling water flow, an update to the UFSAR is required.



The above 2 cases used a Southwest corner room (1(2)VY02A coolers) maximum temperature of 153 °F. The previously analyzed temperature was 150 °F. As stated above, 153 °F was chosen to achieve the desired heat transfer rate for the VY02 room cooler. As long as the heat transfer rate of at least 646,235 BTU/hr is achieved, the room temperature will stay \leq 153 °F. The EQ binders associated with the components in this room will be updated to qualify the components for this temperature.

Attachments:

- A. Data Report for 1(2)VY01A (8 pgs)
- B. Data Report for 1(2)VY02A (8 pgs)
- C. Data Report for 1(2)VY02A w/ 158 gpm (8 pgs)



04-25-2012 14:13:19 PROTO-HX 4.01 by Proto-Power Corporation (SN#PHX-1002)

ComEd -- LaSalle

Data Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged

Air Coil Heat Exchanger Input Parameters

	Air-Side		Tube-Side	
Flow	21,179.00	acfm	150.00 g	
Mass Flow	•	lbm/hr	0.00 1	
Dry Bulb (Inlet Temperature)	150.00		105.00 °	
Inlet Wet Bulb Temperature	92.00		105.00	•
Inlet Relative Humidity	0.00			
Dry Bulb (Outlet Temperature)	109.40		115.30 °	F
Outlet Wet Bulb Temperature	84.10		11000	-
Outlet Relative Humidity	0.00			
Гube Fluid Name			Fresh W	ater
Tube-Side Fouling			0.001	1500
Air-Side Fouling			0.000	0000
Design Q (BTU/hr)			750	,000
Atmospheric Pressure (psia)			14	.315
Design Sensible Heat Ratio				1.00
Performance Factor (% Reduction)			0	.000
Coil Flow Direction			Counter F	Flow
Fin Type			Circular	
Configuration (for Air-Side h)			VY Coolers 01A/	
	j = EXP	[-2.5088 +	-0.3436 * LOG(Re)]
Coil Length (in)			104	.250
Fin Pitch (Fins/Inch)			10	.000
Fin Conductivity (BTU/hr·ft·°F)				.000
Fin Tip Thickness (inches)				0120
Fin Root Thickness (inches)				0120
Circular Fin Height (inches)			1	.495
Number of Coils Per Unit				2
Number of Tube Rows				8
Number of Tubes Per Row			2	0.00
Active Tubes Per Row			1	9.00
Tube Inside Diameter (in)			0.5	5270
Tube Outside Diameter (in)			0.6	5250
Longitudinal Tube Pitch (in)			1	.500
Transverse Tube Pitch (in)			1	.452
Number of Serpentines			1	.000
Tube Conductivity (BTU/hr-ft-°F)				5.00
, ,				•





Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure (psia)

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

75.00
18,098.00
107.00
148.00
12.76
0.00
14.315



Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged



Extrapolation Calculation Summary

·	Air-Side	Tube-Side	·	
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F)	0.00
Inlet Temperature (°F)	148.00	107.00	j Factor	0.0000
Outlet Temperature (°F)	114.50	122.05	Air-Side ho (BTU/hr·ft².°F)	0.00
Inlet Specific Humidity			Tube Wall Resistance (hr·ft²-°F/BTU)	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft2.°F/BTU)	0.02832467
			U Overall (BTU/hr·ft²-°F)	
			Effective Area (ft²)	6,880.52
			LMTD	0.00
			Total Heat Transferred (BTU/hr)	560,505
			Surface Effectiveness (Eta)	0.0000
			Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr) Heat to Condensate (BTU/hr)	560,505



Extrapolation Calculation for Row 1(Dry)

_	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F) 1,013.40
Inlet Temperature (°F)	148.00	118.98	j Factor 0.0082
Outlet Temperature (°F)	141.17	122.05	Air-Side ho (BTU/hr·ft².°F) 8.22
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	144.58	120.5178	,
Skin Temperature (°F)	126.85	123.0132	U Overall (BTU/hr·ft².°F) 5.56
Velocity ***	3,364.26	2.9125	Effective Area (ft²) 860.06
Reynold's Number	793**	21,205	LMTD 23.88
Prandtl Number	0.7254	3.6151	Total Heat Transferred (BTU/hr) 114,284
Bulk Visc (lbm/ft·hr)	0.0490	1.3399	
Skin Visc (lbm/ft·hr)	0.0000	1.3091	Surface Effectiveness (Eta) 0.9188
Density (lbm/ft³)	0.0623	61.7036	Sensible Heat Transferred (BTU/hr) 114,284
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0162	0.3702	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	12.76		` ,
Relative Humidity Out (%)	15.16		



* Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged

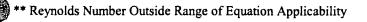
Extrapolation Calculation for Row 2(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F) 998.	.60
Inlet Temperature (°F)	141.17	116.36	j Factor 0.00)82
Outlet Temperature (°F)	135.35	118.98	Air-Side ho (BTU/hr·ft².°F) 8.	.19
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft ² -°F/BTU) 0.000314	130
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU) 0.028324	67
Average Temp (°F)	138.26	117.6724		
Skin Temperature (°F)	123.10	119.8303	U Overall (BTU/hr·ft².°F) 5.	.54
Velocity ***	3,364.26	2.9105	Effective Area (ft²) 860.	.06
Reynold's Number	799**	20,641	LMTD 20.	.43
Prandtl Number	0.7260	3.7235	Total Heat Transferred (BTU/hr) 97,3	394
Bulk Visc (lbm/ft·hr)	0.0486	1.3765		
Skin Visc (lbm/ft·hr)	0.0000	1.3486	Surface Effectiveness (Eta) 0.91	90
Density (lbm/ft³)	0.0629	61.7474	Sensible Heat Transferred (BTU/hr) 97,3	94
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3692	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	15.16		•	
Relative Humidity Out (%)	17.62			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F)	985.92
Inlet Temperature (°F)	135.35	114.13	j Factor	0.0082
Outlet Temperature (°F)	130.38	116.36	Air-Side ho (BTU/hr-ft2.°F)	8.17
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.0F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	132.86	115.2463		
Skin Temperature (°F)	119.90	117.1108	U Overall (BTU/hr·ft².°F)	5.53
Velocity ***	3,364.26	2.9087	Effective Area (ft²)	860.06
Reynold's Number	805**	20,164	LMTD	17.48
Prandtl Number	0.7264	3.8202	Total Heat Transferred (BTU/hr)	83,087
Bulk Visc (lbm/ft·hr)	0.0483	1.4091	,	ŕ
Skin Visc (lbm/ft·hr)	0.0000	1.3839	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft³)	0.0634	61.7839	Sensible Heat Transferred (BTU/hr)	83,087
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	ŕ
K (BTU/hr·ft·°F)	0.0160	0.3684	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	17.62		,	
Relative Humidity Out (%)	20.10			



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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr-ft2.°F)	975.07
Inlet Temperature (°F)	130.38	112.22	j Factor	0.0081
Outlet Temperature (°F)	126.14	114.13	Air-Side ho (BTU/hr-ft2.°F)	8.15
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2-°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	128.26	113.1757	- '	
Skin Temperature (°F)	117.17	114.7854	U Overall (BTU/hr·ft².°F)	5.51
Velocity ***	3,364.26	2.9073	Effective Area (ft²)	860.06
Reynold's Number	810**	19,760	LMTD	14.97
Prandtl Number	0.7268	3.9061	Total Heat Transferred (BTU/hr)	70,945
Bulk Visc (lbm/ft·hr)	0.0480	1.4379	, and the second se	
Skin Visc (lbm/ft·hr)	0.0000	1.4154	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0639	61.8144	Sensible Heat Transferred (BTU/hr)	70,945
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3677	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	20.10		,	
Relative Humidity Out (%)	22.52			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

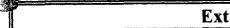
_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft²-°F)	965.76
Inlet Temperature (°F)	126.14	110.59	j Factor	0.0081
Outlet Temperature (°F)	122.52	112.22	Air-Side ho (BTU/hr·ft².°F)	8.13
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	124.33	111.4071	- '	
Skin Temperature (°F)	114.83	112.7959	U Overall (BTU/hr·ft².°F)	5.50
Velocity ***	3,364.26	2.9061	Effective Area (ft²)	860.06
Reynold's Number	814**	19,417	LMTD	12.82
Prandtl Number	0.7271	3.9819	Total Heat Transferred (BTU/hr)	60,626
Bulk Visc (lbm/ft·hr)	0.0478	1.4633	· · · · ·	·
Skin Visc (lbm/ft·hr)	0.0000	1.4433	Surface Effectiveness (Eta)	0.9196
Density (lbm/ft³)	0.0643	61.8400	Sensible Heat Transferred (BTU/hr)	60,626
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	-
K (BTU/hr-ft-°F)	0.0158	0.3670	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	22.52		,	
Relative Humidity Out (%)	24.87			

* Reynolds Number Outside Range of Equation Applicability

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^{***} Air Mass Velocity (Lbm/hr·ft2), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F) 957.79)
Inlet Temperature (°F)	122.52	109.20	j Factor 0.0081	
Outlet Temperature (°F)	119.42	110.59	Air-Side ho (BTU/hr·ft².°F) 8.12	-
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430)
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.02832467	,
Average Temp (°F)	120.97	109.8952		
Skin Temperature (°F)	112.83	111.0927	U Overall (BTU/hr·ft².°F) 5.49)
Velocity ***	3,364.26	2.9051	Effective Area (ft²) 860.06)
Reynold's Number	818**	19,126	LMTD 10.99)
Prandtl Number	0.7273	4.0486	Total Heat Transferred (BTU/hr) 51,842	2
Bulk Visc (lbm/ft·hr)	0.0475	1.4856		
Skin Visc (lbm/ft·hr)	0.0000	1.4679	Surface Effectiveness (Eta) 0.9197	7
Density (lbm/ft³)	0.0646	61.8615	Sensible Heat Transferred (BTU/hr) 51,842	2
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3665	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	24.87			
Relative Humidity Out (%)	27.10			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F) 950.95
Inlet Temperature (°F)	119.42	108.01	j Factor 0.0081
Outlet Temperature (°F)	116.77	109.20	Air-Side ho (BTU/hr·ft².°F) 8.11
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	118.09	108.6021	
Skin Temperature (°F)	111.12	109.6340	U Overall (BTU/hr· ft^2 .°F) 5.48
Velocity ***	3,364.26	2.9042	Effective Area (ft²) 860.06
Reynold's Number	821**	18,878	LMTD 9.42
Prandtl Number	0.7275	4.1072	Total Heat Transferred (BTU/hr) 44,357
Bulk Visc (lbm/ft·hr)	0.0474	1.5051	
Skin Visc (lbm/ft/hr)	0.0000	1.4895	Surface Effectiveness (Eta) 0.9198
Density (lbm/ft³)	0.0649	61.8797	Sensible Heat Transferred (BTU/hr) 44,357
Cp (BŤÙ/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0156	0.3660	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	27.10		•
Relative Humidity Out (%)	29.18		



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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 - 148 °F air side, 17,100 cfm, 107 °F water side, 75 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,878.21	37,240.41	Tube-Side hi (BTU/hr·ft².°F)	945.09
Inlet Temperature (°F)	116.77	106.99	j Factor (0.0081
Outlet Temperature (°F)	114.50	108.01	Air-Side ho (BTU/hr·ft².°F)	8.09
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft².°F/BTU) 0.000	31430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.028	32467
Average Temp (°F)	115.63	107.4955	,	
Skin Temperature (°F)	109.66	108.3843	U Overall (BTU/hr·ft².°F)	5.47
Velocity ***	3,364.26	2.9035	Effective Area (ft²)	860.06
Reynold's Number	824**	18,666	LMTD	8.08
Prandtl Number	0.7277	4.1584	Total Heat Transferred (BTU/hr)	37,971
Bulk Visc (lbm/ft·hr)	0.0472	1.5221	,	•
Skin Visc (lbm/ft·hr)	0.0000	1.5084	Surface Effectiveness (Eta)	0.9199
Density (lbm/ft³)	0.0652	61.8950	Sensible Heat Transferred (BTU/hr)	37,971
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0156	0.3656	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	29.18			
Relative Humidity Out (%)	31.12			

^{**} Reynolds Number Outside Range of Equation Applicability





Formulas from Sec	ction 6.7 for iteration process to determine in	let airflow	for extrapolation	conditions
Total P:	P =		14.315	psia
Dry Bulb T OUT:	T1 =		114.5	F
Specific Hum.:	W =		0.0202	
H2O Vap. P:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =		0.450285048	
		Rv =	85.778	(ft-lbf)/(lbm-R)
		Ra =		(ft-lbf)/(lbm-R)
Dry Air P:	Pa = P - Pv =		13.864715	psia
Dry Air rho OUT:	rho.out = (144/Ra)*(Pa/(459.67+T1)) =		0.065175	lbm/ft^3
Dry Air rho IN:	rho.in = (144/Ra)*(Pa/(459.67+T2)) =		0.061582	lbm/ft^3
Dry Bulb T IN:	T2 =		148	F
Outlet Air Flow:	V =		17100	cfm
cfm.in	cfm.in = V*(rho.out/rho.in) =		18097.70	acfm



04-25-2012 13:51:45 PROTO-HX 4.01 by Proto-Power Corporation (SN#PHX-1002)

ComEd -- LaSalle

Data Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged

Air Coil Heat Exchanger Input Parameters

ass Flow Bulb (Inlet Temperature) Bulb (In		Air-Side		Tube-Side
Bulb (Inlet Temperature) 150.00 °F 105.00 °F to Wet Bulb Temperature 92.00 °F to Wet Bulb Temperature 109.40 °F 115.30 °F to Wet Bulb Temperature 109.40 °F 115.30 °F to Wet Bulb Temperature 84.10 °F to Wet Bulb Temperature 109.00 % to Wet Bulb Temperature 109.40 °F to Wet Bulb Temperature	low	21,179.00	acfm	150.00 gpm
tet Wet Bulb Temperature et Relative Humidity	Mass Flow			0.00 lbm/
tet Relative Humidity Bulb (Outlet Temperature) Bulb (Outlet Bulb (Outlet Temperature) Bulb (Outlet	Ory Bulb (Inlet Temperature)			105.00 °F
Bulb (Outlet Temperature) tlet Wet Bulb Temperature tlet Relative Humidity be Fluid Name be-Side Fouling -Side VY Coolers 01A/02A -Side Fouling -	nlet Wet Bulb Temperature			
tlet Wet Bulb Temperature tlet Relative Humidity De Fluid Name De Fluid Name De Fluid Name De Side Fouling De Sign Q (BTU/hr) De Sign Q (BTU/hr) De Sign Sensible Heat Ratio Deformance Factor (% Reduction) Deformance Facto	nlet Relative Humidity			
telet Relative Humidity De Fluid Name De Fluid Name De Fluid Fouling De Fluid Name De Side Fouling De State Foul				115.30 °F
be Fluid Name be-Side Fouling				
De-Side Fouling 0.001500 0.000000 0.000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.0000000 0.00000000		0.00	70	
Conductivity (BTU/hr ft °F) Cond	ube Fluid Name			
sign Q (BTU/hr) mospheric Pressure (psia) sign Sensible Heat Ratio formance Factor (% Reduction) il Flow Direction Type Tippe Circular Fins Infiguration (for Air-Side h) il Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Root Thickness (inches) Tip Height (inches) mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row the Inside Diameter (in) the Outside Diameter (in)				
Inospheric Pressure (psia) Isign Sensible Heat Ratio Informance Factor (% Reduction) It Flow Direction Itype Ity	Air-Side Fouling			0.000000
sign Sensible Heat Ratio formance Factor (% Reduction) il Flow Direction Type Circular Fins I LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] il Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row the Inside Diameter (in) be Outside Diameter (in) cular V Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] 104.250 10.000 104.250 10.000 105.270 106.250 107.200 108.2000 109.200	Design Q (BTU/hr)			750,000
If Flow Direction Type Infiguration (for Air-Side h) It Length (in) It Length (in) It Conductivity (BTU/hr-ft-°F) It Root Thickness (inches) It Root Thickness (inches) It Root Thickness (inches) It Root Thickness (inches) It Derive of Tubes Per Row It Tubes Per Row It De Inside Diameter (in) It De Outside Diameter (in) It De Outside Diameter (in) It provides the first of Serpentines It provides the form of Serpentines It provides the form of Coultry (BTU/hr-ft-°F) It provides the first of Coultry (BTU/hr-	Atmospheric Pressure (psia)			14.315
Counter Flow Circular Fins (Type Circular Fins Infiguration (for Air-Side h) LaSalle VY Coolers 01A/02A $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ id Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Tip Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Tip Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Tip Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Tip Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Coular Fin Height (inches) Tip Thickness (inches) Coular Fin Height (inches) Coular Fin Height (inches) 1.495 Thickness (inches) Coular Fin Height (inches) Coular Fin Height (inches) 1.495 Thickness (inches) Coular Fin Height (inches) 1.495 Thickness (i	Design Sensible Heat Ratio			
Type Circular Fins Infiguration (for Air-Side h) LaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ It Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) The Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Tip Thickness (Performance Factor (% Reduction)			0.000
Infiguration (for Air-Side h) LaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Id Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Coular Fin Height (inches) Independent of Tube Rows Independent of Tubes Per Row The Inside Diameter (in) The Outside Diameter	oil Flow Direction			Counter Flow
j = EXP[-2.5088 + -0.3436 * LOG(Re)] il Length (in) $Pitch (Fins/Inch)$ $Conductivity (BTU/hr·ft·°F)$ $Tip Thickness (inches)$ $Root Thickness (inches)$ $Cular Fin Height (inches)$ $The example of Coils Per Unit$ $The example of Tubes Per Row$ $The example of Tubes Per Row$ $The example of Tubes Per Row$ $Tubes Pe$	in Type			Circular Fins
il Length (in) Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row to Elnside Diameter (in) Conductivity (BTU/hr·ft·°F) 128.000 129.00120 129.001	Configuration (for Air-Side h)		LaSalle	VY Coolers 01 A/02 A
Pitch (Fins/Inch) Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) The Root Thickness (inches) Cular Fin Height (inches) The Root Thickness (inches) Cular Fin Height (inches) The Root Thickness (inches) The Root Thickness (inches) Thickness (inches)		j = EXF	P[-2.5088 +	+ -0.3436 * LOG(Re)
Conductivity (BTU/hr·ft·°F) Tip Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) Tip Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) The Coils Per Unit Thickness (inches) Thickne	oil Length (in)			104.250
Tip Thickness (inches) Root Thickness (inches) Cular Fin Height (inches) The Thickness (inches) Cular Fin Height (inches) The Thickness (inches) Cular Fin Height (inches) The Coils Per Unit The Thickness (inches) The Coils Per Unit The Thickness (inches) The Coils Per Unit The Per Coils Per Unit The Thickness (inches) The Coils Per Unit The Per Coils Per	in Pitch (Fins/Inch)			10.000
Root Thickness (inches) cular Fin Height (inches) mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row be Inside Diameter (in) be Outside Diameter (in) cular Fin Height (inches) 0.0120 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2	in Conductivity (BTU/hr·ft·°F)			128.000
mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row be Inside Diameter (in) be Outside Diameter (in) ngitudinal Tube Pitch (in) unsverse Tube Pitch (in) mber of Serpentines 1.495 2 2 20.00 19.00 0.5270 0.6250 1.500 1.452				
mber of Coils Per Unit mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row be Inside Diameter (in) be Outside Diameter (in) ngitudinal Tube Pitch (in) ansverse Tube Pitch (in) mber of Serpentines 2 20.00 19	·			
mber of Tube Rows mber of Tubes Per Row tive Tubes Per Row 19.00 be Inside Diameter (in) be Outside Diameter (in) ngitudinal Tube Pitch (in) 1.500 ansverse Tube Pitch (in) 1.452 mber of Serpentines 1.000	ircular Fin Height (inches)			1.495
mber of Tubes Per Row tive Tubes Per Row 19.00 be Inside Diameter (in) 0.5270 be Outside Diameter (in) 0.6250 ngitudinal Tube Pitch (in) 1.500 unsverse Tube Pitch (in) 1.452 mber of Serpentines 1.000	lumber of Coils Per Unit			
tive Tubes Per Row 19.00 be Inside Diameter (in) be Outside Diameter (in) ngitudinal Tube Pitch (in) ansverse Tube Pitch (in) 1.500 1.452 mber of Serpentines 1.000	Number of Tube Rows			
be Inside Diameter (in) be Outside Diameter (in) ngitudinal Tube Pitch (in) ansverse Tube Pitch (in) 1.500 1.452 mber of Serpentines 1.000	Number of Tubes Per Row			
be Outside Diameter (in) ngitudinal Tube Pitch (in) nsverse Tube Pitch (in) mber of Serpentines 0.6250 1.500 1.452	Active Tubes Per Row			19.00
ngitudinal Tube Pitch (in) nsverse Tube Pitch (in) 1.500 1.452 mber of Serpentines 1.000	ube Inside Diameter (in)			0.5270
mber of Serpentines 1.452 1.452	Tube Outside Diameter (in)			0.6250
mber of Serpentines 1.000	ongitudinal Tube Pitch (in)			1.500
•	ransverse Tube Pitch (in)			1.452
•	umhar of Sarnantinos			1 000
225.00	•			
	abe Conductivity (B10/III-II-F)			223.00





Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure (psia)

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,212.00
Tube Inlet Temp (°F)	107.00
Air Inlet Temp (°F)	153.00
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	14.315

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged

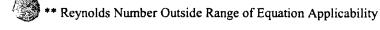


	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F)	0.00
Inlet Temperature (°F)	153.00	107.00	j Factor	0.0000
Outlet Temperature (°F)	114.36	119.71	Air-Side ho (BTU/hr-ft2.°F)	0.00
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²-°F/BTU)	0.02832467
			U Overall (BTU/hr·ft².°F)	
			Effective Area (ft²)	6,880.52
			LMTD	0.00
			Total Heat Transferred (BTU/hr)	681,320
			Surface Effectiveness (Eta)	0.0000
			Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr) Heat to Condensate (BTU/hr)	681,320



Extrapolation Calculation for Row 1(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F)	1,341.67
Inlet Temperature (°F)	153.00	116.88	j Factor	0.0081
Outlet Temperature (°F)	144.40	119.71	Air-Side ho (BTU/hr·ft².°F)	8.49
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2-°F/BTU) (0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	148.70	118.2967	,	
Skin Temperature (°F)	125.88	120.7965	U Overall (BTU/hr·ft².°F)	5.84
Velocity ***	3,527.02	4.1917	Effective Area (ft²)	860.06
Reynold's Number	827**	29,901	LMTD	30.19
Prandtl Number	0.7250	3.6993	Total Heat Transferred (BTU/hr)	151,661
Bulk Visc (lbm/ft·hr)	0.0493	1.3683	,	
Skin Visc (lbm/ft·hr)	0.0000	1.3364	Surface Effectiveness (Eta)	0.9164
Density (lbm/ft³)	0.0617	61.7379	Sensible Heat Transferred (BTU/hr)	151,661
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0163	0.3695	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	12.76		,	
Relative Humidity Out (%)	15.80			



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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F)	1,323.45
Inlet Temperature (°F)	144.40	114.55	j Factor	0.0081
Outlet Temperature (°F)	137.31	116.88	Air-Side ho (BTU/hr·ft².°F)	8.46
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	140.86	115.7147	-	
Skin Temperature (°F)	121.99	117.8022	U Overall (BTU/hr·ft²·°F)	5.82
Velocity ***	3,527.02	4.1891	Effective Area (ft²)	860.06
Reynold's Number	835**	29,168	LMTD	24.96
Prandtl Number	0.7258	3.8012	Total Heat Transferred (BTU/hr)	124,935
Bulk Visc (lbm/ft·hr)	0.0488	1.4027		
Skin Visc (lbm/ft·hr)	0.0000	1.3748	Surface Effectiveness (Eta)	0.9167
Density (lbm/ft³)	0.0624	61.7769	Sensible Heat Transferred (BTU/hr)	124,935
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3686	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	15.80		` ,	
Relative Humidity Out (%)	18.94			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F) 1,308.	.37
Inlet Temperature (°F)	137.31	112.62	j Factor 0.00	
Outlet Temperature (°F)	131.47	114.55	Air-Side ho (BTU/hr-ft ² .°F) 8.	.43
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft².°F/BTU) 0.000314	30
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU) 0.028324	67
Average Temp (°F)	134.39	113.5865	. ,	
Skin Temperature (°F)	118.78	115.3281	U Overall (BTU/hr·ft².°F) 5.	.80
Velocity ***	3,527.02	4.1869	Effective Area (ft²) 860.	.06
Reynold's Number	842**	28,569	LMTD 20.	.66
Prandtl Number	0.7263	3.8888	Total Heat Transferred (BTU/hr) 103,0	155
Bulk Visc (lbm/ft·hr)	0.0484	1.4321	,	
Skin Visc (lbm/ft·hr)	0.0000	1.4080	Surface Effectiveness (Eta) 0.91	69
Density (lbm/ft ³)	0.0630	61.8084	Sensible Heat Transferred (BTU/hr) 103,0	55
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0160	0.3678	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	18.94		` ,	
Relative Humidity Out (%)	22.09			

* Reynolds Number Outside Range of Equation Applicability

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^{***} Air Mass Velocity (Lbm/hr ft2), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F)	1,295.89
Inlet Temperature (°F)	131.47	111.04	j Factor	0.0080
Outlet Temperature (°F)	126.64	112.62	Air-Side ho (BTU/hr·ft².°F)	8.41
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	129.06	111.8301	-	
Skin Temperature (°F)	116.14	113.2821	U Overall (BTU/hr·ft ² .°F)	5.78
Velocity ***	3,527.02	4.1852	Effective Area (ft²)	860.06
Reynold's Number	848**	28,078	LMTD	17.11
Prandtl Number	0.7268	3.9635	Total Heat Transferred (BTU/hr)	85,102
Bulk Visc (lbm/ft·hr)	0.0481	1.4571		
Skin Visc (lbm/ft·hr)	0.0000	1.4364	Surface Effectiveness (Eta)	0.9171
Density (lbm/ft³)	0.0636	61.8339	Sensible Heat Transferred (BTU/hr)	85,102
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3672	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	22.09		` ,	
Relative Humidity Out (%)	25.14			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F) 1,285.54	ļ
Inlet Temperature (°F)	126.64	109.72	j Factor 0.0080	
Outlet Temperature (°F)	122.66	111.04	Air-Side ho (BTU/hr·ft².°F) 8.39	į
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430	j
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU) 0.02832467	,
Average Temp (°F)	124.65	110.3790		
Skin Temperature (°F)	113.95	111.5888	U Overall (BTU/hr·ft².°F) 5.77	,
Velocity ***	3,527.02	4.1838	Effective Area (ft ²) 860.06	,
Reynold's Number	853**	27,675	LMTD 14.17	,
Prandtl Number	0.7271	4.0271	Total Heat Transferred (BTU/hr) 70,341	
Bulk Visc (lbm/ft·hr)	0.0478	1.4784		
Skin Visc (lbm/ft·hr)	0.0000	1.4606	Surface Effectiveness (Eta) 0.9173	j
Density (lbm/ft³)	0.0640	61.8546	Sensible Heat Transferred (BTU/hr) 70,341	
Cp (BTU/lbm-°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3667	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	25.14		,,	
Relative Humidity Out (%)	28.03			



^{**} Reynolds Number Outside Range of Equation Applicability

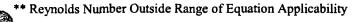
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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F) 1,2	76.97
Inlet Temperature (°F)	122.66	108.64	j Factor 0	.0080
Outlet Temperature (°F)	119.36	109.72	Air-Side ho (BTU/hr·ft².°F)	8.37
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2.°F/BTU) 0.0003	31430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU) 0.0283	32467
Average Temp (°F)	121.01	109.1793	•	
Skin Temperature (°F)	112.14	110.1867	U Overall (BTU/hr-ft ² .°F)	5.76
Velocity ***	3,527.02	4.1826	Effective Area (ft²) 8	60.06
Reynold's Number	857**	27,343	LMTD	11.74
Prandtl Number	0.7273	4.0809	Total Heat Transferred (BTU/hr) 5.	8,184
Bulk Visc (lbm/ft·hr)	0.0475	1.4963		
Skin Visc (lbm/ft·hr)	0.0000	1.4812	Surface Effectiveness (Eta) 0	.9174
Density (lbm/ft³)	0.0644	61.8716	Sensible Heat Transferred (BTU/hr) 5	8,184
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0157	0.3662	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	28.03		,	
Relative Humidity Out (%)	30.71			



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F) 1,269.	.86
Inlet Temperature (°F)	119.36	107.74	j Factor 0.00	080
Outlet Temperature (°F)	116.63	108.64	Air-Side ho (BTU/hr·ft²-°F) 8.	.36
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft².°F/BTU) 0.000314	130
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU) 0.028324	67
Average Temp (°F)	117.99	108.1866		
Skin Temperature (°F)	110.64	109.0251	U Overall (BTU/hr·ft².°F) 5.	.75
Velocity ***	3,527.02	4.1817	Effective Area (ft ²) 860.	.06
Reynold's Number	861**	27,069	LMTD 9.	.74
Prandtl Number	0.7275	4.1263	Total Heat Transferred (BTU/hr) 48,1	59
Bulk Visc (lbm/ft·hr)	0.0474	1.5115	, , ,	
Skin Visc (lbm/ft·hr)	0.0000	1.4987	Surface Effectiveness (Eta) 0.91	75
Density (lbm/ft³)	0.0647	61.8854	Sensible Heat Transferred (BTU/hr) 48,1	.59
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3659	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	30.71		` ,	
Relative Humidity Out (%)	33.15			



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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 108 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,113.67	53,626.19	Tube-Side hi (BTU/hr·ft².°F) 1,263.	97
Inlet Temperature (°F)	116.63	106.99	j Factor 0.00	80
Outlet Temperature (°F)	114.36	107.74	Air-Side ho (BTU/hr·ft².°F) 8.	35
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft².°F/BTU) 0.000314	30
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU) 0.028324	67
Average Temp (°F)	115.49	107.3648	,	
Skin Temperature (°F)	109.40	108.0624	U Overall (BTU/hr·ft².°F) 5.	74
Velocity ***	3,527.02	4.1809	Effective Area (ft²) 860.	06
Reynold's Number	864**	26,843	LMTD 8.	.07
Prandtl Number	0.7277	4.1645	Total Heat Transferred (BTU/hr) 39,8	83
Bulk Visc (lbm/ft·hr)	0.0472	1.5242	,	
Skin Visc (lbm/ft·hr)	0.0000	1.5134	Surface Effectiveness (Eta) 0.91	76
Density (lbm/ft³)	0.0649	61.8968	Sensible Heat Transferred (BTU/hr) 39,8	83
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3656	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	33.15		. ,	
Relative Humidity Out (%)	35.34			







Total P:	ction 6.7 for iteration process to determine in	101 01111011	14.315	
	r-			<u> </u>
Dry Bulb T OUT:	T1 =		114.36	F
Specific Hum.:	W =		0.023	
H2O Vap. P:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =		0.510475042	
		Rv =		(ft-lbf)/(lbm-R)
		Ra =	53.352	(ft-lbf)/(lbm-R)
Dry Air P:	Pa = P - Pv =		13.80452	psia
Dry Air rho OUT:	rho.out = (144/Ra)*(Pa/(459.67+T1)) =		0.064908	lbm/ft^3
Dry Air rho IN:	rho.in = (144/Ra)*(Pa/(459.67+T2)) =		0.060814	lbm/ft^3
Dry Bulb T IN:	T2 =		153	F
Outlet Air Flow:	V =		18000	cfm
cfm.in	cfm.in = V*(rho.out/rho.in) =		19211.64	acfm



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ComEd -- LaSalle

Data Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged

Air Coil Heat Exchanger Input Parameters

	Air-Side		Tube-Side	~
Flow Mass Flow	21,179.00 0.00	acfm lbm/hr	150.00 gpm 0.00 lbm/k	ır
Dry Bulb (Inlet Temperature) Inlet Wet Bulb Temperature	150.00 92.00	°F	105.00 °F	
Inlet Relative Humidity Dry Bulb (Outlet Temperature) Outlet Wet Bulb Temperature Outlet Relative Humidity	0.00 109.40 84.10 0.00	°F °F	115.30 °F	
Tube Fluid Name Tube-Side Fouling Air-Side Fouling			Fresh Water 0.001500 0.000000	-
Design Q (BTU/hr) Atmospheric Pressure (psia) Design Sensible Heat Ratio Performance Factor (% Reduction)			750,000 14.315 1.00 0.000	
Coil Flow Direction Fin Type Configuration (for Air-Side h)	j = EXP		Counter Flow Circular Fins Y Coolers 01A/02A 0.3436 * LOG(Re)]	
Coil Length (in) Fin Pitch (Fins/Inch) Fin Conductivity (BTU/hr·ft·°F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches)			104.250 10.000 128.000 0.0120 0.0120 1.495	
Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row			2 8 20.00 19.00	
Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in)			0.5270 0.6250 1.500 1.452	07 200
Number of Serpentines Tube Conductivity (BTU/hr·ft-°F)			1.000 225.00	97-200 Rev. A05 Attachment C Page C1 of C8





Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure (psia)

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	158.00
Air Flow (acfm)	19,248.00
Tube Inlet Temp (°F)	107.00
Air Inlet Temp (°F)	153.00
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	14.315

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr-ft2.°F)	0.00
Inlet Temperature (°F)	153.00	107.00	j Factor	0.0000
Outlet Temperature (°F)	113.28	115.98	Air-Side ho (BTU/hr·ft².°F)	0.00
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU)	0.02832467
			U Overall (BTU/hr·ft².°F)	
			Effective Area (ft²)	6,880.52
			LMTD	0.00
			Total Heat Transferred (BTU/hr)	701,741
			Surface Effectiveness (Eta)	0.0000
			Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr) Heat to Condensate (BTU/hr)	701,741



Extrapolation Calculation for Row 1(Dry)

	Air-Side_	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,786.84
Inlet Temperature (°F)	153.00	113.82	j Factor	0.0081
Outlet Temperature (°F)	143.40	115.98	Air-Side ho (BTU/hr·ft².°F)	8.50
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
Average Temp (°F)	148.20	114.9014		
Skin Temperature (°F)	122.69	117.0014	U Overall (BTU/hr·ft².°F)	5.97
Velocity ***	3,533.63	6.1272	Effective Area (ft²)	860.06
Reynold's Number	829**	42,337	LMTD	33.06
Prandtl Number	0.7251	3.8343	Total Heat Transferred (BTU/hr)	169,688
Bulk Visc (lbm/ft·hr)	0.0492	1.4138		
Skin Visc (lbm/ft·hr)	0.0000	1.3854	Surface Effectiveness (Eta)	0.9163
Density (lbm/ft³)	0.0618	61.7890	Sensible Heat Transferred (BTU/hr)	169,688
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0163	0.3683	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	12.76			
Relative Humidity Out (%)	16.21			



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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F) 1,767.91
Inlet Temperature (°F)	143.40	112.09	j Factor 0.0081
Outlet Temperature (°F)	135.75	113.82	Air-Side ho (BTU/hr·ft²·°F) 8.46
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	139.57	112.9565	
Skin Temperature (°F)	119.18	114.6465	U Overall (BTU/hr·ft ² .°F) 5.95
Velocity ***	3,533.63	6.1244	Effective Area (ft²) 860.06
Reynold's Number	838**	41,538	LMTD 26.43
Prandtl Number	0.7259	3.9153	Total Heat Transferred (BTU/hr) 135,127
Bulk Visc (lbm/ft·hr)	0.0487	1.4410	, , ,
Skin Visc (lbm/ft·hr)	0.0000	1.4173	Surface Effectiveness (Eta) 0.9166
Density (lbm/ft³)	0.0626	61.8176	Sensible Heat Transferred (BTU/hr) 135,127
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0161	0.3676	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	16.21		•
Relative Humidity Out (%)	19.73		



Extrapolation Calculation for Row 3(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,752.78
Inlet Temperature (°F)	135.75	110.72	j Factor	0.0080
Outlet Temperature (°F)	129.65	112.09	Air-Side ho (BTU/hr·ft².°F)	8.43
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	132.70	111.4066		
Skin Temperature (°F)	116.38	112.7661	U Overall (BTU/hr·ft²·°F)	5.93
Velocity ***	3,533.63	6.1222	Effective Area (ft²)	860.06
Reynold's Number	846**	40,905	LMTD	21.14
Prandtl Number	0.7265	3.9819	Total Heat Transferred (BTU/hr)	107,769
Bulk Visc (lbm/ft·hr)	0.0483	1.4633	, ,	ŕ
Skin Visc (lbm/ft·hr)	0.0000	1.4437	Surface Effectiveness (Eta)	0.9169
Density (lbm/ft³)	0.0632	61.8400	Sensible Heat Transferred (BTU/hr)	107,769
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	ŕ
K (BTU/hr·ft·°F)	0.0160	0.3670	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	19.73		,	
Relative Humidity Out (%)	23.19			

^{**} Reynolds Number Outside Range of Equation Applicability

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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged

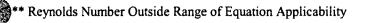
Extrapolation Calculation for Row 4(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F) 1,740.6	58
Inlet Temperature (°F)	129.65	109.62	j Factor 0.008	30
Outlet Temperature (°F)	124.78	110.72	Air-Side ho (BTU/hr·ft².°F) 8.4	11
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft²-°F/BTU) 0.0003143	30
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft²-°F/BTU) 0.0283246	57
Average Temp (°F)	127.21	110.1699	- '	
Skin Temperature (°F)	114.15	111.2629	U Overall (BTU/hr·ft²-°F) 5.9	€1
Velocity ***	3,533.63	6.1204	Effective Area (ft²) 860.0	
Reynold's Number	852**	40,403	LMTD 16.9	€2
Prandtl Number	0.7269	4.0364	Total Heat Transferred (BTU/hr) 86,05	54
Bulk Visc (lbm/ft·hr)	0.0479	1.4815		
Skin Visc (lbm/ft·hr)	0.0000	1.4654	Surface Effectiveness (Eta) 0.917	71
Density (lbm/ft³)	0.0638	61.8576	Sensible Heat Transferred (BTU/hr) 86,05	54
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3666	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	23.19		•	
Relative Humidity Out (%)	26.45			

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,730.99
Inlet Temperature (°F)	124.78	108.74	j Factor	0.0080
Outlet Temperature (°F)	120.88	109.62	Air-Side ho (BTU/hr-ft2.°F)	8.39
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft²-°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr-ft ² .°F/BTU)	0.02832467
Average Temp (°F)	122.83	109.1819		
Skin Temperature (°F)	112.37	110.0604	U Overall (BTU/hr·ft ² .°F)	5.90
Velocity ***	3,533.63	6.1191	Effective Area (ft²)	860.06
Reynold's Number	857**	40,003	LMTD	13.55
Prandtl Number	0.7272	4.0807	Total Heat Transferred (BTU/hr)	68,781
Bulk Visc (lbm/ft·hr)	0.0477	1.4963	,	
Skin Visc (lbm/ft·hr)	0.0000	1.4831	Surface Effectiveness (Eta)	0.9173
Density (lbm/ft³)	0.0642	61.8715	Sensible Heat Transferred (BTU/hr)	68,781
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3662	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	26.45			
Relative Humidity Out (%)	29.44			



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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,723.23
Inlet Temperature (°F)	120.88	108.04	j Factor	0.0080
Outlet Temperature (°F)	117.77	108.74	Air-Side ho (BTU/hr·ft²-°F)	8.38
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2-°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	119.33	108.3920		
Skin Temperature (°F)	110.94	109.0979	U Overall (BTU/hr·ft ² .°F)	5.89
Velocity ***	3,533.63	6.1180	Effective Area (ft²)	860.06
Reynold's Number	861**	39,684	LMTD	10.86
Prandtl Number	0.7275	4.1168	Total Heat Transferred (BTU/hr)	55,019
Bulk Visc (lbm/ft·hr)	0.0474	1.5083		
Skin Visc (lbm/ft·hr)	0.0000	1.4976	Surface Effectiveness (Eta)	0.9174
Density (lbm/ft³)	0.0645	61.8826	Sensible Heat Transferred (BTU/hr)	55,019
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3660	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	29.44		,	
Relative Humidity Out (%)	32.10		·	



Extrapolation Calculation for Row 7(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,717.01
Inlet Temperature (°F)	117.77	107.48	j Factor	0.0080
Outlet Temperature (°F)	115.28	108.04	Air-Side ho (BTU/hr·ft².°F)	8.36
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	116.52	107.7600		
Skin Temperature (°F)	109.80	108.3270	U Overall (BTU/hr·ft².°F)	5.88
Velocity ***	3,533.63	6.1171	Effective Area (ft²)	860.06
Reynold's Number	864**	39,430	LMTD	8.70
Prandtl Number	0.7276	4.1460	Total Heat Transferred (BTU/hr)	44,037
Bulk Visc (lbm/ft·hr)	0.0473	1.5180		
Skin Visc (lbm/ft·hr)	0.0000	1.5093	Surface Effectiveness (Eta)	0.9175
Density (lbm/ft³)	0.0648	61.8914	Sensible Heat Transferred (BTU/hr)	44,037
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3657	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	32.10		, ,	
Relative Humidity Out (%)	34.44			

^{**} Reynolds Number Outside Range of Equation Applicability

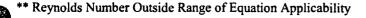
97-200 Rev. A05 Attachment C Page C6 of C8

^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 - 153 °F air side, 18,000 cfm, 107 °F water side, 158 gpm, Design FF, 1 tube plugged

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft².°F)	1,712.02
Inlet Temperature (°F)	115.28	107.03	j Factor	0.0080
Outlet Temperature (°F)	113.28	107.48	Air-Side ho (BTU/hr-ft2.°F)	8.35
Inlet Specific Humidity	0.023032		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.023032		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	114.28	107.2540	<u>-</u> ` ,	
Skin Temperature (°F)	108.89	107.7094	U Overall (BTU/hr·ft ^{2.} °F)	5.88
Velocity ***	3,533.63	6.1164	Effective Area (ft²)	860.06
Reynold's Number	867**	39,226	LMTD	6.98
Prandtl Number	0.7278	4.1697	Total Heat Transferred (BTU/hr)	35,265
Bulk Visc (lbm/ft·hr)	0.0471	1.5259	,	,
Skin Visc (lbm/ft·hr)	0.0000	1.5188	Surface Effectiveness (Eta)	0.9176
Density (lbm/ft³)	0.0650	61.8983	Sensible Heat Transferred (BTU/hr)	35,265
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	,
K (BTU/hr·ft·°F)	0.0156	0.3655	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	34.44		,	
Relative Humidity Out (%)	36.45			







Total P:	P =		14.315	psia
Dry Bulb T OUT:	T1 =		113.28	F
Specific Hum.:	W =		0.023	
H2O Vap. P:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =		0.510475042	psia
		Rv =	85.778	(ft-lbf)/(lbm-R)
		Ra =	53.352	(ft-lbf)/(lbm-R)
Dry Air P:	Pa = P - Pv =		13.80452	psia
Dry Air rho OUT:	rho.out = (144/Ra)*(Pa/(459.67+T1)) =		0.065030	lbm/ft^3
Dry Air rho IN:	rho.in = (144/Ra)*(Pa/(459.67+T2)) =		0.060814	lbm/ft^3
Dry Bulb T IN:	T2 =		153	F
Outlet Air Flow:	V =		18000	cfm
cfm.in	cfm.in = V*(rho.out/rho.in) =		19247.86	acfm





ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Page 1 Last Page No. 6 1 Design Analysis (Minor Revision) Revision: 2 A04 97-200 Analysis No.: 1 Title: 3 VY Cooler Thermal Performance Model - 1(2)VY01A and 1(2)VY02A Revision: 5 EC/ECR No.: 1 384525 000 Station(s): 7 LaSalle Unit No.: 8 02 Safety/QA Class: 9 SR System Code(s): 10 HP, E22, DG, VY Yes 🗌 No 🛛 Is this Design Analysis Safeguards Information? " If yes, see SY-AA-101-106 Does this Design Analysis contain Unverified Assumptions? 12 Yes ☐ No 🛛 If yes, ATI/AR#: N/A This Design Analysis SUPERCEDES: 13 N/A in its entirety. Description of Changes (list affected pages): " EC 384525 revised the flows in Division 3 of the Unit 2 CSCS. This revision makes the changes made in Revision A03 applicable to both Units. Disposition of Changes: 15 As shown in Attachment A of Revision A03, the changes made are acceptable. The additional 50 gpm is acceptable. No formal heat transfer analysis will be performed. Preparer: 16 Sean Tanton Print Name Alternate Calculations Testing 🗌 Method of Review: 17 Detailed Review 🛛 Reviewer: 18 Matthew Cosenza Print Name Review Independent review 🖂 Peer review Notes: 19 (For External Analyses Only) N/A N/A N/A External Approver: 20 Print Name Sign Name Date Exelon Reviewer 21 N/A N/A N/A Print Name Sign Name Date Exelon Approver: 22 Dan Schmit Print Name

Sign Name



Page 1



ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet

Design Analysis (I	Design Analysis (Minor Revision)		Last Page No. 1		
Analysis No.: '	97-200	Revision: '	A03.		
Title: '	VY Cooler Thermal Performance Mo	odel - 1(2)VY0	1A and 1(2)VY02A		
EC/ECR No.: 1	370853	Revision: 1	000		
Station(s): '	LaSalle				
Unit No.: *	01				
Safety/QA Class: 1	SR				
System Code(s): "	P HP, E22, DG				
Is this Design Ana	lysis Safeguards Information? "	Yes 🗌	No 🗵 If yes, see S	/-AA-101-106	
Does this Design Ar	alysis contain Unverified Assumption	s? '' Yes 🗌	No 🛛 If yes, ATI/AF	R#: N/A	
This Design Analy	sis SUPERCEDES: " N/A			n its entirety.	
To recover available recover margin, 10t to the 1E22-C001 p documents the chair Note that this analy Unit 1 (1VY02A coordisposition of Chair The minimum flow flow through the countait have been run	sis covers the 1(2)VY02A and the 1(2) oler). The flows shown for the remaining anges: " required to remove the design heat to olers is increasing by 50 gpm, the he in this calculation will remain bounding tubes to a point that would exceed	S001 cooler. Ogiven to the 1V 2)VY01A cooler ping coolers are that of 646,235 at transfer will the	Of this 100 gpm, 50 gpm Y02A cooler. This mino rs. This revision only ap not impacted by this re Btu/hr has not changed be greater and the previse in flow will not increase	will be returned revision pplies to Div. 3, vision. Because the ous scenarios se the velocity of	
Preparer: *	Sean Tanton	Sean V	Littera Sign Harns	5/3//11	
Method of Review		ate Calculatio	ns 🔲 Testing 🗌	- 2 048	
Reviewer: *	Matthew Cosenza	Mean	En	6/1/11	
Review Notes: **	Independent review 🖾 Pee	er review 🗌	Sign Pales	fine .	
(For Enema Analyses Orby) External Approve			N/A	N/A	
Exelon Reviewer	Print Name N/A Print Name		Sign Name N/A Sign Name	Onte N/A Ente	
Exelon Approver:	² Dan Schmit		Elisait	4/1/11	

ATTACHMENT 2 Design Analysis Minor Revision Cover Sheet Page 1 of

		4 Plus 4# A	Last Page No. 3 -
Analysis No.	97-200	Page A1 - A7 A+1 B	Revision A02
EC/ECR No.	356225	Par B1-B7	Revision 0
Title:	VY Cooler Thermal Performance	Model - 1(2)VY01A and 1(2)VY02A	
Station(s)	LaSalle	ls this Design Analysis Safeguards?	Yes ☐ No 🏻
Unit No.:	01/02	Does this Design Analysis Contain Unverified Assumptions?	Yes ☐ No ⊠
Safety Class	SR		
System Code	VY	ATI/AR#	
Description of (Change		
		required into the 1(2)VY01A coolers by 5 w.The 1(2)VY02A coolers were not change	
new maximum	louing factor at this reduced all no	w. The T(2)V TOZA coolers were not charg	ged.
			,
Disposition of C	Changes (include additional pages	as required)	
•	heets. The change is acceptable.	,	
			:
Preparer Te	erry Martin	72.2	7/6/05
	Print Name	Sign Name	Date
Reviewer/	DAN SCHMIT	Da Submit	7/6/05
_	Print Name	Sign Name	Date
Method of Revi	iew 🗹 Detailed Review	Alternate Calculations	Testing
Review Notes:	walk- los	1500 (1). Chi	<i></i>
Approver	Print Name		7-6-05
(For External Analyses O		Sign Name	Date
Exelon Review		O's a Ni	B
Approver	Print Name	Sign Name	Date
, (bb) 0 4 e)	Print Name	Sign Name	Date

Purpose:

The purpose of this minor revision is to revise the thermal model of the 1(2)VY01A coolers for a 5% reduction in airflow. This assessment will evaluate the adequacy of these heat exchangers with a maximum allowable inlet service water temperature of 104°F, using the design fouling factor of 0.02832467 hr*ft²*°F/BTU, and 5% tube plugging. Another case will be run to find the maximum fouling factor with the 5% reduction in air flow and 5% of the tubes plugged.

The design inputs consist of Reference 1 listed below.

The assumptions indicated in section 5.0 of Reference 1 are still valid.

References:

1. Calculation No. 97-200, Rev. A, "VY Cooler Thermal Performance Model – 1(2)VY01A and 1(2)VY02A."

Identification of Computer Programs:

Proto Hx version 4.01 is used for this minor revision. The same software was used for the other revisions in this calculation.

Method of Analysis and Acceptance Criteria:

The existing heat exchanger model will be revised by changing the input of the air inlet flow rate. The 5% reduction is calculated on the exit of the cooler. This reduction in flow along with the 5% plugged tubes, design fouling factor, and 104°F incoming cooling water was used to determine the thermal margin of the coolers and the maximum fouling factor. The acceptance criteria will be for the calculated heat transfer to exceed the LaSalle design heat load of 517,239 BTU/hr for 1(2)VY01A coolers (See Reference 1, Table 1). The original benchmark model developed for these heat exchangers demonstrated a correlation to vendor performance specification within an assumed 5% margin.

Analysis:

All input parameters except for air flow rate have remained the same and will not change for this model. Proto HX requires the inlet air flow rate, but our flow device is located on the exit of the heat exchanger. The current analyzed exit flow rate is taken from the 8th row of the cooler (see Reference 1 Rev A00 Attachment B, page B8), which is 70,628.98 lbm/hr. Dividing this mass flow rate by the density (which is also on that same page) and converting to minutes gives an exit flow rate of 18,000 CFM. Reducing this number by 5% results in an exit flow rate of 17,100 CFM. Manipulation of the inlet flow rate was used until the exit flow rate is 17,100 CFM.

When the Service Water inlet temperature is 104°F for the limiting flow rate of 75gpm, a design fouling factor of 0.02832467 hr*ft²*°F/BTU, and a 5% tube plugging allowance, 47-200 A03 Page 2 the new total heat transfer is 603,150 BTU/hr. The thermal margin is calculated as

Qcalculated – Qrequired, which is 603,150 - 517,239 BTU/hr = 85,911 or 16.6% Gross Thermal Margin. Allowing for 5% model uncertainty, the net margin is 603,150(0.95) - 517,239 BTU/hr = 55,754 or 10.8% net Thermal Margin.

The maximum fouling factor with the same assumptions as above and a 5% model uncertainty is 0.07593245 hr*ft²*°F/BTU.

Results / Conclusion:

The 1(2)VY01A coolers were found to have adequate thermal margin for a maximum lake temperature of 104°F when operated at design fouling conditions (0.02832467 hr*ft²*°F/BTU), a 5% tube plugging allowance, and a 5% reduction in air flow rate. The maximum fouling factor is 0.07593245 hr*ft²*°F/BTU. A reduced air flow rate of 17,100 ACFM (95% of 18,000) may therefore be used as acceptance criteria for airside flow rate testing (e.g. LTS-200-19).

Attachments:

Attachment "A" – Proto-Hx Calc. Report for 1(2)VY01A

(CSCS=104°F @ design fouling, 5% tube plugged, 5% reduction in flow)

Attachment "B" – Proto-Hx Calc. Report for 1(2)VY01A

(CSCS=104°F Max FF, 5% tube plugged, 5% reduction in flow)

06-09-2005 14:41:20 PROTO-HX 4.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow

Air Coil Heat Exchanger Input Parameters

	Air-Side		Tube-Side	
Flow	21,179.00	acfm	150.00	gpm
Mass Flow		lbm/hr		lbm/hr
Dry Bulb (Inlet Temperature)	150.00		105.00	°F
Inlet Wet Bulb Temperature	92.00			
Inlet Relative Humidity	0.00			
Dry Bulb (Outlet Temperature)	109.40		115.30	°F
Outlet Wet Bulb Temperature	84.10			
Outlet Relative Humidity	0.00	% 0	· · · · · · · · · · · · · · · · · · ·	
Tube Fluid Name			Fresh '	
Tube-Side Fouling				1500
Air-Side Fouling			0.00	00000
Design Q (BTU/hr)			75	0,000
Atmospheric Pressure (psia)			1	4.315
Design Sensible Heat Ratio				1.00
Performance Factor (% Reduction)				0.000
Coil Flow Direction			Counter	Flow
Fin Type			Circula	r Fins
Configuration (for Air-Side h)			Y Coolers 01A	
	j = EXP	?[-2.5088 + -	0.3436 * LOG	(Re)]
Coil Length (in)			10	4.250
Fin Pitch (Fins/Inch)				0.000
Fin Conductivity (BTU/hr·ft·°F)				8.000
Fin Tip Thickness (inches)				.0120
Fin Root Thickness (inches)				.0120
Circular Fin Height (inches)				1.495
Number of Coils Per Unit				2
Number of Tube Rows				8
Number of Tubes Per Row				20.00
Active Tubes Per Row				19.00
Tube Inside Diameter (in)			0	.5270
Tube Outside Diameter (in)			0	.6250
Longitudinal Tube Pitch (in)				1.500
Transverse Tube Pitch (in)				1.452
Number of Serpentines				1.000
Tube Conductivity (BTU/hr·ft·°F)			2:	25.00



1.432 1.000 AH A 225.00 Page A1 of A7

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure (psia)

Tube Flow (gpm)

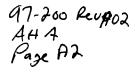
Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	18,186.00
Tube Inlet Temp (°F)	104.00
Air Inlet Temp (°F)	148.00
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	14.315



Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	0.00
Inlet Temperature (°F)	148.00	104.00	j Factor	0.0000
Outlet Temperature (°F)	112.12	120.20	Air-Side ho (BTU/hr·ft².°F)	0.00
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²-°F/BTU)	0.02832467
			U Overall (BTU/hr·ft².°F)	
			Effective Area (ft²)	6,880.52
			LMTD	0.00
			Total Heat Transferred (BTU/hr)	603,150
			Surface Effectiveness (Eta)	0.0000
			Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr) Heat to Condensate (BTU/hr)	603,150



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	1,004.28
Inlet Temperature (°F)	148.00	116.90	j Factor	0.0082
Outlet Temperature (°F)	140.70	120.20	Air-Side ho (BTU/hr·ft².°F)	8.24
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	144.35	118.5507		
Skin Temperature (°F)	125.37	121.2532	U Overall (BTU/hr·ft ² ·°F)	5.57
Velocity ***	3.380.62	2.9130	Effective Area (ft²)	860.06
Reynold's Number	797**	20,828	LMTD	25.60
Prandtl Number	0.7255	3.6895	Total Heat Transferred (BTU/hr)	122,664
Bulk Visc (lbm/ft·hr)	0.0490	1.3650		
Skin Visc (lbm/ft·hr)	0.0000	1.3307	Surface Effectiveness (Eta)	0.9186
Density (lbm/ft³)	0.0623	61.7340	Sensible Heat Transferred (BTU/hr)	122,664
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3695	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	12.76		` ,	
Relative Humidity Out (%)	15.34			



^{**} Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F. Design FF, 5% Plug, 5% Reduction in Flow



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	988.35
Inlet Temperature (°F)	140.70	114.09	j Factor	0.0082
Outlet Temperature (°F)	134.48	116.90	Air-Side ho (BTU/hr·ft².°F)	8.21
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.0F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr-ft ² .°F/BTU)	0.02832467
Average Temp (°F)	137.59	115.4974		
Skin Temperature (°F)	121.35	117.8395	U Overall (BTU/hr·ft²·°F)	5.55
Velocity ***	3,380.62	2.9108	Effective Area (ft²)	860.06
Reynold's Number	804**	20,226	LMTD	21.93
Prandtl Number	0.7261	3.8100	Total Heat Transferred (BTU/hr)	104,623
Bulk Visc (lbm/ft·hr)	0.0486	1.4056		
Skin Visc (lbm/ft·hr)	0.0000	1.3743	Surface Effectiveness (Eta)	0.9188
Density (lbm/ft³)	0.0630	61.7801	Sensible Heat Transferred (BTU/hr)	104,623
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3685	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	15.34			
Relative Humidity Out (%)	18.03			

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 974.69
Inlet Temperature (°F)	134.48	111.69	j Factor 0.0081
Outlet Temperature (°F)	129.17	114.09	Air-Side ho (BTU/hr·ft².°F) 8.19
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	131.82	112.8918	
Skin Temperature (°F)	117.92	114.9196	U Overall (BTU/hr· ft^2 .°F) 5.53
Velocity ***	3.380.62	2.9090	Effective Area (ft²) 860.06
Reynold's Number	810**	19,718	LMTD 18.79
Prandtl Number	0.7265	3.9181	Total Heat Transferred (BTU/hr) 89,336
Bulk Visc (lbm/ft·hr)	0.0482	1.4419	
Skin Visc (lbm/ft·hr)	0.0000	1.4136	Surface Effectiveness (Eta) 0.9191
Density (lbm/ft³)	0.0636	61.8185	Sensible Heat Transferred (BTU/hr) 89,336
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3676	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	18.03		•
Relative Humidity Out (%)	20.76		97-200 Rev



^{**} Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	962.97
Inlet Temperature (°F)	129.17	109.64	j Factor	0.0081
Outlet Temperature (°F)	124.62	111.69	Air-Side ho (BTU/hr·ft².°F)	8.17
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft²-°F/BTU) 0.0	00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr-ft ² .°F/BTU) 0.0	02832467
Average Temp (°F)	126.90	110.6660		
Skin Temperature (°F)	114.98	112.4202	U Overall (BTU/hr·ft².°F)	5.51
Velocity ***	3,380.62	2.9075	Effective Area (ft²)	860.06
Reynold's Number	815**	19,287	LMTD	16.11
Prandtl Number	0.7269	4.0144	Total Heat Transferred (BTU/hr)	76,356
Bulk Visc (lbm/ft·hr)	0.0479	1.4741	·	
Skin Visc (lbm/ft·hr)	0.0000	1.4486	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft ³)	0.0641	61.8506	Sensible Heat Transferred (BTU/hr)	76,356
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	·
K (BTU/hr·ft·°F)	0.0158	0.3668	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	20.76		, ,	
Relative Humidity Out (%)	23.47			

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	952.92
Inlet Temperature (°F)	124.62	107.89	j Factor	0.0081
Outlet Temperature (°F)	120.74	109.64	Air-Side ho (BTU/hr·ft².°F)	8.15
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	122.68	108.7629	,	
Skin Temperature (°F)	112.47	110.2792	U Overall (BTU/hr·ft².°F)	5.50
Velocity ***	3.380.62	2.9062	Effective Area (ft²)	860.06
Reynold's Number	820**	18,921	LMTD	13.81
Prandtl Number	0.7272	4.0998	Total Heat Transferred (BTU/hr)	65,316
Bulk Visc (lbm/ft·hr)	0.0477	1.5026	,	,
Skin Visc (lbm/ft·hr)	0.0000	1.4799	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0645	61.8774	Sensible Heat Transferred (BTU/hr)	65,316
Cp (BTÙ/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	·
K (BTU/hr·ft·°F)	0.0157	0.3661	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	23.47		` ,	
Relative Humidity Out (%)	26.12		60.3	



^{*} Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 9	44.29
Inlet Temperature (°F)	120.74	106.38	j Factor 0	.0081
Outlet Temperature (°F)	117.41	107.89	Air-Side ho (BTU/hr·ft².°F)	8.14
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft²-°F/BTU) 0.0003	31430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU) 0.0283	32467
Average Temp (°F)	119.08	107.1344		
Skin Temperature (°F)	110.32	108.4442	U Overall (BTU/hr·ft².°F)	5.48
Velocity ***	3.380.62	2.9052	Effective Area (ft²) 8	60.06
Reynold's Number	824**	18,610	LMTD	11.85
Prandtl Number	0.7275	4.1753	Total Heat Transferred (BTU/hr) 5	5,913
Bulk Visc (lbm/ft·hr)	0.0474	1.5278		
Skin Visc (lbm/ft·hr)	0.0000	1.5075	Surface Effectiveness (Eta) 0	.9195
Density (lbm/ft³)	0.0649	61.9000	Sensible Heat Transferred (BTU/hr) 5	5,913
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3655	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	26.12			
Relative Humidity Out (%)	28.66			

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	936.89
Inlet Temperature (°F)	117.41	105.10	j Factor	0.0081
Outlet Temperature (°F)	114.56	106.38	Air-Side ho (BTU/hr·ft².°F)	8.12
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.0	0031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU) 0.0	2832467
Average Temp (°F)	115.99	105.7400	,	
Skin Temperature (°F)	108.48	106.8708	U Overall (BTU/hr·ft ² .°F)	5.47
Velocity ***	3.380.62	2.9043	Effective Area (ft²)	860.06
Reynold's Number	827**	18,345	LMTD	10.17
Prandtl Number	0.7277	4.2417	Total Heat Transferred (BTU/hr)	47,894
Bulk Visc (lbm/ft·hr)	0.0472	1.5498	,	
Skin Visc (lbm/ft·hr)	0.0000	1.5319	Surface Effectiveness (Eta)	0.9197
Density (lbm/ft³)	0.0652	61.9190	Sensible Heat Transferred (BTU/hr)	47,894
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3650	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	28.66		· · · · ·	
Relative Humidity Out (%)	31.06		97-200	Rev AO2

* Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Design FF, 5% Plug, 5% Reduction in Flow

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	67,203.40	37,264.79	Tube-Side hi (BTU/hr-ft ² .°F)	930.53
Inlet Temperature (°F)	114.56	103.99	j Factor	0.0081
Outlet Temperature (°F)	112.12	105.10	Air-Side ho (BTU/hr·ft².°F)	8.11
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	113.34	104.5452		
Skin Temperature (°F)	106.90	105.5210	U Overall (BTU/hr·ft²·°F)	5.47
Velocity ***	3,380.62	2.9035	Effective Area (ft²)	860.06
Reynold's Number	830**	18,119	LMTD	8.73
Prandtl Number	0.7278	4.3000	Total Heat Transferred (BTU/hr)	41,047
Bulk Visc (lbm/ft·hr)	0.0471	1.5692		
Skin Visc (lbm/ft·hr)	0.0000	1.5534	Surface Effectiveness (Eta)	0.9198
Density (lbm/ft ³)	0.0655	61.9351	Sensible Heat Transferred (BTU/hr)	41,047
Cp (BŤÙ/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3645	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	31.06			
Relative Humidity Out (%)	33.30			

^{**} Reynolds Number Outside Range of Equation Applicability



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Data Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05

Air Coil Heat Exchanger Input Parameters

	Air-Side		Tube-Side		_	
Flow	21,179.00	acfm	150.00	gpm		
Mass Flow	0.00	lbm/hr	0.00	lbm/h	r	
Dry Bulb (Inlet Temperature)	150.00	°F	105.00	°F		
Inlet Wet Bulb Temperature	92.00	°F				
Inlet Relative Humidity	0.00	%				
Dry Bulb (Outlet Temperature)	109.40	°F	115.30	°F		
Outlet Wet Bulb Temperature	84.10	°F				
Outlet Relative Humidity	0.00	%			_	
Tube Fluid Name			Fresh			
Tube-Side Fouling				04000		
Air-Side Fouling			0.00	00400		
Design Q (BTU/hr)			75	0,000		
Atmospheric Pressure (psia)			1	4.315		
Design Sensible Heat Ratio				1.00		
Performance Factor (% Reduction)				0.000		
Coil Flow Direction			Counter	Flow		
Fin Type			Circula	r Fins		
Configuration (for Air-Side h)			Y Coolers 01 A			
<i>y</i>	j = EXP	2[-2.5088 + -	·0.3436 * LOG	(Re)]		
Coil Length (in)			10	4.250		
Fin Pitch (Fins/Inch)			1	0.000		
Fin Conductivity (BTU/hr·ft.°F)			12	8.000		
Fin Tip Thickness (inches)			0	.0120		
Fin Root Thickness (inches)		-	0	.0120		
Circular Fin Height (inches)				1.495		
Number of Coils Per Unit				2		
Number of Tube Rows				8		
Number of Tubes Per Row				20.00		
Active Tubes Per Row				19.00	•	
Tube Inside Diameter (in)			0	.5270		
Tube Outside Diameter (in)				.6250		
Longitudinal Tube Pitch (in)				1.500		
Transverse Tube Pitch (in)				1.452		
\/					97-200	Rev A
Number of Serpentines				1.000	97-200 AH B Page Bl	
					741 ()	
Tube Conductivity (BTU/hr·ft·°F)			2	25.00	0 11	- 1

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure (psia)

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	18,075.00
Tube Inlet Temp (°F)	104.00
Air Inlet Temp (°F)	148.00
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	14.315

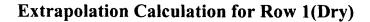
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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05



Extrapolation Calculation Summary

	Air-Side	Tube-Side	,	
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	0.00
Inlet Temperature (°F)	148.00	104.00	j Factor	0.0000
Outlet Temperature (°F)	114.87	118.87	Air-Side ho (BTU/hr·ft².°F)	0.00
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU)	0.07593245
			U Overall (BTU/hr·ft².°F)	
			Effective Area (ft²)	6,880.52
			LMTD	0.00
			Total Heat Transferred (BTU/hr)	553,584
			Surface Effectiveness (Eta)	0.0000
		·	Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr) Heat to Condensate (BTU/hr)	553,584



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 998.3	2
Inlet Temperature (°F)	148.00	116.10	j Factor 0.008	2
Outlet Temperature (°F)	141.83	118.87	Air-Side ho (BTU/hr·ft².°F) 8.2	1
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU) 0.0003143	0
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.0759324	5
Average Temp (°F)	144.91	117.4817	- · ,	
Skin Temperature (°F)	128.95	119.7606	U Overall (BTU/hr·ft².°F) 4.3	9
Velocity ***	3.359.98	2.9122	Effective Area (ft²) 860.0	6
Reynold's Number	792**	20,617	LMTD 27.3	0
Prandtl Number	0.7254	3.7310	Total Heat Transferred (BTU/hr) 103,11	7
Bulk Visc (lbm/ft·hr)	0.0490	1.3790	, ,	
Skin Visc (lbm/ft·hr)	0.0000	1.3495	Surface Effectiveness (Eta) 0.918	9
Density (lbm/ft³)	0.0622	61.7503	Sensible Heat Transferred (BTU/hr) 103,11	7
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3692	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	12.76			
Relative Humidity Out (%)	14.91			



^{**} Reynolds Number Outside Range of Equation Applicability

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Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 984.7	9
Inlet Temperature (°F)	141.83	113.66	j Factor 0.008	2
Outlet Temperature (°F)	136.39	116.10	Air-Side ho (BTU/hr·ft².°F) 8.1	9
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft²-°F/BTU) 0.0003143	0
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.0759324	5
Average Temp (°F)	139.11	114.8760		
Skin Temperature (°F)	125.00	116.9114	U Overall (BTU/hr·ft².°F) 4.3	8
Velocity ***	3,359.98	2.9104	Effective Area (ft²) 860.0	6
Reynold's Number	798**	20,105	LMTD 24.1	2
Prandtl Number	0.7259	3.8354	Total Heat Transferred (BTU/hr) 90,84	6
Bulk Visc (lbm/ft·hr)	0.0487	1.4142		
Skin Visc (lbm/ft·hr)	0.0000	1.3866	Surface Effectiveness (Eta) 0.919	1
Density (lbm/ft³)	0.0628	61.7894	Sensible Heat Transferred (BTU/hr) 90,84	6
Cp (BŤÙ/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3683	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	14.91		, ,	
Relative Humidity Out (%)	17.15			

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

_	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 972.82
Inlet Temperature (°F)	136.39	111.50	j Factor 0.0082
Outlet Temperature (°F)	131.60	113.66	Air-Side ho (BTU/hr·ft².°F) 8.17
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU) 0.07593245
Average Temp (°F)	134.00	112.5798	,
Skin Temperature (°F)	121.53	114.3961	U Overall (BTU/hr·ft².°F) 4.37
Velocity ***	3.359.98	2.9088	Effective Area (ft²) 860.06
Reynold's Number	803**	19,657	LMTD 21.31
Prandtl Number	0.7264	3.9313	Total Heat Transferred (BTU/hr) 80,084
Bulk Visc (lbm/ft·hr)	0.0484	1.4464	
Skin Visc (lbm/ft·hr)	0.0000	1.4208	Surface Effectiveness (Eta) 0.9193
Density (lbm/ft³)	0.0633	61.8230	Sensible Heat Transferred (BTU/hr) 80,084
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0160	0.3675	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	17.15		· · · · · · · · · · · · · · · · · · ·
Relative Humidity Out (%)	19.46		10.0



^{**} Reynolds Number Outside Range of Equation Applicability

41-FO RWAO. Att B Page 64

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05



Extrapolation Calculation for Row 4(Dry)

	Air-Side_	Tube-Side	
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F) 962.23
Inlet Temperature (°F)	131.60	109.61	j Factor 0.0082
Outlet Temperature (°F)	127.37	111.50	Air-Side ho (BTU/hr·ft².°F) 8.15
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²-°F/BTU) 0.07593245
Average Temp (°F)	129.48	110.5551	
Skin Temperature (°F)	118.47	112.1747	U Overall (BTU/hr· \mathfrak{f}^2 .°F) 4.36
Velocity ***	3.359.98	2.9074	Effective Area (ft²) 860.06
Reynold's Number	808**	19,265	LMTD 18.84
Prandtl Number	0.7267	4.0193	Total Heat Transferred (BTU/hr) 70,636
Bulk Visc (lbm/ft·hr)	0.0481	1.4758	
Skin Visc (lbm/ft·hr)	0.0000	1.4522	Surface Effectiveness (Eta) 0.9194
Density (lbm/ft³)	0.0638	61.8521	Sensible Heat Transferred (BTU/hr) 70,636
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3667	Heat to Condensate (BTU/hr)
Relative Humidity In (%)	19.46		·
Relative Humidity Out (%)	21.79		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	952.85
Inlet Temperature (°F)	127.37	107.93	j Factor	0.0081
Outlet Temperature (°F)	123.64	109.61	Air-Side ho (BTU/hr·ft².°F)	8.13
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.07593245
Average Temp (°F)	125.51	108.7689		
Skin Temperature (°F)	115.76	110.2121	U Overall (BTU/hr·ft².°F)	4.35
Velocity ***	3,359.98	2.9062	Effective Area (ft²)	860.06
Reynold's Number	812**	18,922	LMTD	16.66
Prandtl Number	0.7270	4.0995	Total Heat Transferred (BTU/hr)	62,333
Bulk Visc (lbm/ft·hr)	0.0478	1.5026	,	ŕ
Skin Visc (lbm/ft·hr)	0.0000	1.4809	Surface Effectiveness (Eta)	0.9196
Density (lbm/ft³)	0.0642	61.8773	Sensible Heat Transferred (BTU/hr)	62,333
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	Ź
K (BTU/hr·ft·°F)	0.0158	0.3661	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	21.79		,	
Relative Humidity Out (%)	24.11		97-2	00 Routo.

AH B 1 mg 15

^{**} Reynolds Number Outside Range of Equation Applicability

Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	944.56
Inlet Temperature (°F)	123.64	106.45	j Factor	0.0081
Outlet Temperature (°F)	120.35	107.93	Air-Side ho (BTU/hr-ft²-°F)	8.11
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr-ft2.°F/BTU)	0.07593245
Average Temp (°F)	121.99	107.1924		
Skin Temperature (°F)	113.38	108.4777	U Overall (BTU/hr·ft ^{2.} °F)	4.34
Velocity ***	3,359.98	2.9052	Effective Area (ft²)	860.06
Reynold's Number	816**	18,621	LMTD	14.73
Prandtl Number	0.7273	4.1726	Total Heat Transferred (BTU/hr)	55,030
Bulk Visc (lbm/ft·hr)	0.0476	1.5269		
Skin Visc (lbm/ft·hr)	0.0000	1.5070	Surface Effectiveness (Eta)	0.9197
Density (lbm/ft³)	0.0645	61.8992	Sensible Heat Transferred (BTU/hr)	55,030
Cp (BŤÙ/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3655	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	24.11			
Relative Humidity Out (%)	26.40			

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	937.22
Inlet Temperature (°F)	120.35	105.15	j Factor	0.0081
Outlet Temperature (°F)	117.44	106.45	Air-Side ho (BTU/hr·ft²·°F)	8.10
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.07593245
Average Temp (°F)	118.89	105.8003	•	
Skin Temperature (°F)	111.27	106.9444	U Overall (BTU/hr·ft².°F)	4.34
Velocity ***	3.359.98	2.9043	Effective Area (ft²)	860.06
Reynold's Number	819**	18,356	LMTD	13.03
Prandtl Number	0.7275	4.2388	Total Heat Transferred (BTU/hr)	48,601
Bulk Visc (lbm/ft·hr)	0.0474	1.5489		
Skin Visc (lbm/ft·hr)	0.0000	1.5308	Surface Effectiveness (Eta)	0.9198
Density (lbm/ft³)	0.0649	61.9182	Sensible Heat Transferred (BTU/hr)	48,601
Cp (BTÙ/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3650	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	26.40		· · ·	
Relative Humidity Out (%)	28.64		97	-200 Rev



^{**} Reynolds Number Outside Range of Equation Applicability

97-200 Rev AUZ AH B Pase Bb

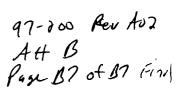
Calculation Report for 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, Max FF, 5% Plug, reduction in air flow 7/6/05

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	·	
Mass Flow (lbm/hr)	66,793.22	37,264.79	Tube-Side hi (BTU/hr·ft².°F)	930.72
Inlet Temperature (°F)	117.44	103.99	j Factor	0.0081
Outlet Temperature (°F)	114.87	105.15	Air-Side ho (BTU/hr-ft2-°F)	8.09
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr-ft2.°F/BTU) (0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft².°F/BTU)	0.07593245
Average Temp (°F)	116.15	104.5707	<u>-</u>	
Skin Temperature (°F)	109.41	105.5885	U Overall (BTU/hr·ft².°F)	4.33
Velocity ***	3.359.98	2.9036	Effective Area (ft²)	860.06
Reynold's Number	822**	18,123	LMTD	11.53
Prandtl Number	0.7277	4.2987	Total Heat Transferred (BTU/hr)	42,938
Bulk Visc (lbm/ft·hr)	0.0472	1.5688		
Skin Visc (lbm/ft·hr)	0.0000	1.5523	Surface Effectiveness (Eta)	0.9199
Density (lbm/ft³)	0.0651	61.9348	Sensible Heat Transferred (BTU/hr)	42,938
Cp (BŤÙ/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3645	Heat to Condensate (BTU/hr)	
Relative Humidity In (%)	28.64			
Relative Humidity Out (%)	30.79			

^{**} Reynolds Number Outside Range of Equation Applicability





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DESIGN ANALY Major REV Num		lc. #97-200 Mino	r Rev Number: (01	PAGE NO. 1	
[] BRAIDWOOD STATION [] BYRON STATION [] CLINTON STATION [] DRESDEN STATION [X] LASALLE CO. STATION [] QUAD CITIES STATION		DE	DESCRIPTION CODE:(C018)		M10	
		DI	SCIPLINE CODE:	(C011)	M	
Unit: [] 0 [X]		3 SY	STEM CODE: (C	011)	VY	
TITLE: VY COOLER THERMAL PERFORMANCE MODEL - 1(2)VY01A and 1(2)VY02A						
[X] Safety Related [] Augmented Quality [] Non-Safety Related						
ATTRIBUTES (C016)						
TYPE	VALU	E	TYPE		VALUE	
Elevation	694'					
Software	PROTO-HX					
COMPONENT EP	N: (C014 Panel)	DOCUME	NT NUMBERS: (C	012 Panel)	(Design Analyses References)	
EPN	TYPE	Type/Sub	Document N	umber	Input (Y/N)	
1VY01A	H15	DCD/	EC#337494		Υ	
		EVAL				
2VY01A	H15	1		· · · · · · · · · · · · · · · · · · ·		
1VY02A	H15	/				
2VY02A	H15	/				
		1				
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REMARKS:			1			

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS NO.	97-200	REV: A01 PAGE	NO. 2	
impact of an error "flag" message number is outside the range of indicates a LOG (base 10) in the	ge on the printou equation applica e Fin Configurati	porated): evaluated issues associats of Proto-Hx, which states that the bility. 2) the "Data Report" output for equation for the Colburn 'j' facto is as the natural log (Ln). The calc.	e Air Side Reynolds or the air coolers r, however the	
Electronic Calculation Data F computer runs were performed	•	This data is same as previous minor vision)	revision; no	
(Program Name, Version, File Name extension/size/date/hour/min)				
Design impact review complete (If yes, attach impact review shows a prepared by:B_L. Davenper	eet) ort/	Sign Sign Sign Sign Sign Sign Sign Sign	1 6-06-52 Date 1 6/10/02 Date	
This Design Analysis supers	edes:	N/A	in its entirety.	
Supplemental Review Regula	ed? [[]]Yes	L) No.	1.00	
[] Additional Review []	Special Review	Team:		
Additional Reviewer or Speci	al Review Team	A Secretary of the second seco	Signal Date	
Special Review Textus (IN/A to	r AdditionaliRe		per des	
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Approved by:	ـــ) a	1 6/10/12	
- Prin		Sign	Date	
External Design Analysis Rev	<u>/iew</u> (Attachmei	nt 3 Attached)		
Reviewed by:	,	1	1	
- Print		Sign	Date	
		/ Sign	/ Date	

Purpose/Objective

The purpose of this minor revision is to assess the following: 1) the impact of error "flag" message on the printouts of Proto-Hx, which states that the Air Side Reynolds number is outside the range of equation applicability. An example of this flag can be found on Attachment G, page 4. 2) the "Data Report" output for the air coolers (example Attachment G, page 2) indicates a LOG (base 10) in the Fin Configuration equation for the Colburn 'j' factor, however Equation 9 of this calculation shows this as the natural log (Ln).

Methodology and Acceptance Criteria

N/A, this is an assessment of the current calculation.

Assumptions / Engineering Judgments

Assumptions and engineering judgements are documented within this analysis.

Design Inputs

N/A, this minor revision utilizes those of the current calculation.

References

- 1. SEAG 02-000086 (copy attached)
- 2. Heat Transfer-Professional Version, Lindon C. Thomas, 2nd Ed., 1999.

Analysis

- 1) On page 13, the Colburn 'j' factor versus Reynolds Number (Re) relationship is given. This relationship was derived in this calculation to more closely match the manufacturer's heat transfer capability. The Colburn 'j' factor relationship is based on the information in Attachment D. This attachment shows the straight line relationship between the 'j' factor and Re number when plotted on a log-log scale, with Re number end points between 1000 and 8000. This relationship was used to derive Equation 9, which is input into the computer model with the two end points. Even though the calculated Re is less than 1000 in some cases (it is normally in the range of approx. 800 to 1000), the program still uses the Equation 9 relationship with the actual Re. The computer program in this case is flagging that it had to extrapolate past the 1000 end point it was given. Reference 2, page 553 shows this relationship to be linear down to a Re of 600 for a similar type of finned tube. Based on engineering judgement, it is therefore reasonable to extrapolate this line to a somewhat lower Re down to a Reynolds number of approximately 800. Thus the results of the calculations are acceptable.
- 2) Equation 9 in the body of the calculation, which indicates Ln, is correct and Ln is the function being used by the program. A check of the 'j' factor numbers indicated on the computer output in the calculation show that the program is using the natural log Ln. The program manufacturer, Proto-Power, was contacted on 4-03-02. They indicated that the LOG on the Data Report represents indefinite text output and they confirmed



that the program is indeed using the natural log (Ln) function for its calculations. (A letter/fax was obtained from Proto-Power on 4-03-02 confirming this discussion. The fax has been assigned file number SEAG 02-000086). A copy of this letter is attached (see Attachment A of this minor revision.

Summary and Conclusions

Based on the above discussion, the calculation results are acceptable as-is.

DESIGN ANALY IN 97-200, Rev. ADI P. 01 ATTACHMENT A PAGE AlOFAI



WER CORPORATION

A Utility Engineering Subsidiary

15 THAMES STREET GROTON, CT 06340 www.protopower.com

SEAG Number

02-000086

MEMORANDUM

File No. 908SOF/050119/M02001

To: Brian Davenport

From: Joseph G. Fayan July Change

Date: April 3, 2002

Subject: PROTO-HX Air Coil Module

Brian.

The PROTO-HX Data Sheet Output Report for Air Coils shows the equation for "Configuration (for Air-Side h)" with the "LOG" term in the equation. This in fact represents the "Natural Log" and not "Log Base 10." The equation actually uses the Natural Log (LN) term, however, the output report is ambiguous in printing "LOG".

If you have any other questions, please feel free to give me a call.

Sorry for the confusion.

JGF:bai

CC: Joseph G. Fayan Job File

LASALLE CALCULATION

EDITORIAL – COMMENT TO CALCULATION

			1		
Affecting Calculation No.: 9	1-200	Rev: AOO	FOR Refer	Page No. of	<u> </u>
The use of this form	shall be limited to doc	ument corrections	of editorial nature	e. Return to Sylvia Venecia	1
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Approved by:					
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CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 1 of 2

DESIGN ANALYS Major REV Numb	oer: A		r Rev Number:	00	PAGE NO. 1
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[X] LASALLE CO. [] QUAD CITIES	STATION	DIS	CIPLINE CODE:	(C011)	М
Unit: [] 0 [X] 1	[X]2 []	3 SY	STEM CODE: (C	011)	VY
TITLE: VY Cooler Thermal Performance Model – 1(2)VY01A and 1(2)VY02A					
[X] Safety Re	lated	[] Augme	nted Quality	[] Non-Safety Related
		ATTRIB	UTES (C016)		
TYPE	VALU	JE	TYPE		VALUE
Elevation	694	,			
Software	Proto-	HX			
				i	
COMPONENT EPI	N: (C014 Panel)	JAMOS	IT NUMBERS: (C	012 Panel)	(Design Analyses References)
EPN	TYPE	Type/Sub	Document N	umber	Input (Y/N)
1VY01A	H15	EC/DCP	EC# 33401	7	Y
2VY01A	H15	1			
1VY02A	H15	1			
2VY02A	H15	1			
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		1			
REMARKS: NA					

CC-AA-309 - ATTACHMENT 1 - Design Analysis Approval Page 2 of 2

DESIGN ANALYSIS	NO. 97-200		REV: A00	PAGE NO. 2
	emperature and cald ed for the Unit 1 and	culated thermal m	argins with the	nodel for 104°F design fouling factor (1/2VY01A) and HPCS
Electronic Calculation	n Data Files: ProtoH	X 3.02, vy-0102a.p	hx, 1152 KB, 11/	02/2001, 2:14 am
(Program Name, Vers	ion, File Name extensi	ion/size/date/hour/r	nin)	
Design impact review (If yes, attach impact i] Yès [X] N/A, I	Per EC#: <u>3340</u>	17
Prepared by: Jeff W.		- Jan	Vandtier	1 3-7.02
Reviewed by: Brian	Print L. Davenport	1871	Bign	/ 5 /0 * 0 レ
Method of Review:	Print [X] Detailed []	Alternate [] T	Sign est	Date
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External Design Ana	llysis Review (Attach	ment 3 Attached)		
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Do any ASSUMPTIONS Tracked By: AT#, EC	s / Engineering Judg # etc.)	GEMENTS require la	ter verification?	[] Yes [X] No -
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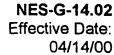




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8.0 ATTACHMENTS:	7		
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Attachment "B" - Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design FF, 5% Plugged)	B1 to B17		
Attachment "C" – Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (For VY01, CSCS=104°F @ Max. Allowable FF, w\ 5% plugged) (For VY02, CSCS=104°F @ Design FF, Room Temp. = 150°F)	C1 to C17		









CALCULATION NO. 97-200

REV. NO. A00

PAGE NO. 4 of 7

1.0 PURPOSE/OBJECTIVE

The purpose of this minor revision is to revise the thermal model of the A RHR Pump Room Coolers (1/2VY01A) and the HPCS Pump Room Coolers (1/2VY02A) using a 104°F Service Water inlet temperature. This assessment will evaluate the adequacy of these heat exchangers during a maximum allowable inlet service water temperature of 104°F. Also a maximum design fouling factor will be determined.

2.0 METHODOLOGY AND ACCEPTANCE CRITERIA

The existing heat exchanger model will be revised by changing the input of the "Tube Inlet Temp." from 100°F to 104°F and simulated for the following conditions: design fouling factor and design fouling factor with a 5% tube plugging allowance. The acceptance criteria will be for the thermal margin at each stated condition to exceed the LaSalle design heat load of 517,239 BTU/hr for 1/2VY01A and 646,235 BTU/hr for 1/2VY02A (Ref. 1, table 1). Additional conservatism was built into this acceptance criteria by assuming a 5% uncertainty in the Proto-HX heat transfer calculations. The original benchmark model developed for these heat exchangers demonstrated a correlation to vendor performance specification well within this assumed 5% margin.

A final case will be evaluated which determines the maximum acceptable fouling factor at which the design heat load can be accommodated including heat transfer model uncertainty and a 5% tube plugging allowance.

3.0 ASSUMPTIONS / ENGINEERING JUDGMENTS

The assumptions indicated in section 5.0 of Reference 1 are still valid.

4.0 DESIGN INPUTS

The design inputs consist of References 1 listed below.

5.0 REFERENCES

- 1. Calculation No. 97-200, Rev. A, "VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A."
- 2. Calculation No. L-002457, Rev. 4, "LaSalle County Station Ultimate Heat Sink Analysis".



NES-G-14.02 Effective Date: 04/14/00

CALCULATION PAGE

CALCULATION NO. 97-200

REV. NO. A00

PAGE NO. 5 of 7

6.0 CALCULATIONS

The current calculation model is based on a Service Water inlet temperature of 100°F with a varying service water flow rates. Based on Reference 1 Calculations, the limiting flow rates, heat transfer rates, and thermal margins are as follows:

Table 1: At Limiting Flow rates, 100°F Service Water Inlet Temp. and Overall FF = 0.03976622

hr*ft2*oF/BTU (Ref. 1, table 9).

Cooler	Limiting Flow Rate (gpm)	Q _{required} (BTU/hr)	Q _{available} (BTU/hr)	Thermal Margin (%)
1(2)VY01A	75	517,239	675,177	30.5%
1(2)VY02A	108	646,235	707,030	9.4%

Thermal margin is calculated by the following method:

Required Heat Load - Calculated Heat Transfer = Thermal Margin

[Equation 1]

To express this as a percent of the required heat load, the following method is used:

$$\frac{ThermalM \text{ arg } in}{\text{Re } quiredHeatLoad} \times 100\% = \% ThermalM \text{ arg } in$$

[Equation 2]

When the Service Water inlet temperature is increased to 104°F for the same limiting flow rate, but with a design overall fouling factor of 0.02832467 hr*ft2*°F/BTU, the new thermal margins are shown in Table 2.

Table 2: At Limiting Flow rates, 104°F Service Water Inlet Temp. and Design Overall FF =

0.02832467 hr*ft²*°F/BTU [Attachment A].

Cooler	Limiting Flow Rate (gpm)	Q _{required} (BTU/hr)	Q _{available} (BTU/hr)	Thermal Margin (%)
1(2)VY01A	75	517,239	629,279	21.7%
1(2)VY02A	108	646,235	659,062	2.0%



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Furthermore, if we consider the above conditions (in Table 2) and factor in a 5% tube plugging allowance the following Thermal Margins are calculated in Attachment B.

Table 3: At Limiting Flow rates, 104°F Service Water Inlet Temp., Design FF = 0.02832467

hr*ft²*°F/BTU and 5% plugged [Attachment B].

Cooler	Limiting Flow Rate (gpm)	Q _{required} (BTU/hr)	Q _{availabie} (BTU/hr)	Thermal Margin (%)
1(2)VY01A	75	517,239	625,070	20.8%
1(2)VY02A	108	646,235	653,739	1.2%

In addition, the maximum allowable Fouling Factors for each cooler, while maintaining at least a 5% thermal margin at 104°F inlet service water temperature with a 5% tube plugging allowance, are listed in Table 4.

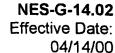
Table 4: Maximum Allowable Fouling Factors at 104°F Service Water inlet temp. and 5% plugged.

[Attachment C].

Cooler	Maximum Overall FF
1(2)VY01A	0.0949
1(2)VY02A	Note 1

Note 1: As demonstrated by the results in tables 2 and 3, air cooler 1(2)VY02A does not have analytical thermal margin in excess of the assumed 5% model uncertainty at the elevated inlet service water temperature of 104°F, room air temperature of 148°F and the design overall fouling factor of 0.02832467 hr*ft²*oF/BTU. However an additional Proto-HX run at a room air temperature of 150°F, service water inlet temperature of 104°F, no tubes plugged and the design overall fouling factor of 0.02832467 hr*ft²*oF/BTU demonstrated in excess of the 5% thermal margin needed to account for analytical uncertainty [Attachment C]. This is discussed further in the summary and conclusion section below.









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7.0 SUMMARY AND CONCLUSIONS

The A RHR Pump Room Coolers (1/2VY01A) and HPCS Pump Room Coolers (1/2VY02A) were found to have adequate thermal margin for a maximum lake temperature of 104°F when operated at design fouling conditions (the design overall fouling factor of 0.02832467 hr*ft²*°F/BTU). The maximum allowable overall fouling factor for the 1(2)VY01A coolers is 0.0949 hr*ft²*°F/BTU (includes an allowance for 5% of the tubes to be plugged).

For the 1(2)VY02A coolers the maximum allowable fouling factor is equal to the design overall fouling factor of 0.02832467 hr*ft²*°F/BTU (this does NOT include a 5% tube plugging allowance). It should be noted that the inlet air temperature was increased 2°F (from 148°F to 150°F) to achieve the desired thermal margin of 5%. A review of the EQ equipment in the room determined that all EQ components are qualified for temperature exceeding 150°F for the first 24 hours of the LOCA. The time at which the service water inlet temperature could experience 104°F is short term in nature and bounded by the 24-hour period specified above. The post LOCA peak service water temperature profile is documented within reference 2. Figure G7.1 within reference 2 demonstrates that the maximum post accident service water temperatures remain well below 100 °F except for a short period of time within the first day after the SCRAM occurs.

8.0 ATTACHMENTS:

Attachment "A" – Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design Fouling)

Attachment "B" – Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design FF, 5% Plugged)

Attachment "C" – Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (For VY01, CSCS=104°F @ Max. Allowable FF, w\ 5% plugged) (For VY02, CSCS=104°F @ Design FF, Room Temp. = 150°F)

Final Page (Last Page)



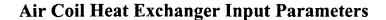
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Attachment "A"

Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design Fouling)

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF



	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
- C (DMIII)		7 .70.000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure Sensible Heat Ratio		14.315
Performance Factor (% Reduction)		1.00 0.000
renormance racioi (78 Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
37 1 00 11 D 77 1		_
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
V 1 CG		
Number of Serpentines)F)	1.000
Tube Wall Conductivity (BTU/hr-ft-	r)	225.00

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	19,120.00
Tube Inlet Temp (°F)	104.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F)
Inlet Temperature (°F)	148.00	104.00	j Factor
Outlet Temperature (°F)	112.40	120.93	Air-Side ho (BTU/hr·ft².°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft²·°F)
Velocity ***			Effective Area (ft^2) 7,242.65
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 629,279
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 629,279
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)



	Air-Side_	Tube-Side	• .
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 967.24
Inlet Temperature (°F)	148.00	117.56	j Factor 0.0082
Outlet Temperature (°F)	140.90	120.93	Air-Side ho (BTU/hr·ft².°F) 8.24
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ² .°F/BTU) 0.02832467
Average Temp (°F)	144.45	119.24	
Skin Temperature (°F)	125.98	121.97	U Overall (BTU/ $hr \cdot ft^2 \cdot {}^{\circ}F$) 5.55
Velocity ***	3,376.53	2.77	Effective Area (ft²) 905.33
Reynold's Number	796**	19,916	LMTD 25.01
Prandtl Number	0.7254	3.6630	Total Heat Transferred (BTU/hr) 125,565
Bulk Visc (lbm/ft·hr)	0.0490	1.3561	
Skin Visc (lbm/ft·hr)		1.3218	Surface Effectiveness (Eta) 0.9186
Density (lbm/ft³)	0.0623	61.7233	Sensible Heat Transferred (BTU/hr) 125,565
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0162	0.3698	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment A Page No. A4 of A17

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 951.58
Inlet Temperature (°F)	140.90	114.66	j Factor 0.0082
Outlet Temperature (°F)	134.79	117.56	Air-Side ho (BTU/hr-ft².°F) 8.21
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²·°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	137.84	116.11	
Skin Temperature (°F)	121.93	118.49	U Overall (BTU/hr· ft^2 .°F) 5.52
Velocity ***	3,376.53	2.77	Effective Area (ft²) 905.33
Reynold's Number	803**	19,327	LMTD 21.57
Prandtl Number	0.7260	3.7855	Total Heat Transferred (BTU/hr) 107,856
Bulk Visc (lbm/ft·hr)	0.0486	1.3974	
Skin Visc (lbm/ft·hr)		1.3658	Surface Effectiveness (Eta) 0.9189
Density (lbm/ft³)	0.0630	61.7710	Sensible Heat Transferred (BTU/hr) 107,856
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0161	0.3687	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

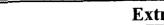
	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 938.05
Inlet Temperature (°F)	134.79	112.17	j Factor 0.0082
Outlet Temperature (°F)	129.55	114.66	Air-Side ho (BTU/hr·ft²·°F) 8.18
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	132.17	113.41	
Skin Temperature (°F)	118.45	115.49	U Overall (BTU/hr·ft².°F) 5.50
Velocity ***	3,376.53	2.76	Effective Area (ft²) 905.33
Reynold's Number	809**	18,827	LMTD 18.61
Prandtl Number	0.7265	3.8961	Total Heat Transferred (BTU/hr) 92,745
Bulk Visc (lbm/ft·hr)	0.0483	1.4346	
Skin Visc (lbm/ft·hr)		1.4057	Surface Effectiveness (Eta) 0.9191
Density (lbm/ft³)	0.0635	61.8109	Sensible Heat Transferred (BTU/hr) 92,745
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0160	0.3678	Heat to Condensate (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment A Page No. A5 of A11

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 926.37
Inlet Temperature (°F)	129.55	110.02	j Factor 0.0081
Outlet Temperature (°F)	125.03	112.17	Air-Side ho (BTU/hr·ft².°F) 8.16
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr ft².ºF/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²·°F/BTU) 0.02832467
Average Temp (°F)	127.29	111.09	
Skin Temperature (°F)	115.45	112.90	U Overall (BTU/hr·ft².°F) 5.49
Velocity ***	3,376.53	2.76	Effective Area (ft²) 905.33
Reynold's Number	814**	18,399	LMTD 16.07
Prandtl Number	0.7269	3.9956	Total Heat Transferred (BTU/hr) 79,826
Bulk Visc (lbm/ft·hr)	0.0479	1.4679	
Skin Visc (lbm/ft·hr)		1.4417	Surface Effectiveness (Eta) 0.9193
Density (lbm/ft³)	0.0640	61.8445	Sensible Heat Transferred (BTU/hr) 79,826
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3669	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F)	916.28
Inlet Temperature (°F)	125.03	108.17	j Factor	0.0081
Outlet Temperature (°F)	121.14	110.02	Air-Side ho (BTU/hr·ft².°F)	8.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU)	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	123.08	109.10		
Skin Temperature (°F)	112.87	110.67	U Overall (BTU/hr·ft².°F)	5.47
Velocity ***	3,376.53	2.76	Effective Area (ft²)	905.33
Reynold's Number	818**	18,034	LMTD	13.88
Prandtl Number	0.7272	4.0846	Total Heat Transferred (BTU/hr)	68,762
Bulk Visc (lbm/ft·hr)	0.0477	1.4976		
Skin Visc (lbm/ft·hr)		1.4740	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0644	61.8727	Sensible Heat Transferred (BTU/hr)	68,762
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3662	Heat to Condensate (BTU/hr)	
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^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>A</u> Page No. <u>A6</u> of <u>A17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 907.56
Inlet Temperature (°F)	121.14	106.58	j Factor 0.0081
Outlet Temperature (°F)	117.79	108.17	Air-Side ho (BTU/hr·ft².°F) 8.13
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	119.46	107.38	
Skin Temperature (°F)	110.64	108.75	U Overall (BTU/hr·ft²-°F) 5.46
Velocity ***	3,376.53	2.76	Effective Area (ft²) 905.33
Reynold's Number	822**	17,722	LMTD 11.99
Prandtl Number	0.7274	4.1639	Total Heat Transferred (BTU/hr) 59,274
Bulk Visc (lbm/ft·hr)	0.0474	1.5240	·
Skin Visc (lbm/ft·hr)		1.5028	Surface Effectiveness (Eta) 0.9196
Density (lbm/ft³)	0.0648	61.8966	Sensible Heat Transferred (BTU/hr) 59,274
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0157	0.3656	Heat to Condensate (BTU/hr)
www.n 1.1 - N.I	Damas of Caustian		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

Air-Side	Tube-Side	
70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 900.01
117.79	105.21	j Factor 0.0081
114.89	106.58	Air-Side ho (BTU/hr·ft².°F) 8.12
0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
116.34	105.89	
108.72	107.09	U Overall (BTU/hr·ft²·°F) 5.45
3,376.53	2.76	Effective Area (ft²) 905.33
826**	17,454	LMTD 10.37
0.7276	4.2343	Total Heat Transferred (BTU/hr) 51,127
0.0473	1.5474	
	1.5285	Surface Effectiveness (Eta) 0.9197
0.0651	61.9169	Sensible Heat Transferred (BTU/hr) 51,127
0.2402	0.9989	Latent Heat Transferred (BTU/hr)
0.0156	0.3650	Heat to Condensate (BTU/hr)
	70,654.85 117.79 114.89 0.0203 0.0203 116.34 108.72 3,376.53 826** 0.7276 0.0473 0.0651 0.2402	70,654.85 37,262.20 117.79 105.21 114.89 106.58 0.0203 105.89 108.72 107.09 3,376.53 2.76 826** 17,454 0.7276 4.2343 0.0473 1.5474 1.5285 0.0651 61.9169 0.2402 0.9989

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>A</u> Page No. <u>A7</u> of <u>A/7</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF

Extrapolation Calculation for Row 8(Dry)

	Air-Side_	Tube-Side	
Mass Flow (lbm/hr)	70,654.85	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 893.49
Inlet Temperature (°F)	114.89	104.02	j Factor 0.0081
Outlet Temperature (°F)	112.40	105.21	Air-Side ho (BTU/hr· ft^2 .°F) 8.11
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	113.64	104.61	
Skin Temperature (°F)	107.06	105.65	U Overall (BTU/hr·ft².°F) 5.44
Velocity ***	3,376.53	2.76	Effective Area (ft²) 905.33
Reynold's Number	829**	17,224	LMTD 8.96
Prandtl Number	0.7278	4.2966	Total Heat Transferred (BTU/hr) 44,124
Bulk Visc (lbm/ft·hr)	0.0471	1.5680	
Skin Visc (lbm/ft·hr)		1.5513	Surface Effectiveness (Eta) 0.9198
Density (lbm/ft³)	0.0654	61.9342	Sensible Heat Transferred (BTU/hr) 44,124
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0155	0.3646	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>A</u> Page No. <u>AY</u> of <u>AI7</u>



Inlet Air Flowrate Calculator - 1(2)VY01A

Total P:

P≃

Dry Bulb T OUT: T=

Specific Hum.:

H2O Vap P:

Pv = (W*Rv*P)/(Ra+(W*Rv) =

0.020274

Inlet Air Flow 19120 acfm

0.451875 psia

112.4 F

14.315 psia

85.778 (ft-lbf)/(lbm-R)

Rv = Ra =

53.352 (ft-lbf)/(lbm-R)

13.86313 psia

0.0654 lbm/ft³

0.061575 lbm/ft³

148 F

18000 cfm

Dry Air P:

Pa = P - Pv =

Dry Air rho IN:

Dry Air rho OUT: rho a = $(144/Ra)^*(Pa/(459.67+T) =$ rho a = (144/Ra)*(Pa/(459.67+T) =

Dry Bulb T IN:

T=

Outlet Air Flow:

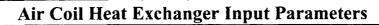
V =

Calculation No. 97-200 Revision No. A00 Attachment A Page No. Ag of All

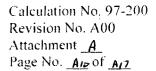
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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF

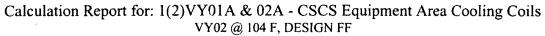


	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
, c		
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	e VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
N. 1. CC. 1. Dealinia		2
Number of Coils Per Unit		2
Number of Tube Rows Number of Tubes Per Row		8 20.00
		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft·	°F)	225.00
Tube Wall Colladelivity (D10/III It	•)	223.00



18:00:16

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Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

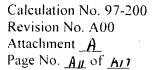
Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Extrapolation Data				
Tube Flow (gpm)	108.00			
Air Flow (acfm)	19,173.00			
Tube Inlet Temp (°F)	104.00			
Air Inlet Temp (°F)	148.0			
Inlet Relative Humidity (%)	12.76			
Inlet Wet Bulb Temp (°F)	0.00			
Atmospheric Pressure	14.315			



Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF



Extrapolation Calculation Summary

	Air-Side_	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft²·°F)
Inlet Temperature (°F)	148.00	104.00	j Factor
Outlet Temperature (°F)	110.81	116.29	Air-Side ho (BTU/hr·ft².°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU), 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	•		
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)
Velocity ***			Effective Area (ft²) 7,242.65
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 659,062
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 659,062
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)



Extrapolation Calculation for Row 1(Dry)

	Air-Side_	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft²·°F) 1,266.21
Inlet Temperature (°F)	148.00	113.53	j Factor 0.0082
Outlet Temperature (°F)	139.65	116.29	Air-Side ho (BTU/hr· ft^2 .°F) 8.25
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	143.82	114.91	
Skin Temperature (°F)	122.08	117.36	U Overall (BTU/hr· ft^2 .°F) 5.70
Velocity ***	3,385.89	3.98	Effective Area (ft²) 905.33
Reynold's Number	799**	27,510	LMTD 28.70
Prandtl Number	0.7255	3.8340	Total Heat Transferred (BTU/hr) 148,029
Bulk Visc (lbm/ft·hr)	0.0490	1.4137	
Skin Visc (lbm/ft·hr)		1.3806	Surface Effectiveness (Eta) 0.9185
Density (lbm/ft³)	0.0624	61.7889	Sensible Heat Transferred (BTU/hr) 148,029
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0162	0.3683	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200
Revision No. A00
Attachment A
Page No. Arc of An

PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft²·°F) 1,249.06
Inlet Temperature (°F)	139.65	111.26	j Factor 0.0082
Outlet Temperature (°F)	132.79	113.53	Air-Side ho (BTU/hr·ft². $^{\circ}$ F) 8.22
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ² .°F/BTU) 0.02832467
Average Temp (°F)	136.22	112.39	
Skin Temperature (°F)	118.31	114.44	U Overall (BTU/hr· ft^2 .°F) 5.67
Velocity ***	3,385.89	3.98	Effective Area (ft²) 905.33
Reynold's Number	807**	26,839	LMTD 23.65
Prandtl Number	0.7262	3.9393	Total Heat Transferred (BTU/hr) 121,509
Bulk Visc (lbm/ft·hr)	0.0485	1.4490	
Skin Visc (lbm/ft·hr)		1.4202	Surface Effectiveness (Eta) 0.9188
Density (lbm/ft³)	0.0632	61.8258	Sensible Heat Transferred (BTU/hr) 121,509
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0160	0.3674	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side_	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,234.94
Inlet Temperature (°F)	132.79	109.40	j Factor 0.0081
Outlet Temperature (°F)	127.16	111.26	Air-Side ho (BTU/hr·ft².°F) 8.19
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	129.97	110.33	
Skin Temperature (°F)	115.21	112.03	U Overall (BTU/hr· ft^2 .°F) 5.66
Velocity ***	3,385.89	3.98	Effective Area (ft²) 905.33
Reynold's Number	813**	26,293	LMTD 19.50
Prandtl Number	0.7267	4.0293	Total Heat Transferred (BTU/hr) 99,875
Bulk Visc (lbm/ft·hr)	0.0481	1.4791	
Skin Visc (lbm/ft·hr)		1.4543	Surface Effectiveness (Eta) 0.9190
Density (lbm/ft³)	0.0638	61.8554	Sensible Heat Transferred (BTU/hr) 99,875
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3667	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment A Page No. A13 of A17

orporation (SN#663-7371) 04/24/02

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F)	1,223.28
Inlet Temperature (°F)	127.16	107.86	j Factor	0.0081
Outlet Temperature (°F)	122.52	109.40	Air-Side ho (BTU/hr·ft².°F)	8.17
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU)	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	124.84	108.63		
Skin Temperature (°F)	112.66	110.04	U Overall (BTU/hr·ft².°F)	5.64
Velocity ***	3,385.89	3.98	Effective Area (ft²)	905.33
Reynold's Number	819**	25,847	LMTD	16.09
Prandtl Number	0.7271	4.1059	Total Heat Transferred (BTU/hr)	82,183
Bulk Visc (lbm/ft·hr)	0.0478	1.5047		
Skin Visc (lbm/ft·hr)		1.4834	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft³)	0.0643	61.8793	Sensible Heat Transferred (BTU/hr)	82,183
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3660	Heat to Condensate (BTU/hr)	
** Daymalda Nyumban Oytaida	Dange of Equation	Annlicability		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,213.65
Inlet Temperature (°F)	122.52	106.60	j Factor 0.0081
Outlet Temperature (°F)	118.70	107.86	Air-Side ho (BTU/hr·ft².°F) 8.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	120.61	107.23	
Skin Temperature (°F)	110.56	108.40	U Overall (BTU/hr·ft²-°F) 5.63
Velocity ***	3,385.89	3.97	Effective Area (ft²) 905.33
Reynold's Number	823**	25,481	LMTD 13.28
Prandtl Number	0.7274	4.1707	Total Heat Transferred (BTU/hr) 67,688
Bulk Visc (lbm/ft·hr)	0.0475	1.5263	
Skin Visc (lbm/ft·hr)		1.5081	Surface Effectiveness (Eta) 0.9194
Density (lbm/ft³)	0.0647	61.8987	Sensible Heat Transferred (BTU/hr) 67,688
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0157	0.3655	Heat to Condensate (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>A</u> Page No. <u>A14</u> of <u>A17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,205.71
Inlet Temperature (°F)	118.70	105.56	j Factor 0.0081
Outlet Temperature (°F)	115.55	106.60	Air-Side ho (BTU/hr· ft^2 .°F) 8.14
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	117.13	106.08	
Skin Temperature (°F)	108.83	107.05	U Overall (BTU/hr· ft^2 ·°F) 5.62
Velocity ***	3,385.89	3.97	Effective Area (ft²) 905.33
Reynold's Number	827**	25,182	LMTD 10.97
Prandtl Number	0.7276	4.2254	Total Heat Transferred (BTU/hr) 55,792
Bulk Visc (lbm/ft·hr)	0.0473	1.5444	
Skin Visc (lbm/ft·hr)		1.5291	Surface Effectiveness (Eta) 0.9195
Density (lbm/ft³)	0.0651	61.9144	Sensible Heat Transferred (BTU/hr) 55,792
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0156	0.3651	Heat to Condensate (BTU/hr)
** Revnolds Number Outside	Range of Equation	Applicability	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F)	1,199.14
Inlet Temperature (°F)	115.55	104.70	j Factor	0.0081
Outlet Temperature (°F)	112.96	105.56	Air-Side ho (BTU/hr·ft².°F)	8.12
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.0	00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.0	02832467
Average Temp (°F)	114.26	105.13		
Skin Temperature (°F)	107.40	105.94	U Overall (BTU/hr·ft².°F)	5.61
Velocity ***	3,385.89	3.97	Effective Area (ft²)	905.33
Reynold's Number	830**	24,935	LMTD	9.06
Prandtl Number	- 0.7278	4.2713	Total Heat Transferred (BTU/hr)	46,015
Bulk Visc (lbm/ft·hr)	0.0471	1.5597		
Skin Visc (lbm/ft·hr)		1.5467	Surface Effectiveness (Eta)	0.9196
Density (lbm/ft³)	0.0654	61.9273	Sensible Heat Transferred (BTU/hr)	46,015
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3647	Heat to Condensate (BTU/hr)	
** Darmalda Number Outsida	Dance of Equation	Applicability		





Calculation No. 97-200 Revision No. A00 Attachment A Page No. Ais of Air

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF



Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,850.70	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,193.72
Inlet Temperature (°F)	112.96	103.99	j Factor 0.0081
Outlet Temperature (°F)	110.81	104.70	Air-Side ho (BTU/hr·ft².°F) 8.11
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	111.89	104.35	
Skin Temperature (°F)	106.22	105.01	U Overall (BTU/hr· ft^2 .°F) 5.60
Velocity ***	3,385.89	3.97	Effective Area (ft²) 905.33
Reynold's Number	833**	24,733	LMTD 7.49
Prandtl Number	0.7279	4.3099	Total Heat Transferred (BTU/hr) 37,972
Bulk Visc (lbm/ft·hr)	0.0470	1.5725	
Skin Visc (lbm/ft·hr)		1.5615	Surface Effectiveness (Eta) 0.9197
Density (lbm/ft³)	0.0656	61.9378	Sensible Heat Transferred (BTU/hr) 37,972
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0155	0.3644	Heat to Condensate (BTU/hr)
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Calculation No. 97-200 Revision No. A00 Attachment A Page No. A16 of A17

Inlet Air Flowrate Calculator - 1(2)VY02A

Total P:

P=

Dry Bulb T OUT: T=

Specific Hum.:

W =

H2O Vap P:

Pv = (W*Rv*P)/(Ra+(W*Rv) =

Dry Air P:

Pa = P - Pv =

Dry Air rho IN:

Dry Air rho OUT: rho a = (144/Ra)*(Pa/(459.67+T) =

Dry Bulb T IN:

Outlet Air Flow:

rho a = (144/Ra)*(Pa/(459.67+T) =

V =

14.315 psia

Inlet Air Flow

110.81 F

19173 acfm

0.020274

0.451875 psia

Rv = 85.778 (ft-lbf)/(lbm-R)

Ra = 53.352 (ft-lbf)/(lbm-R)

13.86313 psia

0.0656 lbm/ft³

0.061575 lbm/ft³

148 F

18000 cfm





CALCULATION NO. 97-200 REVISION NO. A00

PAGE NO. B1 of B17

Attachment "B"

Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design FF, 5% Plugged)

PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG

Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration		VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		19.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Normhan af Camandin -		1.000
Number of Serpentines	E)	1.000
Tube Wall Conductivity (BTU/hr-ft-°	r <i>)</i>	225.00

Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>Bl.</u> of <u>g17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date
Air Flow (acfm)
Air Dry Bulb Temp In (°F)
Air Dry Bulb Temp Out (°F)
Relative Humidity In (%)
Relative Humidity Out (%)
Wet Bulb Temp In (°F)
Wet Bulb Temp Out (°F)
Atmospheric Pressure
Tube Flow (gpm)
Tube Temp In (°F)
Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00	
Air Flow (acfm)	19,113.00	
Tube Inlet Temp (°F)	104.00	
Air Inlet Temp (°F)	148.0	
Inlet Relative Humidity (%)	12.76	
Inlet Wet Bulb Temp (°F)	0.00	
Atmospheric Pressure	14.315	

PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG



Extrapolation Calculation Summary

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F)
Inlet Temperature (°F)	148.00	104.00	j Factor
Outlet Temperature (°F)	112.62	120.76	Air-Side ho (BTU/hr·ft².°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)
Velocity ***			Effective Area (ft^2) 6,880.52
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 625,070
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 625,070
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 1,007.00
Inlet Temperature (°F)	148.00	117.44	j Factor 0.0081
Outlet Temperature (°F)	141.01	120.76	Air-Side ho (BTU/hr· ft^2 .°F) 8.52
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	144.50	119.10	
Skin Temperature (°F)	125.96	121.81	U Overall (BTU/hr· ft^2 ,°F) 5.70
Velocity ***	3,552.94	2.91	Effective Area (ft²) 860.06
Reynold's Number	838**	20,935	LMTD 25.22
Prandtl Number	0.7254	3.6685	Total Heat Transferred (BTU/hr) 123,549
Bulk Visc (lbm/ft·hr)	0.0490	1.3580	
Skin Visc (lbm/ft·hr)		1.3238	Surface Effectiveness (Eta) 0.9162
Density (lbm/ft³)	0.0623	61.7256	Sensible Heat Transferred (BTU/hr) 123,549
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0162	0.3697	Heat to Condensate (BTU/hr)





Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>84</u> of <u>Br7</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 990.92
Inlet Temperature (°F)	141.01	114.58	j Factor 0.0080
Outlet Temperature (°F)	134.98	117.44	Air-Side ho (BTU/hr·ft².°F) 8.49
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	137.99	116.01	
Skin Temperature (°F)	121.96	118.38	U Overall (BTU/ $hr \cdot ft^2 \cdot {}^{\circ}F$) 5.67
Velocity ***	3,552.94	2.91	Effective Area (ft²) 860.06
Reynold's Number	845**	20,325	LMTD 21.82
Prandtl Number	0.7260	3.7895	Total Heat Transferred (BTU/hr) 106,500
Bulk Visc (lbm/ft·hr)	0.0486	1.3987	•
Skin Visc (lbm/ft·hr)		1.3672	Surface Effectiveness (Eta) 0.9164
Density (lbm/ft³)	0.0629	61.7725	Sensible Heat Transferred (BTU/hr) 106,500
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0161	0.3687	Heat to Condensate (BTU/hr)
** Reynolds Number Outside	Range of Equation	n Applicability	



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 976.99
Inlet Temperature (°F)	134.98	112.11	j Factor 0.0080
Outlet Temperature (°F)	129.78	114.58	Air-Side ho (BTU/hr·ft².°F) 8.46
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².ºF/BTU) 0.02832467
Average Temp (°F)	132.38	113.34	
Skin Temperature (°F)	118.50	115.42	U Overall (BTU/hr·ft².°F) 5.65
Velocity ***	3,552.94	2.91	Effective Area (ft²) 860.06
Reynold's Number	851**	19,804	LMTD 18.90
Prandtl Number	0.7265	3.8991	Total Heat Transferred (BTU/hr) 91,897
Bulk Visc (lbm/ft·hr)	0.0483	1.4355	
Skin Visc (lbm/ft·hr)		1.4067	Surface Effectiveness (Eta) 0.9166
Density (lbm/ft³)	0.0635	61.8119	Sensible Heat Transferred (BTU/hr) 91,897
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0160	0.3677	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability

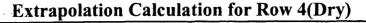


Calculation No. 97-200 Revision No. A00 Attachment _ B Page No. BS of BIT

PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 964.92	
Inlet Temperature (°F)	129.78	109.98	j Factor 0.0080	
Outlet Temperature (°F)	125.29	112.11	Air-Side ho (BTU/hr·ft².°F) 8.44	
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430	
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467	
Average Temp (°F)	127.53	111.04		
Skin Temperature (°F)	115.52	112.86	U Overall (BTU/hr·ft².°F) 5.64	
Velocity ***	3,552.94	2.91	Effective Area (ft²) 860.06	
Reynold's Number	856**	19,358	LMTD 16.37	
Prandtl Number	0.7269	3.9979	Total Heat Transferred (BTU/hr) 79,368	
Bulk Visc (lbm/ft·hr)	0.0480	1.4686		
Skin Visc (lbm/ft·hr)		1.4424	Surface Effectiveness (Eta) 0.9168	
Density (lbm/ft³)	0.0640	61.8452	Sensible Heat Transferred (BTU/hr) 79,368	
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3669	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside Range of Equation Applicability				

Extrapolation Calculation for Row 5(Dry)

	Air-Side_	Tube-Side	·
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft²·°F) 954.45
Inlet Temperature (°F)	125.29	108.13	j Factor 0.0080
Outlet Temperature (°F)	121.40	109.98	Air-Side ho (BTU/hr·ft².°F) 8.42
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU), 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	123.34	109.05	
Skin Temperature (°F)	112.94	110.64	U Overall (BTU/hr· ft^2 .°F) 5.62
Velocity ***	3,552.94	2.91	Effective Area (ft²) 860.06
Reynold's Number	861**	18,975	LMTD 14.19
Prandtl Number	0.7272	4.0866	Total Heat Transferred (BTU/hr) 68,601
Bulk Visc (lbm/ft·hr)	0.0477	1.4982	
Skin Visc (lbm/ft·hr)		1.4745	Surface Effectiveness (Eta) 0.9170
Density (lbm/ft³)	0.0644	61.8733	Sensible Heat Transferred (BTU/hr) 68,601
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3662	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>86</u> of <u>877</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG



Extrapolation Calculation for Row 6(Dry)

Air-Side	Tube-Side	
70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 945.37
121.40	106.54	j Factor 0.0080
118.05	108.13	Air-Side ho (BTU/hr· ft^2 .°F) 8.41
0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
119.72	107.33	
110.71	108.72	U Overall (BTU/hr·ft²-°F) 5.61
3,552.94	2.91	Effective Area (ft²) 860.06
865**	18,646	LMTD 12.30
0.7274	4.1659	Total Heat Transferred (BTU/hr) 59,336
0.0475	1.5246	
	1.5033	Surface Effectiveness (Eta) 0.9171
0.0648	61.8972	Sensible Heat Transferred (BTU/hr) 59,336
0.2402	0.9989	Latent Heat Transferred (BTU/hr)
0.0157	0.3656	Heat to Condensate (BTU/hr)
	70,628.98 121.40 118.05 0.0203 0.0203 119.72 110.71 3,552.94 865** 0.7274 0.0475 0.0648 0.2402 0.0157	70,628.98 37,262.20 121.40 106.54 118.05 108.13 0.0203 107.33 119.72 107.33 110.71 108.72 3,552.94 2.91 865** 18,646 0.7274 4.1659 0.0475 1.5246 1.5033 0.0648 0.2402 0.9989

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft².°F)	937.50
Inlet Temperature (°F)	118.05	105.16	j Factor	0.0080
Outlet Temperature (°F)	115.14	106.54	Air-Side ho (BTU/hr·ft²·°F)	8.39
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU)	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	116.59	105.85		
Skin Temperature (°F)	108.78	107.06	U Overall (BTU/hr·ft².°F)	5.60
Velocity ***	3,552.94	2.90	Effective Area (ft²)	860.06
Reynold's Number	869**	18,364	LMTD	10.67
Prandtl Number	0.7276	4.2365	Total Heat Transferred (BTU/hr)	51,352
Bulk Visc (lbm/ft·hr)	0.0473	1.5481		
Skin Visc (lbm/ft·hr)		1.5290	Surface Effectiveness (Eta)	0.9172
Density (lbm/ft³)	0.0651	61.9176	Sensible Heat Transferred (BTU/hr)	51,352
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3650	Heat to Condensate (BTU/hr)	
		A 11 1 111	•	

** Reynolds Number Outside Range of Equation Applicability



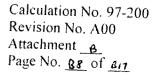
Calculation No. 97-200 Revision No. A00 Attachment <u>a</u> Page No. <u>B1</u> of <u>B17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ 104 F, DESIGN FF, 5% PLUG

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,628.98	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 930.67
Inlet Temperature (°F)	115.14	103.96	j Factor 0.0079
Outlet Temperature (°F)	112.62	105.16	Air-Side ho (BTU/hr·ft². $^{\circ}$ F) 8.38
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU); 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	113.88	104.56	
Skin Temperature (°F)	107.11	105.62	U Overall (BTU/hr· ft^2 .°F) 5.59
Velocity ***	3,552.94	2.90	Effective Area (ft²) 860.06
Reynold's Number	872**	18,120	LMTD 9.25
Prandtl Number	0.7278	4.2992	Total Heat Transferred (BTU/br) 44,466
Bulk Visc (lbm/ft·hr)	0.0471	1.5689	
Skin Visc (lbm/ft·hr)		1.5518	Surface Effectiveness (Eta) 0.9173
Density (lbm/ft³)	0.0654	61.9349	Sensible Heat Transferred (BTU/hr) 44,466
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0155	0.3645	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Inlet Air Flowrate Calculator - 1(2)VY01A

Total P:

P=

Dry Bulb T OUT:

T=

Specific Hum.:

W =

H2O Vap P:

Pv = (W*Rv*P)/(Ra+(W*Rv) =

Dry Air P:

Pa = P - Pv =

Dry Air rho OUT: rho a = (144/Ra)*(Pa/(459.67+T) =rho a = (144/Ra)*(Pa/(459.67+T) =

Dry Air rho IN: Dry Bulb T IN:

T=

Outlet Air Flow:

V =

14.315 psia

Inlet Air Flow

112.62 F

19113 acfm

0.020274

0.451875 psia

85.778 (ft-lbf)/(lbm-R)

Ra =

Rv =

53.352 (ft-lbf)/(lbm-R)

13.86313 psia

0.0654 lbm/ft³

0.061575 lbm/ft³

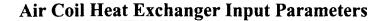
148 F

18000 cfm

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF, 5% PLUG



	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
-		77.000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration		e VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row	. •	20.00
Active Tubes Per Row		19.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft·°	F)	225.00

Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>B</u>10 of <u>B</u>17

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF, 5% PLUG



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

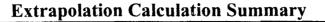
Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,164.00
Tube Inlet Temp (°F)	104.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

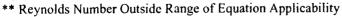
Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF, 5% PLUG



	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F)
Inlet Temperature (°F)	148.00	104.00	j Factor
Outlet Temperature (°F)	111.10	116.20	Air-Side ho (BTU/hr·ft².°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft²·°F)
Velocity ***			Effective Area (ft²) 6,880.52
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 653,739
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 653,739
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,318.81
Inlet Temperature (°F)	148.00	113.50	j Factor 0.0080
Outlet Temperature (°F)	139.81	116.20	Air-Side ho (BTU/hr· ft^2 .°F) 8.53
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	143.90	114.85	
Skin Temperature (°F)	122.15	117.28	U Overall (BTU/hr·ft².°F) 5.85
Velocity ***	3,562.42	4.19	Effective Area (ft²) 860.06
Reynold's Number	841**	28,941	LMTD 28.85
Prandtl Number	0.7255	3.8364	Total Heat Transferred (BTU/hr) 145,141
Bulk Visc (lbm/ft·hr)	0.0490	1.4145	
Skin Visc (lbm/ft·hr)		1.3817	Surface Effectiveness (Eta) 0.9161
Density (lbm/ft³)	0.0624	61.7897	Sensible Heat Transferred (BTU/hr) 145,141
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0162	0.3683	Heat to Condensate (BTU/hr)
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Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>Br</u> of <u>pr</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ 104 F, DESIGN FF, 5% PLUG



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,301.27
Inlet Temperature (°F)	139.81	111.26	j Factor 0.0080
Outlet Temperature (°F)	133.05	113.50	Air-Side ho (BTU/hr·ft².°F) 8.50
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	136.43	112.38	
Skin Temperature (°F)	118.43	114.41	U Overall (BTU/hr· ft^2 .°F) 5.83
Velocity ***	3,562.42	4.19	Effective Area (ft²) 860.06
Reynold's Number	849**	28,248	LMTD 23.88
Prandtl Number	0.7262	3.9400	Total Heat Transferred (BTU/hr) 119,696
Bulk Visc (lbm/ft·hr)	0.0485	1.4493	
Skin Visc (lbm/ft·hr)		1.4206	Surface Effectiveness (Eta) 0.9163
Density (lbm/ft³)	0.0631	61.8260	Sensible Heat Transferred (BTU/hr) 119,696
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0161	0.3674	Heat to Condensate (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

_	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,286.74
Inlet Temperature (°F)	133.05	109.42	j Factor 0.0080
Outlet Temperature (°F)	127.47	111.26	Air-Side ho (BTU/hr·ft².°F) 8.47
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	130.26	110.34	
Skin Temperature (°F)	115.35	112.04	U Overall (BTU/hr·ft².°F) 5.81
Velocity ***	3,562.42	4.19	Effective Area (ft²) 860.06
Reynold's Number	855**	27,680	LMTD 19.78
Prandtl Number	0.7267	4.0288	Total Heat Transferred (BTU/hr) 98,838
Bulk Visc (lbm/ft·hr)	0.0481	1.4790	, , , , , , , , , , , , , , , , , , , ,
Skin Visc (lbm/ft·hr)		1.4541	Surface Effectiveness (Eta) 0.9166
Density (lbm/ft³)	0.0637	61.8552	Sensible Heat Transferred (BTU/hr) 98,838
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3667	Heat to Condensate (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>Bis</u> of <u>Bir</u>

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF, 5% PLUG



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,274.	71
Inlet Temperature (°F)	127.47	107.89	j Factor 0.008	80
Outlet Temperature (°F)	122.86	109.42	Air-Side ho (BTU/hr·ft².°F) 8.4	45
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.0003143	30
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.0283246	67
Average Temp (°F)	125.17	108.65		
Skin Temperature (°F)	112.81	110.07	U Overall (BTU/ $hr \cdot ft^2 \cdot {}^{\circ}F$) 5.	79
Velocity ***	3,562.42	4.18	Effective Area (ft²) 860.0	06
Reynold's Number	861**	27,214	LMTD 16.4	40
Prandtl Number	0.7270	4.1047	Total Heat Transferred (BTU/hr) 81,70	01
Bulk Visc (lbm/ft·hr)	0.0478	1.5043		
Skin Visc (lbm/ft·hr)		1.4829	Surface Effectiveness (Eta) 0.910	68
Density (lbm/ft³)	0.0642	61.8789	Sensible Heat Transferred (BTU/hr) 81,70	01
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3661	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr-ft2.°F)	1,264.72
Inlet Temperature (°F)	122.86	106.63	j Factor	0.0080
Outlet Temperature (°F)	119.04	107.89	Air-Side ho (BTU/hr·ft².°F)	8.43
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2.°F/BTU)	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	120.95	107.26		
Skin Temperature (°F)	110.71	108.44	U Overall (BTU/hr·ft².°F)	5.78
Velocity ***	3,562.42	4.18	Effective Area (ft²)	860.06
Reynold's Number	866**	26,831	LMTD	13.59
Prandtl Number	0.7273	4.1693	Total Heat Transferred (BTU/hr)	67,596
Bulk Visc (lbm/ft·hr)	0.0475	1.5258		
Skin Visc (lbm/ft·hr)		1.5075	Surface Effectiveness (Eta)	0.9169
Density (lbm/ft³)	0.0647	61.8982	Sensible Heat Transferred (BTU/hr)	67,596
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3655	Heat to Condensate (BTU/hr)	
www.maratatatatatatata	Dance of Equation	. A moli og bilita		

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment & Page No. BI4 of BI7

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF, 5% PLUG



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,2	256.44
Inlet Temperature (°F)	119.04	105.59	j Factor 0	0.0080
Outlet Temperature (°F)	115.88	106.63	Air-Side ho (BTU/hr·ft².°F)	8.41
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft²-°F/BTU) 0.000	31430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.028	32467
Average Temp (°F)	117.46	106.11		
Skin Temperature (°F)	108.97	107.09	U Overall (BTU/hr·ft².°F)	5.77
Velocity ***	3,562.42	4.18	Effective Area (ft²)	360.06
Reynold's Number	870**	26,515	LMTD	11.28
Prandtl Number	0.7276	4.2239	Total Heat Transferred (BTU/hr) 5	5,967
Bulk Visc (lbm/ft·hr)	0.0473	1.5440		
Skin Visc (lbm/ft·hr)		1.5284).9171
Density (lbm/ft³)	0.0650	61.9140	Sensible Heat Transferred (BTU/hr) 5	5,967
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3651	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft²·°F) 1,249.57
Inlet Temperature (°F)	115.88	104.72	j Factor 0.0079
Outlet Temperature (°F)	113.27	105.59	Air-Side ho (BTU/hr· ft^2 ·°F) 8.40
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	114.58	105.15	
Skin Temperature (°F)	107.53	105.97	U Overall (BTU/hr· ft^2 .°F) 5.76
Velocity ***	3,562.42	4.18	Effective Area (ft²) 860.06
Reynold's Number	873**	26,255	LMTD 9.36
Prandtl Number	0.7278	4.2701	Total Heat Transferred (BTU/hr) 46,367
Bulk Visc (lbm/ft·hr)	0.0471	1.5593	
Skin Visc (lbm/ft·hr)		1.5461	Surface Effectiveness (Eta) 0.9172
Density (lbm/ft³)	0.0653	61.9269	Sensible Heat Transferred (BTU/hr) 46,367
Cp (BTU/lbm.°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0156	0.3648	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>B15</u> of <u>B17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF, 5% PLUG

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,817.44	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,243.87
Inlet Temperature (°F)	113.27	104.01	j Factor 0.0079
Outlet Temperature (°F)	111.10	104.72	Air-Side ho (BTU/hr·ft².°F) 8.39
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	112.18	104.36	
Skin Temperature (°F)	106.34	105.05	U Overall (BTU/ $hr \cdot ft^2 \cdot {}^{\circ}F$) 5.75
Velocity ***	3,562.42	4.18	Effective Area (ft²) 860.06
Reynold's Number	876**	26,039	LMTD 7.76
Prandtl Number	0.7279	4.3090	Total Heat Transferred (BTU/hr) 38,433
Bulk Visc (lbm/ft·hr)	0.0470	1.5722	
Skin Visc (lbm/ft·hr)		1.5610	Surface Effectiveness (Eta) 0.9173
Density (lbm/ft³)	0.0656	61.9375	Sensible Heat Transferred (BTU/hr) 38,433
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0155	0.3645	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>B</u> Page No. <u>BIL</u> of <u>BI7</u>



Inlet Air Flowrate Calculator - 1(2)VY02A

Total P: Dry Bulb T OUT: T=

Specific Hum.: W =

H2O Vap P:

Pv = (W*Rv*P)/(Ra+(W*Rv) =

Dry Air P: 🕖 Pa = P - Pv =

Dry Air rho OUT: rho a = $(144/Ra)^*(Pa/(459.67+T) =$ rho a = $(144/Ra)^*(Pa/(459.67+T) =$ Dry Air rho IN:

Dry Bulb T IN: T=

Outlet Air Flow: V =

14.315 psia 111.1 F

Inlet Air Flow

19164 acfm

0.020274 0.451875 psia

85.778 (ft-lbf)/(lbm-R)

Rv = Ra = 53.352 (ft-lbf)/(lbm-R)

13.86313 psia 0.0656 lbm/ft³ 0.061575 lbm/ft³

148 F 18000 cfm





CALCULATION NO. 97-200 REVISION NO. A00

PAGE NO. C1 of C17

Attachment "C"

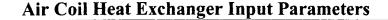
Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (For VY01, CSCS=104°F @ Max. Allowable FF, w\ 5% plugged) (For VY02, CSCS=104°F @ Design FF, Room Temp. = 150°F)

E-FORM

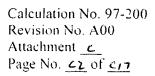
PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Fluid Quantity, Total 150.00 °F 150.00 °F 105.00 °F 105.		Air-Side	Tube-Side
Inlet Wet Bulb Temp	Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Relative Humidity % Outlet Dry Bulb Temperature 109.40 °F 115.30 °F Outlet Wet Bulb Temp 84.10 °F 109.40 °F 115.30 °F Outlet Relative Humidity % ** Tube Fluid Name Fresh Water 0.005000 Air-Side Fouling 0.0005000 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Tubes Per	Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Outlet Dry Bulb Temperature 109.40 °F 115.30 °F Outlet Wet Bulb Temp 84.10 °F 115.30 °F Outlet Relative Humidity % ** Tube Fluid Name Fresh Water 0.005000 Air-Side Fouling 0.000500 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in)	Inlet Wet Bulb Temp	92.00 °F	
Outlet Wet Bulb Temp 84.10 °F Outlet Relative Humidity % Tube Fluid Name Fresh Water Tube Fouling Factor 0.005000 Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Configuration LaSalle VY Coolers 01A/02A Fin Configuration 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500	Inlet Relative Humidity	%	
Outlet Relative Humidity % Tube Fluid Name Fresh Water Tube Fouling Factor 0.005000 Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft of the final Pitch (Fins/Inch) 10.000 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.452 <	Outlet Dry Bulb Temperature		115.30 °F
Tube Fluid Name Fresh Water Tube Fouling Factor 0.005000 Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.452 Number of Serpe	Outlet Wet Bulb Temp	84.10 °F	
Tube Fouling Factor 0.005000 Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452	Outlet Relative Humidity	%%	
Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452	Tube Fluid Name		Fresh Water
Air-Side Fouling 0.000500 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Configuration Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452	Tube Fouling Factor		0.005000
Design Heat Transfer (BTU/hr) Atmospheric Pressure Sensible Heat Ratio Performance Factor (% Reduction) Heat Exchanger Type Fin Type Counter Flow Fin Configuration Coil Finned Length (in) Fin Pitch (Fins/Inch) Fin Pitch (Fins/Inch) Fin Typ Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Transverse Tube Pitch (in) Transverse Tube Pitch (in) 14.315 1.000 Counter Flow Counter Flow Circular Fins LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] 1.000 1.000 1.000 1.000 1.000 1.000 1.0	-		0.000500
Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000			
Sensible Heat Ratio Performance Factor (% Reduction) Heat Exchanger Type Fin Type Circular Fins Fin Configuration Coil Finned Length (in) Fin Pitch (Fins/Inch) Fin Conductivity (BTU/hr ft °F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Transverse Tube Pitch (in) Number of Serpentines 1.000 Counter Flow Circular Fins LaSalle VY Coolers 01A/02A J EXP[-2.5088 + -0.3436 * LOG(Re)] 1.000			
Performance Factor (% Reduction) 0.000 Heat Exchanger Type Fin TypeCounter Flow Circular FinsFin ConfigurationLaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) Fin Pitch (Fins/Inch) 104.250 Fin Pitch (Fins/Inch)Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches)Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches)Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row 20.00 Active Tubes Per RowTube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) 0.5270 1.500 1.452Number of Serpentines 1.000	_		·
Heat Exchanger TypeCounter Flow Circular FinsFin TypeCircular FinsFin ConfigurationLaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch)Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr-ft- $^{\circ}$ F) 128.000 Fin Tip Thickness (inches)Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 0.0120 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per RowNumber of Tubes Per Row 20.00 Active Tubes Per Row 20.00 19.00Tube Inside Diameter (in) 0.5270 10.6250 10.00jtudinal Tube Pitch (in) 0.6250 1.500 1.452Number of Serpentines 1.000			
$\begin{array}{lll} Fin Type & Circular Fins \\ Fin Configuration & LaSalle VY Coolers 01A/02A \\ j = EXP[-2.5088 + -0.3436 * LOG(Re)] \\ \hline Coil Finned Length (in) & 104.250 \\ Fin Pitch (Fins/Inch) & 10.000 \\ Fin Conductivity (BTU/hr·ft·°F) & 128.000 \\ Fin Tip Thickness (inches) & 0.0120 \\ Fin Root Thickness (inches) & 0.0120 \\ Circular Fin Height (inches) & 1.495 \\ \hline Number of Coils Per Unit & 2 \\ Number of Tube Rows & 8 \\ Number of Tubes Per Row & 20.00 \\ Active Tubes Per Row & 19.00 \\ \hline Tube Inside Diameter (in) & 0.5270 \\ Tube Outside Diameter (in) & 0.6250 \\ Longitudinal Tube Pitch (in) & 1.500 \\ Transverse Tube Pitch (in) & 1.452 \\ \hline Number of Serpentines & 1.000 \\ \hline \end{array}$	Performance Factor (% Reduction)		0.000
Fin Configuration $J = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) $I04.250$ Fin Pitch (Fins/Inch) $I0.000$ Fin Conductivity (BTU/hr·ft·°F) $I28.000$ Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Heat Exchanger Type		Counter Flow
j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 19.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Fin Type		Circular Fins
Coil Finned Length (in) Fin Pitch (Fins/Inch) Fin Conductivity (BTU/hr·ft·°F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Transverse Tube Pitch (in) Number of Serpentines 104.250 128.000 128.000 129.00120 129.	Fin Configuration	LaSalle	VY Coolers 01A/02A
Fin Pitch (Fins/Inch)10.000Fin Conductivity (BTU/hr·ft·°F)128.000Fin Tip Thickness (inches)0.0120Fin Root Thickness (inches)0.0120Circular Fin Height (inches)1.495Number of Coils Per Unit2Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000		j = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Fin Pitch (Fins/Inch)10.000Fin Conductivity (BTU/hr·ft·°F)128.000Fin Tip Thickness (inches)0.0120Fin Root Thickness (inches)0.0120Circular Fin Height (inches)1.495Number of Coils Per Unit2Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Coil Finned Length (in)		104.250
Fin Conductivity (BTU/hr·ft·°F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Transverse Tube Pitch (in) Number of Serpentines 128.000 0.0120 0.0120 1.495	_ , <i>,</i> ,		
Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Congitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 0.0120	· · · · · · · · · · · · · · · · · · ·		
Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 0.0120 20.01 20.02 8 Number of Tube Rows 19.00 19.00 19.00 19.00 19.00 19.00 10.00 10.00 10.00	• •		
Circular Fin Height (inches)1.495Number of Coils Per Unit2Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	•		
Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	•		
Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Number of Coils Per Unit		2
Number of Tubes Per Row20.00Active Tubes Per Row19.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000			
Active Tubes Per Row 19.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000			
Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 0.5270 0.6250 1.500 1.452			
Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Metive Tubes Fer Team		17.00
Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	· ·		0.5270
Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000			0.6250
Number of Serpentines 1.000	•		1.500
<u>-</u>	Transverse Tube Pitch (in)		1.452
<u>-</u>	Number of Serpentines		1.000
	<u>-</u>	°F)	



Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

75.00
18,982.00
104.00
148.0
12.76
0.00
14.315

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Extrapolation Calculation Summary

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft².°F)
Inlet Temperature (°F)	148.00	104.00	j Factor
Outlet Temperature (°F)	116.55	118.87	Air-Side ho (BTU/hr·ft²-°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.09491556
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft²-°F)
Velocity ***			Effective Area (ft²) 6,880.52
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 551,834
Bulk Visc (lbm/ft·hr)			•
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 551,834
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)



Extrapolation Calculation for Row 1(Dry)

_	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft²-°F)	98.47
Inlet Temperature (°F)	148.00	116.24	j Factor (0.0081
Outlet Temperature (°F)	142.44	118.87	Air-Side ho (BTU/hr·ft².°F)	8.48
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.000	31430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.094	91556
Average Temp (°F)	145.22	117.56		
Skin Temperature (°F)	130.56	119.71	U Overall (BTU/hr·ft².°F)	4.12
Velocity ***	3,528.59	2.91	Effective Area (ft²)	360.06
Reynold's Number	831**	20,630	LMTD	27.55
Prandtl Number	0.7254	3.7281	Total Heat Transferred (BTU/hr) 9	7,604
Bulk Visc (lbm/ft·hr)	0.0491	1.3780		
Skin Visc (lbm/ft·hr)		1.3501	Surface Effectiveness (Eta)	.9165
Density (lbm/ft³)	0.0622	61.7492	Sensible Heat Transferred (BTU/hr) 9	7,604
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3692	Heat to Condensate (BTU/hr)	





Calculation No. 97-200 Revision No. A00 Attachment <u>c</u> Page No. <u>c4</u> of <u>c11</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 9	85.60
Inlet Temperature (°F)	142.44	113.89	j Factor 0	.0081
Outlet Temperature (°F)	137.45	116.24	Air-Side ho (BTU/hr·ft².°F)	8.46
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.0003	31430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.0949	91556
Average Temp (°F)	139.94	115.07		
Skin Temperature (°F)	126.76	117.03	U Overall (BTU/hr·ft².°F)	4.11
Velocity ***	3,528.59	2.91		60.06
Reynold's Number	837**	20,141		24.78
Prandtl Number	0.7259	3.8275	Total Heat Transferred (BTU/hr) 8	7,561
Bulk Visc (lbm/ft·hr)	0.0487	1.4115		
Skin Visc (lbm/ft·hr)		1.3851	· /	.9167
Density (lbm/ft³)	0.0627	61.7865	,	7,561
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3683	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 974.02
Inlet Temperature (°F)	137.45	111.78	j Factor 0.0080
Outlet Temperature (°F)	132.97	113.89	Air-Side ho (BTU/hr· ft^2 .°F) 8.44
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.09491556
Average Temp (°F)	135.21	112.84	
Skin Temperature (°F)	123.35	114.61	U Overall (BTU/hr·ft².°F) 4.10
Velocity ***	3,528.59	2.91	Effective Area (ft²) 860.06
Reynold's Number	842**	19,705	LMTD 22.28
Prandtl Number	0.7263	3.9205	Total Heat Transferred (BTU/hr) 78,587
Bulk Visc (lbm/ft·hr)	0.0484	1.4427	
Skin Visc (lbm/ft·hr)		1.4178	Surface Effectiveness (Eta) 0.9169
Density (lbm/ft³)	0.0632	61.8193	Sensible Heat Transferred (BTU/hr) 78,587
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0160	0.3676	Heat to Condensate (BTU/hr)
	- 0-	4 11 1 11.	

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200
Revision No. A00
Attachment <u>c</u>
Page No. <u>c5</u> of <u>C11</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 963.58
Inlet Temperature (°F)	132.97	109.88	j Factor 0.0080
Outlet Temperature (°F)	128.95	111.78	Air-Side ho (BTU/hr·ft².°F) 8.42
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.09491556
Average Temp (°F)	130.96	110.83	
Skin Temperature (°F)	120.29	112.45	U Overall (BTU/hr·ft².°F) 4.09
Velocity ***	3,528.59	2.91	Effective Area (ft²) 860.06
Reynold's Number	846**	19,317	LMTD 20.05
Prandtl Number	0.7266	4.0071	Total Heat Transferred (BTU/hr) 70,561
Bulk Visc (lbm/ft·hr)	0.0482	1.4717	
Skin Visc (lbm/ft·hr)		1.4483	Surface Effectiveness (Eta) 0.9170
Density (lbm/ft³)	0.0636	61.8482	Sensible Heat Transferred (BTU/hr) 70,561
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3668	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 954.18
Inlet Temperature (°F)	128.95	108.18	j Factor 0.0080
Outlet Temperature (°F)	125.34	109.88	Air-Side ho (BTU/hr· ft^2 .°F) 8.40
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU) 0.09491556
Average Temp (°F)	127.14	109.03	
Skin Temperature (°F)	117.54	110.50	U Overall (BTU/hr·ft².°F) 4.09
Velocity ***	3,528.59	2.91	Effective Area (ft²) 860.06
Reynold's Number	851**	18,971	LMTD 18.04
Prandtl Number	0.7269	4.0875	Total Heat Transferred (BTU/hr) 63,378
Bulk Visc (lbm/ft·hr)	0.0479	1.4986	
Skin Visc (lbm/ft·hr)		1.4766	Surface Effectiveness (Eta) 0.9172
Density (lbm/ft³)	0.0640	61.8736	Sensible Heat Transferred (BTU/hr) 63,378
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3662	Heat to Condensate (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200
Revision No. A00
Attachment <u>c</u>
Page No. <u>c4</u> of <u>c17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 945.71
Inlet Temperature (°F)	125.34	106.65	j Factor 0.0080
Outlet Temperature (°F)	122.09	108.18	Air-Side ho (BTU/hr- $ft^{2,\circ}F$) 8.39
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.09491556
Average Temp (°F)	123.71	107.42	
Skin Temperature (°F)	115.07	108.74	U Overall (BTU/hr·ft².°F) 4.08
Velocity ***	3,528.59	2.91	Effective Area (ft²) 860.06
Reynold's Number	855**	18,662	LMTD 16.23
Prandtl Number	0.7272	4.1621	Total Heat Transferred (BTU/hr) 55,946
Bulk Visc (lbm/ft·hr)	0.0477	1.5234	
Skin Visc (lbm/ft·hr)		1.5029	Surface Effectiveness (Eta) 0.9173
Density (lbm/ft³)	0.0643	61.8961	Sensible Heat Transferred (BTU/hr) 56,946
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3656	Heat to Condensate (BTU/hr)
** Reynolds Number Outside	Range of Equation	Annlicability	

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft²-°F) 938.08
Inlet Temperature (°F)	122.09	105.28	j Factor 0.0080
Outlet Temperature (°F)	119.17	106.65	Air-Side ho (BTU/hr·ft².°F) 8.37
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft ² .°F/BTU) 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.09491556
Average Temp (°F)	120.63	105.96	· ,
Skin Temperature (°F)	112.86	107.17	U Overall (BTU/hr·ft².°F) 4.07
Velocity ***	3,528.59	2.90	Effective Area (ft ²) 860.06
Reynold's Number	858**	18,386	LMTD 14.61
Prandtl Number	0.7274	4.2309	Total Heat Transferred (BTU/hr) 51,182
Bulk Visc (lbm/ft·hr)	0.0475	1.5463	
Skin Visc (lbm/ft·hr)		1.5273	Surface Effectiveness (Eta) 0.9174
Density (lbm/ft³)	0.0647	61.9160	Sensible Heat Transferred (BTU/hr) 51,182
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0157	0.3651	Heat to Condensate (BTU/hr)
** Daymolde Number Outside	Dange of Equation	Annlicability	·

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>C</u> Page No. <u>e1</u> of <u>C11</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY01 @ MAX FF, w\ 5% PLUG

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,144.89	37,262.20	Tube-Side hi (BTU/hr·ft².°F) 931.21
Inlet Temperature (°F)	119.17	104.04	j Factor 0.0080
Outlet Temperature (°F)	116.55	105.28	Air-Side ho (BTU/hr-ft².°F) 8.36
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²·°F/BTU); 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU) 0.09491556
Average Temp (°F)	117.86	104.66	
Skin Temperature (°F)	110.86	105.75	U Overall (BTU/hr· ft^2 ·°F) 4.07
Velocity ***	3,528.59	2.90	Effective Area (ft²) 860.06
Reynold's Number	861**	18,138	LMTD 13.15
Prandtl Number	0.7276	4.2944	Total Heat Transferred (BTU/hr) 46,015
Bulk Visc (lbm/ft·hr)	0.0473	1.5673	
Skin Visc (lbm/ft·hr)		1.5497	Surface Effectiveness (Eta) 0.9175
Density (lbm/ft³)	0.0650	61.9336	Sensible Heat Transferred (BTU/hr) 46,015
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0156	0.3646	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability

Calculation No. 97-200 Revision No. A00 Attachment <u>c</u> Page No. <u>cs</u> of <u>c17</u>

Inlet Air Flowrate Calculator - 1(2)VY01A

Total P: Dry Bulb T OUT:

P=

T=

Specific Hum.:

W =

H2O Vap P:

 $Pv = (W^*Rv^*P)/(Ra+(W^*Rv) =$

0.020274 0.451875 psia

116.55 F

14.315 psia

Rv =

85.778 (ft-lbf)/(ibm-R)

Inlet Air Flow

18982 acfm

Ra =

53.352 (ft-lbf)/(lbm-R)

13.86313 psia

0.0649 lbm/ft³

0.061575 lbm/ft³

148 F

18000 cfm

Dry Air P:

Pa = P - Pv =

Dry Air rho OUT: rho a = (144/Ra)*(Pa/(459.67+T) =Dry Air rho IN:

rho a = (144/Ra)*(Pa/(459.67+T) =

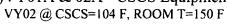
Dry Bulb T IN:

T=

Outlet Air Flow: V =

> Calculation No. 97-200 Revision No. A00 Attachment c Page No. <u>cq</u> of <u>c11</u>

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils



Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	<u>%</u>	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
•		0.00000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
C	j = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Coil Finned Langth (in)		104.250
Coil Finned Length (in) Fin Pitch (Fins/Inch)		104.250
Fin Conductivity (BTU/hr·ft·°F)		10.000
Fin Tip Thickness (inches)		128.000
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		0.0120 1.495
Circular Fill Height (inches)		1.493
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Comentings		1 000
Number of Serpentines Tube Wall Conductivity (BTU/hr-ft-	PF)	1.000
Tube wan Conductivity (DIO/III'II'	1')	225.00

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ CSCS=104 F, ROOM T=150 F

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

108.00
19,162.00
104.00
150.0
12.76
0.00
14.315

PROTO-HX 3.01 by Proto-Power Corporation (SN#663-7371)

ComEd -- LaSalle

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ CSCS=104 F, ROOM T=150 F



0.00031430
0.02832467
7,242.65
686,379
686,379
0.0283 7,2 68



	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,269.63
Inlet Temperature (°F)	150.00	113.97	j Factor 0.0082
Outlet Temperature (°F)	141.26	116.85	Air-Side ho (BTU/hr·ft ² . $^{\circ}$ F) 8.23
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft²-°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	145.63	115.41	
Skin Temperature (°F)	122.89	117.96	U Overall (BTU/hr·ft²·°F) 5.69
Velocity ***	3,367.24	3.98	Effective Area (ft²) 905.33
Reynold's Number	793**	27,644	LMTD 30.00
Prandtl Number	0.7253	3.8137	Total Heat Transferred (BTU/hr) 154,454
Bulk Visc (lbm/ft·hr)	0.0491	1.4069	
Skin Visc (lbm/ft·hr)		1.3727	Surface Effectiveness (Eta) 0.9187
Density (lbm/ft³)	0.0622	61.7815	Sensible Heat Transferred (BTU/hr) 154,454
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0163	0.3685	Heat to Condensate (BTU/hr)
when that he original	Daniel of Counting	. A mali adhilitar	

^{**} Reynolds Number Outside Range of Equation Applicability

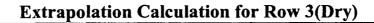


Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ CSCS=104 F, ROOM T=150 F



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F)	1,251.77
Inlet Temperature (°F)	141.26	111.60	j Factor	0.0082
Outlet Temperature (°F)	134.08	113.97	Air-Side ho (BTU/hr·ft².°F)	8.19
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	137.67	112.78		
Skin Temperature (°F)	118.95	114.91	U Overall (BTU/hr·ft².°F)	5.66
Velocity ***	3,367.24	3.98	Effective Area (ft²)	905.33
Reynold's Number	801**	26,943	LMTD	24.70
Prandtl Number	0.7260	3.9226	Total Heat Transferred (BTU/hr)	126,678
Bulk Visc (lbm/ft·hr)	0.0486	1.4434		
Skin Visc (lbm/ft·hr)		1.4137	Surface Effectiveness (Eta)	0.9190
Density (lbm/ft³)	0.0629	61.8201	Sensible Heat Transferred (BTU/hr)	126,678
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3675	Heat to Condensate (BTU/hr)	
** Revnolds Number Outside	Range of Equation	Applicability		



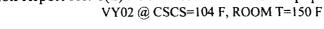
	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,237.05
Inlet Temperature (°F)	134.08	109.66	j Factor 0.0082
Outlet Temperature (°F)	128.19	111.60	Air-Side ho (BTU/hr· ft^2 .°F) 8.17
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	131.14	110.63	
Skin Temperature (°F)	115.71	112.40	U Overall (BTU/hr·ft².°F) 5.65
Velocity ***	3,367.24	3.98	Effective Area (ft²) 905.33
Reynold's Number	808**	26,373	LMTD 20.36
Prandtl Number	0.7266	4.0159	Total Heat Transferred (BTU/hr) 104,043
Bulk Visc (lbm/ft·hr)	0.0482	1.4746	
Skin Visc (lbm/ft·hr)		1.4490	Surface Effectiveness (Eta) 0.9193
Density (lbm/ft³)	0.0636	61.8510	Sensible Heat Transferred (BTU/hr) 104,043
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0159	0.3668	Heat to Condensate (BTU/hr)
Cp (BTU/lbm·°F)	0.0159	0.3668	· · · · · · · · · · · · · · · · · · ·

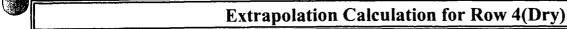
^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Page No. 213 of C17

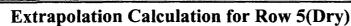
Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,224.91
Inlet Temperature (°F)	128.19	108.06	j Factor 0.0081
Outlet Temperature (°F)	123.35	109.66	Air-Side ho (BTU/hr·ft².°F) 8.14
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	125.77	108.86	
Skin Temperature (°F)	113.06	110.33	U Overall (BTU/hr· ft^2 .°F) 5.63
Velocity ***	3,367.24	3.98	Effective Area (ft²) 905.33
Reynold's Number	813**	25,908	LMTD 16.79
Prandtl Number	0.7270	4.0953	Total Heat Transferred (BTU/hr) 85,551
Bulk Visc (lbm/ft·hr)	0.0478	1.5011	
Skin Visc (lbm/ft·hr)		1.4791	Surface Effectiveness (Eta) 0.9195
Density (lbm/ft³)	0.0641	61.8760	Sensible Heat Transferred (BTU/hr) 85,551
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3661	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,214.90
Inlet Temperature (°F)	123.35	106.75	j Factor 0.0081
Outlet Temperature (°F)	119.36	108.06	Air-Side ho (BTU/hr·ft²-°F) 8.12
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²·°F/BTU) 0.02832467
Average Temp (°F)	121.36	107.41	
Skin Temperature (°F)	110.87	108.63	U Overall (BTU/hr· ft^2 .°F) 5.62
Velocity ***	3,367.24	3.97	Effective Area (ft²) 905.33
Reynold's Number	818**	25,527	LMTD 13.85
Prandtl Number	0.7273	4.1625	Total Heat Transferred (BTU/hr) 70,414
Bulk Visc (lbm/ft·hr)	0.0476	1.5235	
Skin Visc (lbm/ft·hr)		1.5047	Surface Effectiveness (Eta) 0.9196
Density (lbm/ft³)	0.0645	61.8962	Sensible Heat Transferred (BTU/hr) 70,414
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0157	0.3656	Heat to Condensate (BTU/hr)
** Daniel Jakhandan Oakida	Dames of Equation	. A amlicability	

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>C</u> Page No. <u>C14</u> of <u>C11</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils VY02 @ CSCS=104 F, ROOM T=150 F



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr ft².°F)	1,206.63
Inlet Temperature (°F)	119.36	105.67	j Factor	0.0081
Outlet Temperature (°F)	116.08	106.75	Air-Side ho (BTU/hr·ft².°F)	8.11
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU)	0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	117.72	106.21		
Skin Temperature (°F)	109.07	107.22	U Overall (BTU/hr·ft².°F)	5.61
Velocity ***	3,367.24	3.97	Effective Area (ft²)	905.33
Reynold's Number	822**	25,215	LMTD	11.43
Prandtl Number	0.7276	4.2192	Total Heat Transferred (BTU/hr)	58,002
Bulk Visc (lbm/ft·hr)	0.0473	1.5424		
Skin Visc (lbm/ft·hr)		1.5264	Surface Effectiveness (Eta)	0.9198
Density (lbm/ft³)	0.0649	61.9126	Sensible Heat Transferred (BTU/hr)	58,002
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0156	0.3651	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft².°F) 1,199.81
Inlet Temperature (°F)	116.08	104.78	j Factor 0.0081
Outlet Temperature (°F)	113.37	105.67	Air-Side ho (BTU/hr·ft².°F) 8.10
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr-ft ² -°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft²-°F/BTU) 0.02832467
Average Temp (°F)	114.73	105.22	
Skin Temperature (°F)	107.58	106.06	U Overall (BTU/hr·ft².°F) 5.60
Velocity ***	3,367.24	3.97	Effective Area (ft²) 905.33
Reynold's Number	825**	24,959	LMTD 9.43
Prandtl Number	0.7278	4.2668	Total Heat Transferred (BTU/hr) 47,809
Bulk Visc (lbm/ft·hr)	0.0471	1.5582	
Skin Visc (lbm/ft·hr)		1.5447	Surface Effectiveness (Eta) 0.9199
Density (lbm/ft³)	0.0652	61.9260	Sensible Heat Transferred (BTU/hr) 47,809
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0156	0.3648	Heat to Condensate (BTU/hr)
44 D 11 M 1 O 4 11.	n cr	A 12 1. 2124.	

^{**} Reynolds Number Outside Range of Equation Applicability



Calculation No. 97-200 Revision No. A00 Attachment <u>c</u> Page No. <u>C15</u> of <u>C17</u>

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ CSCS=104 F, ROOM T=150 F

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft²·°F) 1,194.18
Inlet Temperature (°F)	113.37	104.04	j Factor 0.0081
Outlet Temperature (°F)	111.14	104.78	Air-Side ho (BTU/hr·ft²-°F) 8.09
Inlet Specific Humidity	0.0213		Tube Wall Resistance (hr·ft².°F/BTU) 0.00031430
Outlet Specific Humidity	0.0213		Overall Fouling (hr·ft².°F/BTU) 0.02832467
Average Temp (°F)	112.26	104.41	
Skin Temperature (°F)	106.36	105.10	U Overall (BTU/hr·ft ² .°F) 5.59
Velocity ***	3,367.24	3.97	Effective Area (ft²) 905.33
Reynold's Number	828**	24,749	LMTD 7.79
Prandtl Number	0.7279	4.3068	Total Heat Transferred (BTU/hr) 39,429
Bulk Visc (lbm/ft·hr)	0.0470	1.5714	
Skin Visc (lbm/ft·hr)		1.5601	Surface Effectiveness (Eta) 0.9200
Density (lbm/ft³)	0.0655	61.9369	Sensible Heat Transferred (BTU/hr) 39,429
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0155	0.3645	Heat to Condensate (BTU/hr)





Calculation No. 97-200 Revision No. A00 Attachment c Page No. Cib of Cit

Inlet Air Flowrate Calculator - 1(2)VY02A

Total P:

₽≈

Dry Bulb T OUT: T=

W = Specific Hum.:

H2O Vap P:

Pv = (W*Rv*P)/(Ra+(W*Rv) =

Dry Air P:

Pa = P - Pv =

Dry Air rho IN:

Dry Air rho OUT: rho a = (144/Ra)*(Pa/(459.67+T) =rho a = (144/Ra)*(Pa/(459.67+T) =

Dry Buib T IN:

T=

Outlet Air Flow: V = 14.315 psia

Inlet Air Flow

111.14 F

19162 acfm

0.020274

0.451875 psia

85.778 (ft-lbf)/(lbm-R)

53.352 (ft-lbf)/(lbm-R)

Rv =

Ra =

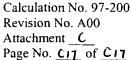
13.86313 psia

0.0656 lbm/ft³

0.061575 lbm/ft³

148 F

18000 cfm





PROTO-POWER CORPORATION CALCULATION TITLE SHEET

CLIENT:

Commonwealth Edison

PROJECT:

LaSalle Station GL 89-13 Heat Exchanger Testing Program

CALCULATION TITLE:

VY Cooler Thermal Performance Model -- 1(2)VY01A and

1(2)VY02A

CALCULATION NO.:

97-200

FILE NO.:

31-003

COMPUTER CODE & VERSION (if applicable): PROTO-HX™, Version 3.01

REV	TOTAL NO. OF PAGES	ORIGINATOR/DATE	VERIFIER/DATE	APPROVAL/DATE
A	205	Lloyd Philpot FERENT 6/24/92	Merid Aboye	Jac Conselly
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Form No.: <u>PI050101</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

Ref.: P&I 5-1

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	verified by M. Aboye		JOB NO. 31-003		
CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing				
VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A					

Revision History

Revision	Revision Description
A	Original Issue



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	VERIFIED BY M. Aboye		JOB NO. 31-003		
CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing				
VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A					

CALCULATION VERIFICATION FORM

Approach Checked:	,		EXTENT OF VERIFICA	ATION:
ripproudit districts.	ल	N/A 🔲	Complete Calculation:	
Logic Checked:	Q,	N/A 🔲		
Arithmetic Checked:		N/A 🔲	Revised areas only:	
Alternate Method (Attach Brief Summary)		N/A □		
Computer Program Used		N/A []	Other (describe below):	П
(Attach Listing)	ليا	17//1	omer (describe below).	
Other		N/A		
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Form No.: <u>PI050103</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

Ref.: <u>P&I 5-1</u>

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CLIENT	Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing				
TITLE						

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VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A			

LIST OF ATTACHMENTS

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A	Attachment A to Proto-Power Calculation 97-200 Rev. A: Design Input Data Selected References	13
В	Attachment B to Proto-Power Calculation 97-200 Rev. A: Cooler Inspection Photographs 1VY01A and 1VY02A	3
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205

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Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing		
VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A			

1. PURPOSE

The purpose of this calculation is to develop a thermal performance analysis model for the Commonwealth Edison (ComEd) LaSalle Station NW and SW cubicle area coolers 1(2)VY01A and 1(2)VY02A. This model can be used for the analysis of heat exchanger thermal performance test data as part of the LaSalle Station GL 89-13 heat exchanger testing program or for any other engineering analysis subject to the limitations itemized below.

Once developed, the model is used to identify the thermal margin of the heat exchanger at specified performance conditions as follows:

- at LaSalle Station Reference Conditions as currently defined in the LaSalle Station design and licensing basis; and
- at lower service water flow rates (with increased fouling) to support service water system rebalancing efforts.

The thermal performance model documented in this calculation has been created and used with PROTO-HX, Version 3.01. The model can be used with previous versions of PROTO-HX and produce identical results as long as the following restriction is upheld:

 Air coils analyzed in Version 3.0 or earlier can be analyzed only in non-condensing modes of operation.

Current limitations of use for PROTO-HX are established by the limits on fluid properties included within the software. Fluid properties contained within PROTO-HX are currently limited to the following temperature ranges:

• Air:

32-320°F

• Water:

32-500°F

2. BACKGROUND

LaSalle Station is in the process of implementing a heat exchanger thermal performance monitoring program and a service water system flow balancing program in response to the requirements of NRC Generic Letter 89-13. Development of an analytical model in PROTO-HXTM, Version 3.01, will allow timely analysis of data resulting from the test program and will ensure the limiting flow requirements for the coolers are adequately defined.



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VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A				

3. DESIGN INPUTS

The thermal performance model is developed using PROTO-HXTM, Version 3.01. PROTO-HXTM was developed and validated in accordance with Proto-Power's Nuclear Software Quality Assurance Program (SQAP). This program meets the requirements of 10CFR50 Appendix B, 10CFR21, and ANSI NQA-1, and was developed in accordance with the guidelines and standards contained in ANSI/IEEE Standard 730/1984 and ANSI NQA-2b-1991. PROTO-HXTM Version 3.01 was verified and approved for use as documented in Reference (1).

The design inputs for this calculation consist of the heat exchanger design basis performance requirements (Table 1), performance specifications (Table 2) and construction details (Table 3) provided by the heat exchanger manufacturer data sheet (Attachment A) or other design documents as referenced. Construction details give the necessary information for model construction while performance specifications are used to benchmark the model.

VY cooler thermal performance in this calculation will be assessed only with respect to the nominal accident conditions (i.e., design basis LOCA) with no tubes plugged. Condensing modes of operation and tube plugging margins are not addressed.

Table 1: LaSalle Station Reference Conditions

Parameter	Value	Reference*
Heat Rate 1(2)VY01A (BTU/hr)	517,239	2
Heat Rate 1(2)VY02A (BTU/hr)	646,235	3
Atmospheric Pressure (in-w.g.)	-0.4	4
Air-Side Inlet Temperature Dry Bulb (°F)	148	4
Fan Volumetric Flow Rate (cfm)	18,000	18,19
Tube-Side Flow Rate (gpm)	150	5
Tube-Side Inlet Temperature (°F)	100	6

^{*}Selected references included as Attachment A



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VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A			

Table 2: Vendor Specified Performance

Parameter	Value	Reference*
Air-Side Fouling Factor (Design)	0	Assumption (1)
Air-Side Entering Fluid Flow Rate (scfm)	17,330	7
Air-Side Inlet Dry Bulb Temperature (°F)	150	7
Air-Side Inlet Wet Bulb Temperature (°F)	92	7
Air-Side Outlet Dry Bulb Temperature (°F)	109.4	7
Air-Side Outlet Wet Bulb Temperature (°F)	84.1	7
Tube Side Fouling Factor (Design)	0.0015	8
Tube Side Fluid Type	Service Water (Fresh)	9,10
Tube Side Fluid Flow Rate, Total (gpm)	150	7
Tube Side Inlet Temperature (°F)	105	7
Tube Side Outlet Temperature (°F)	115.3	7
Design Q (BTU/hr)	750,000	7

^{*}Selected references included as Attachment A



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	VERIFIED BY M. Aboye		JOB NO. 31-003	
CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testin		Heat Exchanger Testing	
VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A				

Table 3: Construction Details

Parameter	Value	Reference(1)
Heat Exchanger Type and relative direction of Tubeside and Air flow.	Carrier Air Coil Counter flow	7,11
Fin Type	Spiral	7,8
Coil Finned Length (in)	108.00 specified (2) 104.25 effective (2)	7 20
Fin Pitch (fins/in)	10.0	7
Fin Material	ASTM B209 Aluminum	7
Fin Conductivity (BTU/hr-ft-°F)	128	16
Fin Thickness (in)	0.012	7
Fin Height (in)	1.495	20
Number of Coils per Unit	2	7
Number of Tube Rows	8	7
Number of Tubes per Row	20	7
Number of Plugged Tubes	0	-
Tube Outside Diameter (in)	0.625 (3)	7
Tube Wall Thickness (in)	0.049	7
Tube Inside Diameter (in)	0.527	7
Longitudinal (horizontal) Tube Pitch (in)	Unavailable - see Section 6	-
Transverse (vertical) Tube Pitch (in)	1.452	20
Tube Layout	Staggered	20
Number of Serpentines	1 (i.e., "Full Circuiting")	7
Tube Wall Material	SB75 Copper	7
Tube Wall Conductivity (BTU/hr-ft-°F)	225	12
Sensible Heat Ratio	1	(Section 6.3)

Notes:

- (1) Selected references included as Attachment A
- (2) The Reference 7 coil finned length will be used for benchmarking to vendor performance data per Section 6.0. The Reference 20 effective coil finned length will be used for subsequent analyses.
- (3) The Reference 7 tube OD is within the tolerance of Reference 20 and will be used in lieu of Ref. 20.



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VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A			

4. APPROACH

This calculation utilizes plant/vendor fabrication specifications provided in Section 3.0 to develop a thermal performance prediction model for the 1(2)VY01A/02A coolers. The calculation then benchmarks the model by comparing the heat transfer rate calculated by PROTO-HXTM Version 3.01 with the manufacturer's specifications for thermal performance. The Colburn j-factor vs. Reynolds Number relationship is adjusted as necessary to meet the manufacturer's performance specifications. After the model is benchmarked, it will be used to determine the margin between the available and required heat removal rates and to establish a revised limiting flow rate in support of service water system re-balancing efforts.

5. ASSUMPTIONS

- 1. The fouling factor specified in Reference (8) is for the tube-side only and design air-side fouling is zero. Future validation of this assumption is not required.
- 2. The slope of the "Colburn j-factor vs. Reynolds Number" curve is the same for the current coil and the standard coil represented by curve "CF-9.05-3/4 J-A" in the PROTO-HXTM "h-configurations" Library. This assumption is based on physical similarities between the VY coolers and the standard configuration represented by "CF-9.05-3/4 J-A" as elaborated in Section 6, below. The model benchmarking process described in Section 6 brings the model into precise agreement with the vendor performance data making initial configuration selection immaterial. The only difference caused by initial configuration selection that would be detectable in analysis results is when analyses are performed over a very wide range (orders of magnitude) of air-side Reynolds numbers. A wide range of Reynolds numbers causes the slight variation in slopes of the j-factor equations of different configurations to become more obvious. Given the fixed fan flow rate and a relatively tight band of normal operating and Reference conditions, along with the fact that benchmarking conditions are extremely close to Reference conditions, such wide variations in Reynolds numbers are not anticipated. Future validation of this assumption is not required.
- 3. The vendor-supplied performance specifications of Reference (7) (included as Attachment A) are considered to be an accurate reflection of the as-built performance of each VY Cooler. Future validation of this assumption is not required.
- 4. The VY cooler spiral fin geometry is closely approximated by the PROTO-HX™ circular fin configuration. This is due to the relatively tight fin pitch configuration resulting in a

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- negligible difference in fin/tube outside surface area. This assumption is supported in Attachment K. Future validation of this assumption is not required.
- 5. In transitioning from the original vendor specified inlet air temperature of 150°F to the current licensing limit of 148°F, the inlet air vapor density is assumed to have remained unchanged. This increases the inlet relative humidity causing a slight reduction in the air mass flow rate. Future validation of this assumption is not required.

6. ANALYSIS

6.1 Tube Pitch

The longitudinal tube pitch is not directly available from the coil data sheet or Reference 20. It can be estimated based on the geometry of the coil. Per Reference (7), the coil stack depth is 12.00 inches. Dividing the stack depth evenly between 8 tube rows yields a longitudinal (horizontal) tube pitch of 1.500 inches.

6.2 Coil Configuration

The coil configuration for modeling coolers 1(2)VY01A and 1(2)VY02A is selected based on the physical characteristics of the coil. There are no coils in the PROTO-HX™ library that exactly match the configuration of the VY coolers. The configuration "CF-9.05-3/4 J-A" shown in Figure 1 provides the closest match based on similarities of layout geometry: staggered tube rows, horizontal tube pitch slightly greater than vertical tube pitch, similar fin height, identical fin thickness and similar fin pitch. The "CF-9.05-3/4 J-A" configuration also represents a relatively compact coil which correlates well to the VY coils as evidenced in the coil photographs included as Attachment B.

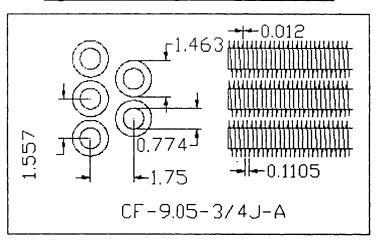
PROTO-HX[™] does not include spiral fin configurations in the analytical methodology employed. However, for the given fin pitch, the difference in calculated fin surface area between the VY cooler spiral fin configuration and the PROTO-HX[™] circular fin configuration is negligible. The negligible difference is illustrated further in Attachment K using a simplified area comparison.





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Figure 1 Coil Configuration CF-9.05-3/4 J-A





6.3 Sensible Heat Ratio

The value input in the model for the Sensible Heat Ratio (SHR) is used only when one of the "Constant Heat Load" calculation/extrapolation methods of PROTO-HXTM is used (i.e., "Constant Heat and Cold Inlet Temperature" or "Constant Heat and Hot Outlet Temperature"). The SHR can be assigned any value between 0 and 1 and represents the fraction of the total specified (constant) heat load that is due to sensible cooling alone. An input of 1.0 in the SHR field tells PROTO-HXTM that the specified constant heat is 100% sensible heat with no condensation occurring. Use of any value less than 1.0 presumes some knowledge as to what fraction of the specified heat load is due to condensation (i.e., latent heat transfer). The value of SHR currently in the model is 1.0, but like any other model input, the SHR can be changed at any time.

6.4 Derivation of Benchmarking Inputs

The PROTO-HXTM model is benchmarked using the performance data provided by the cooler manufacturer. In order to benchmark the model, the vendor specified conditions must be converted into appropriate units for PROTO-HXTM input. The only input requiring adjustment is the specified air-side flow rate of 17,330 *scfm*. PROTO-HXTM requires air-side flow rate to be given at actual inlet air conditions (units of *acfm*).



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The correction of *scfin* to *acfin* is made as follows (holding mass flow rate constant for the defining case):

$$\dot{m} = (scfm) x (\rho_{std}) x \left(\frac{60 min}{1 hr}\right) = (acfm) x (\rho_{actual}) x \left(\frac{60 min}{1 hr}\right)$$
 Equation (1)

where:

 \dot{m} = mass flow (lbm/hr)

scfm = volumetric flow rate at standard conditions (ft³/min)

 ρ_{std} = standard density of 0.075 lbm/ft³

acfm = volumetric flow rate at specified (non-standard) conditions (ft³/min)

 ρ_{actual} = density of dry air at specified inlet temperature and humidity (lbm/ft³)

Rearranging terms yields the following correction factor for converting scfm to inlet acfm:

(acfm) = (scfm) x
$$\frac{(\rho_{std})}{(\rho_{actual})}$$
 Equation (2)

Local Standard Atmospheric Pressure

To derive the dry air density for the inlet air conditions, the amount of moisture in the air and the local atmospheric pressure must be accounted for. Per Reference (13), local atmospheric pressure was accounted for by specifying a flow at standard density (17,330 scfm) as well as an actual flow (18,000 acfm at 70°F and 40% relative humidity at site elevation). The difference between the two flow rates will provide the assumed air density as follows:

$$(\rho_{\text{actual}}) = (\text{scfm}) \times \frac{(\rho_{\text{std}})}{(\text{acfm})} = (17,330) \times \frac{0.07500}{18,000} = 0.0722 \text{ lbm/ft}^3$$

The local atmospheric pressure is found by iterative solution using Reference (14) as shown in Attachment H. Pressure input is varied with the specified temperature and humidity conditions



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held constant until a dry air density of 0.0722 lbm/ft³ is reached. The result of the iterative process is as follows:

Given per Reference (13)

Dry Bulb Temperature:

70.00°F

Relative Humidity:

40.00 %

Derived above

Dry Air Density:

0.0722 lbm/ft³

Derived per Attachment H

Specific Humidity:

0.00638 lbmv/lbma

Atmospheric Pressure:

14.3150 psia

Dry Air Pressure:

14.1697 psia

Vapor Pressure:

0.1453 psia

Vapor Density:

0.00046 lbm/ft^3

The result is that an atmospheric pressure of 14.315 psia at 70°F and 40% relative humidity will give the requisite air density.

Actual Air Flow Rate

The next step is to define the actual air flow rate at the inlet conditions included by the vendor in the Reference (7) performance specification (Table 2).

The moist air conditions corresponding to the vendor specified performance conditions are as follows:

Given per Reference (7)

Dry Bulb Temperature:

150.00°F

Wet Bulb Temperature:

92.00°F

Derived above

Atmospheric Pressure:

14.315 psia

Derived per Attachment H

Relative Humidity:

12.18 %

Specific Humidity:

0.02034 lbmv/lbma

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TITLE V	VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A			

Dry Air Pressure:

13.8617 psia

Vapor Pressure:

0.4533 psia

Dry Air Density:

0.06137 lbm/ft³

Vapor Density:

0.001248 lbm/ft^3

The actual volumetric flow rate at vendor specified inlet conditions is then calculated as:

(acfm) = (scfm)
$$x \frac{(\rho_{std})}{(\rho_{actual})}$$
 = (17,330) $x \frac{0.07500}{0.06137}$ = 21,179 ft³/min

Summary of PROTO-HXTM Inputs for Model Benchmarking

Tube-Side Flow Rate	150 gpm
Tube-Side Inlet Temperature	105°F
Air-Side Flow Rate	21,179 acfm
Air-Side Inlet Temperature Dry Bulb	150°F
Air-Side Inlet Temperature Wet Bulb	92°F
Atmospheric Pressure	14.315 psia

6.5 Model Benchmarking

Model benchmarking is performed to compare thermal performance as predicted by the model to thermal performance specified by the cooler vendor. A significant impact on the model predicted performance is the outside (air-side) heat transfer coefficient. The benchmarking process adjusts the model correlation for outside heat transfer coefficient to match vendor performance data.

An extensive source of information pertaining to the outside heat transfer coefficient for air coolers is provided by Reference (15). This widely-recognized publication provides heat transfer correlations for specific coil configurations. The format used in Reference (15), and subsequently adopted by other researchers, is to provide a plot of the Colburn j-factor vs. Reynolds Number for each configuration.

Alternatively, to permit modeling of coils which do not adequately fit the library configurations and for which no test data correlation is available, PROTO-HXTM allows the generation of a coil unique formulation for outside heat transfer coefficient. This is done through establishing a unique Colburn j-factor for the coil.



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Reference (15) defines the Colburn j-factor as follows.

Let:

$$c_{pa}$$
 = Specific heat of air (Btu/lb_m-°F)

$$k_a =$$
 Thermal conductivity of air (Btu/hr-ft-°F)

$$m_a =$$
 Absolute viscosity of air (lb_m/ft-hr)

$$r_a =$$
 Density of air (lb_m/ft^3)

$$A_{min}$$
 = Minimum air-side flow area (Section 3.3.8) (in²)

$$A_I =$$
 Frontal Area (Section 3.3.8) (in²)

$$D_H$$
 = Hydraulic diameter (Section 3.3.8) (ft)

$$d_O$$
 = Tube outside diameter (in)

$$j =$$
 Colburn j-Factor

$$N_C$$
 = Number of coils per unit

$$N_L =$$
 Number of active tube rows

$$Q_a =$$
 Specified air flow rate (acfm)

$$S_L =$$
 Longitudinal Tube Pitch (in)

$$S_T$$
 = Transverse Tube Pitch (in)

The Prandtl Number for air, $Pr_{\mathcal{C}}$ (a dimensionless parameter), is given by:

$$Pr_a = \frac{c_{pa} \ \mu_a}{k_a}$$

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The mass flow rate of air per coil, M_a (lb_m/hr), is calculated based on the input total air flow and the number of coils per unit:

$$M_a = \frac{60 \, \rho_a \, Q_a}{N_C}$$
 Equation (4)

The bulk-stream mass flux, $G(lb_m/hr-ft^2)$, is:

$$G = \frac{144 M_a}{A_{\text{MIN}}}$$
 Equation (5)

The Colburn j-factor is defined in terms of the Stanton Number, St_a , as:

$$j = St_a Pr_a^{2/3} = \left(\frac{h_o}{G_{c_{pa}}}\right) Pr_a^{2/3}$$
 Equation (6)

Therefore, the outside heat transfer coefficient, h_O (Btu/hr-ft²-oF), may be defined in terms of the *j*-factor:

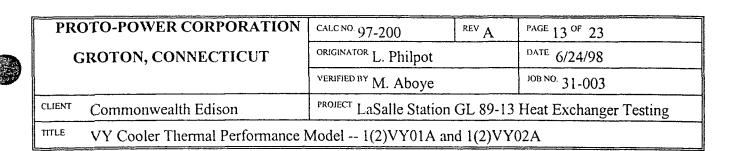
$$h_o = \frac{j G c_{pa}}{P r_o^{2/3}}$$
 Equation (7)

Per Reference (15), the *j*-factor for the various coil configurations tested are provided as functions of the Reynolds Number based on hydraulic diameter, $D_H(in)$:

$$j = f(Re_a)$$
 where: $Re_a = \frac{G D_H}{\mu_a}$ Equation (8)

The standard air-side configuration for coil type CF-9.05-3/4 J-A, provided in PROTO-HXTM's Library, was initially selected based on the physical similarities between the present coil and that represented by CF-9.05-3/4 J-A as described in Section 6.2. However, the heat transfer rate under design operating conditions using the standard configuration was slightly greater than the value specified by the manufacturer (see performance run in Attachment C). For this reason, a





new curve relating the Colburn j-factor and Reynolds Number was generated according to the following procedure:

- The slope of the linear standard curve was calculated.
- A new curve, parallel to the standard curve, was defined such that the new j-intercept is slightly lower.
- A design performance run was then executed using the new Colburn j-factor versus Reynolds Number curve, and the resulting heat transfer rate was compared to the manufacturer's value.
- The above two steps were repeated until the calculated heat transfer rate closely matched the manufacturer's value.



The resulting relationship between Reynolds Number and Colburn j-Factor is represented by the following table and associated equation:

Table 4: Reynolds Number and Colburn i-Factor

Reynolds Number	Colburn j-Factor (Standard)	Colburn j-Factor (Custom)
1000	0.009	0.00758
8000	0.0044	0.00371

$$j = e^{[-2.5088 - 0.3436 * Ln(Re)]}$$

Equation (9)

Equation (9) was added to the PROTO-HX[™] Library for use in conjunction with Area Coolers 1(2)VY01A and 1(2)VY02A.

As noted in Assumption (2) and implemented above, the slope of the "Colburn j-factor vs. Reynolds Number" curve is assumed to be the same for the VY coolers and the standard coil represented by curve CF-9.05-3/4 J-A in the PROTO-HXTM "h-configurations" Library. This assumption is considered reasonable based on the following:

- there are only minor variations in the slope of different j-factor correlations; and,
- there is only a slight variation in the air-side Reynolds Number between anticipated test conditions and the extrapolated accident conditions. The only variation is

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expected to be caused by air inlet temperature variations (i.e., volumetric flow rate in cfm will be nearly constant, while air flow in acfm will vary with temperature and inlet humidity).

An excerpt from Reference (15), illustrating the j-factor relationship with Reynolds number, is included as Attachment D.

6.6 Effective Coil Finned Length

Reference 20 identified the fact that the fined coil length exposed to air flow was less than that specified by the coil vendor in Reference 7. Model benchmarking used the vendor specified length to be consistent with the vendor specified performance. The effective length is entered into the model for all subsequent analysis. An effective coil finned length of 104.25 inches is used per Reference 20.

6.7 Extrapolation Conditions

The LaSalle Station Reference Conditions defined in Table 1 are slightly different than the vendor specified performance conditions listed in Table 2 and require conversion to units for input into PROTO-HXTM.

Air-Side Pressure

Air-side pressure should account for the local elevation above sea level. Chapter 26, Table 1A, of Reference (16) provides elevation and standard atmospheric pressure data for the local area around La Salle.

Interpolating between data points to derive the pressure associated with the elevation of the VY coolers given by Reference (17) provides the following:

Pressure	
(psia)	
14.337	Reference (16)
14.308	Reference (16)
14.329	Interpolation between above points at VY elevation
	(psia) 14.337 14.308



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Per Reference (4), the coil pressure is -0.4 inches of water gauge. Using the density of water at 60°F, the specified pressure is calculated as illustrated below:

Coil Pressure	Water Density	Coil Pressure	Atm Pressure	Coil Pressure
(inwg)	(lbm/ft ³⁾	(psig)	(psia)	(psia)
-0.4	62.36445	-0.014	14.329	14.315

This pressure matches the pressure derived from the original coil specification in Section 6.4.

Air-Side Flow Rate

In order for PROTO-HXTM to calculate the air mass flow rate for a given extrapolation condition, the inlet dry bulb temperature, total pressure, and relative humidity or wet bulb temperature must be specified. The inlet dry bulb temperature and pressure for the LaSalle Station Reference Conditions are listed in Table 1. The inlet relative humidity is adjusted by holding the vapor density constant from the vendor specified condition to the LaSalle Station Reference Condition (i.e., 148°F in lieu of 150°F per Assumption 5).

Given per Section 6.4

Vapor Density: 0.001248 lbm/ft^3

Reference Condition

Dry Bulb Temperature: 148.00°F Atmospheric Pressure: 14.315 psia

Derived per Attachment H

Wet Bulb Temperature: 91.6°F Relative Humidity: 12.76 %

Since fans are constant volume equipment, the air volumetric flow rate of 18,000 cfm specified in References (18) and (19) remains the same for all coil outlet conditions. The air mass flow rate through the coil, however, will vary with the temperature of the air going through the fan (i.e., at coil outlet temperature). Deriving the inlet air flow rate for input to PROTO-HXTM requires an iterative solution as follows:

- take an initial guess at the coil outlet air temperature at the same specific humidity as the coil inlet:
- calculate the dry air density at the selected coil outlet air temperature;



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- calculate the coil inlet air flow rate by multiplying the fan capacity (cfm) by the ratio of the coil outlet dry air density to the coil inlet dry air density (to maintain constant mass flow across the coil) [Equation (2)];
- run the model with the inlet air flow rate derived above;
- check the predicted coil outlet air temperature; and
- repeat the process (substituting the predicted coil outlet air temperature for the initial guess) until the coil outlet air temperature does not change from one iteration to the next

The iteration process described above was completed twice for this model for a clean (f = 0.0) and service (f = design) condition with results as follows:

Clean:

$$(cfm_{in}) = (cfm_{out}) \times \frac{(\rho_{out})}{(\rho_{in})} = (18,000) \times \frac{(0.06631929)}{(0.061575103)} = 19,387 (Fan Temperature = 104.53)$$

Service:

$$(cfm_{in}) = (cfm_{out}) \times \frac{(\rho_{out})}{(\rho_{in})} = (18,000) \times \frac{(0.06609320)}{(0.061575103)} = 19,321 (Fan Temperature = 106.46)$$

Summary of PROTO-HXTM Inputs for Extrapolation to Reference Conditions

The Extrapolation conditions are defined as the vendor data sheet conditions without high energy line break modified for ultimate heat sink temperature and room limiting temperature per the LaSalle Station UFSAR Reference (4). The required PROTO-HXTM inputs for these conditions are as follows:

Tube-Side Flow Rate150 gpmTube-Side Inlet Temperature100°F

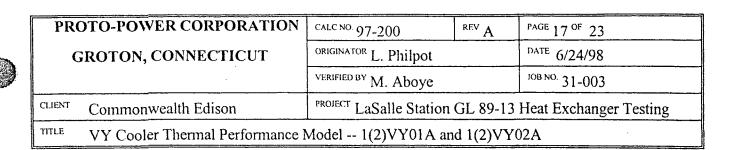
Air-Side Flow Rate (varies with temperature)

Air-Side Inlet Temperature -- Dry Bulb
Air-Side Inlet Humidity
12.76%
Atmospheric Pressure
14.315 psia

6.8 Thermal Margin Assessment

The available thermal margin is defined as the difference between the available and the required heat removal rates at reference conditions. The maximum available heat removal rate (q_{clean}) is calculated using the benchmarked PROTO-HXTM model and the inlet conditions defined in





Section 6.7 with zero fouling. By comparing the available heat removal rate calculated with zero fouling to the required heat removal rate, the maximum available margin is determined. A similar comparison is made between the required heat load to the available heat load at design fouling conditions (q_{service}) .

For the purposes of this thermal margin assessment, thermal margin is defined as follows:

Margin (BTU / hr) = $q_{available} - q_{required}$ Equation (10)

Margin (%) =
$$\left(\frac{q_{\text{available}} - q_{\text{required}}}{q_{\text{required}}}\right) \times 100$$
 Equation (11)

where:

q_{available} = the predicted heat capacity of the cooler at the specified conditions (BTU/hr)

q_{required} = the heat capacity required of the cooler to fulfill design basis requirements (BTU/hr)

6.9 Limiting Cooling Water Flow Analysis

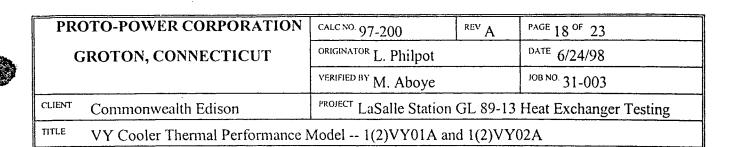
In support of the LaSalle Station efforts to re-balance the CSCS Equipment Cooling Water System, specification of a minimum acceptable cooling water flow to the VY coolers is desired. For conservatism, the design fouling factors associated with the limiting flow analysis are increased to 0.002 on both the tube and air sides of the cooler. Increasing the design fouling factors increases the fouling margin of the cooler at the reduced flow rates.

Limiting flows are established by iterating with the performance model. The cooling water flow rate is incrementally reduced with each iteration until the target thermal margin is achieved. For the case of 1(2)VY01A, the target thermal margin is approximately 30% with the increased design fouling factors. For the case of 1(2)VY02A, the target thermal margin is approximately 10% with the increased design fouling factors.

6.10 Fouling Sensitivity Analysis

To assess the sensitivity of the 1(2)VY01A and 1(2)VY02A coolers to tube-side fouling accumulations, a series of iterations are performed. With each iteration, the design tube-side fouling factor is incrementally increased from a value of 0.0000 to 0.0040. The heat removal





capability resulting from each fouling increment is compared to the required heat load to assess the thermal margin. Thermal margin is calculated using Equations (10) and (11).

7. RESULTS

7.1 Model Benchmarking

The first model case was based on the standard CF-9.05-3/4 J-A configuration available from the PROTO-HXTM library. The results of this initial benchmarking case are presented in Table 5. The PROTO-HXTM reports associated with the initial benchmark case are included as Attachment C.

Table 5: Initial Benchmark Case -- Standard CF-9.05-3/4 J-A Configuration

Cooler	Design q ⁽¹⁾ (BTU/hr)	PROTO-HX™ Predicted q (BTU/hr)	Percent Difference
1(2)VY01A 1(2)VY02A	750,000	775,120	+3.35%

⁽¹⁾ Heat rate specified by cooler vendor

Based on the results of the initial benchmark case with the standard CF-9.05-3/4 J-A configuration, another case was completed using a customized Colburn J-Factor. This case demonstrated adequate benchmarking of the model to the vendor specified performance. A subsequent comparison run was made following the adjustment of the coil finned length to match the length identified in Reference 20. The results of the final benchmarking cases are presented in Table 6. The PROTO-HXTM reports associated with the final benchmarking cases are included as Attachment E.

Table 6: Final Benchmark Case -- Customized Colburn J-Factor

Cooler	Design q ⁽¹⁾ (BTU/hr)	Predicted q (BTU/hr)	Percent Difference	
1(2)VY01A 1(2)VY02A	750,000	749,965 (2)	-0.0047%	
1(2)VY01A 1(2)VY02A	750,000	746,297 (3)	-0.49%	

Notes:

- (1) Heat rate specified by cooler vendor
- (2) With specified coil finned length per Reference 7 (benchmarking basis)
- (3) With effective coil finned length per Reference 20 (subsequent analysis basis)



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	VERIFIED BY M. Aboye	_	^{JOB NO.} 31-003
CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing		
TITLE VY Cooler Thermal Performance	Model 1(2)VY01A ar	nd 1(2)VY	702A

7.2 Thermal Margin Analysis

Prior to defining margin, the predicted heat transfer capacity of the cooler $(q_{available})$ is defined. The predicted heat transfer capacities at LaSalle Station Reference Conditions for both clean (zero fouling) and service (design fouling) conditions are summarized in Table 7 below.

Table 7: Heat Transfer Capacity

Fouling Condition	Heat Transfer Capacity (BTU/hr)
Clean $(f = 0.0000)$	779,018
Service $(f = 0.0015)$	741,876

The thermal margin assessment relates the predicted capacity of the cooler at clean and service conditions to the required capacity under reference conditions. The comparison is provided in Table 8. The PROTO-HXTM reports associated with the thermal margin assessment are included as Attachments F and G for zero and design fouling conditions, respectively.

Table 8: Thermal Margin at LaSalle Station Reference Conditions (f = 0.0000/0.0015)

Cooler	Fouling (f)	q _{required} (BTU/hr)	q _{available} (BTU/hr)	Margin (BTU/hr)	Margin (%)
1(2)VY01A	zero	517,239	779,018	261,779	50.61
	design	517,239	741,876	224,637	43.43
1(2)VY02A	zero	646,235	779,018	132,783	20.55
	design	646,235	741,876	95,641	14.80

7.3 Limiting Cooling Water Flow Rate Analysis

The limiting cooling water flow analysis calculated the lowest possible cooling water flow that would provide a thermal margin of approximately 30% for the 1(2)VY01A coolers and a thermal margin of 10% for the 1(2)VY02A coolers with an adjusted design fouling of 0.002 air-side and 0.002 tube-side. The results of the iterations to identify the limiting flow rate are summarized in



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	VERIFIED BY M. Aboye		JOB NO. 31-003		
Client Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing				
TITLE VY Cooler Thermal Performance N					

Table 9. The 108 gpm Case was added as a limiting flow case for 1(2)VY02A since available system flow is limited by pump capability. The PROTO-HXTM reports associated with the limiting flow analysis for both coolers are included as Attachment I.

Table 9: Limiting Cooling Water Flow Rate at Reference Conditions (f = 0.0020/0.0020)

Cooler	Limiting Flow Rate	q _{required} (BTU/hr)	q _{available} (BTU/hr)	Margin (BTU/hr)	Margin (%)
1(2)VY01A	75 gpm	517,239	675,177	157,938	30.53
1(2)VY02A	115 gpm	646,235	710,964	64,729	10.02

1(2)VY02A 108 gpm 646,235 707,030 60,795 9.41	1(2)VY02A	108 gpm	646,235	707,030	60,795	9.41
---	-----------	---------	---------	---------	--------	------

The uncertainty in the analytical methodology used to identify the limiting flow for 1(2)VY02A is presented in Attachment J. The result of the uncertainty assessment is that the uncertainty in the PROTO-HXTM extrapolated heat transfer rate ranges from ± 4.27 to $\pm 4.88\%$ for the ranges of cooling water flow evaluated. An uncertainty of $\pm 4.90\%$ is used to conservatively bound the analysis of Attachment J. The adjusted thermal margin is calculated using Equation (11) after subtracting the uncertainty from the available heat rate. The results are presented in Table 10 below.

Table 10: Limiting Cooling Water Flow Rate at Reference Conditions (f = 0.0020/0.0020)

Cooler	Limiting Flow Rate	q _{required} (BTU/hr)	q _{available} (BTU/hr)	Nominal Margin (%)	Adjusted Margin (%)
1(2)VY01A	75 gpm	517,239	675,177	30.53	24.14
1(2)VY02A	115 gpm	646,235	710,964	10.02	4.62





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	VERIFIED BY M. Aboye		JOB NO. 31-003		
CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing				
TITLE VY Cooler Thermal Performance Model 1(2)VY01A and 1(2)VY02A					

7.4 Fouling Sensitivity Analysis

The results of the fouling sensitivity analysis are included in Tables 11 and 12. The PROTO-HXTM reports associated with the fouling sensitivity analysis for both coolers and a graphical presentation of the results are included as Attachment M. The 108 gpm Case is used to represent the 1(2)VY02A coolers since this flow rate will bound that of the 115 gpm Case. It should be noted that neither the Tables below or the figure in Attachment M have taken analytical uncertainty into account since the intent of this exercise is to assess the change in thermal margin (i.e., the slope of the curves in Attachment M). Analytical uncertainty treated as a bias on the results will have a negligible effect on the slope of the curves. Consideration of uncertainty would, however, change the point at which a thermal margin of 0% is reached.

Table 11: Fouling Sensitivity Analysis -- 1(2)VY01A at 75 gpm

Air-Side f	Tube-Side f	Required q	Available q	%Margin
0.0020	0.0000	517,239	723,937	39.96%
0.0020	0.0010	517,239	698,599	35.06%
0.0020	0.0020	517,239	675,177	30.53%
0.0020	0.0030	517,239	651,570	25.97%
0.0020	0.0040	517,239	630,961	21.99%

Table 12: Fouling Sensitivity Analysis -- 1(2)VY02A at 108 gpm

Air-Side f	Tube-Side f	Required q	Available q	%Margin
0.0020	0.0000	646,235	756,011	16.99%
0.0020	0.0010	646,235	731,028	13.12%
0.0020	0.0020	646,235	707,030	9.41%
0.0020	0.0030	646,235	683,298	5.74%
0.0020	0.0040	646,235	660,999	2.28%

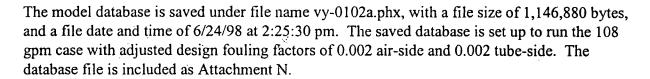


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C	GROTON, CONNECTICUT	ORIGINATOR L. Philpot		DATE 6/24/98
		verified by M. Aboye		^{JOB NO.} 31-003
LIENT	Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing		
TITLE	VY Cooler Thermal Performance N	Model 1(2)VY01A ar	nd 1(2)VY	02A

8. CONCLUSIONS

A model for the LaSalle County Station Units 1 & 2 NW and SW Cubicle Area Coolers was developed using PROTO-HXTM Version 3.01. The model was benchmarked and validated using the performance specifications provided by the cooler vendor. The close correlation with vendor specified and model predicted thermal performance confirms that the model is to be considered acceptable for use in the GL 89-13 heat exchanger testing program and related performance analyses.

The available thermal margin for the coolers has been defined for the nameplate rated flow of 150 gpm and for reduced flow rates of 75 gpm, 108 gpm, and 115 gpm in support of service water system flow requirements. Inclusion of a conservative assessment of the uncertainty in the analytical methods of PROTO-HXTM has provided high confidence in the thermal margins defined by the model for all cases.



9. REFERENCES

- Heat Exchanger Thermal Performance Modeling Software Program PROTO-HXTM Version 3.01 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision E, dated 11/5/97
- 2. LaSalle Calculation L-001078, Revision 2, RHR Pump A Cubicle Cooler Ventilation System
- 3. LaSalle Calculation L-001221, Revision 2, HPCS Pump Cubicle Cooler Ventilation System
- 4. LaSalle Station Updated Final Safety Analysis Report, Table 3.11-8, Harsh Environment Zone H6 -- Bounding Environmental Conditions Inside the ECCS Cubicles (Attachment A)
- 5. LaSalle Station Updated Final Safety Analysis Report, Section 9.2.1, ECCS Equipment Cooling Water System (Attachment A)
- 6. LaSalle Station Updated Final Safety Analysis Report, Section 9.2.6, Ultimate Heat Sink (Attachment A)



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CLIENT Commonwealth Edison	PROJECT LaSalle Station GL 89-13 Heat Exchanger Testing					
TITLE VY Cooler Thermal Performance						

- 7. Drawing 28SW404543, "CSCS Equipment Area Cooling Coils," original issue, 7/21/76 (Attachment A)
- 8. LaSalle Calculation L-000581, Revision 0, Evaluation of the CSCS Cubicle Area Coolers Operation with a Reduced Cooling Water Inlet Temperature
- 9. Drawing M-87, Sheet 3, "CSCS Equipment Cooling Water System," Revision F dated 5/4/88
- 10. Drawing M-134, Sheet 3, "CSCS Equipment Cooling Water System," Revision F dated 5/25/82
- 11. Bahnson Drawings 2605-1-11,12,13, & 14 (Attachment A)
- 12. Standards of the Tubular Exchanger Manufacturers Association (TEMA), Seventh Edition, 1988
- 13. Specification Number J-2582, Heat Exchange Coils and Cabinets, La Salle County Units 1 and 2, Revision 1, dated 1/16/75 (Attachment A)
- 14. Proto-Power Calculation 96-069, Revision -, Fluid Properties Moist Air Range 8° to 300°F
- 15. Compact Heat Exchangers, W.M. Kays and A.L. London, McGraw Hill, Third Edition, 1984. (excerpt Attachment C)
- 16. 1997 ASHRAE Handbook -- Fundamentals, inch pound Edition, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta, GA (excerpt Attachment A)
- 17. Drawing M-1366, Sheet 2, "Reactor Building Ventilation System -- Elevation 694'-6" West," Revision F dated 5/17/82
- 18. Drawing M-1464, "CSCS Equipment Cooling System," Revision B dated 5/12/88
- 19. Drawing M-1465, "CSCS Equipment Cooling System," Revision B dated 5/12/88
- 20. Coil Walkdown Data, ComEd NDIT No. LS-0835 (Attachment L)



Attachment A to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: A

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Reference +

LSCS-UFSAR

TABLE 3.11-8

HARSH ENVIRONMENT ZONE H6 - BOUNDING ENVIRONMENTAL

CONDITIONS INSIDE THE ECCS CUBICLES

(EXCLUDING LPCS/RCIC CUBICLE) IN THE REACTOR BUILDING

WHEN THE ECCS EQUIPMENT IS OPERATING

The maximum cubicle temperature is 148°F, 90% relative humidity and at atmospheric pressure for the duration of 100 days. The total number of hours the cubicle is at 148°F will be ~22,110 hours (~921 days). The 100 days accident conditions are included.

Radiation: 1 x 10⁷ rads gamma (integrated)

Pressure: -0.4 inch W.G.

1(2) VY 01A 1(2) VY 02A

NOTE: The bounding radiation dose > (normal service radiation dose integrated over 40 years + accident does + 10% margin on the accident dose per IEEE 323-1974, Section 6.3.2.5).

TABLE 3.11-8

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LSCS-UFSAR

Reference 5



- LPCS pump motor cooling coil -4 gpm
- northwest cubicle area cooling coil 150 gpm 6.
- southwest cubicle area cooling coil 150 gpm 7.
- northeast cubicle area cooling coil 200 gpm 8.
- 9. southeast cubicle area cooling coil - 180 gpm
- 10. emergency makeup to fuel pool - 50 gpm minimum
- 11. containment flood - 300 gpm maximum.
- b. System classifications are as shown in Section 3.2. All portions of this system are protected from the effects of tornados, missiles, pipe whip, and flooding.
- c. To meet single failure criteria, the CSCS-ECWS for each unit is designed as three independent subsystems, one of which is shared between units (Drawing Nos. M-87 and M-134).
- d. Strainers are provided to prevent plugging of cooled component heat transfer passages. All strainers include provisions for backwashing without significantly affecting system operation.

Organic fouling of heat transfer surfaces will be minimized by the chemical feed system which will treat the service water tunnel inlet flow with oxidizing biocides. However, the chemical feed system should not be considered auxiliary equipment required for the CSCS-ECW systems to perform their function. Therefore, the operability of the CSCS-ECW systems should not be tied to the operability of the chemical feed system. Connections and isolation valves are also provided immediately upstream and downstream of each cooled component for injection and circulation of biocidal agents, if necessary.

- To detect leakage of radioactivity to the environment, radiation monitors are installed in the CSCS-ECWS immediately downstream of cooled components that contain radioactive fluids. The CSCS-ECWS discharge lines from these components are capable of remote manual isolation from the main control room.
- Design of system piping and components is based on a 40-year life. f. Exterior surfaces of all buried system piping is protected by bituminous coatings and wrappings and provisions for cathodic protection are installed where such protection is found to be required based on electrical potential measurements. The design of all system piping includes a corrosion allowance of at least 0.08 inches.

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the normally closed portions the integrity and operability are checked.

9.2.6 Ultimate Heat Sink

The ultimate heat sink (UHS) provides sufficient cooling water to permit the safe shutdown and cooldown of the station for 30 days with no makeup for both normal and accident conditions.

9.2.6.1 Design Bases

9.2.6.1.1 Safety Design Bases

The ultimate heat sink has the following design bases:

- a. to provide sufficient water volume permitting a safe shutdown and cooldown of the station for 30 days with no water makeup for both normal operating and accident conditions the maximum permissible water temperature supplied to the plant is taken as 100° F;
- b. to withstand the most severe postulated natural phenomenon as discussed in Chapter 2.0;
- c. to withstand the postulated site-related incidents as discussed in Subsection 2.5.5; and
- d. to provide water for fire protection equipment.

A more detailed physical description of the ultimate heat sink is provided in Sections 2.4 and 2.5.

9.2.6.1.2 Power Generation Design Bases

The ultimate heat sink, as a safety system, is not used during normal plant operations. Therefore, the ultimate heat sink has no power generation bases.

9.2.6.2 System Description

In the unlikely event that the main dike is breached, the cooling lake for the La Salle County Station is designed to hold 460 acre-feet of water with a surface area of 83 acres. This remaining water constitutes the ultimate heat sink for the station, and has a depth of approximately 5 feet and a top water elevation established at 690 feet. Figures 2.4-4 and 9.2-1 illustrate the physical layout and area capacity of the ultimate heat sink.

9.2.6.3 Safety Evaluation

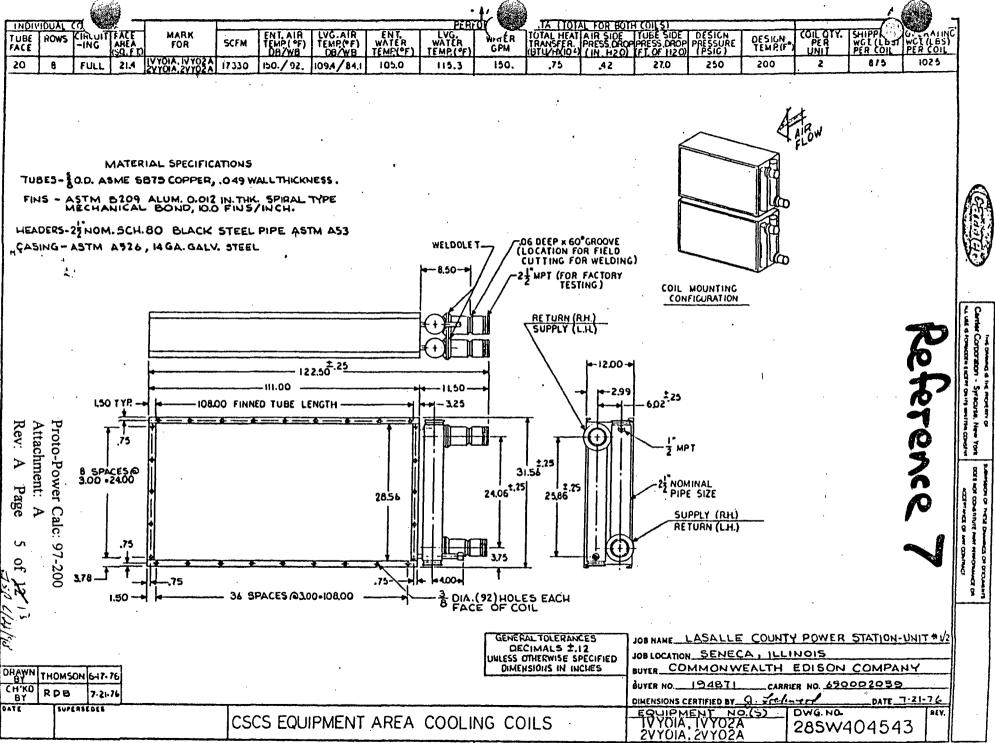
The station's ultimate water requirements (Units 1 and 2) in gpm are summarized below.

Proto-Power Calc: 97-200
Attachment: A ALP ([])

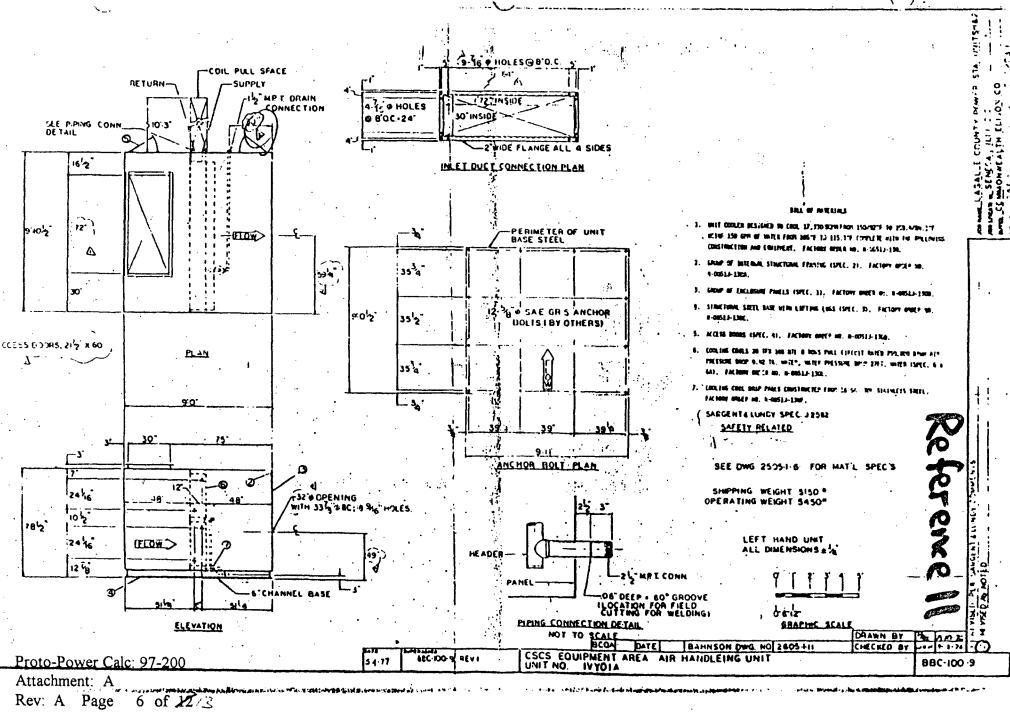
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9.2-18

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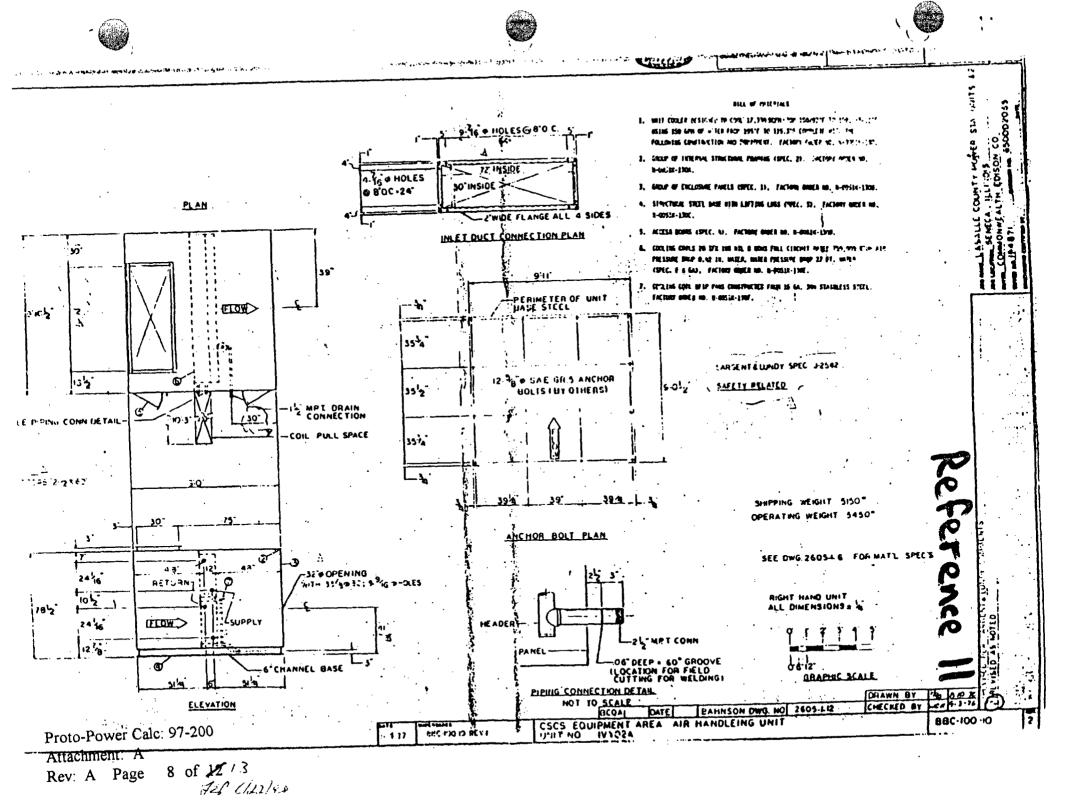






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GENERAL QUALITY ASSURANCE PROCEDURE



TITLE & APPROVAL PAGE

Reference 13

"SAFETY RELATED ITEMS ARE PART OF THIS SPECIFICATION"

Client	CECO	
Specification Title	Heat Exchange Coils and Cabinets	
Specification Number	J-2582	
Project Identification	La Salle County - Units 1 and 2	
Project Number	4266-00/4267-00	
Department	Mechanical/HVAC	

<u> </u>				
REV	DATE	PREPARER	APPROVER	PURPOSE OF ISSUE
1	1-1675	P.N. Mehroha	WIC Brown	Issue to CECO for bids.
				•
			Attachmen	er Calc: 97-200 t: A Page 10 of 12 13 Jef 6/22/48

						v			
		Function or Service	Control Room	Auxiliary Electric Equipment	Primary Contain- ment Vent.	CSCS Eqpt. Area Cooling	CSCS Eqpt. Area Cooling	CSCS Eqpt. Area Cooling	
		Equipment Numbers	OVCO2AA OVCO2AB	OVEOLAA OVEOLAB	1VP03AA 1VP03AB 2VP03AA 2VP03AB	1VYO1A 1VYO2A 2VYO1A 2VYO2A	1VYO3A 2VYO3A	1VY04A 2VY04A	
		Safety related or Nonsafety related (SR or NSR)	SR	SR	NSR	SR and ASME III	SR and ASME III	SR and	
403	•	PERFORMANCE DATA (HEAT EXCHANGE COIL CABINETS)					1 1 1		
403.	. 1	Mode of Operation	Cooling	Cooling	Cooling	Cooling	Cooling	Cooling	
	a.	Entering Air Dry Bulb,(°F)	81.8	81.9	135	150	150	150	Vqq.
	b.	Entering Air Wet Bulb(°F)	63.1	63.2	92				Add.
	с.	Leaving Air Dry Bulb(°F)	54.3	54.9	65	110	110	110	Add.
_	d .	Leaving Air Wet Bulb(°F)	52.8	53.2	63				Add
4-7	e.	Actual Air Quantity at 70°F, 40% RH and Site Elevation (ft /min)	26340	31300	50000	18000	26400	k8500	
->	f.	Standard Air Quantity at .075 lb/ft ³ (Std ft ³ /min)	253 80	30100	48150	17330	25420	27450	
	g.	Cooling Medium	R-22	R-22	Chilled	Water	Water	Water	
שי ע על	h.	Evaporator Refrigerant Tempera-ture(°F)	42	42	Water			***************************************	Add
rotc ttac	i.	Entering Water Temperature.(°F)		<u></u>	46	105.	105.	105.	
hme	j.	Maximum Water Quantity(gal/min)			1200	150.	220.	240	
Proto-Power Calc: 97-200 Attachment: A Rev: A Page 11 of 1	k.	Minimum Total Heat Exchange Capacity(Btu/h)	797,000	936,000	6.55x10 ⁶	748,700	1.1×10^6	1.19 x 10 ⁶	
alc: 97	1.	Minimum Sensible Heat Exchange Capacity(Btu/h)	725,000	847,000	3.63x10 ⁶	748,700	1.1 × 10 ⁶	1.19×10^6	
7-200 of 12/3	m.	Maximum Coil Face Velocity(ft/min)	600	600	600	700	700	700	

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Reference

Reference 16

Table IA Heating and Wind Design Conditions-United States

										eme W	turi		st Mont				 • •	S'O to Di	Ann	ual Ext	
				Eicv.	StdP		Heatin	<u> </u>		Speed			4",		·		.6%	0.1%		an DB	Std
Station	WMO	£at.	long.	lt	psia	Dates	99 6%	99%	l%	2.5%	\$ °.	¥5	MB	42	MDB	MW	PWD	MWSPY	CD Max	Min	Kas
West Palm Beach	722030	26.68	80 12	20	14 685	6193	43	47	24	31	ļэ	24	69	20	70	ij	(50	12 11	0 94	15	30
GEORGIA	_,	_				44.				_					_						
Albany	7.22160	31.53	84 18		14.593	8.793	27	1(1	:9	17	15	[9]	50	18	50		160	9 35		6	2.2
Athens	723110	33.95	83.32		14.270	6:93	26	25	10	17	15	202	40	13	40	10	290	9 77		11	35
Atlanta	722190	33.65			14 155	6193	18	24	22	19	17	23	17	21	36	11	320 320	9 30		9	3.5
Augusta	722180	33.37	81.97		14.617	6193	.11	25	20	18	1.5	°i	41	14	46	i	290	9 25		13	3.7
Brunswick	722137	31.15	81.38		14 685	8293	36	34	18	17	16	19	49	18	49	8	350	10 25		22	2.5
Columbus, Fort Benning	722250	32.33	85.00		14 572	8293	23	27	16	13	J.	17	46	15	46	3	320	n 24		14	2.9
Colorabus, Menn Airport	722255	32.52	84.93		14 436	6193	23	27	1.7	15	14	18	44	16	46	7	310	9 11		14	2.3
Macon	722170	32.70	83.65	361	14,505	6193	23	27	!9	1.7	1.5	50	40	18	45	7	120	9 27		14	2.7
Mariena, Dobbins AFB	722270	33.92	84.52	1070	14 136	8293	21	26	18	16	13	.0	35	18	38	y	340	6 10		12	3.6
kome	723200	34.35	85.17	643	14.357	8293	15	21	14	12	10	14	42	13	42	5	340	6 27		4	3.g :
Savannah	722070	32.13	81.20		14 669	6193	26	29	20	17	15	21	-19	19	49	7	270	9 27		18	3.0
Valdosta, Mondy AFR	747810	30.97	83.20	233	14,572	8293	30	34	15	13	12	10	53	14	52	1	360	5 30		21	2.5
Valdosta, Regional Airport	722166	10.78	83.28	203	14 588	8293	28	31	17	15	14	18	55	16	₹6	4	340	8 30	K) 99	17	3.2
Waycross	722130	31.25	82.40	151	14.615	8293	29	32	16	14	12	16	52	14	52	4	250	7 24	6 98	2)	7
HAWAII .																					
Ewa, Barbers Paint KAS	911780	21.32	158.07	49	14.609	8293	59	61	20	18	16-	22	73	19	7.5	5	∔ 0	11 6	0 93	35	1.6
Itilo	912850	19.72	155.07	36	14 676	6193	61	63	19	16	14	21	76	18	76	7	230	12 11	0 88	58	1.6
Honoidia	911820	21.35	157.93	16	14.687	6193	61	63	23	21	20	23	74	21	75	5	320	15 0	0 91	58	1.9
Kahului	911900	20.90	156.43	66	14.661	6193	59	61	27	25	24	32	76	28	76	6	160		0 92	54	
Kaneahe, MCAS	911760	21.45	157 77	10	14.690	8293	67	68	20	18	17	21	74	19	74	7	190		0 88	40	1.4
Lihue	911650	21.98	159.35	148	14.617	6193	60	62	26	24	21	25	73	23	73	8	270	14 6	0 87	57	1.4
Motokai	911860	21.15	157.10	449	14.458	8293	60	61	24	22	21	22	74	21	74	4	70		0 92	43	4
IDAHO																		•			
Boise	726810	43.57	116.22	2867	13.235	6193	2	9	24	21	ts	22	37	19	37	6	130	11 32	0 101	-4	2.7
Burkey	725867	42.55	113.77	4150	12.621	8293	5	2	23	21	19	23	30	22	28	7	60	8 28		-11	4
idaho Falis	725785		112.07		12.346	8293	-12	-6	27	23	21	28	32	23	29	7	360	12 18		-20	3.6
Levistro	727830	46.38	117.02	1437	13.948	8293	6	15	20	17	14	24	38	20	40	5	280	7 31		3	2.7
Mountain Home, AFB	726815		115.87		13.173	8293	Ŏ	5	23	21	18	23	33	21	31	2	90	8 3.5		-6	3.2
Mullan	727836		115.80			8293	-1	7	10	10	9	11	18	9	21	- 2	10		0 92	-7	2
Pocatello	725780			4478	12.468	6193	-7	o	29	25	23	30	36	27	36	6	50	11 25		-15	2.3
ILLINOIS					••		-	-								J	-747	2.			-
Belleville, Scott AFB	724338	38.55	89.85	453	14,457	8293	3	10	21	18	15	23	32	20	31	7	360	7 19	0 100	-3	3.1
Chicago, Meigs Field	725340	41.78	87.75	623	14.367	8293	-4	3	23	22	19	26	17	23	30	12	240	13 22		-10	3.2
Chicago, O'liare Int'l A	725300	41.98		673	14.342	6193	-6	-1	26	23	21	27	24	23	23	10	270	12 23		-10	2.8
Decatur	725316				-14.337	8293	-2	3	24	22	20	27	24	24	27	13	310	12 21		-12	.5.8°
Glenview, NAS	725306	42.08		653	14.352	8293	-3	4	22	19	17	23	17	20	25	11	250	10 24			
Marseilles	744600	41.37	88.68	738	14.308	8293	-,5 -,5	4 1	26	22	20	2 3	18	25	25	12				-10	3.1
Malise/Davenport IA	725440	41.45		594	14.383	6193	3 8	-3	26 26	22	20	28 28	16	23		12	290	10 25		-11	4
•	725320	40.67	89.68	663	14.347	6193		-3 -1	26 25	23	20	26 26		23	18		290	12 20		-14	2.7
Peoria Onines	724396			768	14.292	8293	6 4						16		19	9	290	11 19		-12	3.3
Quincy		42.20		741				. 2	26	23	20	28	23	24	22	12	330	12 21			.1.6
Rockford Socialists	725430 724390				14,306	6193	-10	-4	26	23	21	26 27	18	23	20	9	290		•	-16	
Springfield		39.85		614	14.373	6193	-4	2	25	23	21	27	25	24	27	10	270	12 23		-11	2.8
West Chicago	725305	41.92	88.25	/58	14.297	8293	-7	0	23	21	19	25	13	23	20	11	290	Lf 24	0 96	-14	3.2
INDIANA	77/222	10.00	a÷	900			_	_	•-							_		_			
Evansville	724320	38.05		-	14.491	6193	3	9	22	19	17	22	33	20	34	7				-4	2.7
fort Wayne	725330				14.262	6193	-4	2	25	23	20	27	19	24	22	10		12 2			3.6
[ndianapolis	724380				14.272	6193	-3	3	24	21	19	25	26	22	27	8	230			-10	
Lafayette, Purdue Univ	724386				14.376	8293	-5	3	22	20	18	24	26	22	27	9	270				3.8
Peru, Grissom AFB	725335				14.270	8293	-3	4	24	21	18	29	20	24	22	11		-			3.8
South Bend	725350				14.289	6193	-2	3	2.5	23	20	26	22	23	23	13		12 23			3.3
Terre liaute	724373	39.45	87.32	584	14.388	8293	-3	5	23	20	18	23	31	21	32	8	150	11 23	0 96	- 10	3.2
IOWA	_																				
Burlington	725455				14.328		-4	1	21	19	17	24	12	21	13	9	310	11 20	98	10	4
Cedar Rapids	725450	41.88	91.70	869	14,240	8293	-11	-5	25	22	.20	29	12	26	14	10	300	11 18	0 76	- 15	3.6
Des Moines	725460	41 53	93.65	965	14.190	619,1	9	-4	27	24	21	28	14	24	19			12 18			3.4
Fort Dodge	725490	42.55	94 18	1165	14.087	8293	13	7	27	23	21	29	10	26	10	11				17	
Lamoni	725466	40,62	93 95	1122	14.109	8293	-6	0	19	17	15	21	23	19	20	7					4.3
Mason City	725485	43.15	93.33	1214	14.062	6193	-15	-10	27	23	22	30	9	27	12	12		14 20		-23	
Опония	725465				14.251	8293	-5	0	29	26	23	31	20	28	24	13		15 20		-12	
Sinux City	725570				14 119	6193	-11	6	29	25	22	31	14	28	16	11		14 1			
Spencer	726500				£3.998	8293	-16	-1:	24	32	20	25	:3	23	13	10				-20	
•					14.234		-14	-9	27	24	22	29	10	25	13	9					
Waterico	22 400		/ <u>5.</u> 70	G 1 7	. 4.4.34	W171	-14	-,	- '	4.4	± £	7	10	~ .1	13	y	300	13 18	w 76	-20	3.5
Waterico EANSAS	224480	10.66	47.65	1 407	13 925	8293	-1	3	28	25	22	28	32	25	13		7/6	14	0	_	
RANSAS																	360				
RANSAS Concordis	724580														32	13			.0 104	-8	
RANSAS Concordia Dodge Circ	724510	37 77	99,97	2593	13,370	6193	0	6	10	27	24	31	31	27	32	13	10	17 20	0 104	-6	2.8
RANSAS Concordia	724510 724550	37 77 39 05	99,97	2593 1066	13.370 14 (38												10	17 20 9 18	00 104 30 104	-6	2.8 3.1

WMOs = World Meteorological Organization number

Las = lzusude. Ling = kingitude Elev e elevation, ft

StdP = standard pressure at station elevation, psia

DB = dry-bulb temperature, 'F
WS = wind speed, mph
Proto-Power Calc: 97-20

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Reference 16

		Table 3 Prop	erties of Solids				
	Specific		#1	E	Emissivity		
Material Description	Heat, Btu/ib-°F	Density, 46/ft ⁴	Thermal Conductivity, Btu/h-ft-"F	Ratio	Surface Condition		
Atuminum (alloy 1100)	0.214 ^h	171"	128°	0.09 ⁿ	Commercial sheet		
Alaminum bronze				0.20"	Heavily oxidized		
(76% Cu, 22% Zn, 2% Al)	0.099	517°	58*				
Asbestos: Fiber	0.25h	5.50°	0 097 ^a				
Insulation	0.20	36 ^h	0.0926	0.93 ^b	"Paper"		
Ashes, wood	0.20	417	0.0416 (122)				
Asphalt	0.22h	132°	Ω 43 ^h				
Bakelite	0.35*	81u	9.7"				
Bell metal Bissmuth tin	0.086f (122) 0.040*		37.6*				
Brick, building	0.2 ⁿ	123 ^u	0.4h	0.93*			
Brass: Red (85% Cu, 15% Zu)	0.09"	548 ^a	87 ^u	0.030 ^b	Highly polished		
Yellow (65% Cu, 35% Zn)	0.09*	519 ^u	694	0.033 ^{ti}	Highly polished		
Bronze	0.104	530	17 ^d (32)		ang my pensited		
Cadmium	0.055*	540 ¹	53.7 ^h	0.024			
Carbon (gas retort)	0.172		0.20% (2)	0.81			
Cardboard	a aati	2.41	0.04 ^b				
Celfulose Cement (portland clinker)	0.32 ^h 0.16 ^b	3.4 ¹ (20 ¹	0.033 ¹ 0.017 ¹				
Chalk	0.215	1431	0.48*	0.344	About 250°F		
Charcoal (wood)	0.20	152	0.03* (392)	0.2/4	710001 230 F		
Chrome brick	0.17 ^b	200°	0.67 ^b				
Clay	0.22 ^b	63'			,		
Coal	0.3 ^h	90*	0.098' (32)				
Coal tars	0.35h (104)	75 ^k	0.07				
Coke (petroleum, powdered)	0.36h (752)	62 ^h	0.55 (752)		•		
Concrete (stone) Copper (electrolytic)	0.156 ^h (392) 0.092°	144 ^h 556 ^u	0.54 ^b 227 ^e	A 4376			
Cork (granulated)	0.485	5.4 ¹	0.028' (23)	0.0724	Commercial, shiny		
Cotton (fiber)	0.3194	95"	0.024 ^u				
Cryolite (AlF ₃ -3NaF)	0.253 ^b	4181	5.02 /				
Diamond	0.147 ^h	1511	271				
Earth (dry and packed)		95'	0.037*	0.41*			
Felt Fireclay brick	0.198 ^b (212)	20.6 ⁶ 112'	0.03 ^b 0.58 ^b (392)	A 768	4. 102055		
Fluorspar (CaF ₂)	0.198" (212) 0.21 ^b	199*	0.58" (392)	0.75 ⁿ	At 1832"F		
German silver (nickel silver)	0.09 st	545*	194	0.135°	Polished		
Glass: Crown (soda-lime)	0.18 ^{ti}	1544	0.59' (200)	0.94ª	Smooth		
Flint (lead)	0.117"	267°	0.79°				
Heat-resistant "Woo!"	0.20 ^h	1391	0.59' (200)				
Gold	0.157 ^h 0.0312 ^w	3.25′ 1208°	0.022 ^t 172 ^t	0.025	Tickles and delegat		
Graphite: Powder	0.165*	1206-	0.106*	0.02ª	Highly polished		
Impervious	0.16°	1174	75*	0.75 ⁿ			
Gypsum	0.259 th	78 ^b	0.25 ^b	0.903b	On a smooth plate		
Hemp (fiber)	0.323*	93"			<u> </u>		
lce: 32°F	0.4874	57.5 ^b	1.3 ^h	0.95*			
~4°F	0.465 ^t		1.41*				
Iron: Cast	0.12" (212)	450°	27.6 ^h (129)	0.435*	Freshly turned		
Wrought Lead	0.0309*	485° 707°	34.9 ^h 20.1 ^u	0.94 ^h 0.28 ⁿ	Dull, oxidized Gray, oxidized		
Leather (sole)	0.0309	62.4 ^h	0.092 ^b	0.28"	Gray, oxidized		
Limestone	0.217 ^h	1034	0.54 ^b	0.36* to 0.90	At 145 to 380°F		
Linen	▼ :=: •		0.05h	0 100.70			
Litharge (lead monoxide)	0.055 ^b	490h	-				
Magnesia: Powdered	0.234h (212)	49.7h	0.35h (117)				
Light carbonate Magnesite brick	0.222 ^h (212)	13 ⁶ 158 ⁶	0.034 ^h 2.2 ^h (400)				
			· · · · · · · · · · · · · · · · · · ·				
Magnesium Marble	0 241 ^h 0.21 ^h	162 ^b	1 2p	0.554	Oxidized		
Marque Nickel, polished	0.105 ^a	162" 555 "	1 5" 34.4"	0.931 ⁿ 0.045 ⁿ	Light gray, polished Electroplated		
Paints: White lacquer	*******	27.29.29	23.3	0.80 ^{rl}	Lace to plant		
White cname!				0.91*	On rough plate		
Black lacquer				0 80 _u	•		
Black shellac		634	0.15"	0.91"	"Matte" finish		
Flat black facquer Aluminum facquer				0.96°	On cough place		
Alamani rac quei				0.39 ⁿ	On rough plate		

^{*}Data source unknown

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Notes: 1. Values are for morn temperature unless otherwise noted in parentheses

^{2.} Superscript letters indicate data source from the section on References.

Attachment B to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

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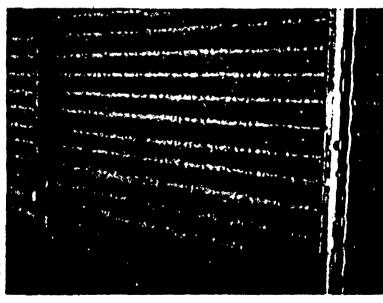




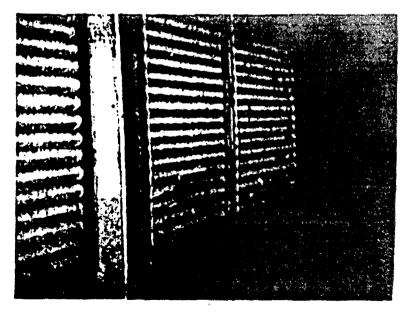
LA SALLE COUNTY STATION MEAT EXCHANGER (WATER TO AIR) DATABASE

EQUIPMENT NUMBER/ NAME	INSPECT DATE	B A S E	P PHOTO H STORAGE O LOCATION I ====================================	GENERAL APPEARANCE	TUBE CONDITION	FINS COMDITION	DEFECTS	RECOMMENDED	A C T I O N S ACTUAL RESERVERSHEESERS
1VYO1C "A" RHR AREA COOLER	09/15/92	Ħ	Y BTN/XAPSHOT HX#1	VERY CLEAN. NO DEBRIS.	NO DAMAGE OR LEAKS FOUND.	CLEAN NO DEBRIS. A FEW FINS BENT.	HONE.	NONE NEEDED.	N/A

VYOIA - Cooler VYOIC - Cooler Fan



IVYOIC OUTLET SIDE 9/15/92



NYOIC WLETSIDE 9/15/92

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- --



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LA SALLE COUNTY STATION HEAT EXCHANGER (WATER TO AIR) DATABASE

EOUIPMENT NUMBER/ NAME	INSPECT DATE	B I A I S (E	P PHOTO H STORAGE D LOCATION F EXELEMBERALE	GENERAL APPEARANCE	TUBE CONDITION	FINS CONDITION SEEDERESES	DEFECTS	CORRECTIVE RECOMMENDED	A C T I O N S ACTUAL
1VYO2C HPCS AREA COOLER	09/01/92 k	I Y	BTH / XAPSHOT HX#1	VERY CLEAN. NO DEBRIS FOUND.	CLEAN, NO DAMAGE NOTICED.	JUST A FEW FINS BENT. GENERAL	NONE.	NOME.	N/A

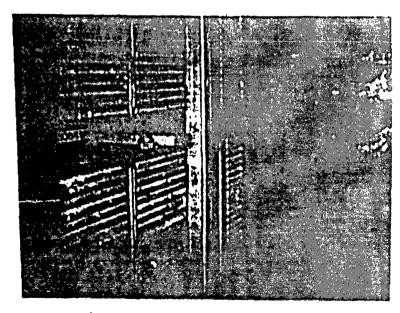
CONDITION IS VERY CLEAN.

VYOJA - Cooler VYOJC - Cooler Fan



INYORC INLETSIDE

9/1/92



14/02C OUTET SITE

9/1/92

Attachment C to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: C

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils



Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
,		
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	; EVDf 2 2222	CF-9.05-3/4J A + -0.3441 * LOG(Re)]
	J ~ EAF[-2.5555	+-0.3441 · LOG(Re)]
Coil Finned Length (in)		108.000
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft	·oE)	1.000
rube wan Conductivity (D10/III'II	1.)	225.00

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

wet Build Tellip Out (17)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

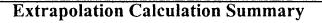
_	
Tube Flow (gpm)	150.00
Air Flow (acfm)	21,179.00
Tube Inlet Temp (°F)	105.00
Air Inlet Temp (°F)	150.0
Inlet Relative Humidity (%)	0.00
Inlet Wet Bulb Temp (°F)	92.00
Atmospheric Pressure	14.315

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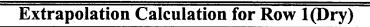
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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Initial Benchmark Case -- Standard Coil



	Air-Side	Tube-Side		<i>y</i>
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	,
Inlet Temperature (°F)	150.00	105.00	j Factor	
Outlet Temperature (°F)	110.28	115.42	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,503.18
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	775,120
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	775,120
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,639.65
Inlet Temperature (°F)	150.00	112.82	j Factor	0.0095
Outlet Temperature (°F)	140.10	115.42	Air-Side ho (BTU/hr·ft².°F)	10.20
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	145.05	114.12		
Skin Temperature (°F)	122.46	116.51	U Overall (BTU/hr·ft²·°F)	6.72
Velocity ***	3,598.07	5.53	Effective Area (ft²)	937.90
Reynold's Number	848**	37,906	LMTD	30.66
Prandtl Number	0.7254	3.8666	Total Heat Transferred (BTU/hr)	193,146
Bulk Visc (lbm/ft·hr)	0.0491	1.4247	,	
Skin Visc (lbm/ft·hr)		1.3920	Surface Effectiveness (Eta)	0.9017
Density (lbm/ft³)	0.0624	61.8006	Sensible Heat Transferred (BTU/hr)	193,146
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3680	Heat to Condensate (BTU/hr)	
** D11-311	D CD .:	4 11 1 111	•	

** Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Initial Benchmark Case -- Standard Coil



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,618.86
Inlet Temperature (°F)	140.10	110.78	j Factor	0.0095
Outlet Temperature (°F)	132.32	112.82	Air-Side ho (BTU/hr·ft².°F)	10.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	136.21	111.80		
Skin Temperature (°F)	118.38	113.70	U Overall (BTU/hr·ft².°F)	6.69
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	857**	37,051	LMTD	24.20
Prandtl Number	0.7262	3.9648	Total Heat Transferred (BTU/hr)	151,828
Bulk Visc (lbm/ft·hr)	0.0485	1.4576		
Skin Visc (lbm/ft·hr)		1.4304	Surface Effectiveness (Eta)	0.9020
Density (lbm/ft³)	0.0632	61.8343	Sensible Heat Transferred (BTU/hr)	151,828
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0160	0.3672	Heat to Condensate (BTU/hr)	
Average Temp (°F) Skin Temperature (°F) Velocity *** Reynold's Number Prandtl Number Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp (BTU/lbm·°F)	118.38 3,598.07 857** 0.7262 0.0485 0.0632 0.2402	113.70 5.52 37,051 3.9648 1.4576 1.4304 61.8343 0.9988	Effective Area (ft²) LMTD Total Heat Transferred (BTU/hr) Surface Effectiveness (Eta) Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)	937.90 24.20 151,828 0.9020

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,602.43
Inlet Temperature (°F)	132.32	109.17	j Factor	0.0095
Outlet Temperature (°F)	126.20	110.78	Air-Side ho (BTU/hr·ft².°F)	10.12
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	129.26	109.98		
Skin Temperature (°F)	115.17	111.49	U Overall (BTU/hr·ft ² .°F)	6.67
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	865**	36,382	LMTD	19.11
Prandtl Number	0.7267	4.0450	Total Heat Transferred (BTU/hr)	119,548
Bulk Visc (lbm/ft·hr)	0.0481	1.4844		
Skin Visc (lbm/ft·hr)		1.4620	Surface Effectiveness (Eta)	0.9024
Density (lbm/ft³)	0.0639	61.8603	Sensible Heat Transferred (BTU/hr)	119,548
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3665	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability

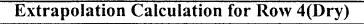


Proto-Power Calc: 97-200

Attachment: C

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Initial Benchmark Case -- Standard Coil



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,589.45
Inlet Temperature (°F)	126.20	107.91	j Factor	0.0094
Outlet Temperature (°F)	121.37	109.17	Air-Side ho (BTU/hr·ft².°F)	10.09
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
Average Temp (°F)	123.78	108.54		
Skin Temperature (°F)	112.65	109.74	U Overall (BTU/hr·ft².°F)	6.65
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	871**	35,858	LMTD	15.11
Prandtl Number	0.7271	4.1100	Total Heat Transferred (BTU/hr)	94,256
Bulk Visc (lbm/ft·hr)	0.0477	1.5061		
Skin Visc (lbm/ft·hr)		1.4878	Surface Effectiveness (Eta)	0.9026
Density (lbm/ft³)	0.0644	61.8805	Sensible Heat Transferred (BTU/hr)	94,256
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3660	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside	Range of Fountion	Applicability		

^{*} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft²-°F)	1,579.19
Inlet Temperature (°F)	121.37	106.91	j Factor	0.0094
Outlet Temperature (°F)	117.55	107.91	Air-Side ho (BTU/hr·ft².°F)	10.07
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU)	0.02832467
Average Temp (°F)	119.46	107.41		
Skin Temperature (°F)	110.65	108.36	U Overall (BTU/hr·ft².°F)	6.64
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	876**	35,447	LMTD	11.95
Prandtl Number	0.7274	4.1625	Total Heat Transferred (BTU/hr)	74,393
Bulk Visc (lbm/ft·hr)	0.0474	1.5235		
Skin Visc (lbm/ft·hr)		1.5087	Surface Effectiveness (Eta)	0.9028
Density (lbm/ft³)	0.0648	61.8962	Sensible Heat Transferred (BTU/hr)	74,393
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3656	Heat to Condensate (BTU/hr)	
** Darmalda Mumban Outsida	Daniel of Canadia	- A 11 1- 11 (4)		

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: C

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*** Air Mass Velocity (Lbm/hr ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Initial Benchmark Case -- Standard Coil

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,571.08
Inlet Temperature (°F)	117.55	106.12	j Factor	0.0094
Outlet Temperature (°F)	114.54	106.91	Air-Side ho (BTU/hr·ft².°F)	10.05
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	116.05	106.51		
Skin Temperature (°F)	109.08	107.27	U Overall (BTU/hr·ft².°F)	6.63
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	880**	35,123	LMTD	9.45
Prandtl Number	0.7277	4.2047	Total Heat Transferred (BTU/hr)	58,765
Bulk Visc (lbm/ft·hr)	0.0472	1.5376		
Skin Visc (lbm/ft·hr)		1.5256	Surface Effectiveness (Eta)	0.9029
Density (lbm/ft³)	0.0652	61.9085	Sensible Heat Transferred (BTU/hr)	58,765
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3653	Heat to Condensate (BTU/hr)	
** Paymolds Number Outside	Pance of Equation	Applicability		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

Air-Side	Tube-Side		
77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².ºF)	1,564.65
114.54	105.49	j Factor	0.0094
112.16	106.12	Air-Side ho (BTU/hr·ft².°F)	10.03
0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
113.35	105.81		
107.84	106.41	U Overall (BTU/hr·ft².°F)	6.62
3,598.07	5.52	Effective Area (ft²)	937.90
884**	34,868	LMTD	7.48
0.7278	4.2386	Total Heat Transferred (BTU/hr)	46,450
0.0471	1.5488		
	1.5392	Surface Effectiveness (Eta)	0.9031
0.0654	61.9181	Sensible Heat Transferred (BTU/hr)	46,450
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
0.0155	0.3650	Heat to Condensate (BTU/hr)	
	77,999.05 114.54 112.16 0.0203 0.0203 113.35 107.84 3,598.07 884*** 0.7278 0.0471 0.0654 0.2402	77,999.05 74,508.32 114.54 105.49 112.16 106.12 0.0203 0.0203 113.35 105.81 107.84 106.41 3,598.07 5.52 884** 34,868 0.7278 4.2386 0.0471 1.5488 1.5392 0.0654 61.9181 0.2402 0.9989	77,999.05 74,508.32 Tube-Side hi (BTU/hr·ft².°F) 114.54 105.49 j Factor 112.16 106.12 Air-Side ho (BTU/hr·ft².°F) 0.0203 Tube Wall Resistance (hr·ft².°F/BTU 0.0203 Overall Fouling (hr·ft².°F/BTU) 113.35 105.81 107.84 106.41 U Overall (BTU/hr·ft².°F) 3,598.07 5.52 Effective Area (ft²) 884** 34,868 LMTD 0.7278 4.2386 Total Heat Transferred (BTU/hr) 0.0471 1.5488 Surface Effectiveness (Eta) 0.0654 61.9181 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability

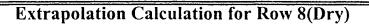


Proto-Power Calc: 97-200

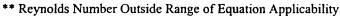
Attachment: C

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Initial Benchmark Case -- Standard Coil



Tube-Side hi (BTU/hr-ft2.°F)	
1000 0100 111 (210.111 11 1)	1,559.57
j Factor	0.0094
Air-Side ho (BTU/hr·ft².°F)	10.02
Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Overall Fouling (hr·ft².°F/BTU)	0.02832467
U Overall (BTU/hr·ft ² .°F)	6.61
Effective Area (ft²)	937.90
LMTD	5.92
Total Heat Transferred (BTU/hr)	36,735
Surface Effectiveness (Eta)	0.9032
Sensible Heat Transferred (BTU/hr)	36,735
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	
	j Factor Air-Side ho (BTU/hr·ft²-°F) Tube Wall Resistance (hr·ft²-°F/BTU Overall Fouling (hr·ft²-°F/BTU) U Overall (BTU/hr·ft²-°F) Effective Area (ft²) LMTD Total Heat Transferred (BTU/hr) Surface Effectiveness (Eta) Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)





Proto-Power Calc: 97-200

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Attachment D to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

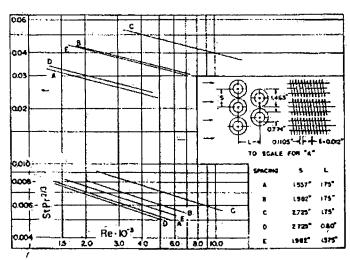
Attachment: D

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Fig. 10-89 Finned circular tubes, surface CF-9.05-3/4J. (Data of Jameson.)



Tube outside diameter = $0.774 \text{ in} = 19.66 \times 10^{-3} \text{ m}$

Fin pitch = 9.05 per in = 356 per m

Fin thickness = 0.012 in = 0.305×10^{-3} m

Fin area/total area = 0.835

Free-flow area/frontal area, σ = 0.455 0.572 0.688 0.537 0.572 Heat transfer area/ total volume, α = 108 85.1 61.9 135 $108 \text{ ft}^2/\text{ft}^3$ = 354 279 203 443 354 mi^2/m^3

Note: Minimum free-flow area in all cases occurs in the spaces transverse to the How, except for D_i in which the minimum area is in the diagonals.

Proto-Power Calc: 97-200

Attachment: D

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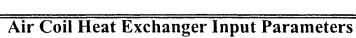
Attachment E to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: E

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Final Benchmark Case -- Custom Coil



	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
,		
Heat Exchanger Type Fin Type		Counter Flow Circular Fins
Fin Configuration	I aCalla	VY Coolers 01A/02A
Tin Configuration		+ -0.3436 * LOG(Re)]
	J - EAF (-2.3086	+-0.3430 · LOG(Re)]
Coil Finned Length (in)	•	108.000
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft	·°F)	225.00
The second of th	- ,	225.00

Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark Case -- Custom Coil



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Zatta potation 2	
Tube Flow (gpm)	150.00
Air Flow (acfm)	21,179.00
Tube Inlet Temp (°F)	105.00
Air Inlet Temp (°F)	150.0
Inlet Relative Humidity (%)	0.00
Inlet Wet Bulb Temp (°F)	92.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark Case -- Custom Coil

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft²·°F)	
Inlet Temperature (°F)	150.00	105.00	j Factor	
Outlet Temperature (°F)	111.57	115.11	Air-Side ho (BTU/hr·ft²-°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ² .°F/BTU)	0.02832467
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,503.18
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	749,965
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	749,965
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr-ft2-°F)	1,637.56
Inlet Temperature (°F)	150.00	112.75	j Factor	0.0080
Outlet Temperature (°F)	140.99	115.11	Air-Side ho (BTU/hr·ft².°F)	8.59
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
Average Temp (°F)	145.50	113.93		
Skin Temperature (°F)	121.51	116.10	U Overall (BTU/hr·ft²-°F)	5.98
Velocity ***	3,598.07	5.53	Effective Area (ft²)	937.90
Reynold's Number	847**	37,836	LMTD	31.35
Prandtl Number	0.7253	3.8745	Total Heat Transferred (BTU/hr)	175,742
Bulk Visc (lbm/ft·hr)	0.0491	1.4273		
Skin Visc (lbm/ft·hr)		1.3974	Surface Effectiveness (Eta)	0.9155
Density (lbm/ft³)	0.0623	61.8034	Sensible Heat Transferred (BTU/hr)	175,742
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0163	0.3679	Heat to Condensate (BTU/hr)	
*** ** * * * * * * * * * * * * * * * * *			·	

^{**} Reynolds Number Outside Range of Equation Applicability

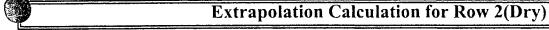


Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Final Benchmark Case -- Custom Coil



	Air-Side Tu	ube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,618.52
Inlet Temperature (°F)	140.99	110.84	j Factor	0.0080
Outlet Temperature (°F)	133.73	112.75	Air-Side ho (BTU/hr·ft².°F)	8.56
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ² .°F/BTU)	0.02832467
Average Temp (°F)	137.36	111.79		
Skin Temperature (°F)	117.93	113.57	U Overall (BTU/hr·ft².°F)	5.95
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	856**	37,048	LMTD	25.39
Prandtl Number	0.7261	3.9651	Total Heat Transferred (BTU/hr)	141,802
Bulk Visc (lbm/ft·hr)	0.0486	1.4577		
Skin Visc (lbm/ft·hr)		1.4323	Surface Effectiveness (Eta)	0.9158
Density (lbm/ft³)	0.0631	61.8344	Sensible Heat Transferred (BTU/hr)	141,802
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3672	Heat to Condensate (BTU/hr)	
Inlet Specific Humidity Outlet Specific Humidity Average Temp (°F) Skin Temperature (°F) Velocity *** Reynold's Number Prandtl Number Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp (BTU/lbm·°F)	0.0203 0.0203 137.36 117.93 3,598.07 856** 0.7261 0.0486	111.79 113.57 5.52 37,048 3.9651 1.4577 1.4323 61.8344 0.9988	Tube Wall Resistance (hr·ft²-°F/BTU Overall Fouling (hr·ft²-°F/BTU) U Overall (BTU/hr·ft²-°F) Effective Area (ft²) LMTD Total Heat Transferred (BTU/hr) Surface Effectiveness (Eta) Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)	0.000314 0.028324 5. 937. 25. 141,8

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft²-°F)	1,603.09
Inlet Temperature (°F)	133.73	109.30	j Factor	0.0080
Outlet Temperature (°F)	127.86	110.84	Air-Side ho (BTU/hr·ft².°F)	8.53
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	130.79	110.07		
Skin Temperature (°F)	115.04	111.52	U Overall (BTU/hr·ft².°F)	5.94
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	863**	36,416	LMTD	20.58
Prandtl Number	0.7266	4.0408	Total Heat Transferred (BTU/hr)	114,578
Bulk Visc (lbm/ft·hr)	0.0482	1.4830		
Skin Visc (lbm/ft·hr)		1.4616	Surface Effectiveness (Eta)	0.9161
Density (lbm/ft³)	0.0637	61.8590	Sensible Heat Transferred (BTU/hr)	114,578
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3666	Heat to Condensate (BTU/hr)	
## D 11 37 1 0	n cn			

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Final Benchmark Case -- Custom Coil

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr-ft2.°F)	1,590.59
Inlet Temperature (°F)	127.86	108.06	j Factor	0.0080
Outlet Temperature (°F)	123.11	109.30	Air-Side ho (BTU/hr·ft²·°F)	8.50
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	125.48	108.68		
Skin Temperature (°F)	112.71	109.86	U Overall (BTU/hr·ft ² ·°F)	5.92
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	869**	35,909	LMTD	16.69
Prandtl Number	0.7270	4.1037	Total Heat Transferred (BTU/hr)	92,686
Bulk Visc (lbm/ft·hr)	0.0478	1.5039		
Skin Visc (lbm/ft·hr)		1.4861	Surface Effectiveness (Eta)	0.9163
Density (lbm/ft³)	0.0642	61.8786	Sensible Heat Transferred (BTU/hr)	92,686
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3661	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside	Range of Equation	Applicability		

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

Air-Side	Tube-Side		
77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft²·°F)	1,580.44
123.11	107.05	j Factor	0.0079
119.26	108.06	Air-Side ho (BTU/hr·ft².°F)	8.48
0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
121.18	107.55		
110.82	108.51	U Overall (BTU/hr·ft².°F)	5.91
3,598.07	5.52	Effective Area (ft²)	937.90
874**	35,499	LMTD	13.54
0.7273	4.1558	Total Heat Transferred (BTU/hr)	75,047
0.0476	1.5213		
	1.5065	Surface Effectiveness (Eta)	0.9164
0.0646	61.8943	Sensible Heat Transferred (BTU/hr)	75,047
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
0.0157	0.3656	Heat to Condensate (BTU/hr)	
	77,999.05 123.11 119.26 0.0203 0.0203 121.18 110.82 3,598.07 874** 0.7273 0.0476 0.0646 0.2402	77,999.05 74,508.32 123.11 107.05 119.26 108.06 0.0203 0.0203 121.18 107.55 110.82 108.51 3,598.07 5.52 874** 35,499 0.7273 4.1558 0.0476 1.5213 1.5065 0.0646 61.8943 0.2402 0.9989	77,999.05 74,508.32 Tube-Side hi (BTU/hr·ft²-°F) 123.11 107.05 j Factor 119.26 108.06 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 121.18 107.55 110.82 108.51 U Overall (BTU/hr·ft²-°F) 3,598.07 5.52 Effective Area (ft²) 874** 35,499 LMTD 0.7273 4.1558 Total Heat Transferred (BTU/hr) 0.0476 1.5213 1.5065 Surface Effectiveness (Eta) 0.0646 61.8943 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark Case -- Custom Coil

Extrapolation Calculation for Row 6(Dry)

Air-Side	Tube-Side	·	
77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,572.22
119.26	106.23	j Factor	0.0079
116.14	107.05	Air-Side ho (BTU/hr·ft².°F)	8.47
0.0203		Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
117.70	106.64		
109.29	107.42	U Overall (BTU/hr·ft²-°F)	5.90
3,598.07	5.52	Effective Area (ft²)	937.90
878**	35,169	LMTD	10.99
0.7276	4.1987	Total Heat Transferred (BTU/hr)	60,810
0.0473	1.5356		
	1.5233	Surface Effectiveness (Eta)	0.9166
0.0650	61.9068	Sensible Heat Transferred (BTU/hr)	60,810
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
0.0156	0.3653	Heat to Condensate (BTU/hr)	
	77,999.05 119.26 116.14 0.0203 0.0203 117.70 109.29 3,598.07 878** 0.7276 0.0473 0.0650 0.2402	77,999.05 74,508.32 119.26 106.23 116.14 107.05 0.0203 0.0203 117.70 106.64 109.29 107.42 3,598.07 5.52 878** 35,169 0.7276 4.1987 0.0473 1.5356 1.5233 0.0650 0.2402 0.9989	77,999.05 74,508.32 Tube-Side hi (BTU/hr·ft²-°F) 119.26 106.23 j Factor 116.14 107.05 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 117.70 106.64 109.29 107.42 U Overall (BTU/hr·ft²-°F) 3,598.07 5.52 Effective Area (ft²) 878** 35,169 LMTD 0.7276 4.1987 Total Heat Transferred (BTU/hr) 0.0473 1.5356 1.5233 Surface Effectiveness (Eta) 0.0650 61.9068 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².ºF)	1,565.54
Inlet Temperature (°F)	116.14	105.57	j Factor	0.0079
Outlet Temperature (°F)	113.62	106.23	Air-Side ho (BTU/hr·ft².°F)	8.46
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	114.88	105.90		
Skin Temperature (°F)	108.05	106.54	U Overall (BTU/hr·ft²-°F)	5.89
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	882**	34,902	LMTD	8.92
Prandtl Number	0.7277	4.2341	Total Heat Transferred (BTU/hr)	49,305
Bulk Visc (lbm/ft·hr)	0.0472	1.5473		
Skin Visc (lbm/ft·hr)		1.5372	Surface Effectiveness (Eta)	0.9167
Density (lbm/ft³)	0.0653	61.9169	Sensible Heat Transferred (BTU/hr)	49,305
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft-°F)	0.0156	0.3650	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark Case -- Custom Coil

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,560.11
Inlet Temperature (°F)	113.62	105.03	j Factor	0.0079
Outlet Temperature (°F)	111.57	105.57	Air-Side ho (BTU/hr·ft².°F)	8.45
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	112.59	105.30		
Skin Temperature (°F)	107.05	105.82	U Overall (BTU/hr·ft².°F)	5.89
Velocity ***	3,598.07	5.52	Effective Area (ft²)	937.90
Reynold's Number	885**	34,686	LMTD	7.24
Prandtl Number	0.7279	4.2631	Total Heat Transferred (BTU/hr)	39,996
Bulk Visc (lbm/ft·hr)	0.0470	1.5569		
Skin Visc (lbm/ft·hr)		1.5486	Surface Effectiveness (Eta)	0.9168
Density (lbm/ft³)	0.0655	61.9250	Sensible Heat Transferred (BTU/hr)	39,996
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3648	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark - Effective Coil Length

Air Coil Heat Exchanger Input Parameters

•	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	e VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		. 8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft		
race wan conductivity (B10/iii it	·°F)	225.00

Attachment: E Rev: A Page

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	150.00
Air Flow (acfm)	21,179.00
Tube Inlet Temp (°F)	105.00
Air Inlet Temp (°F)	150.0
Inlet Relative Humidity (%)	0.00
Inlet Wet Bulb Temp (°F)	92.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: E

Rev: A Page 10 of 15

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Final Benchmark - Effective Coil Length

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr-ft2.°F)	
Inlet Temperature (°F)	150.00	105.00	j Factor	
Outlet Temperature (°F)	111.76	115.02	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU 0.00031436	0
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.0283246	7
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²) 7,242.6	5
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr) 746,29	7
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 746,29	7
Cp (BTU/lbm.°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,637.06
Inlet Temperature (°F)	150.00	112.69	j Factor	0.0079
Outlet Temperature (°F)	141.13	115.02	Air-Side ho (BTU/hr·ft².°F)	8.79
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	145.56	113.86		
Skin Temperature (°F)	121.59	116.08	U Overall (BTU/hr·ft²·°F)	6.07
Velocity ***	3,727.50	5.53	Effective Area (ft²)	905.33
Reynold's Number	878**	37,810	LMTD	31.49
Prandtl Number	0.7253	3.8775	Total Heat Transferred (BTU/hr)	173,186
Bulk Visc (lbm/ft·hr)	0.0491	1.4283		
Skin Visc (lbm/ft·hr)		1.3978	Surface Effectiveness (Eta)	0.9137
Density (lbm/ft³)	0.0623	61.8044	Sensible Heat Transferred (BTU/hr)	173,186
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0163	0.3679	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark - Effective Coil Length

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr-ft2.°F)	1,618.25
Inlet Temperature (°F)	141.13	110.81	j Factor	0.0079
Outlet Temperature (°F)	133.94	112.69	Air-Side ho (BTU/hr-ft2-°F)	8.76
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	137.53	111.75		
Skin Temperature (°F)	118.04	113.57	U Overall (BTU/hr·ft².°F)	6.05
Velocity ***	3,727.50	5.52	Effective Area (ft²)	905.33
Reynold's Number	887**	37,032	LMTD	25.61
Prandtl Number	0.7261	3.9670	Total Heat Transferred (BTU/hr)	140,305
Bulk Visc (lbm/ft·hr)	0.0486	1.4583		
Skin Visc (lbm/ft·hr)		1.4323	Surface Effectiveness (Eta)	0.9140
Density (lbm/ft³)	0.0630	61.8350	Sensible Heat Transferred (BTU/hr)	140,305
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3672	Heat to Condensate (BTU/hr)	
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^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft²·°F)	1,602.95
Inlet Temperature (°F)	133.94	109.28	j Factor	0.0079
Outlet Temperature (°F)	128.10	110.81	Air-Side ho (BTU/hr·ft²-°F)	8.73
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ^{2.} °F/BTU)	0.02832467
Average Temp (°F)	131.02	110.04		
Skin Temperature (°F)	115.16	111.53	U Overall (BTU/hr·ft².°F)	6.03
Velocity ***	3,727.50	5.52	Effective Area (ft²)	905.33
Reynold's Number	894**	36,406	LMTD	20.84
Prandtl Number	0.7266	4.0420	Total Heat Transferred (BTU/hr)	113,821
Bulk Visc (lbm/ft·hr)	0.0482	1.4834		
Skin Visc (lbm/ft·hr)		1.4614	Surface Effectiveness (Eta)	0.9143
Density (lbm/ft³)	0.0637	61.8594	Sensible Heat Transferred (BTU/hr)	113,821
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3666	Heat to Condensate (BTU/hr)	
			·	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Final Benchmark - Effective Coil Length



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,590.49
Inlet Temperature (°F)	128.10	108.04	j Factor	0.0079
Outlet Temperature (°F)	123.37	109.28	Air-Side ho (BTU/hr·ft².°F)	8.70
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	125.73	108.66		
Skin Temperature (°F)	112.82	109.88	U Overall (BTU/hr·ft².°F)	6.02
Velocity ***	3,727.50	5.52	Effective Area (ft²)	905.33
Reynold's Number	900**	35,901	LMTD	16.96
Prandtl Number	0.7270	4.1046	Total Heat Transferred (BTU/hr)	92,439
Bulk Visc (lbm/ft·hr)	0.0478	1.5043		
Skin Visc (lbm/ft·hr)		1.4858	Surface Effectiveness (Eta)	0.9145
Density (lbm/ft³)	0.0642	61.8789	Sensible Heat Transferred (BTU/hr)	92,439
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3661	Heat to Condensate (BTU/hr)	
44 D 11 37 1 0 (11	D CF	A 11 1 11.		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,580.35
Inlet Temperature (°F)	123.37	107.03	j Factor	0.0078
Outlet Temperature (°F)	119.52	108.04	Air-Side ho (BTU/hr·ft²-°F)	8.68
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	121.44	107.53		
Skin Temperature (°F)	110.92	108.53	U Overall (BTU/hr·ft².°F)	6.01
Velocity ***	3,727.50	5.52	Effective Area (ft²)	905.33
Reynold's Number	905**	35,491	LMTD	13.82
Prandtl Number	0.7273	4.1567	Total Heat Transferred (BTU/hr)	75,142
Bulk Visc (lbm/ft·hr)	0.0476	1.5216		
Skin Visc (lbm/ft·hr)		1.5062	Surface Effectiveness (Eta)	0.9147
Density (lbm/ft³)	0.0646	61.8945	Sensible Heat Transferred (BTU/hr)	75,142
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3656	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



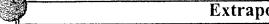
Proto-Power Calc: 97-200

Attachment: E

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark - Effective Coil Length



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,572.09
Inlet Temperature (°F)	119.52	106.20	j Factor	0.0078
Outlet Temperature (°F)	116.38	107.03	Air-Side ho (BTU/hr·ft².°F)	8.67
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	117.95	106.62		
Skin Temperature (°F)	109.38	107.43	U Overall (BTU/hr·ft².°F)	6.00
Velocity ***	3,727.50	5.52	Effective Area (ft²)	905.33
Reynold's Number	910**	35,160	LMTD	11.26
Prandtl Number	0.7275	4.1998	Total Heat Transferred (BTU/hr)	61,127
Bulk Visc (lbm/ft·hr)	0.0474	1.5359		
Skin Visc (lbm/ft·hr)		1.5231	Surface Effectiveness (Eta)	0.9148
Density (lbm/ft³)	0.0650	61.9071	Sensible Heat Transferred (BTU/hr)	61,127
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3653	Heat to Condensate (BTU/hr)	
** D 11 N 1 O 1 1	D. CE M.	. A 11 1 1954		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

BTU/hr·ft ² .°F) 1,565.36
0.0078
$TU/hr \cdot ft^2 \cdot °F)$ 8.66
sistance (hr·ft².°F/BTU 0.00031430
g (hr·ft².°F/BTU) 0.02832467
$U/hr \cdot ft^2 \cdot {}^{\circ}F)$ 5.99
(ft^2) 905.33
9.18
nsferred (BTU/hr) 49,756
iveness (Eta) 0.9149
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ansferred (BTU/hr)
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^{**} Reynolds Number Outside Range of Equation Applicability

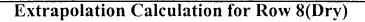


Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Final Benchmark - Effective Coil Length



Air-Side	Tube-Side		
77,999.05	74,508.32	Tube-Side hi (BTU/hr·ft².°F)	1,559.87
113.83	104.99	j Factor	0.0078
111.76	105.54	Air-Side ho (BTU/hr·ft².°F)	8.65
0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
112.79	105.26		
107.10	105.81	U Overall (BTU/hr·ft².°F)	5.98
3,727.50	5.52	Effective Area (ft²)	905.33
916**	34,673	LMTD	7.48
0.7279	4.2648	Total Heat Transferred (BTU/hr)	40,520
0.0470	1.5575		
	1.5487	Surface Effectiveness (Eta)	0.9150
0.0655	61.9254	Sensible Heat Transferred (BTU/hr)	40,520
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	•
0.0155	0.3648	Heat to Condensate (BTU/hr)	
	77,999.05 113.83 111.76 0.0203 0.0203 112.79 107.10 3,727.50 916** 0.7279 0.0470 0.0655 0.2402	77,999.05 74,508.32 113.83 104.99 111.76 105.54 0.0203 0.0203 112.79 105.26 107.10 105.81 3,727.50 5.52 916** 34,673 0.7279 4.2648 0.0470 1.5575 1.5487 0.0655 61.9254 0.2402 0.9989 0.0155 0.3648	77,999.05 74,508.32 Tube-Side hi (BTU/hr·ft².°F) 113.83 104.99 j Factor 111.76 105.54 Air-Side ho (BTU/hr·ft².°F) 0.0203 Tube Wall Resistance (hr·ft².°F/BTU) 0.0203 Overall Fouling (hr·ft².°F/BTU) 112.79 105.26 107.10 105.81 U Overall (BTU/hr·ft².°F) 3,727.50 5.52 Effective Area (ft²) 916** 34,673 LMTD 0.7279 4.2648 Total Heat Transferred (BTU/hr) 0.0470 1.5575 Surface Effectiveness (Eta) 0.0655 61.9254 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr) 0.0155 0.3648 Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Attachment F to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: F

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type	r	Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft-	°F)	225.00

Proto-Power Calc: 97-200

Attachment: F

Rev: A Page 2 of 8

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Fouling Was Input by User

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	150.00
Air Flow (acfm)	19,387.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315
Input Fouling Factor	0.000000

Proto-Power Calc: 97-200

Attachment: F

Rev: A Page 3 of 8



Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Extrapolation Calculation Summary

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr ft2.°F)
Inlet Temperature (°F)	148.00	100.00	j Factor
Outlet Temperature (°F)	104.53	110.41	Air-Side ho (BTU/hr-ft²-°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft²-°F/BTU 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²-°F/BTU)
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)
Velocity ***			Effective Area (ft²) 7,242.65
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 779,018
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 779,018
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,598.27
Inlet Temperature (°F)	148.00	107.62	j Factor	0.0082
Outlet Temperature (°F)	136.42	110.41	Air-Side ho (BTU/hr·ft².°F)	8.30
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft².°F/BTU)	
Average Temp (°F)	142.21	109.01		
Skin Temperature (°F)	111.82	111.75	U Overall (BTU/hr·ft²-°F)	6.98
Velocity ***	3,423.68	5.53	Effective Area (ft²)	905.33
Reynold's Number	810**	36,069	LMTD	32.85
Prandtl Number	0.7256	4.0884	Total Heat Transferred (BTU/hr)	207,508
Bulk Visc (lbm/ft·hr)	0.0489	1.4988	·	
Skin Visc (lbm/ft·hr)		1.4583	Surface Effectiveness (Eta)	0.9181
Density (lbm/ft³)	0.0628	61.8739	Sensible Heat Transferred (BTU/hr)	207,508
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3662	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: F

Rev: A Page 4 of 8

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,575.85
Inlet Temperature (°F)	136.42	105.50	j Factor	0.0081
Outlet Temperature (°F)	127.59	107.62	Air-Side ho (BTU/hr-ft ² .°F)	8.26
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	
Average Temp (°F)	132.01	106.56		
Skin Temperature (°F)	108.73	108.68	U Overall (BTU/hr·ft ² .°F)	6.94
Velocity ***	3,423.68	5.52	Effective Area (ft²)	905.33
Reynold's Number	820**	35,177	LMTD	25.19
Prandtl Number	0.7265	4.2025	Total Heat Transferred (BTU/hr)	158,199
Bulk Visc (lbm/ft·hr)	0.0482	1.5368		
Skin Visc (lbm/ft·hr)		1.5040	Surface Effectiveness (Eta)	0.9184
Density (lbm/ft³)	0.0637	61.9079	Sensible Heat Transferred (BTU/hr)	158,199
Cp (BTU/lbm.°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0160	0.3653	Heat to Condensate (BTU/hr)	
Outlet Specific Humidity Average Temp (°F) Skin Temperature (°F) Velocity *** Reynold's Number Prandtl Number Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp (BTU/lbm·°F)	0.0203 132.01 108.73 3,423.68 820** 0.7265 0.0482 0.0637 0.2402 0.0160	108.68 5.52 35,177 4.2025 1.5368 1.5040 61.9079 0.9989	Overall Fouling (hr-ft²-°F/BTU) U Overall (BTU/hr-ft²-°F) Effective Area (ft²) LMTD Total Heat Transferred (BTU/hr) Surface Effectiveness (Eta) Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)	6.9 905 25. 158,19

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F) 1,558.67
Inlet Temperature (°F)	127.59	103.87	j Factor 0.0081
Outlet Temperature (°F)	120.85	105.50	Air-Side ho (BTU/hr·ft².°F) 8.23
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU 0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)
Average Temp (°F)	124.22	104.69	
Skin Temperature (°F)	106.36	106.32	U Overall (BTU/hr·ft²·°F) 6.91
Velocity ***	3,423.68	5.52	Effective Area (ft²) 905.33
Reynold's Number	829**	34,502	LMTD 19.34
Prandtl Number	0.7271	4.2930	Total Heat Transferred (BTU/hr) 120,920
Bulk Visc (lbm/ft·hr)	0.0478	1.5669	
Skin Visc (lbm/ft·hr)		1.5406	Surface Effectiveness (Eta) 0.9187
Density (lbm/ft³)	0.0645	61.9332	Sensible Heat Transferred (BTU/hr) 120,920
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)	0.0158	0.3646	Heat to Condensate (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,545.48
Inlet Temperature (°F)	120.85	102.63	j Factor	0.0081
Outlet Temperature (°F)	115.68	103.87	Air-Side ho (BTU/hr·ft².°F)	8.20
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft².°F/BTU)	
Average Temp (°F)	118.26	103.25		
Skin Temperature (°F)	104.55	104.52	U Overall (BTU/hr·ft².°F)	6.88
Velocity ***	3,423.68	5.52	Effective Area (ft²)	905.33
Reynold's Number	835**	33,989	LMTD	14.86
Prandtl Number	0.7275	4.3645	Total Heat Transferred (BTU/hr)	92,611
Bulk Visc (lbm/ft·hr)	0.0474	1.5905		•
Skin Visc (lbm/ft·hr)		1.5697	Surface Effectiveness (Eta)	0.9190
Density (lbm/ft³)	0.0650	61.9522	Sensible Heat Transferred (BTU/hr)	92,611
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3640	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside	Range of Equation	n Applicability		

Extrapolation Calculation for Row 5(Dry)

			·	
	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,535.34
Inlet Temperature (°F)	115.68	101.68	j Factor	0.0080
Outlet Temperature (°F)	111.72	102.63	Air-Side ho (BTU/hr·ft².°F)	8.18
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	
Average Temp (°F)	113.70	102.15		
Skin Temperature (°F)	103.15	103.13	U Overall (BTU/hr·ft².°F)	6.87
Velocity ***	3,423.68	5.52	Effective Area (ft²)	905.33
Reynold's Number	840**	33,597	LMTD	11.43
Prandtl Number	0.7278	4.4206	Total Heat Transferred (BTU/hr)	71,038
Bulk Visc (lbm/ft·hr)	0.0471	1.6091		
Skin Visc (lbm/ft·hr)		1.5926	Surface Effectiveness (Eta)	0.9191
Density (lbm/ft³)	0.0655	61.9666	Sensible Heat Transferred (BTU/hr)	71,038
Cp (BTU/lbm.°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3636	Heat to Condensate (BTU/hr)	
	:			

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Extrapolation Calculation for Row 6(Dry)

Air-Side	Tube-Side		
71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,527.56
111.72	100.95	j Factor	0.0080
108.67	101.68	Air-Side ho (BTU/hr·ft².°F)	8.16
0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.0F/BTU)	
110.19	101.31		
102.08	102.06	U Overall (BTU/hr·ft ² .°F)	6.85
3,423.68	^c 5.52	Effective Area (ft²)	905.33
844**	33,298	LMTD	8.79
0.7280	4.4644	Total Heat Transferred (BTU/hr)	54,554
0.0469	1.6236		
	1.6106	Surface Effectiveness (Eta)	0.9193
0.0659	61.9776	Sensible Heat Transferred (BTU/hr)	54,554
0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
0.0155	0.3633	Heat to Condensate (BTU/hr)	
	71,641.50 111.72 108.67 0.0203 0.0203 110.19 102.08 3,423.68 844** 0.7280 0.0469 0.0659 0.2402	71,641.50 74,586.94 111.72 100.95 108.67 101.68 0.0203 0.0203 110.19 101.31 102.08 102.06 3,423.68 5.52 844** 33,298 0.7280 4.4644 0.0469 1.6236 1.6106 0.0659 61.9776 0.2402 0.9990	71,641.50 74,586.94 Tube-Side hi (BTU/hr·ft²-°F) 111.72 100.95 j Factor 108.67 101.68 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 110.19 101.31 102.08 102.06 U Overall (BTU/hr·ft²-°F) 3,423.68 5.52 Effective Area (ft²) 844** 33,298 LMTD 0.7280 4.4644 Total Heat Transferred (BTU/hr) 0.0469 1.6236 1.6106 Surface Effectiveness (Eta) 0.0659 61.9776 Sensible Heat Transferred (BTU/hr) 0.2402 0.9990 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,521.56
Inlet Temperature (°F)	108.67	100.38	j Factor	0.0080
Outlet Temperature (°F)	106.33	100.95	Air-Side ho (BTU/hr·ft².°F)	8.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	
Average Temp (°F)	107.50	100.66		
Skin Temperature (°F)	101.26	101.25	U Overall (BTU/hr-ft2-°F)	6.84
Velocity ***	3,423.68	5.52	Effective Area (ft²)	905.33
Reynold's Number	848**	33,069	LMTD	6.77
Prandtl Number	0.7282	4.4985	Total Heat Transferred (BTU/hr)	41,933
Bulk Visc (lbm/ft·hr)	0.0467	1.6348		
Skin Visc (lbm/ft·hr)		1.6247	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0661	61.9859	Sensible Heat Transferred (BTU/hr)	41,933
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0154	0.3630	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: F

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Zero Fouling

Extrapolation Calculation for Row 8(Dry)

516.95
0.0080
8.14
31430
6.84
905.33
5.21
32,255
0.9195
32,255
3

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: F

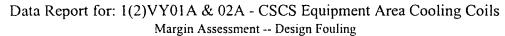
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Attachment G to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: G

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	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001500
Air-Side Fouling		0.000000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft·	°F)	225.00
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Proto-Power Calc: 97-200

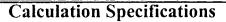
Attachment: G

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

150.00
19,321.00
100.00
148.0
12.76
0.00
14.315

Proto-Power Calc: 97-200

Attachment: G

Rev: A Page 3 of 8



Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	106.46	109.94	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft ² .°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	741,876
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	741,876
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,595.06
Inlet Temperature (°F)	148.00	107.53	j Factor	0.0082
Outlet Temperature (°F)	137.97	109.94	Air-Side ho (BTU/hr·ft².°F)	8.29
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2-°F/BTU 0	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ² .°F/BTU) 0	0.02832467
Average Temp (°F)	142.99	108.74		
Skin Temperature (°F)	116.80	111.10	U Overall (BTU/hr·ft².°F)	5.82
Velocity ***	3,412.02	5.53	Effective Area (ft²)	905.33
Reynold's Number	806**	35,968	LMTD	34.00
Prandtl Number	0.7256	4.1010	Total Heat Transferred (BTU/hr)	179,064
Bulk Visc (lbm/ft·hr)	0.0489	1.5030	,	·
Skin Visc (lbm/ft·hr)		1.4678	Surface Effectiveness (Eta)	0.9182
Density (lbm/ft³)	0.0626	61.8778	Sensible Heat Transferred (BTU/hr)	179,064
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0162	0.3661	Heat to Condensate (BTU/hr)	
** D 1.4 - M	D CT	A 11 1 111	,	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: G

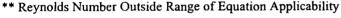
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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,575.52
Inlet Temperature (°F)	137.97	105.62	j Factor	0.0081
Outlet Temperature (°F)	129.99	107.53	Air-Side ho (BTU/hr·ft².°F)	8.25
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	133.98	106.58		
Skin Temperature (°F)	113.03	108.48	U Overall (BTU/hr·ft².°F)	5.79
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	815**	35,184	LMTD	27.20
Prandtl Number	0.7264	4.2016	Total Heat Transferred (BTU/hr)	142,681
Bulk Visc (lbm/ft·hr)	0.0484	1.5365		
Skin Visc (lbm/ft·hr)		1.5070	Surface Effectiveness (Eta)	0.9185
Density (lbm/ft³)	0.0635	61.9076	Sensible Heat Transferred (BTU/hr)	142,681
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0160	0.3653	Heat to Condensate (BTU/hr)	
** Daynolde Number Outside	Pange of Fountion	Applicability		





	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².ºF)	1,559.89
Inlet Temperature (°F)	129.99	104.09	j Factor	0.0081
Outlet Temperature (°F)	123.61	105.62	Air-Side ho (BTU/hr·ft².°F)	8.22
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	126.80	104.85		
Skin Temperature (°F)	110.02	106.39	U Overall (BTU/hr·ft².°F)	5.77
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	823**	34,563	LMTD	21.78
Prandtl Number	0.7269	4.2848	Total Heat Transferred (BTU/hr)	113,876
Bulk Visc (lbm/ft·hr)	0.0479	1.5641		
Skin Visc (lbm/ft·hr)		1.5395	Surface Effectiveness (Eta)	0.9188
Density (lbm/ft³)	0.0642	61.9309	Sensible Heat Transferred (BTU/hr)	113,876
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3646	Heat to Condensate (BTU/hr)	
Inlet Specific Humidity Outlet Specific Humidity Average Temp (°F) Skin Temperature (°F) Velocity *** Reynold's Number Prandtl Number Bulk Visc (lbm/ft·hr) Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp (BTU/lbm·°F)	0.0203 0.0203 126.80 110.02 3,412.02 823** 0.7269 0.0479 0.0642 0.2402	104.85 106.39 5.52 34,563 4.2848 1.5641 1.5395 61.9309 0.9989	Tube Wall Resistance (hr·ft²-°F/BTU Overall Fouling (hr·ft²-°F/BTU) U Overall (BTU/hr·ft²-°F) Effective Area (ft²) LMTD Total Heat Transferred (BTU/hr) Surface Effectiveness (Eta) Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)	0.0003143 0.0283246 5.7 905.3 21.7 113,87

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

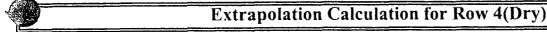
Attachment: G

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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

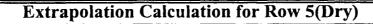
Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,547.37
Inlet Temperature (°F)	123.61	102.87	j Factor	0.0081
Outlet Temperature (°F)	118.51	104.09	Air-Side ho (BTU/hr-ft².°F)	8.19
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.02832467
Average Temp (°F)	121.06	103.48		
Skin Temperature (°F)	107.62	104.72	U Overall (BTU/hr-ft ^{2,o} F)	5.76
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	829**	34,070	LMTD	17.46
Prandtl Number	0.7273	4.3531	Total Heat Transferred (BTU/hr)	91,006
Bulk Visc (lbm/ft·hr)	0.0476	1.5868		
Skin Visc (lbm/ft·hr)		1.5664	Surface Effectiveness (Eta)	0.9190
Density (lbm/ft³)	0.0647	61.9493	Sensible Heat Transferred (BTU/hr)	91,006
Cp (BTU/lbm.°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3641	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside	Range of Equation	n Applicability		

^{**} Reynolds Number Outside Range of Equation Applicability



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft²-°F)	1,537.35
Inlet Temperature (°F)	118.51	101.89	j Factor	0.0081
Outlet Temperature (°F)	114.44	102.87	Air-Side ho (BTU/hr·ft².°F)	8.17
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.02832467
Average Temp (°F)	116.48	102.38		
Skin Temperature (°F)	105.70	103.38	U Overall (BTU/hr·ft².°F)	5.75
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	834**	33,678	LMTD	13.99
Prandtl Number	0.7276	4.4089	Total Heat Transferred (BTU/hr)	72,805
Bulk Visc (lbm/ft·hr)	0.0473	1.6052		
Skin Visc (lbm/ft·hr)		1.5885	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft³)	0.0652	61.9637	Sensible Heat Transferred (BTU/hr)	72,805
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3637	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



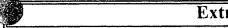
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,529.34
Inlet Temperature (°F)	114.44	101.11	j Factor	0.0081
Outlet Temperature (°F)	111.17	101.89	Air-Side ho (BTU/hr·ft².°F)	8.16
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.02832467
Average Temp (°F)	112.81	101.50		
Skin Temperature (°F)	104.17	102.32	U Overall (BTU/hr·ft².°F)	5.74
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	839**	33,365	LMTD	11.22
Prandtl Number	0.7279	4.4545	Total Heat Transferred (BTU/hr)	58,294
Bulk Visc (lbm/ft·hr)	0.0470	1.6203		
Skin Visc (lbm/ft·hr)		1.6063	Surface Effectiveness (Eta)	0.9193
Density (lbm/ft³)	0.0656	61.9751	Sensible Heat Transferred (BTU/hr)	58,294
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3634	Heat to Condensate (BTU/hr)	
** Darmalda Numban Outsida	Dance of Counties	. Amuliaabilim		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

			·	
	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,522.84
Inlet Temperature (°F)	111.17	100.48	j Factor	0.0080
Outlet Temperature (°F)	108.56	101.11	Air-Side ho (BTU/hr·ft²·°F)	8.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft ^{2.} °F/BTU)	0.02832467
Average Temp (°F)	109.87	100.80	<u>-</u>	
Skin Temperature (°F)	102.93	101.44	U Overall (BTU/hr·ft².°F)	5.73
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	842**	33,115	LMTD	9.01
Prandtl Number	0.7280	4.4916	Total Heat Transferred (BTU/hr)	46,707
Bulk Visc (lbm/ft·hr)	0.0468	1.6325	,	·
Skin Visc (lbm/ft·hr)		1.6213	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0659	61.9842	Sensible Heat Transferred (BTU/hr)	46,707
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0155	0.3631	Heat to Condensate (BTU/hr)	
			•	

^{**} Reynolds Number Outside Range of Equation Applicability



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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Margin Assessment -- Design Fouling



Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft².°F)	1,517.67
Inlet Temperature (°F)	108.56	99.98	j Factor	0.0080
Outlet Temperature (°F)	106.46	100.48	Air-Side ho (BTU/hr·ft².°F)	8.14
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02832467
Average Temp (°F)	107.51	100.23		
Skin Temperature (°F)	101.94	100.75	U Overall (BTU/hr·ft².°F)	5.72
Velocity ***	3,412.02	5.52	Effective Area (ft²)	905.33
Reynold's Number	845**	32,915	LMTD	7.23
Prandtl Number	0.7282	4.5216	Total Heat Transferred (BTU/hr)	37,443
Bulk Visc (lbm/ft·hr)	0.0467	1.6424		
Skin Visc (lbm/ft·hr)		1.6333	Surface Effectiveness (Eta)	0.9195
Density (lbm/ft³)	0.0661	61.9914	Sensible Heat Transferred (BTU/hr)	37,443
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0154	0.3629	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



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Attachment H to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: H

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Moist Air Properties

Equations for calculating moist air properties are compiled and/or derived in Proto-Power Calculation 96-069, Reference (1), relying on References (2) and (3) as the principal sources of information. This attachment summarizes the equations pertinent to the moist air conditions calculated for heat exchanger model development. The applicable material has been extracted from Reference (1) leaving equation numbering as it appears in Reference (1) for ease of cross reference.

1. Nomenclature

 $m_a = Mass of Dry Air, lbm$

 $m_v = Mass of Water Vapor, lbm$

P = Atmospheric Pressure, lbf/in²

 $P_a = Dry Air Pressure, lbf/in^2$

 $P_s = Saturated Air Pressure, lbf/in^2$

 $P_v = \text{Water Vapor Pressure, lbf/in}^2$

 $R_a = Gas constant of Dry Air$

 $R_v = Gas constant of Water Vapor$

T = Dry Bulb Temperature, °F

T_w = Wet Bulb Temperature, °F

 $V = Moist air Volume, ft^3$

W = Moist air Specific Humidity

 $x_v = Mole$ Fraction of Water Vapor in Moist Air

 x_s = Mole Fraction of Water Vapor in Saturated Air

 ϕ = Moist Air Relative Humidity

 $\rho = Moist air Density, lbm/ft^3$

 $\rho_a = \text{Dry Air Density, lbm/ft}^3$

 $\rho_v = \text{Water Vapor Density, lbm/ft}^3$

2. References

- (1) Proto-Power Calculation 96-069, Fluid Properties Moist Air Range 8°F to 300°F, Revision -, dated 12/2/96
- (2) Heating Ventilating, and Air Conditioning Analysis and Design, F. C. McQuiston and J. D. Parker, Second Edition, John Wiley & Sons, Inc., 1982
- (3) ASHRAE Handbook 1981 Fundamentals, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., 1982



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3. MOIST AIR DENSITY

For dry air:

$$P_a = P - P_v$$

Equation [4]

$$\rho_a = \left(\frac{144}{R_a}\right) \frac{P_a}{(459.67 + T)}$$

Equation [5]

where:

$$R_a = 53.352 (ft-lbf)/(lbm-{}^{\circ}R)$$

For water vapor:

$$\rho_{\nu} = \left(\frac{144}{R_{\nu}}\right) \frac{P_{\nu}}{\left(459.67 + T\right)}$$

Equation [6]



where:

$$R_v = 85.778 \text{ (ft-lbf)/(lbm-}^{\circ}\text{R)}$$

For moist air:

$$\rho = \rho_a + \rho_v$$

Equation [7]

4. SATURATED WATER VAPOR PRESSURE

$$P_s(T) = a + bT + cT^2 + dT^3 + eT^4 + fT^5$$

Equation [8]

Where:

a = 0.02358607

 $b \approx 0.001007276$

 $c \approx 0.00001888033$

 $d \approx 0.000003775047$

 $e \approx 4.871208E-10$

f = 2.109071E-11



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5. WATER VAPOR PRESSURE

$$f(T_w) = a + bT_w + cT_w^2 + dT_w^3 + eT_w^4 + fT_w^5$$

Equation [9]

$$P_{v}(P,T,T_{w}) = \frac{\left[\left(2T_{w} - T - 2800\right)f(T_{w})\right] - P(T_{w} - T)}{\left(T_{w} - 2800\right)}$$

Equation [10]

Where:

a = 0.02358607

b = 0.001007276

c = 0.00001888033

d = 0.0000003775047

e = 4.871208E-10

f = 2.109071E-11

$$P_{\nu} = \frac{WR_{\nu} P}{R_a + (WR_{\nu})}$$

Equation [11]

6. MOIST AIR SPECIFIC HUMIDITY



$$W = \frac{m_v}{m_a} = \frac{\rho_v}{\rho_a}$$

Equation [12]

Where:

$$m_{\nu} = \frac{P_{\nu} V}{R_{\nu} \left(459.67 + T \right)}$$

Equation [13]

$$m_a = \frac{P_a V}{R_a \left(459.67 + T\right)}$$

Equation [14]

7. Moist Air Relative Humidity

$$\phi = \frac{x_v}{x_s} = \frac{P_v}{P_s}$$

Equation [15]



Proto-Power Calc: 97-200

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Moist Air Properties -- Given Dry Bulb and Relative Humidity

Total Pressure:

P =

14.315

psia

Dry Bulb Temperature:

T =

70

٥F

Moist Air Relative Humidity:

RH =

40

%

psia

psia

psia

lbm/ft³

Saturated Air Pressure:

Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$

0.363236046

Equation [8]

Vapor Pressure:

Pv = RH*Ps

0.145294418

Equation [15]

Dry Air Pressure:

Pa =P - Pv =

14.16970558

Equation [4]

Dry Air Density:

Rho a = (144/53.352)*(Pa/(459.67+T)) =

0.072204994 lbm/ft³ Equation [5]

Water Vapor Density:

Rho v = (144/85.778)*(Pv/(459.67+T)) =

0.000460501

Equation [6]

Moist Air Density:

Rho = Rho a + Rho v =

lbm/ft³ 0.072665495

Equation [7]

Specific Humidity:

W = Rho v / Rho a =

0.006377682

Equation [12]

Equation Coefficients:

a =

b =

c =

e = f =

d =

2.358607E-02 1.007276E-03

1.888033E-05

3.775047E-07

4.871208E-10

2.109071E-11

Attachment: H Rev: A Page Proto-Power Calc: 97-200 of 13

* Coil Specification Conditions



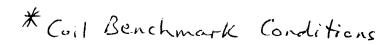




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Moist Air Properties -- Given Dry Bulb and Wet Bulb Temperatures

Total Pressure:	P =	14.315	psia	
Dry Bulb Temperature:	T =	150	°F	
Wet Bulb Temperature:	Tw =	92.00	°F	
Wet Bulb Temp. Function:	$F(Tw) = a+(b*Tw)+(c*Tw^2)+(d*Tw^3)+(e*Tw^4)+(f*Tw^5) =$	0.743918919		Equation [9]
Water Vapor Pressure:	Pv = (((2*Tw-T-2800)*F(Tw))-P*(Tw-T))/(Tw-2800) =	0.453253224	psia	Equation [10]
Dry Air Pressure:	Pa =P - Pv =	13.86174678	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.061367004	lbm/ft ³	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001248052	lbm/ft ³	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.062615056	lbm/ft ³	Equation [7]
Saturated Air Pressure:	Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$	3.721743953	psia	Equation [8]
Moist Air Specific Humidity:	W = Rho v / Rho a =	0.020337508		Equation [12]
Moist Air Relative Humidity:	RH = Pv /Ps =	12.17852	%	Equation [15]
Equation Coefficients:	a = b = c = d = e = f =	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10 2.109071E-11		











Total Pressure:	P = :	14.315	psia	
Dry Bulb Temperature:	T =	148	°F	
Wet Bulb Temperature:	Tw =	91.60	°F	
Wet Bulb Temp. Function:	$F(Tw) = a+(b*Tw)+(c*Tw^2)+(d*Tw^3)+(e*Tw^4)+(f*Tw^5) =$	0.734713202		Equation [9]
Water Vapor Pressure:	Pv = (((2*Tw-T-2800)*F(Tw))-P*(Tw-T))/(Tw-2800) =	0.451915914	psia	Equation [10]
Dry Air Pressure:	Pa =P - Pv =	13.86308409	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.061574919	lbm/ft ³	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001248465	lbm/ft ³	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.062823384	lbm/ft ³	Equation [7]
Saturated Air Pressure:	Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$	3.541336347	psia	Equation [8]
Moist Air Specific Humidity:	W = Rho v / Rho a =	0.020275546		Equation [12]
Moist Air Relative Humidity:	RH = Pv /Ps =	12.76117	%	Equation [15]
Equation Coefficients:	a = b = c = d = e = f =	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10 2.109071E-11		

* LaSalle Station Reference Conditions

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Moist Air Properties -- Given Dry Bulb and Relative Humidity

Total Pressure: P =

14.315

psia

Dry Bulb Temperature:

T =

148

*

٥F

Moist Air Relative Humidity:

RH =

12.76

%

Saturated Air Pressure:

Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$

3.541336347

psia

Equation [8]

Vapor Pressure:

Pv = RH*Ps

0.451874518

psia

lbm/ft³

Equation [15]

Dry Air Pressure:

Pa =P - Pv =

13.86312548

psia Equation [4]

Dry Air Density:

Rho a = (144/53.352)*(Pa/(459.67+T)) =

0.061575103 lbm/ft³

Equation [5]

Water Vapor Density:

Rho v = (144/85.778)*(Pv/(459.67+T)) =

0.001248351

Equation [6]

Moist Air Density:

Rho = Rho a + Rho v =

0.062823454 lbm/ft³

Equation [7]

Specific Humidity:

W = Rho v / Rho a =

0.020273629

Equation [12]

Equation Coefficients:

a =

2.358607E-02

1.007276E-03

b = c =

1.888033E-05

d =

3.775047E-07

e = f = 0.773047E-0

4.871208E-10

2.109071E-11

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* LaSalle Station Reference Conditions (RH = 12.76%)







Total Pressure: P = 14.315 psia Inlet Air Flow ٥F **Dry Bulb Temperature:** 104.53 T = 19386.84858 Specific Humidity: W = 0.020273629 Water Vapor Pressure: Pv = (W*Rv*P)/(Ra+(W*Rv)) =Equation [11] 0.451874518 psia Dry Air Pressure: Pa = P - Pv =Equation [4] 13.86312548 psia Dry Air Density: Rho a = (144/53.352)*(Pa/(459.67+T)) =0.066319289 lbm/ft³ Equation [5] Water Vapor Density: Rho v = (144/85.778)*(Pv/(459.67+T)) =lbm/ft³ 0.001344533 Equation [6] Moist Air Density: Rho = Rho a + Rho v = lbm/ft³ 0.067663821 Equation [7] Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$ Saturated Air Pressure: 1.087702551 Equation [8] psia Moist Air Relative Humidity: RH = Pv/Ps =41.54394211 Equation [15] **Equation Coefficients:** a = 2.358607E-02 b = 1.007276E-03 1.888033E-05 d =3.775047E-07 4.871208E-10

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* Coil Outlet Conditions (Clean)

f =

2.109071E-11







2.109071E-11

Moist Air Properties -- Given Dry Bulb and Specific Humidity

Total Pressure:	P =	14.315	psia	Inlet Air Flow
Dry Bulb Temperature:	T =	106.46	°F	19320.75666
Specific Humidity:	W =	0.020273629		
Water Vapor Pressure:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =	0.451874518	psia	Equation [11]
Dry Air Pressure:	Pa =P - Pv =	13.86312548	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.066093199	lbm/ft ³	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001339949	lbm/ft ³	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.067433148	lbm/ft ³	Equation [7]
Saturated Air Pressure:	Ps = $a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$	1.15128943	psia	Equation [8]
Moist Air Relative Humidity:	RH = Pv /Ps =	39.24942818	%	Equation [15]
Equation Coefficients:	a = b = c = d = e =	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10		

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* Coil Outlet Conditions (Service)

f =









	Total Pressure:	P =	14.315	psia	Inlat Air Flow
	Dry Bulb Temperature:	T =	109.96	°F .	Inlet Air Flow 19202.04338
	Specific Humidity:	W =	0.020273629		
	Water Vapor Pressure:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =	0.451874518	psia	Equation [11]
	Dry Air Pressure:	Pa =P - Pv =	13.86312548	psia	Equation [4]
	Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.0656871	lbm/ft ³	Equation [5]
	Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001331716	lbm/ft ³	Equation [6]
	Moist Air Density:	Rho = Rho a + Rho v =	0.067018816	lbm/ft ³	Equation [7]
	Saturated Air Pressure:	Ps = $a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$	1.274809374	psia	Equation [8]
	Moist Air Relative Humidity:	RH = Pv /Ps =	35.44643829	%	Equation [15]
Proto-Power Calc: 97-200 Attachment: H Rev: A Page 11 of 13	Equation Coefficients: ** ** ** ** ** ** ** ** **	a= b= c= d= e= f= Conditions (Limiting Flow	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10 2.109071E-11	om)	







Total Pressure:	P =	14.315	psia	Inlet Air Flow
Dry Bulb Temperature:	T =	108.29	°F	19258.50406
Specific Humidity:	W =	0.020273629		
Water Vapor Pressure:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =	0.451874518	psia	Equation [11]
Dry Air Pressure:	Pa =P - Pv =	13.86312548	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.065880243	lbm/ft ³	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001335632	lbm/ft ³	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.067215874	lbm/ft ³	Equation [7]
Saturated Air Pressure:	Ps = $a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$	1.214518345	psia	Equation [8]
Moist Air Relative Humidity:	RH = Pv /Ps =	37.20606771	%	Equation [15]
Equation Coefficients: ** Coil Outlet C	a= b= c= d= e= f= onditions (Limiting Flow - 1	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10 2.109071E-11		
	Dry Bulb Temperature: Specific Humidity: Water Vapor Pressure: Dry Air Pressure: Dry Air Density: Water Vapor Density: Moist Air Density: Saturated Air Pressure: Moist Air Relative Humidity:	Dry Bulb Temperature: $T =$ Specific Humidity: $W =$ Water Vapor Pressure: $Pv = (W^*Rv^*P)/(Ra+(W^*Rv)) =$ Dry Air Pressure: $Pa = P - Pv =$ Dry Air Density: $Rho a = (144/53.352)^*(Pa/(459.67+T)) =$ Water Vapor Density: $Rho v = (144/85.778)^*(Pv/(459.67+T)) =$ Moist Air Density: $Rho = Rho a + Rho v =$ Saturated Air Pressure: $Ps = a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$ Moist Air Relative Humidity: $RH = Pv/Ps =$	Dry Bulb Temperature: $T =$ 108.29 Specific Humidity: $W =$ 0.020273629 Water Vapor Pressure: $Pv = (W^*Rv^*P)/(Ra+(W^*Rv)) =$ 0.451874518 Dry Air Pressure: $Pa = P - Pv =$ 13.86312548 Dry Air Density: $Rho \ a = (144/53.352)^*(Pa/(459.67+T)) =$ 0.065880243 Water Vapor Density: $Rho \ v = (144/85.778)^*(Pv/(459.67+T)) =$ 0.001335632 Moist Air Density: $Rho = Rho \ a + Rho \ v =$ 0.067215874 Saturated Air Pressure: $Ps = a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$ 1.214518345 Moist Air Relative Humidity: $RH = Pv/Ps =$ 37.20606771	Dry Bulb Temperature: T = 108.29 °F Specific Humidity: W = 0.020273629 V Water Vapor Pressure: Pv = (W*Rv*P)/(Ra+(W*Rv)) = 0.451874518 psia Dry Air Pressure: Pa =P - Pv = 13.86312548 psia Dry Air Density: Rho a = (144/53.352)*(Pa/(459.67+T)) = 0.065880243 lbm/ft³ Water Vapor Density: Rho v = (144/85.778)*(Pv/(459.67+T)) = 0.001335632 lbm/ft³ Moist Air Density: Rho = Rho a + Rho v = 0.067215874 lbm/ft³ Saturated Air Pressure: Ps = a+(b*T)+(c*T²)+(d*T³)+(e*T⁴)+(f*T⁵) = 1.214518345 psia Moist Air Relative Humidity: RH = Pv /Ps = 37.20606771 %







Total Pressure:	P =	14.315	psia	Inlet Air Flow
Dry Bulb Temperature:	T =	108.08	°F	19265.62742
Specific Humidity:	W =	0.020273629		
Water Vapor Pressure:	Pv = (W*Rv*P)/(Ra+(W*Rv)) =	0.451874518	psia	Equation [11]
Dry Air Pressure:	Pa =P - Pv =	13.86312548	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.065904611	lbm/ft ³	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001336126	lbm/ft ³	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.067240736	lbm/ft ³	Equation [7]
Saturated Air Pressure:	Ps = $a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$	1.207113757	psia	Equation [8]
Moist Air Relative Humidity:	RH = Pv /Ps =	37.43429442	%	Equation [15]
Equation Coefficients:	a= b= c= d= e= f= onditions (Limiting Flow -1	2.358607E-02 1.007276E-03 1.888033E-05 3.775047E-07 4.871208E-10 2.109071E-11)	
	Dry Bulb Temperature: Specific Humidity: Water Vapor Pressure: Dry Air Pressure: Dry Air Density: Water Vapor Density: Moist Air Density: Saturated Air Pressure: Moist Air Relative Humidity:	Dry Bulb Temperature: $T =$ Specific Humidity: $W =$ Water Vapor Pressure: $Pv = (W^*Rv^*P)/(Ra+(W^*Rv)) =$ Dry Air Pressure: $Pa = P - Pv =$ Dry Air Density: $Rho a = (144/53.352)^*(Pa/(459.67+T)) =$ Water Vapor Density: $Rho v = (144/85.778)^*(Pv/(459.67+T)) =$ Moist Air Density: $Rho = Rho a + Rho v =$ Saturated Air Pressure: $Ps = a+(b^*T)+(c^*T^2)+(d^*T^3)+(e^*T^4)+(f^*T^5) =$ Moist Air Relative Humidity: $RH = Pv/Ps =$	Dry Bulb Temperature: T = 108.08 Specific Humidity: W = 0.020273629 Water Vapor Pressure: Pv = (W*Rv*P)/(Ra+(W*Rv)) = 0.451874518 Dry Air Pressure: Pa = P - Pv = 13.86312548 Dry Air Density: Rho a = (144/53.352)*(Pa/(459.67+T)) = 0.065904611 Water Vapor Density: Rho v = (144/85.778)*(Pv/(459.67+T)) = 0.001336126 Moist Air Density: Rho = Rho a + Rho v = 0.067240736 Saturated Air Pressure: Ps = a+(b*T)+(c*T²)+(d*T³)+(e*T⁴)+(f*T⁵) = 1.207113757 Moist Air Relative Humidity: RH = Pv /Ps = 37.43429442	Dry Bulb Temperature: T = 108.08 °F Specific Humidity: W = 0.020273629 Common Notes (W*Rv*P)/(Ra+(W*Rv)) = 0.451874518 psia Water Vapor Pressure: Pa =P - Pv = 13.86312548 psia Dry Air Density: Rho a = (144/53.352)*(Pa/(459.67+T)) = 0.065904611 lbm/ft³ Water Vapor Density: Rho v = (144/85.778)*(Pv/(459.67+T)) = 0.001336126 lbm/ft³ Moist Air Density: Rho = Rho a + Rho v = 0.067240736 lbm/ft³ Saturated Air Pressure: Ps = a+(b*T)+(c*T²)+(d*T³)+(e*T⁴)+(f*T⁵) = 1.207113757 psia Moist Air Relative Humidity: RH = Pv /Ps = 37.43429442 %

Attachment I to Proto-Power Calculation 97-200 Revision A

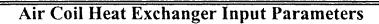
Proto-Power Calc: 97-200

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	· · · · · · · · · · · · · · · · · · ·
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
		+ -0.3436 * LOG(Re)]
Cail Finned Langth (in)		, , , -
Coil Finned Length (in) Fin Pitch (Fins/Inch)		104.250
Fin Conductivity (BTU/hr·ft·°F)		10.000 128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
• • • • • • • • • • • • • • • • • • • •		1.475
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1 000
Tube Wall Conductivity (BTU/hr-ft-	·°F)	1.000 225.00
1 455 Wall Conductivity (D10/III II	1)	223.00

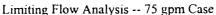
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

_	
Tube Flow (gpm)	75.00
Air Flow (acfm)	19,202.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: I

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Limiting Flow Analysis -- 75 gpm Case



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	109.96	118.09	Air-Side ho (BTU/hr-ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	675,177
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	675,177
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	953.95
Inlet Temperature (°F)	148.00	114.57	j Factor	0.0082
Outlet Temperature (°F)	140.61	118.09	Air-Side ho (BTU/hr·ft²·°F)	8.26
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.03976622
Average Temp (°F)	144.30	116.33		
Skin Temperature (°F)	125.07	119.22	U Overall (BTU/hr·ft².°F)	5.22
Velocity ***	3,391.01	2.77	Effective Area (ft²)	905.33
Reynold's Number	800**	19,386	LMTD	27.78
Prandtl Number	0.7255	3.7764	Total Heat Transferred (BTU/hr)	131,195
Bulk Visc (lbm/ft·hr)	0.0490	1.3943		
Skin Visc (lbm/ft·hr)		1.3564	Surface Effectiveness (Eta)	0.9184
Density (lbm/ft³)	0.0623	61.7676	Sensible Heat Transferred (BTU/hr)	131,195
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0162	0.3688	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability

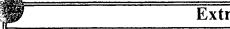


Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 75 gpm Case



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	937.48
Inlet Temperature (°F)	140.61	111.52	j Factor	0.0082
Outlet Temperature (°F)	134.20	114.57	Air-Side ho (BTU/hr-ft²-°F)	8.23
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	137.40	113.04		
Skin Temperature (°F)	120.67	115.59	U Overall (BTU/hr·ft ² .°F)	5.20
Velocity ***	3,391.01	2.77	Effective Area (ft²)	905.33
Reynold's Number	807**	18,774	LMTD	24.19
Prandtl Number	0.7261	3.9116	Total Heat Transferred (BTU/hr)	113,794
Bulk Visc (lbm/ft·hr)	0.0486	1.4398		
Skin Visc (lbm/ft·hr)		1.4043	Surface Effectiveness (Eta)	0.9187
Density (lbm/ft³)	0.0630	61.8163	Sensible Heat Transferred (BTU/hr)	113,794
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0161	0.3676	Heat to Condensate (BTU/hr)	
** Daynalda Number Outside	Danca of Equation	. A melioobilis.		

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	923.12
Inlet Temperature (°F)	134.20	108.86	j Factor	0.0081
Outlet Temperature (°F)	128.63	111.52	Air-Side ho (BTU/hr·ft².°F)	8.20
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	131.42	110.19		
Skin Temperature (°F)	116.84	112.44	U Overall (BTU/hr·ft².°F)	5.18
Velocity ***	3,391.01	2.76	Effective Area (ft²)	905.33
Reynold's Number	813**	18,249	LMTD	21.08
Prandtl Number	0.7266	4.0355	Total Heat Transferred (BTU/hr)	98,800
Bulk Visc (lbm/ft·hr)	0.0482	1.4812		
Skin Visc (lbm/ft·hr)		1.4484	Surface Effectiveness (Eta)	0.9189
Density (lbm/ft³)	0.0636	61.8573	Sensible Heat Transferred (BTU/hr)	98,800
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3666	Heat to Condensate (BTU/hr)	
			· · · · · · · · · · · · · · · · · · ·	

^{**} Reynolds Number Outside Range of Equation Applicability



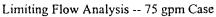
Proto-Power Calc: 97-200

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*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	910.59
Inlet Temperature (°F)	128.63	106.56	j Factor	0.0081
Outlet Temperature (°F)	123.80	108.86	Air-Side ho (BTU/hr·ft².°F)	8.18
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.03976622
Average Temp (°F)	126.21	107.71		
Skin Temperature (°F)	113.52	109.69	U Overall (BTU/hr·ft².°F)	5.16
Velocity ***	3,391.01	2.76	Effective Area (ft²)	905.33
Reynold's Number	819**	17,797	LMTD	18.38
Prandtl Number	0.7270	4.1483	Total Heat Transferred (BTU/hr)	85,857
Bulk Visc (lbm/ft·hr)	0.0479	1.5188		
Skin Visc (lbm/ft·hr)		1.4886	Surface Effectiveness (Eta)	0.9191
Density (lbm/ft³)	0.0641	61.8920	Sensible Heat Transferred (BTU/hr)	85,857
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3657	Heat to Condensate (BTU/hr)	
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^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	899.66
Inlet Temperature (°F)	123.80	104.55	j Factor	0.0081
Outlet Temperature (°F)	119.59	106.56	Air-Side ho (BTU/hr·ft².°F)	8.16
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	121.69	105.56		
Skin Temperature (°F)	110.63	107.30	U Overall (BTU/hr·ft².°F)	5.15
Velocity ***	3,391.01	2.76	Effective Area (ft²)	905.33
Reynold's Number	823**	17,408	LMTD	16.03
Prandtl Number	0.7273	4.2505	Total Heat Transferred (BTU/hr)	74,667
Bulk Visc (lbm/ft·hr)	0.0476	1.5528		
Skin Visc (lbm/ft·hr)		1.5252	Surface Effectiveness (Eta)	0.9193
Density (lbm/ft³)	0.0646	61.9215	Sensible Heat Transferred (BTU/hr)	74,667
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0157	0.3649	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 75 gpm Case



Extrapolation Calculation for Row 6(Dry)

Air-Side	Tube-Side	·	
70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	890.12
119.59	102.81	j Factor	0.0081
115.93	104.55	Air-Side ho (BTU/hr·ft².°F)	8.15
0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
117.76	103.68		
108.11	105.21	U Overall (BTU/hr·ft².°F)	5.13
3,391.01	2.76	Effective Area (ft²)	905.33
828**	17,071	LMTD	13.98
0.7276	4.3429	Total Heat Transferred (BTU/hr)	64,980
0.0473	1.5834		
	1.5583	Surface Effectiveness (Eta)	0.9194
0.0650	61.9466	Sensible Heat Transferred (BTU/hr)	64,980
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
0.0156	0.3642	Heat to Condensate (BTU/hr)	
	70,957.87 119.59 115.93 0.0203 0.0203 117.76 108.11 3,391.01 828** 0.7276 0.0473 0.0650 0.2402	70,957.87 37,293.47 119.59 102.81 115.93 104.55 0.0203 104.55 0.0203 117.76 103.68 108.11 105.21 3,391.01 2.76 828** 17,071 0.7276 4.3429 0.0473 1.5834 1.5583 0.0650 61.9466 0.2402 0.9989	70,957.87 37,293.47 Tube-Side hi (BTU/hr·ft²-°F) 119.59 102.81 j Factor 115.93 104.55 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 117.76 103.68 108.11 105.21 U Overall (BTU/hr·ft²-°F) 3,391.01 2.76 Effective Area (ft²) 828** 17,071 LMTD 0.7276 4.3429 Total Heat Transferred (BTU/hr) 0.0473 1.5834 1.5583 Surface Effectiveness (Eta) 0.0650 61.9466 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	881.79
Inlet Temperature (°F)	115.93	101.29	j Factor	0.0081
Outlet Temperature (°F)	112.74	102.81	Air-Side ho (BTU/hr-ft2.°F)	8.13
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU)	0.03976622
Average Temp (°F)	114.33	102.05		
Skin Temperature (°F)	105.92	103.40	U Overall (BTU/hr·ft².°F)	5.12
Velocity ***	3,391.01	2.76	Effective Area (ft²)	905.33
Reynold's Number	832**	16,780	LMTD	12.20
Prandtl Number	0.7278	4.4260	Total Heat Transferred (BTU/hr)	56,584
Bulk Visc (lbm/ft·hr)	0.0471	1.6109		
Skin Visc (lbm/ft·hr)		1.5881	Surface Effectiveness (Eta)	0.9196
Density (lbm/ft³)	0.0654	61.9680	Sensible Heat Transferred (BTU/hr)	56,584
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0156	0.3636	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 75 gpm Case

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr-ft²-°F)	874.52
Inlet Temperature (°F)	112.74	99.97	j Factor	0.0081
Outlet Temperature (°F)	109.96	101.29	Air-Side ho (BTU/hr·ft².°F)	8.12
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.03976622
Average Temp (°F)	111.35	100.63		
Skin Temperature (°F)	104.01	101.81	U Overall (BTU/hr-ft2.°F)	5.11
Velocity ***	3,391.01	2.76	Effective Area (ft²)	905.33
Reynold's Number	835**	16,528	LMTD	10.65
Prandtl Number	0.7280	4.5004	Total Heat Transferred (BTU/hr)	49,300
Bulk Visc (lbm/ft·hr)	0.0469	1.6354		
Skin Visc (lbm/ft·hr)		1.6149	Surface Effectiveness (Eta)	0.9197
Density (lbm/ft³)	0.0657	61.9863	Sensible Heat Transferred (BTU/hr)	49,300
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3630	Heat to Condensate (BTU/hr)	

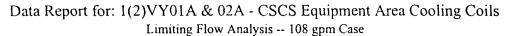
^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	115 30 053
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F %	
Outlet Relative Humidity	70	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft-	°F)	225.00
• `		

Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,258.50
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Limiting Flow Analysis -- 108 gpm Case



Extrapolation Calculation Summary

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)
Inlet Temperature (°F)	148.00	100.00	j Factor
Outlet Temperature (°F)	108.29	113.17	Air-Side ho (BTU/hr·ft².°F)
Inlet Specific Humidity			Tube Wall Resistance (hr·ft²-°F/BTU 0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.03976622
Average Temp (°F)			
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)
Velocity ***			Effective Area (ft^2) 7,242.65
Reynold's Number			LMTD
Prandtl Number			Total Heat Transferred (BTU/hr) 707,030
Bulk Visc (lbm/ft·hr)			
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr) 707,030
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,246.55
Inlet Temperature (°F)	148.00	110.31	j Factor	0.0082
Outlet Temperature (°F)	139.36	113.17	Air-Side ho (BTU/hr·ft².°F)	8.27
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.03976622
Average Temp (°F)	143.68	111.74		
Skin Temperature (°F)	121.18	114.33	U Overall (BTU/hr·ft².°F)	5.35
Velocity ***	3,400.99	3.98	Effective Area (ft²)	905.33
Reynold's Number	803**	26,688	LMTD	31.73
Prandtl Number	0.7255	3.9675	Total Heat Transferred (BTU/hr)	153,749
Bulk Visc (lbm/ft·hr)	0.0490	1.4585		
Skin Visc (lbm/ft·hr)		1.4217	Surface Effectiveness (Eta)	0.9183
Density (lbm/ft³)	0.0625	61.8352	Sensible Heat Transferred (BTU/hr)	153,749
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3672	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Limiting Flow Analysis -- 108 gpm Case



Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,228.62
Inlet Temperature (°F)	139.36	107.92	j Factor	0.0081
Outlet Temperature (°F)	132.18	110.31	Air-Side ho (BTU/hr·ft².°F)	8.24
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.03976622
Average Temp (°F)	135.77	109.11		
Skin Temperature (°F)	116.99	111.30	U Overall (BTU/hr·ft².°F)	5.33
Velocity ***	3,400.99	3.98	Effective Area (ft²)	905.33
Reynold's Number	811**	25,996	LMTD	26.49
Prandtl Number	0.7262	4.0838	Total Heat Transferred (BTU/hr)	127,833
Bulk Visc (lbm/ft·hr)	0.0485	1.4973		
Skin Visc (lbm/ft·hr)		1.4649	Surface Effectiveness (Eta)	0.9186
Density (lbm/ft³)	0.0632	61.8725	Sensible Heat Transferred (BTU/hr)	127,833
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0160	0.3662	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

Air-Side	Tube-Side		
71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,213.64
132.18	105.94	j Factor	0.0081
126.21	107.92	Air-Side ho (BTU/hr·ft².°F)	8.21
0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
129.19	106.93		
113.51	108.77	U Overall (BTU/hr·ft².°F)	5.31
3,400.99	3.98	Effective Area (ft²)	905.33
818**	25,424	LMTD	22.12
0.7267	4.1849	Total Heat Transferred (BTU/hr)	106,417
0.0481	1.5310		
	1.5025	Surface Effectiveness (Eta)	0.9189
0.0639	61.9028	Sensible Heat Transferred (BTU/hr)	106,417
0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
0.0159	0.3654	Heat to Condensate (BTU/hr)	
	71,166.65 132.18 126.21 0.0203 0.0203 129.19 113.51 3,400.99 818** 0.7267 0.0481 0.0639 0.2402	71,166.65 53,702.59 132.18 105.94 126.21 107.92 0.0203 0.0203 129.19 106.93 113.51 108.77 3,400.99 3.98 818** 25,424 0.7267 4.1849 0.0481 1.5310 1.5025 0.0639 61.9028 0.2402 0.9989	71,166.65 53,702.59 Tube-Side hi (BTU/hr·ft²-°F) 132.18 105.94 j Factor 126.21 107.92 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 129.19 106.93 113.51 108.77 U Overall (BTU/hr·ft²-°F) 3,400.99 3.98 Effective Area (ft²) 818** 25,424 LMTD 0.7267 4.1849 Total Heat Transferred (BTU/hr) 0.0481 1.5310 1.5025 Surface Effectiveness (Eta) 0.0639 61.9028 Sensible Heat Transferred (BTU/hr) 0.2402 0.9989 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Limiting Flow Analysis -- 108 gpm Case



Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr-ft2.°F)	1,201.11
Inlet Temperature (°F)	126.21	104.29	j Factor	0.0081
Outlet Temperature (°F)	121.22	105.94	Air-Side ho (BTU/hr·ft².°F)	8.19
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	123.72	105.11		
Skin Temperature (°F)	110.61	106.66	U Overall (BTU/hr·ft².°F)	5.30
Velocity ***	3,400.99	3.98	Effective Area (ft²)	905.33
Reynold's Number	824**	24,952	LMTD	18.48
Prandtl Number	0.7272	4.2722	Total Heat Transferred (BTU/hr)	88,681
Bulk Visc (lbm/ft·hr)	0.0477	1.5600		
Skin Visc (lbm/ft·hr)		1.5352	Surface Effectiveness (Eta)	0.9191
Density (lbm/ft³)	0.0644	61.9275	Sensible Heat Transferred (BTU/hr)	88,681
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3647	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,190.65
Inlet Temperature (°F)	121.22	102.91	j Factor	0.0081
Outlet Temperature (°F)	117.07	104.29	Air-Side ho (BTU/hr·ft²·°F)	8.17
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	119.15	103.60		
Skin Temperature (°F)	108.20	104.90	U Overall (BTU/hr·ft².°F)	5.29
Velocity ***	3,400.99	3.97	Effective Area (ft²)	905.33
Reynold's Number	829**	24,560	LMTD	15.45
Prandtl Number	0.7275	4.3472	Total Heat Transferred (BTU/hr)	73,965
Bulk Visc (lbm/ft·hr)	0.0474	1.5848		
Skin Visc (lbm/ft·hr)		1.5634	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft³)	0.0649	61.9477	Sensible Heat Transferred (BTU/hr)	73,965
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
$K (BTU/hr \cdot ft \cdot {}^{\circ}F)$	0.0157	0.3642	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 108 gpm Case



Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side			
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,181.90	
Inlet Temperature (°F)	117.07	101.76	j Factor	0.0081	
Outlet Temperature (°F)	113.60	102.91	Air-Side ho (BTU/hr·ft².°F)	8.15	
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430	
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622	
Average Temp (°F)	115.34	102.33			
Skin Temperature (°F)	106.18	103.43	U Overall (BTU/hr·ft².°F)	5.28	
Velocity ***	3,400.99	3.97	Effective Area (ft²)	905.33	
Reynold's Number	833**	24,235	LMTD	12.92	
Prandtl Number	0.7277	4.4115	Total Heat Transferred (BTU/hr)	61,737	
Bulk Visc (lbm/ft·hr)	0.0472	1.6061			
Skin Visc (lbm/ft·hr)		1.5876	Surface Effectiveness (Eta)	0.9194	
Density (lbm/ft³)	0.0653	61.9643	Sensible Heat Transferred (BTU/hr)	61,737	
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)		
K (BTU/hr·ft·°F)	0.0156	0.3637	Heat to Condensate (BTU/hr)		
** Develop Number Outside Dance of Equation Applicability					

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

Air-Side	Tube-Side		
71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,174.58
113.60	100.79	j Factor	0.0081
110.71	101.76	Air-Side ho (BTU/hr·ft².°F)	8.14
0.0203		Tube Wall Resistance (hr-ft2-°F/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.03976622
112.15	101.27		
104.49	102.20	U Overall (BTU/hr·ft².°F)	5.27
3,400.99	3.97	Effective Area (ft²)	905.33
837**	23,965	LMTD	10.81
0.7279	4.4663	Total Heat Transferred (BTU/hr)	51,562
0.0470	1.6242		
	1.6084	Surface Effectiveness (Eta)	0.9195
0.0656	61.9780	Sensible Heat Transferred (BTU/hr)	51,562
0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
0.0155	0.3633	Heat to Condensate (BTU/hr)	
	71,166.65 113.60 110.71 0.0203 0.0203 112.15 104.49 3,400.99 837** 0.7279 0.0470 0.0656 0.2402	71,166.65 53,702.59 113.60 100.79 110.71 101.76 0.0203 0.0203 112.15 101.27 104.49 102.20 3,400.99 3.97 837** 23,965 0.7279 4.4663 0.0470 1.6242 1.6084 0.0656 61.9780 0.2402 0.9990	71,166.65 53,702.59 Tube-Side hi (BTU/hr·ft²-°F) 113.60 100.79 j Factor 110.71 101.76 Air-Side ho (BTU/hr·ft²-°F) 0.0203 Tube Wall Resistance (hr·ft²-°F/BTU 0.0203 Overall Fouling (hr·ft²-°F/BTU) 112.15 101.27 104.49 102.20 U Overall (BTU/hr·ft²-°F) 3,400.99 3.97 Effective Area (ft²) 837** 23,965 LMTD 0.7279 4.4663 Total Heat Transferred (BTU/hr) 0.0470 1.6242 1.6084 Surface Effectiveness (Eta) 0.0656 61.9780 Sensible Heat Transferred (BTU/hr) 0.2402 0.9990 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Limiting Flow Analysis -- 108 gpm Case

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft²-°F)	1,168.45
Inlet Temperature (°F)	110.71	99.99	j Factor	0.0080
Outlet Temperature (°F)	108.29	100.79	Air-Side ho (BTU/hr·ft².°F)	8.13
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.0F/BTU)	0.03976622
Average Temp (°F)	109.50	100.39		
Skin Temperature (°F)	103.09	101.17	U Overall (BTU/hr·ft².°F)	5.26
Velocity ***	3,400.99	3.97	Effective Area (ft²)	905.33
Reynold's Number	840**	23,740	LMTD	9.05
Prandtl Number	0.7281	4.5129	Total Heat Transferred (BTU/hr)	43,086
Bulk Visc (lbm/ft·hr)	0.0468	1.6396		
Skin Visc (lbm/ft·hr)		1.6261	Surface Effectiveness (Eta)	0.9196
Density (lbm/ft³)	0.0659	61.9893	Sensible Heat Transferred (BTU/hr)	43,086
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0154	0.3629	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Limiting Flow Analysis -- 115 gpm Case



Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)	•	0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
<u> </u>		+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Active Tubes I et Now		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft-	°F)	225.00

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	115.00
Air Flow (acfm)	19,266.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

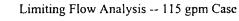
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	108.08	112.47	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft²-°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft²-°F/BTU)	0.03976622
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	710,964
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	710,964
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,306.21
Inlet Temperature (°F)	148.00	109.72	j Factor	0.0082
Outlet Temperature (°F)	139.18	112.47	Air-Side ho (BTU/hr·ft².°F)	8.27
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	143.59	111.09		
Skin Temperature (°F)	120.62	113.62	U Overall (BTU/hr·ft ^{2.} °F)	5.37
Velocity ***	3,402.31	4.24	Effective Area (ft²)	905.33
Reynold's Number	803**	28,236	LMTD	32.29
Prandtl Number	0.7255	3.9956	Total Heat Transferred (BTU/hr)	157,023
Bulk Visc (lbm/ft·hr)	0.0490	1.4678		
Skin Visc (lbm/ft·hr)		1.4317	Surface Effectiveness (Eta)	0.9183
Density (lbm/ft³)	0.0625	61.8444	Sensible Heat Transferred (BTU/hr)	157,023
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3669	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 115 gpm Case



Extrapolation Calculation for Row 2(Dry)

1,288.13
1,200.13
0.0081
8.24
TU 0.00031430
0.03976622
5.35
905.33
26.78
129,763
0.9186
r) 129,763

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,273.11
Inlet Temperature (°F)	131.90	105.57	j Factor	0.0081
Outlet Temperature (°F)	125.87	· 107.45	Air-Side ho (BTU/hr·ft².°F)	8.21
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.03976622
Average Temp (°F)	128.88	106.51		
Skin Temperature (°F)	113.06	108.28	U Overall (BTU/hr·ft².°F)	5.33
Velocity ***	3,402.31	4.23	Effective Area (ft²)	905.33
Reynold's Number	818**	26,955	LMTD	22.23
Prandtl Number	0.7268	4.2049	Total Heat Transferred (BTU/hr)	107,371
Bulk Visc (lbm/ft·hr)	0.0480	1.5376	,	
Skin Visc (lbm/ft·hr)		1.5101	Surface Effectiveness (Eta)	0.9189
Density (lbm/ft³)	0.0639	61.9086	Sensible Heat Transferred (BTU/hr)	107,371
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0159	0.3653	Heat to Condensate (BTU/hr)	
Skin Visc (lbm/ft·hr) Density (lbm/ft³) Cp (BTU/lbm·°F)	0.0639 0.2402	1.5101 61.9086 0.9989	Sensible Heat Transferred (BTU/hr) Latent Heat Transferred (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 115 gpm Case



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,260.64
Inlet Temperature (°F)	125.87	104.01	j Factor	0.0081
Outlet Temperature (°F)	120.87	105.57	Air-Side ho (BTU/hr·ft².°F)	8.19
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	123.37	104.79		
Skin Temperature (°F)	110.23	106.27	U Overall (BTU/hr·ft².°F)	5.32
Velocity ***	3,402.31	4.23	Effective Area (ft²)	905.33
Reynold's Number	824**	26,480	LMTD	18.46
Prandtl Number	0.7272	4.2880	Total Heat Transferred (BTU/hr)	88,937
Bulk Visc (lbm/ft·hr)	0.0477	1.5652		
Skin Visc (lbm/ft·hr)		1.5414	Surface Effectiveness (Eta)	0.9191
Density (lbm/ft³)	0.0645	61.9318	Sensible Heat Transferred (BTU/hr)	88,937
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0158	0.3646	Heat to Condensate (BTU/hr)	
** Darmalda Numbar Outaida	Panas of Equation	. Annliashilite	•	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,250.27
Inlet Temperature (°F)	120.87	102.72	j Factor	0.0081
Outlet Temperature (°F)	116.73	104.01	Air-Side ho (BTU/hr·ft².°F)	8.17
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft2-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.03976622
Average Temp (°F)	118.80	103.36		
Skin Temperature (°F)	107.89	104.60	U Overall (BTU/hr·ft².°F)	5.31
Velocity ***	3,402.31	4.23	Effective Area (ft²)	905.33
Reynold's Number	829**	26,089	LMTD	15.34
Prandtl Number	0.7275	4.3589	Total Heat Transferred (BTU/hr)	73,733
Bulk Visc (lbm/ft·hr)	0.0474	1.5887	, ,	
Skin Visc (lbm/ft·hr)		1.5682	Surface Effectiveness (Eta)	0.9192
Density (lbm/ft³)	0.0649	61.9508	Sensible Heat Transferred (BTU/hr)	73,733
Cp (BTU/lbm·°F)	0.2402	0.9989	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0157	0.3641	Heat to Condensate (BTU/hr)	
445 1137 1 0 111	D 650 :			

^{**} Reynolds Number Outside Range of Equation Applicability



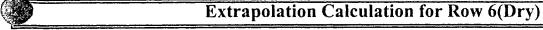
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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Limiting Flow Analysis -- 115 gpm Case



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,194.37	57,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,241.66
Inlet Temperature (°F)	116.73	101.65	j Factor	0.0081
Outlet Temperature (°F)	113.30	102.72	Air-Side ho (BTU/hr·ft².°F)	8.15
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
Average Temp (°F)	115.02	102.18		
Skin Temperature (°F)	105.94	103.22	U Overall (BTU/hr·ft ² .°F)	5.30
Velocity ***	3,402.31	4.23	Effective Area (ft²)	905.33
Reynold's Number	834**	25,766	LMTD	12.75
Prandtl Number	0.7277	4.4190	Total Heat Transferred (BTU/hr)	61,173
Bulk Visc (lbm/ft·hr)	0.0472	1.6086	,	
Skin Visc (lbm/ft·hr)		1.5911	Surface Effectiveness (Eta)	0.9194
Density (lbm/ft³)	0.0653	61.9663	Sensible Heat Transferred (BTU/hr)	61,173
Cp (BTU/lbm.°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	•
K (BTU/hr·ft·°F)	0.0156	0.3636	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 7(Dry)

Air-Side	Tube-Side		
71,194.37	57,183.32	Tube-Side hi (BTU/hr-ft2.°F)	1,234.50
113.30	100.76	j Factor	0.0081
110.45	101.65	Air-Side ho (BTU/hr·ft².°F)	8.14
0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.03976622
111.87	101.20		
104.33	102.07	U Overall (BTU/hr·ft².°F)	5.29
3,402.31	4.23	Effective Area (ft²)	905.33
837**	25,499	LMTD	10.60
0.7279	4.4700	Total Heat Transferred (BTU/hr)	50,784
0.0470	1.6254	,	,
	1.6106	Surface Effectiveness (Eta)	0.9195
0.0656	61.9789	Sensible Heat Transferred (BTU/hr)	50,784
0.2402	0.9990	Latent Heat Transferred (BTU/hr)	·
0.0155	0.3633	Heat to Condensate (BTU/hr)	
	71,194.37 113.30 110.45 0.0203 0.0203 111.87 104.33 3,402.31 837** 0.7279 0.0470 0.0656 0.2402	71,194.37 57,183.32 113.30 100.76 110.45 101.65 0.0203 0.0203 111.87 101.20 104.33 102.07 3,402.31 4.23 837** 25,499 0.7279 4.4700 0.0470 1.6254 1.6106 0.0656 61.9789 0.2402 0.9990	71,194.37 57,183.32 Tube-Side hi (BTU/hr·ft².°F) 113.30 100.76 j Factor 110.45 101.65 Air-Side ho (BTU/hr·ft².°F) 0.0203 Tube Wall Resistance (hr·ft².°F/BTU 0.0203 Overall Fouling (hr·ft².°F/BTU) 111.87 101.20 104.33 102.07 U Overall (BTU/hr·ft².°F) 3,402.31 4.23 Effective Area (ft²) 837** 25,499 LMTD 0.7279 4.4700 Total Heat Transferred (BTU/hr) 0.0470 1.6254 1.6106 Surface Effectiveness (Eta) 0.0656 61.9789 Sensible Heat Transferred (BTU/hr) 0.2402 0.9990 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability



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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Limiting Flow Analysis -- 115 gpm Case

Extrapolation Calculation for Row 8(Dry)

1 100 00		
7,183.32	Tube-Side hi (BTU/hr·ft².°F)	1,228.54
100.02	j Factor	0.0080
100.76	Air-Side ho (BTU/hr·ft²·°F)	8.13
	Tube Wall Resistance (hr-ft2-°F/BTU	0.00031430
	Overall Fouling (hr·ft².°F/BTU)	0.03976622
100.39		
101.11	U Overall (BTU/hr·ft².°F)	5.28
4.23	Effective Area (ft²)	905.33
25,278	LMTD	8.82
4.5130	Total Heat Transferred (BTU/hr)	42,181
1.6396		
1.6270	Surface Effectiveness (Eta)	0.9196
61.9894	Sensible Heat Transferred (BTU/hr)	42,181
0.9990	Latent Heat Transferred (BTU/hr)	
0.3629	Heat to Condensate (BTU/hr)	
	100.76 100.39 101.11 4.23 25,278 4.5130 1.6396 1.6270 61.9894 0.9990	j Factor loo.76 Air-Side ho (BTU/hr·ft².°F) Tube Wall Resistance (hr·ft².°F/BTU Overall Fouling (hr·ft².°F/BTU) loo.39 lol.11 U Overall (BTU/hr·ft².°F) 4.23 Effective Area (ft²) 25,278 LMTD 4.5130 Total Heat Transferred (BTU/hr) l.6396 l.6270 Surface Effectiveness (Eta) 61.9894 Sensible Heat Transferred (BTU/hr) 0.9990 Latent Heat Transferred (BTU/hr)

^{**} Reynolds Number Outside Range of Equation Applicability





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Attachment J to Proto-Power Calculation 97-200 Revision A

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Proto-HX Analytical Uncertainty Calculation [Circular Fin Air Coil Application]

Purpose

The purpose of the following calculation is to evaluate the analytical uncertainty associated with the analysis of test data and the computation of heat transfer rate at a given extrapolation condition. This calculation focuses only on the parameters that are not measured during the thermal performance test but factor into the analysis of the test results. Test parameter measurement uncertainty is treated separately in the test uncertainty analysis. The calculation of analytical uncertainty is derived for a typical eight-row Air Cooler.

Governing Heat Transfer Equations

Heat transfer calculations associated with a heat exchanger generally reduce to satisfying the following equations:

1)
$$q = U A_0 LMTD$$

Where:

q = Heat transfer rate at test conditions (BTU/hr)

U = Overall heat transfer coefficient at test conditions (BTU/hr-°F-ft²)

 A_0 = Heat transfer surface area referenced to outside (air-side) surface (ft^2)

LMTD = Log Mean Temperature Difference at test conditions (°F)

and

2)
$$q = \dot{m} c_{p} (T_{c_{o}} - T_{c_{i}}) = \rho Q c_{p} \Delta T$$

Where:

q = Heat transfer rate at test conditions (BTU/hr)

m = Mass flow rate at test conditions (lbm/hr)

 c_n = Specific heat of cooling water at test conditions (Btu/lb_m-°F)

 T_{ci} = Tube-side inlet temperature at test conditions (°F)

 T_{co} = Tube-side outlet temperature at test conditions (°F)

 ρ = Density of tube-side fluid at average bulk temperature at test conditions (lb_m/ft^3)

Q = Volumetric flow rate of tube-side fluid at test conditions (gpm)

The first equation is used, in Proto-HX, to evaluate the heat transfer rate from test data. The analytical uncertainties associated with evaluating the fluid properties are usually the only contributors to the overall uncertainty when using this equation. For a given test condition, the right hand side of the second equation is evaluated such that it matches the measured heat

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transfer rate, "q". In Proto-HX, this means iterating on fouling factor, and therefore "U", until the heat transfer equation is satisfied.

The following equations are used for this iteration:

$$R = \frac{1}{U} = \frac{A_o \ LMTD_{Test}}{q_{Test}}$$

Where:

R = Overall heat transfer thermal resistance at test conditions (hr-°F-ft²/BTU)

U = Overall heat transfer coefficient at test conditions (BTU/hr-°F-ft²)

 A_0 = Outside heat transfer surface area (ft^2)

LMTD = Log Mean Temperature Difference at test conditions (°F)

q = Heat transfer rate at test conditions (BTU/hr)

and

4)
$$R_f = R - \frac{1}{h_o \eta_x} - R_w - \left(\frac{A_o}{A_i}\right) \frac{1}{h_i}$$

Where:

 R_f = Fouling resistance (hr-°F-ft²/BTU)

R = Overall heat transfer thermal resistance at test conditions (hr-°F-ft²/BTU)

h_o = Outside convection film coefficient at test conditions (BTU/hr-°F-ft²)

 η_c = Fin surface effectiveness

 R_w = Wall thermal resistance at test conditions (hr- $^{\circ}F$ -ft²/BTU)

 A_0 = Outside heat transfer surface area (ft^2)

 A_i = Inside heat transfer surface area (ft^2)

h_i = Inside convection film coefficient at test conditions (BTU/hr-°F-ft²)

These same equations must be satisfied when evaluating the capacity of a heat exchanger at a given fouling condition (i.e., when extrapolating to the limiting thermal condition). The following equations are used for the extrapolation process:

5)
$$R^* = R_f + \frac{1}{h_o * \eta_s} + R_w^* + \left(\frac{A_o}{A_i}\right) \frac{1}{h_i *}$$

Where:

R* = Overall thermal resistance at extrapolation conditions (hr-°F-ft²/BTU)

 R_f = Calculated fouling resistance (hr- $^{\circ}F$ -ft²/BTU)

h₀* = Outside convection film coefficient at extrapolation conditions (BTU/hr-°F-ft²)

 η_s = Fin surface effectiveness

 R_w^* = Wall thermal resistance at extrapolation conditions(hr- $^{\circ}F$ -ft²/BTU)

 A_0 = Outside heat transfer surface area (f^2)

 A_i = Inside heat transfer surface area (ft²)

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h_i* = Inside convection film coefficient at extrapolation conditions (BTU/hr-°F-ft²)

and

6)
$$q^* = (1/R^*) A_o LMTD^* = U^*A_o LMTD^*$$

where:

 q^* = Heat transfer rate at extrapolation conditions (BTU/hr)

R* = Overall thermal resistance at extrapolation conditions (hr-°F-ft²/BTU)

U* = Overall heat coefficient at extrapolation conditions (BTU/hr-°F-ft²)

Ao = Heat transfer surface area referenced to outside surface (ft^2)

LMTD* = Log Mean Temperature Difference at extrapolation conditions (°F)

Analytical Uncertainty Calculation Methodology

The method for calculating the analytical uncertainty associated with this performance analysis method is illustrated as follows:

Given a function D = f(A,B,C)

The effect on D of slight changes in the independent variables A, B, and C may be calculated by taking the partial derivatives of D with respect to each of the independent variables. Accordingly, the change in the value of D (i.e., Δ D) due to changes in each of the independent variables (Δ A, Δ B, Δ C) may be represented by the following equation:

$$\Delta D = \frac{\partial D}{\partial A} \Delta A + \frac{\partial D}{\partial B} \Delta B + \frac{\partial D}{\partial C} \Delta C$$

If ΔA , ΔB , ΔC are the known (or estimated) errors of the independent variables, then the error, ΔD , associated with the derived value, D, is calculated. The most probable one standard deviation error representative of ΔD would be the statistical root mean squared value derived as follows:

$$\Delta D = \left[\left(\frac{\partial D}{\partial A} \Delta A \right)^2 + \left(\frac{\partial D}{\partial B} \Delta B \right)^2 + \left(\frac{\partial D}{\partial C} \Delta C \right)^2 \right]^{1/2} = U_D$$

Expressing the uncertainty in terms of a percentage of the value of D is simply a matter of including division by the value of D as follows:

$$\frac{U_D}{D} = \left[\left(\frac{\partial D}{\partial A} \right)^2 \left(\frac{\Delta A}{D} \right)^2 + \left(\frac{\partial D}{\partial B} \right)^2 \left(\frac{\Delta B}{D} \right)^2 + \left(\frac{\partial D}{\partial C} \right)^2 \left(\frac{\Delta C}{D} \right)^2 \right]^{1/2}$$

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The next six sections of this document provide a step by step approach to calculating the analytical uncertainty associated with the six thermal performance equations outlined above. The specific terms to be evaluated from these equations are as follows:

- 1) Heat transfer area, A_0 and area uncertainty, U_{A_0}
- 2) Test condition heat transfer rate, q and heat transfer uncertainty, U_q
- 3) Test condition thermal resistance, R and thermal resistance uncertainty, U_R
- 4) Observed overall fouling resistance, R_f fouling resistance uncertainty, U_{R_f}
- 5) Extrapolation condition thermal resistance, R^* and thermal resistance uncertainty, U_{R^*}
- 6) Extrapolation condition heat transfer rate, q^* and heat transfer rate uncertainty, U_{q^*}

All uncertainty equations used in this calculation are based on the methods of Reference [1]. It is assumed that all independent variables in each equation have no influence on each other. For example, in Equation (6), LMTD* and the overall heat transfer coefficient, U*, are independent of each other. More specific assumptions are stated in each section as applicable.



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1) Uncertainty in Calculation of Heat Transfer Area (A₀)

Governing Equation

$$q = U A_0 LMTD$$

For Air Coolers with circular fins, the outside tube surface area, the fin surface area and the total outside surface area are given by the following expressions:

$$A_{o_{Tube}} = \pi N_T N_L L_C d_o (1 - \lambda t_{FR})$$

$$A_{o_{Fin}} = \pi \lambda N_{T} N_{L} L_{C} \left[H_{F} t_{FT} + (H_{F} + d_{o}) \sqrt{\left(\frac{H_{F} - d_{o}}{2}\right)^{2} + \left(\frac{t_{FR} - t_{FT}}{2}\right)^{2}} \right]$$

$$A_{o_{\text{Total}}} = \pi \, N_T \, N_L \, L_C \left\{ d_o \left(1 - \lambda \, t_{FR} \right) + \lambda \left[H_F \, t_{FT} + \left(H_F + d_o \right) \sqrt{\left(\frac{H_F - d_o}{2} \right)^2 + \left(\frac{t_{FR} - t_{FT}}{2} \right)^2} \right] \right\}$$

where:



 $N_{\rm T}$ = Number of tubes per row

 N_L = Number of active tube rows

 L_C = Effective tube (coil) length (in)

d_o = Tube outside diameter (in)

 λ = Fin pitch (fins/inch)

 H_F = Fin height (in)

 t_{FR} = Thickness of fin at root (in)

 t_{FT} = Thickness of fin at tip (in)

For the case where $t_{FR} = t_{FT} = t_{F}$, the total area equation reduces to the following:

$$A_{o_{Total}} = \pi N_{T} N_{L} L_{C} \left\{ d_{o} (1 - \lambda t_{F}) + \lambda \left[H_{F} t_{F} + (H_{F} + d_{o}) \frac{(H_{F} - d_{o})}{2} \right] \right\}$$

$$A_{o_{\text{Total}}} = \pi N_{\text{T}} N_{\text{L}} L_{\text{C}} \left\{ d_{\text{o}} - \lambda d_{\text{o}} t_{\text{F}} + \frac{\lambda}{2} \left[2H_{\text{F}} t_{\text{F}} + H_{\text{F}}^2 - d_{\text{o}}^2 \right] \right\}$$



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Assumptions

$$U_{N_{\tau}} = 0$$

$$U_{N_L} = 0$$

$$U_{i} = 0$$

Analysis

$$\frac{U_{A_o}}{A_o} = \left\{ \left(\frac{\partial A_o}{\partial d_o} \right)^2 \left(\frac{U_{d_o}}{A_o} \right)^2 + \left(\frac{\partial A_o}{\partial L_c} \right)^2 \left(\frac{U_{L_c}}{A_o} \right)^2 + \left(\frac{\partial A_o}{\partial t_F} \right)^2 \left(\frac{U_{t_F}}{A_o} \right)^2 + \left(\frac{\partial A_o}{\partial H_F} \right)^2 \left(\frac{U_{H_F}}{A_o} \right)^2 \right\}^{\frac{1}{2}}$$

where,

$$\left(\frac{\partial A_o}{\partial d_o}\right) = \pi N_T N_L L_c \left\{ (1 - \lambda t_F) - \lambda d_o \right\}$$



$$\left(\frac{\partial A_o}{\partial L_c}\right) = \pi N_T N_L \left\{ d_o - \lambda d_o t_F + \frac{\lambda}{2} \left[2H_F t_F + H_F^2 - d_o^2 \right] \right\}$$

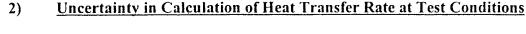
$$\left(\frac{\partial A_o}{\partial t_F}\right) = \pi N_T N_L L_c \lambda \left\{ H_F - d_o \right\}$$

$$\left(\frac{\partial A_o}{\partial H_F}\right) = \pi N_T N_L L_c \lambda \left\{t_F + H_F\right\}$$

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Attachment: J

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Governing Equation

$$q_{Test} = \dot{m} c_p (T_{c_a} - T_{c_i}) = \rho Q c_p \Delta T$$

Assumptions

$$U_{\Delta T} = 0$$

$$U_{Q_{sw}} = 0$$

(i.e., temperature and flow rate in the governing equation are measured values with no analytical uncertainites)

Analysis

$$\frac{U_{q_{\text{test}}}}{q_{\text{test}}} = \left[\left(\frac{\partial q_{\text{test}}}{\partial \rho} \right)^2 \left(\frac{U_{\rho}}{q_{\text{test}}} \right)^2 + \left(\frac{\partial q_{\text{test}}}{\partial Q_{\text{SW}}} \right)^2 \left(\frac{U_{Q}}{q_{\text{test}}} \right)^2 + \left(\frac{\partial q_{\text{test}}}{\partial c_{p}} \right)^2 \left(\frac{U_{c_{p}}}{q_{\text{test}}} \right)^2 + \left(\frac{\partial q_{\text{test}}}{\partial \Delta T} \right)^2 \left(\frac{U_{\Delta T}}{q_{\text{test}}} \right)^2 \right]^{\frac{1}{2}}$$

$$\frac{U_{q_{\text{test}}}}{q_{\text{test}}} = \left[\left(Q_{\text{SW}} c_{p} \Delta T \right)^{2} \left(\frac{U_{\rho}}{q_{\text{test}}} \right)^{2} + \left(\rho Q_{\text{SW}} \Delta T \right)^{2} \left(\frac{U_{c_{p}}}{q_{\text{test}}} \right)^{2} \right]^{\frac{1}{2}}$$

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3) Uncertainty in Calculation of Thermal Resistance at Test Conditions

Governing Equation

$$R = \frac{1}{U} = \frac{A_o \ LMTD_{Test}}{q_{Test}}$$

Assumptions

 $U_{\rm LMTD}$ is negligible

Analysis

$$\frac{U_{R}}{R} = \left[\left(\frac{\partial R}{\partial A_{o}} \right)^{2} \left(\frac{U_{A_{o}}}{R} \right)^{2} + \left(\frac{\partial R}{\partial LMTD} \right)^{2} \left(\frac{U_{LMTD}}{R} \right)^{2} + \left(\frac{\partial R}{\partial q_{test}} \right)^{2} \left(\frac{U_{q_{test}}}{R} \right)^{2} \right]^{\frac{1}{2}}$$

$$\frac{U_{\rm R}}{\rm R} = \left[\left(\frac{\rm LMTD}{\rm q_{test}} \right)^2 \left(\frac{U_{\rm A_o}}{\rm R} \right)^2 + \left(\frac{\rm -A_o LMTD}{\rm q_{test}} \right)^2 \left(\frac{U_{\rm q_{test}}}{\rm R} \right)^2 \right]^{\frac{1}{2}}$$



 $U_{\rm A}$ (Evaluated in Section 1)

 $U_{q_{\text{test}}}$ (Evaluated in Section 2)

J

Proto-Power Calc: 97-200

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4) Uncertainty in Calculation of Fouling Factor at Test Conditions

Governing Equation

$$R_{f} = R - \frac{1}{h_{o} \eta_{s}} - R_{w} - \left(\frac{A_{o}}{A_{i}}\right) \frac{1}{h_{i}} = R - \frac{1}{h_{o} \cdot c_{ff}} - R_{w} - \left(\frac{A_{o}}{A_{i}}\right) \frac{1}{h_{i}}$$

Where,

 $h_{o,eff}$ = effective outside film coefficient = $(h_o) x (\eta_s)$

Assumptions

$$\left(\frac{\partial R_f}{\partial A_o}\right)^2 \left(\frac{U_{A_o}}{R_f}\right)^2 \approx 0$$
$$\left(\frac{\partial R_f}{\partial A_i}\right)^2 \left(\frac{U_{A_i}}{R_f}\right)^2 \approx 0$$

(i.e., the uncertainty in dimensions is negligible compared to the thermal resistance and convection coefficient uncertainties)



Analysis

$$\frac{U_{R_{f}}}{R_{f}} = \left[\left(\frac{\partial R_{f}}{\partial R} \right)^{2} \left(\frac{U_{R}}{R_{f}} \right)^{2} + \left(\frac{\partial R_{f}}{\partial h_{o,eff}} \right)^{2} \left(\frac{U_{h_{o,eff}}}{R_{f}} \right)^{2} + \left(\frac{\partial R_{f}}{\partial R_{w}} \right)^{2} \left(\frac{U_{R_{w}}}{R_{f}} \right)^{2} + \left(\frac{\partial R_{f}}{\partial h_{i}} \right)^{2} \left(\frac{U_{h_{i}}}{R_{f}} \right)^{2} \right]^{\frac{1}{2}}$$

$$\frac{U_{R_{f}}}{R_{f}} = \left[\left(\frac{U_{R}}{R_{f}} \right)^{2} + \left(\frac{1}{h_{o,eff}} \right)^{2} \left(\frac{U_{h_{o,eff}}}{R_{f}} \right)^{2} + \left(\frac{U_{R_{w}}}{R_{f}} \right)^{2} + \left(\frac{A_{o}}{A_{i}} \frac{1}{h_{i}^{2}} \right)^{2} \left(\frac{U_{h_{i}}}{R_{f}} \right)^{2} \right]^{\frac{1}{2}}$$

 $U_{\rm R}$ (Evaluated in Section 3)

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5) Uncertainty in Calculation of Heat Transfer Resistance at Extrapolation Conditions



Governing Equation

$$R^* = R_f + \frac{1}{h_o,_{off}^*} + R_w + \left(\frac{A_o}{A_i}\right) \frac{1}{h_i^*}$$

Assumptions

$$\left(\frac{\partial \mathbf{R}^*}{\partial \mathbf{A}_o}\right)^2 \left(\frac{U_{\mathbf{A}_o}}{\mathbf{R}^*}\right)^2 \approx 0$$

$$\left(\frac{\partial \mathbf{R}^*}{\partial \mathbf{A}_i}\right)^2 \left(\frac{U_{\mathbf{A}_i}}{\mathbf{R}^*}\right)^2 \approx 0$$

(i.e., the uncertainty in dimensions is negligible compared to the thermal resistance and convection coefficient uncertainties)

Analysis



$$\frac{U_{R^*}}{R^*} = \left[\left(\frac{\partial R^*}{\partial R_f} \right)^2 \left(\frac{U_{R_f}}{R^*} \right)^2 + \left(\frac{\partial R^*}{\partial h_{o,eff}^*} \right)^2 \left(\frac{U_{h_{o,eff}^*}}{R^*} \right)^2 + \left(\frac{\partial R^*}{\partial R_w} \right)^2 \left(\frac{U_{R_w}}{R^*} \right)^2 + \left(\frac{\partial R^*}{\partial h_i^*} \right)^2 \left(\frac{U_{h_i^*}}{R^*} \right)^2 \right]^{\frac{1}{2}}$$

$$\frac{U_{R^*}}{R^*} = \left[\left(\frac{U_{R_r}}{R^*} \right)^2 + \left(-\frac{1}{h_{o,eff}^{*2}} \right)^2 \left(\frac{U_{h_{o,eff}^*}}{R^*} \right)^2 + \left(\frac{U_{R_w}}{R^*} \right)^2 + \left(-\frac{A_o}{A_i} \frac{1}{h_i^{*2}} \right)^2 \left(\frac{U_{h_i^*}}{R^*} \right)^2 \right]^{\frac{1}{2}}$$

 $U_{R_{I}}$ (Evaluated in Section 4)

 $U_{\rm R} = 0$ (for extrapolation calculations only, i.e., no fouling calculation)

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6) Uncertainty in Calculation of Heat Transfer Rate at Extrapolation Conditions

Governing Equation

$$q^* = (1/R^*) (A_o) (LMTD^*)$$

Assumptions

$$U_{\rm LMTD} \approx 0.0$$

<u>Analysis</u>

$$\frac{U_{\mathbf{q}^{\bullet}}}{\mathbf{q}^{\bullet}} = \left[\left(\frac{\partial \mathbf{q}^{\bullet}}{\partial \mathbf{R}^{\bullet}} \right)^{2} \left(\frac{U_{\mathbf{R}^{\bullet}}}{\mathbf{q}^{\bullet}} \right)^{2} + \left(\frac{\partial \mathbf{q}^{\bullet}}{\partial \mathbf{A}_{o}} \right)^{2} \left(\frac{U_{\mathbf{Q}^{\bullet}}}{\mathbf{q}^{\bullet}} \right)^{2} + \left(\frac{\partial \mathbf{q}^{\bullet}}{\partial \left(LMTD^{\bullet} \right)} \right)^{2} \left(\frac{U_{LMTD^{\bullet}}}{\mathbf{q}^{\bullet}} \right)^{2} \right]^{\frac{1}{2}}$$

$$\frac{U_{q}^{*}}{q^{*}} = \left[\left(-R^{*-2}A_{o} LMTD^{*} \right)^{2} \left(\frac{U_{R}^{*}}{q^{*}} \right)^{2} + \left(\frac{1}{R^{*}} LMTD^{*} \right)^{2} \left(\frac{U_{A_{o}}}{q^{*}} \right)^{2} \right]^{\frac{1}{2}}$$



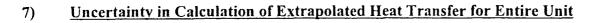
 $U_{\rm R}$ (Evaluated in Section 5)

 U_{A_a} (Evaluated in Section 1)

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The uncertainties in extrapolated heat transfer, computed for each tube row, are combined in the following manner to yield an overall uncertainty value for the entire air cooler.

$$q_{tot} = q_1 + q_2 + q_3 \dots + q_n$$

where, "n" is the number of tube rows in the unit.

$$\frac{Uq_{\text{tot}}}{q_{\text{tot}}} = \left[\left(\frac{\partial q_{\text{tot}}}{\partial q_1} \right)^2 \left(\frac{Uq_1}{q_{\text{tot}}} \right)^2 + \left(\frac{\partial q_{\text{tot}}}{\partial q_2} \right)^2 \left(\frac{Uq_2}{q_{\text{tot}}} \right)^2 + \left(\frac{\partial q_{\text{tot}}}{\partial q_2} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_n} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_n} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_n} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left(\frac{Uq_3}{q_n} \right)^2 + \dots + \left(\frac{\partial q_{\text{tot}}}{\partial q_n} \right)^2 \left($$

Assuming that the extrapolated heat transfer rates of the various rows do not depend on each other, the above expression becomes:

$$\frac{Uq_{\text{tot}}}{q_{\text{tot}}} = \left[\left(\frac{Uq_1}{q_{\text{tot}}} \right)^2 + \left(\frac{Uq_2}{q_{\text{tot}}} \right)^2 + \left(\frac{Uq_3}{q_{\text{tot}}} \right)^2 + \dots \left(\frac{Uq_n}{q_{\text{tot}}} \right)^2 \right]^{1/2}$$

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Definition of Analytical Uncertainty Analysis Terms

Heat transfer area ratio Ao/Ai = Tube inside diameter di (in) = Outside heat transfer area Ao $(ft^2) =$ do (in) = Tube outside diameter

Udo/do (%) = Uncertainty in tube outside diameter (as a percentage) Uncertainty in tube outside diameter (absolute) Udo ≈

Nt =Number of tubes in given row NI = Number of rows in heat exchanger

Fin pitch Lambda (fins/in) = L(Ft) =Tube length

Uncertainty in tube length (as a percentage) UL/L (%) = UL(ft) =Uncertainty in tube length (absolute)

Fin thickness tfin (in) =

Utfin/tfin (%) = Uncertainty in fin thickness (as a percentage) Uncertainty in fin thickness (absolute) Utfin (in) =

hfin (in) = Fin height

Uncertainty in fin height (as a percentage) Uhfin/hfin (%) = Uncertainty in fin height (absolute) Uhfin (in) =

Mdotc (lbm/hr) =Cooling water mass flow rate $Q(Ft^3/hr) =$ Cooling water volumetric flow rate

DT (DegF) =Cooling water temperature difference (inlet to outlet)

 $rho (lbm/ft^3) =$ Cooling water density

Uncertainty in cooling water density (as a percentage) Urho/rho(%) =Urho = Uncertainty in cooling water density (absolute)

Cp (Btu/lbm/DegF) =Cooling water specific heat

UCp/Cp (%) = Uncertainty in cooling water specific heat (as a percentage) UCp = Uncertainty in cooling water specific heat (absolute)

Calculated test heat transfer for coil section qtest (Btu/hr) = Calculated log mean temperature difference LMTD (DegF) =

Heat transfer coefficient Uo = R = (1/Uo) =Heat transfer resistance $Rf[(hr-DegF-ft^2)/Btu] =$ Fouling resistance

Etas =

Outside film coefficient $ho [Btu/(hr-DegF-ft^2)] =$

Effective outside film coefficient $ho(eff) [Btu/(hr-DegF-ft^2)] =$ Uncertainty in outside film coefficient (as a percentage) Uho/ho (%) =

Uho = Uncertainty in outside film coefficient (absolute)

Inside film coefficient $hi [Btu/(hr-DegF-ft^2)] =$

Uhi/hi (%) = Uncertainty in inside film coefficient (as a percentage) Uhi = Uncertainty in inside film coefficient (absolute)

 $Rw [(hr-DegF-ft^2)/Btu] =$ Wall thermal resistance

URw/Rw (%) = Uncertainty in wall resistance (as a percentage) URw = Uncertainty in wall resistance (absolute)

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Analytical Uncertainty Analysis -- Uncertainty Inputs

Parameter	Definition	Value (%)	1
Udo/do	Uncertainty in tube outside diameter	8.00	(1)
ULc/Lc	Uncertainty in coil (tube) length	0.24	(2)
Utfin/tfin	Uncertainty in fin thickness	4.17	(3)
Uhfin/hfin	Uncertainty in circular fin height	1.34	(4)
Urho/rho	Uncertainty in cooling water density	2.00	(5)
UCp/Cp	Uncertainty in cooling water specific heat	2.00	(5)
Uho/ho	Uncertainty in outside film coefficient	15.00	(6)
Uhi/hi	Uncertainty in inside film coefficient	15.00	(7)
URw/Rw	Uncertainty in wall resistance	2.00	(5)

Notes:

- (1) Measurement of 5/8" +/- 0.05" yields an uncertainty of 8.0%
- (2) Measurement of 104.25" +/- 0.25" yields an uncertainty of 0.24%
- (3) Specified as 0.012" with estimated tolerance of 0.0005" yields an uncertainty of 4.17%
- (4) Measurement of 1.495" +/- 0.02" yields an uncertainty of 1.34%
- (5) Uncertainty in property values is estimated as 2%
- (6) Uncertainty in outside film coefficient is estimated as 15%
- (7) Uncertainty in inside film coefficient is estimated as 15%



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Page 2

Tube Wall Conductivity (BTU/hr-ft-°F)



09:09:14

PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

06/22/98

Air Coil Heat Exchanger Input Parameters

		<i>₹</i>
	Air-Side	Tube-Side
Fluid Quantity, Total	21179 acfm	150 gpm
Inlet Dry Bulb Temp	150 °F	105 °F
Inlet Wet Bulb Temp	92 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.4 °F	115.3 °F
Outlet Wet Bulb Temp	84.1 °F	,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,,
Outlet Relative Humidity	%	
Could relative rights and	76	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002
Air-Side Fouling		0.002
Air-Side Founing		0.002
Design Heat Transfer (BTU/hr)		750000
Atmospheric Pressure		14.315
Sensible Heat Ratio		14.313
Performance Factor (% Reduction)		
renormance ractor (% Reduction)		0
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration		LaSalle VY Coolers 01A/02A
, iii comigaranon		j = EXP[-2.5088 + -0.3436 * LOG(Re)]
) = EXT [-2.3000 + -0.3430
Coil Finned Length (in)		104.25
Fin Pitch (Fins/Inch)		10
Fin Conductivity (BTU/hr-ft-°F)		128
Fin Tip Thickness (inches)		0.012
Fin Root Thickness (inches)		0.012
Circular Fin Height (inches)		1.495
· · · · · · · · · · · · · · · · · · ·		1.455
Number of Coils Per Unit		2.000
Number of Tube Rows		8.000
Number of Tubes Per Row		20
Active Tubes Per Row		20
		23
Tube Inside Diameter (in)		0.527
Tube Outside Diameter (in)		0.625
Longitudinal Tube Pitch (in)		1.5
Transverse Tube Pitch (in)		1.452
` '		
Number of Serpentines		1
•		



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PROTO-HX Report -- Fouling Calculation Output



Fouling Calculation Summary

There is no fouling calculation for the rating analysis case.

Uncertainty in use of design fouling in rating analysis is zero.

Blacked-out areas in the sheets that follow are related to the fouling factor calculation and are not applicable

Proto-Power Calc: 97-200

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Page 4

PROTO-HX Report -- Extrapolation Calculation Output for Limiting Flow Case



Extrapolation Calculation Summary

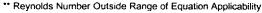
•	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71166.65	53702.59	Tube-Side hi (BTU/hr·ft²-°F)	
Inlet Temperature (°F)	148	100	j Factor	
Outlet Temperature (°F)	108.2854	113.1719	Air-Side ho (BTU/hr-ft²-°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity			Overall Fouling (hr-ft ² -°F/BTU)	0.039766
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr-ft²-°F)	
Velocity ***			Effective Area (ft²)	7242.652
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	707030.5
Bulk Visc (lbm/ft-hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	707030.5
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-°F)			Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr·ft²-°F)	1246.549
Inlet Temperature (°F)	148	110.3055 j Factor	0.008175
Outlet Temperature (°F)	139.3637	113.1719 Air-Side ho (BTU/hr-ft²-°F)	8.272452
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ft ² -°F/BTU)	0.039766
Average Temp (°F)	143.6819	111.7387	
Skin Temperature (°F)	121.1797	114.3282 U Overall (BTU/hr-ft²-°F)	5.351471
Velocity ***	3400.987	3.981516 Effective Area (ft²)	905.3315
Reynold's Number	802.6572	** 26688.33 LMTD	31.73459
Prandtl Number	0.725515	3.967489 Total Heat Transferred (BTU/hr)	153749.5
Bulk Visc (lbm/ft·hr)	0.048968	1.45846	
Skin Visc (lbm/ft·hr)		1.421732 Surface Effectiveness (Eta)	0.918316
Density (Ibm/ft³)	0.062477	61.83519 Sensible Heat Transferred (BTU/hr)	153749.5
Cp (BTU/lbm·°F)	0.240245	0.99882 Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-°F)	0.016215	0.367165 Heat to Condensate (BTU/hr)	
** Revnolds Number Outside F	Range of Equation Applicat	nility	

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr·ft²-°F)	1228.617
Inlet Temperature (°F)	139.3637	107.9223 j Factor	0.008146
Outlet Temperature (°F)	132.1832	110.3055 Air-Side ho (BTU/hr·ft²-°F)	8.238629
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ftz-°F/BTU)	0.039766
Average Temp (°F)	135.7735	109.114	
Skin Temperature (°F)	116.9946	111.2983 U Overall (BTU/hr-ft²-°F)	5.330976
Velocity ***	3400.987	3.979115 Effective Area (ft²)	905.3315
Reynold's Number	810.7773	** 25995.7 LMTD	26.48671
Prandtl Number	0.726209	4.083826 Total Heat Transferred (BTU/hr)	127832.8
Bulk Visc (lbm/ft·hr)	0.048477	1.497319	
Skin Visc (lbm/ft·hr)		1.464863 Surface Effectiveness (Eta)	0.918616
Density (lbm/ft³)	0.063235	61.8725 Sensible Heat Transferred (BTU/hr)	127832.8
Cp (BTU/lbm·°F)	0.240245	0.998845 Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-*F)	0.016037	0.366218 Heat to Condensate (BTU/hr)	
** Dougoldo Numbor Outoido D	anno of Counties Analisah	L-110a	





Extrapolation Calculation for Row 3(Dry)

Proto-Power Calc: 97-200 Air-Side Tube-Side

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PROTO-HX Report -- Extrapolation Calculation Output for Limiting Flow Case



Mass Flow (lbm/hr)	71166.65	53702.59 Tut	be-Side hi (BTU/hr-ft²-°F)	1213.64
Inlet Temperature (°F)	132.1832	105.9385 j Fa	actor	0.008123
Outlet Temperature (°F)	126.2057	107.9223	Air-Side ho (BTU/hr·ft².°F)	8.210501
Inlet Specific Humidity	0.020268	Tut	be Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Ovi	erall Fouling (hr·ft²-°F/BTU)	0.039766
Average Temp (°F)	129.1941	106.9309		
Skin Temperature (°F)	113.5129	108.7712 U (Overall (BTU/hr·ft²-°F)	5.313799
Velocity ***	3400.987	3.977169 Effe	fective Area (ft²)	905.3315
Reynold's Number	817.7239	•• 25	5424.42 LMTD	22.12061
Prandtl Number	0.726741	4.184867 Tol	tal Heat Transferred (BTU/hr)	106416.7
Bulk Visc (lbm/ft·hr)	0.048065	1.530964	,'	
Skin Visc (lbm/ft-hr)		1.502521 Sui	rface Effectiveness (Eta)	0.918865
Density (lbm/ft³)	0.063881	61.90278 Se	ensible Heat Transferred (BTU/hr)	106416.7
Cp (BTU/lbm·°F)	0.240245	0.998873 Lat	tent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-"F)	0.015889	0.365416 He	eat to Condensate (BTU/hr)	
at D. J. H. M. Harrida Dange of Equal		His		

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr-ft²-°F)	1201.114
Inlet Temperature (°F)	126.2057	104.2853 j Factor	0.008103
Outlet Temperature (°F)	121.2244	105.9385 Air-Side ho (BTU/hr-ft²-°F)	8.187088
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ft²-°F/BTU)	0.039766
Average Temp (°F)	123.7151	105.1112	
Skin Temperature (°F)	110.6127	106.6611 U Overall (BTU/hr·ft²-°F)	5.299401
Velocity ***	3400.987	3.975581 Effective Area (ft²)	905.3315
Reynold's Number	823.6471	** 24951.62 LMTD	18.48393
Prandtl Number	0.72715	4.272217 Total Heat Transferred (BTU/hr)	88680.63
Bulk Visc (lbm/ft·hr)	0.04772	1.559974	
Skin Visc (lbm/ft-hr)		1.535208 Surface Effectiveness (Eta)	0.919073
Density (lbm/ft³)	0.064428	61.9275 Sensible Heat Transferred (BTU/hr)	88680.63
Cp (BTU/lbm·°F)	0.240245	0.998902 Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-°F)	0.015766	0.364737 Heat to Condensate (BTU/hr)	
		444	

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr-ft²-°F)	1190.652
Inlet Temperature (°F)	121.2244	102.9065 j Factor	0.008086
Outlet Temperature (°F)	117.0697	104.2853 Air-Side ho (BTU/hr-ft²-°f	8.167578
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ft2-°F/BTU)	0.039766
Average Temp (°F)	119.1471	103.5958	
Skin Temperature (°F)	108.1955	104.8999 U Overall (BTU/hr-ft²-°F)	5.287339
Velocity ***	3400.987	3.974283 Effective Area (ft²)	905.3315
Reynold's Number	828.6851	** 24560.25 LMTD	15.45193
Prandtl Number	0.727467	4.347231 Total Heat Transferred (BTU/hr)	73965.21
Bulk Visc (lbm/ft·hr)	0.04743	1.584832	
Skin Visc (lbm/ft·hr)		1.563402 Surface Effectiveness (Eta)	0.919246
Density (lbm/ft³)	0.064893	61.94772 Sensible Heat Transferred (BTU/hr)	73965.21
Cp (BTU/lbm·°F)	0.240245	0.998929 Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.015664	0.364166 Heat to Condensate (BTU/hr)	Proto-Power Calc: 97-200
** Reynolds Number Outside Ra	ange of Equation Applicat	pility	FIGU-FOWER Carc. 97-200

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Extrapolation Calculation for Row 6(Dry)



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/h	nr-ft²-°F)	1181.899
Inlet Temperature (°F)	117.0697	101.7556 j Factor		0.008071
Outlet Temperature (°F)	113.6019	102.9065 Air-Side	ho (BTU/hr·ft²-°F)	8.151309

PROTO-HX Report -- Extrapolation Calculation Output for Limiting Flow Case



Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overalt Fouling (hr-ft²-°F/BTU)	0.039766
Average Temp (°F)	115.3358 102.3	J,	0.0001.00
Skin Temperature (°F)		274 U Overall (BTU/hr·ft²-°F)	5.277229
Velocity ***		217 Effective Area (ft²)	905.3315
Revnold's Number	832.9599 **	24235.25 LMTD	12.92208
Prandtl Number	0.727713 4.411	482 Total Heat Transferred (BTU/hr)	61737.04
Bulk Visc (lbm/ft-hr)	0.047186 1.606	, .	
Skin Visc (lbm/ft-hr)	1.587	634 Surface Effectiveness (Eta)	0.91939
Density (lbm/ft³)	0.065285 61.96	434 Sensible Heat Transferred (BTU/hr)	61737.04
Cp (BTU/lbm·°F)	0.240244 0.998	954 Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-°F)	0.015578 0.363	684 Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr-ft²-°F)	1174.576
Inlet Temperature (°F)	113.6019	100.7945 j Factor	0.008059
Outlet Temperature (°F)	110.7056	101.7556 Air-Side ho (BTU/hr-ft²-°F)	8.137733
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ftz-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ft ² .°F/BTU)	0.039766
Average Temp (°F)	112.1537	101.2749	
Skin Temperature (°F)	104.4937	102.1964 U Overall (BTU/hr·ft²-°F)	5.268757
Velocity ***	3400.987	3.972339 Effective Area (ft²)	905.3315
Reynold's Number	836.5802	** 23965.08 LMTD	10.80974
Prandtl Number	0.727905	4.466304 Total Heat Transferred (BTU/hr)	51562.15
Bulk Visc (lbm/ft·hr)	0.046982	1.624191	
Skin Visc (lbm/ft·hr)		1.608373 Surface Effectiveness (Eta)	0.919511
Density (lbm/ft³)	0.065617	61.97803 Sensible Heat Transferred (BTU/hr)	51562.15
Cp (BTU/lbm·°F)	0.240244	0.998977 Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.015506	0.363278 Heat to Condensate (BTU/hr)	
** 5		***	

^{**} Reynolds Number Outside Range of Equation Applicability



Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side	
Mass Flow (lbm/hr)	71166.65	53702.59 Tube-Side hi (BTU/hr-ft²-°F)	1168.449
Inlet Temperature (°F)	110.7056	99.99134 j Factor	0.008049
Outlet Temperature (°F)	108.2854	100.7945 Air-Side ho (BTU/hr·ft²-°F)	8.126396
Inlet Specific Humidity	0.020268	Tube Wall Resistance (hr-ft²-°F/BTU)	0.000314
Outlet Specific Humidity	0.020268	Overall Fouling (hr-ft ² -°F/BTU)	0.039766
Average Temp (°F)	109.4955	100.3927	
Skin Temperature (°F)	103.0865	101.1668 U Overall (BTU/hr·ft².°F)	5.261658
Velocity ***	3400.987	3.971615 Effective Area (ft²)	905.3315
Reynold's Number	839.6409	** 23740.2 LMTD	9.045035
Prandtl Number	0.728057	4.512945 Total Heat Transferred (BTU/hr)	43086.43
Bulk Visc (lbm/ft-hr)	0.04681.1	1.639576	
Skin Visc (lbm/ft·hr)		1.626064 Surface Effectiveness (Eta)	0.919611
Density (lbm/ft³)	0.065896	61.98934 Sensible Heat Transferred (BTU/hr)	43086.43
Cp (BTU/lbm·°F)	0.240244	0.998987 Latent Heat Transferred (BTU/hr)	
K (BTU/hr-ft-°F)	0.015447	0.362937 Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

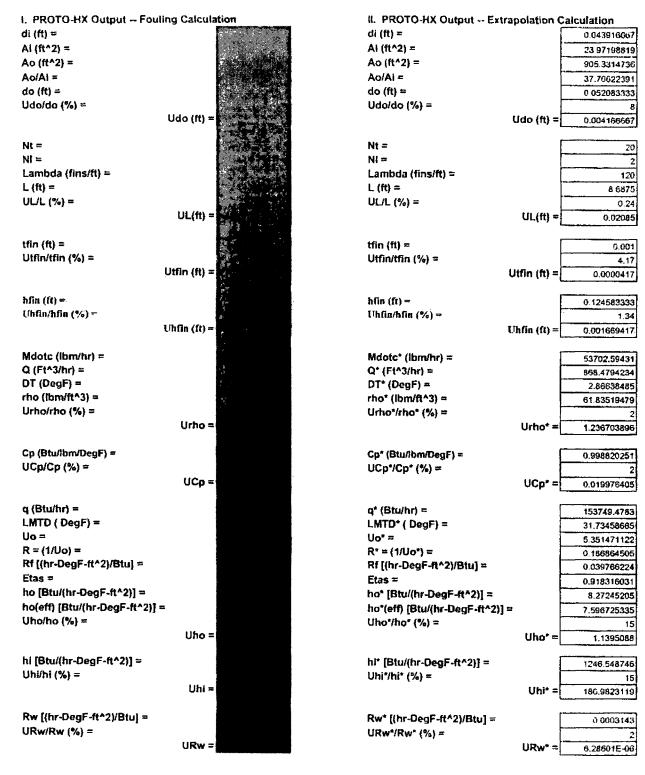
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^{***} Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T



Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 1)





Proto-Power Calc: 97-200

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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 1)

1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451 97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18686	7.59673	1.13951	1246,54875	186.98231	0.00031	0.00001	0.03977	0.00000	0.10843	0.02026

6 Analytical Uncertainty in Extrapolated Heat Transfer

q* R*	UR*	Ασ	UAo	LMTD*	Uq*/q*	Uq*
153749.4783 0.18686	0.02026	905.33147	36.82236	31.73459	0.11581	17805.20662



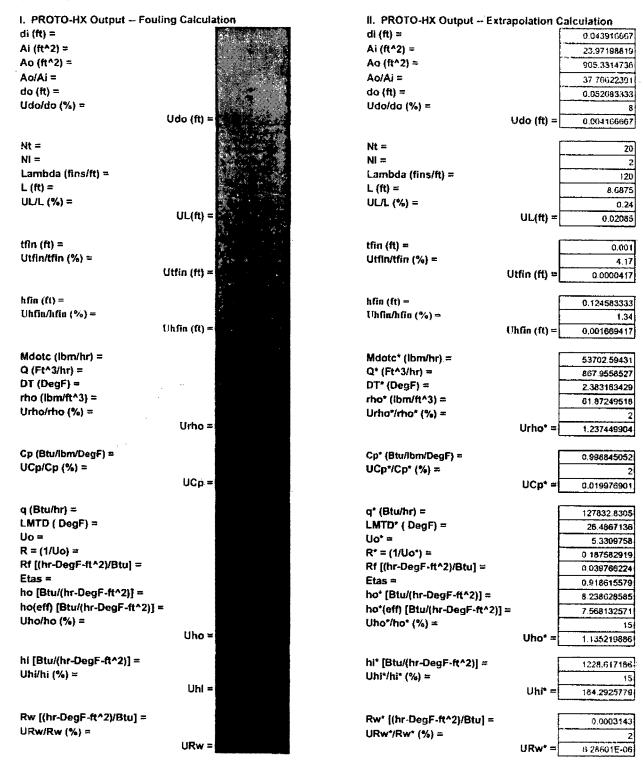
Proto-Power Calc: 97-200

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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 2)





Proto-Power Calc: 97-200

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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 2)

1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	Ĺ	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18758	7.56813	1.13522	1228.61719	184.29258	0.00031	0.00001	0.03977	0.00000	0.10848	0.02035

6 Analytical Uncertainty in Extrapolated Heat Transfer

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
127832.83	05 0.18758	0.02035	905.33147	36.82236	26.48671	0.11586	14810.09844

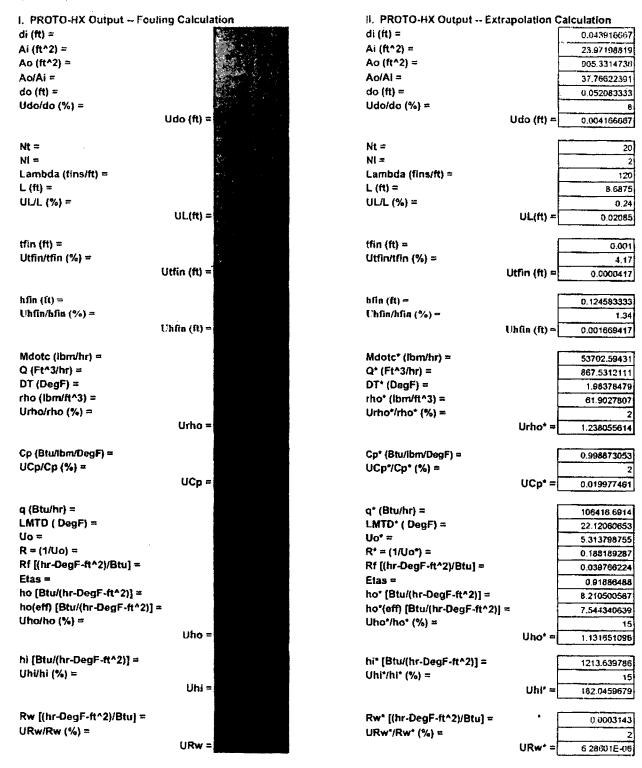


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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 3)





Proto-Power Calc: 97-200

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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 3)

1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18819	7.54434	1.13165	1213.63979	182.04597	0.00031	0.00001	0.03977	0.00000	0.10852	0.02042

6 Analytical Uncertainty in Extrapolated Heat Transfer

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
106416 691	4 0.18819	0.02042	905.33147	36.82236	22.12061	0.11590	12333.18129



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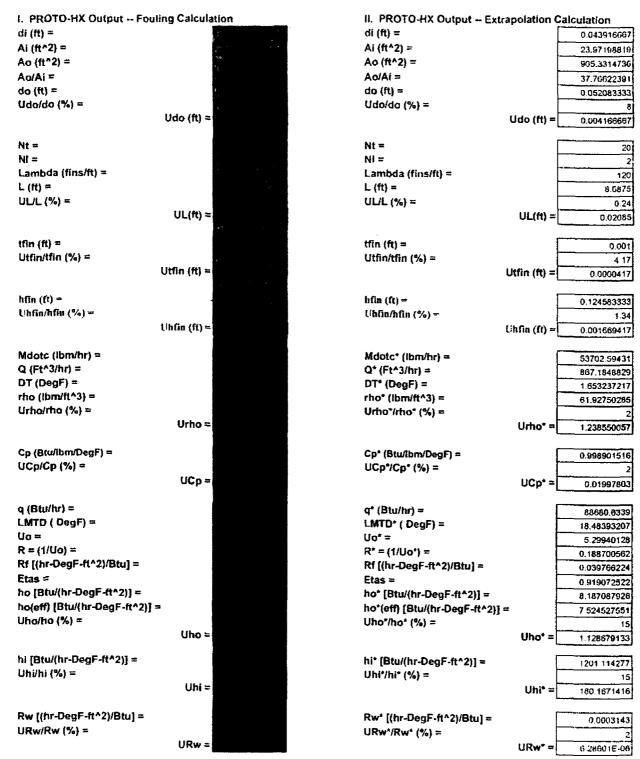
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 4)





Proto-Power Calc: 97-200

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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 4)

1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ha"	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18870	7.52453	1.12868	1201.11428	180.16714	0.00031	0.00001	0.03977	0.00000	0.10856	0.02049

6 Analytical Uncertainty in Extrapolated Heat Transfer

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
88680.6339	0.18870	0.02049	905.33147	36.82236	18 48393	0.11593	10280.57880



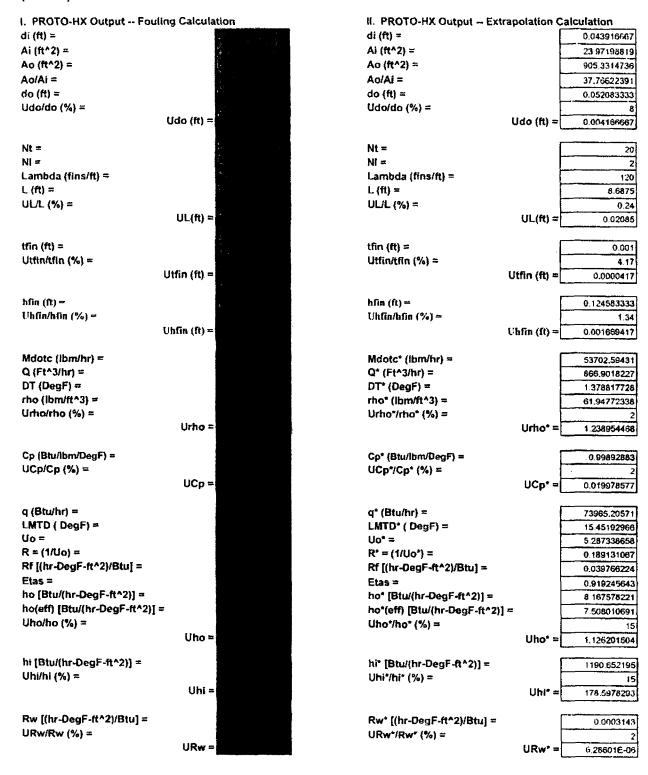
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 5)





Proto-Power Calc: 97-200

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1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L,	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18913	7.50801	1.12620	1190.65220	178.59783	0.00031	0.00001	0.03977	0.00000	0.10859	0.02054

6 Analytical Uncertainty in Extrapolated Heat Transfer

d.	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
73965.2057	0.18913	0.02054	905.33147	36.82236	15.45193	0.11596	8576.66300

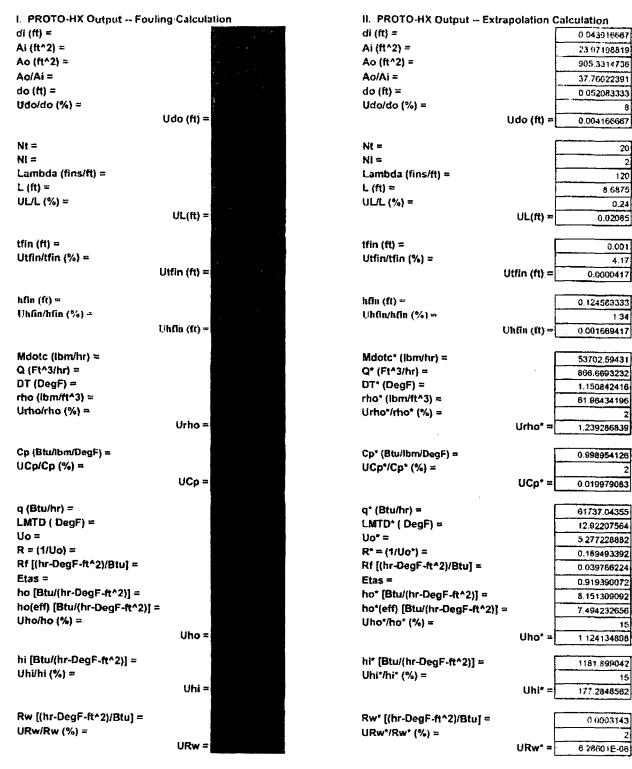


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1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives:	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.18949	7.49423	1.12413	1181.89904	177.28486	0.00031	0.00001	0.03977	0.00000	0.10861	0.02058

6 Analytical Uncertainty in Extrapolated Heat Transfer

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
61737.0435	0.18949	0.02058	905.33147	36.82236	12.92208	0.11598	7160.13511



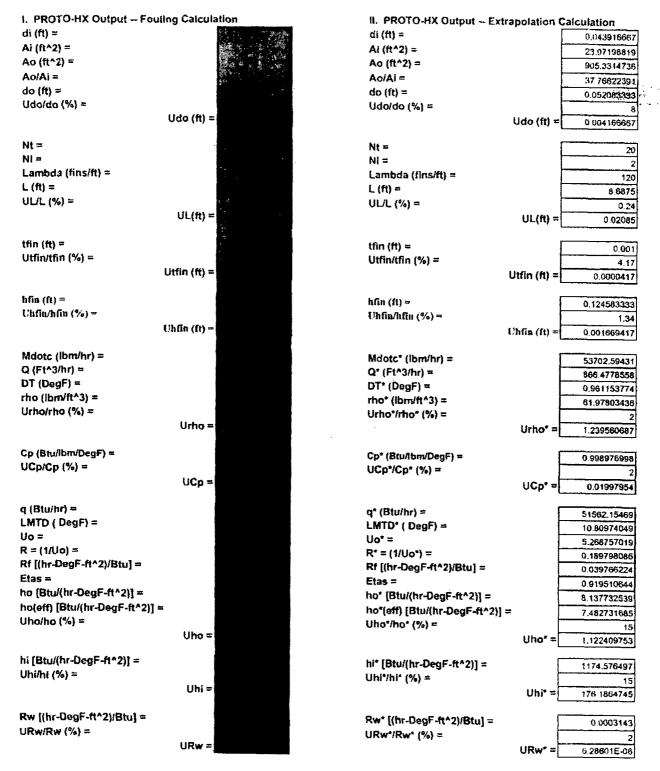
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1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0.00167	0.04067	36.82236
Derivatives	-5862.45		104.21		0497.82		16/51 97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw"	Rf	URf	UR*/R*	UR*
0.18980	7.48273	1.12241	1174.57650	176.18647	0.00031	0.00001	0.03977	0.00000	0.10863	0.02062

6 Analytical Uncertainty in Extrapolated Heat Transfer

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
51562.1547	0.18980	0.02062	905.33147	36.82236	10.80974	0.11600	5981.03791

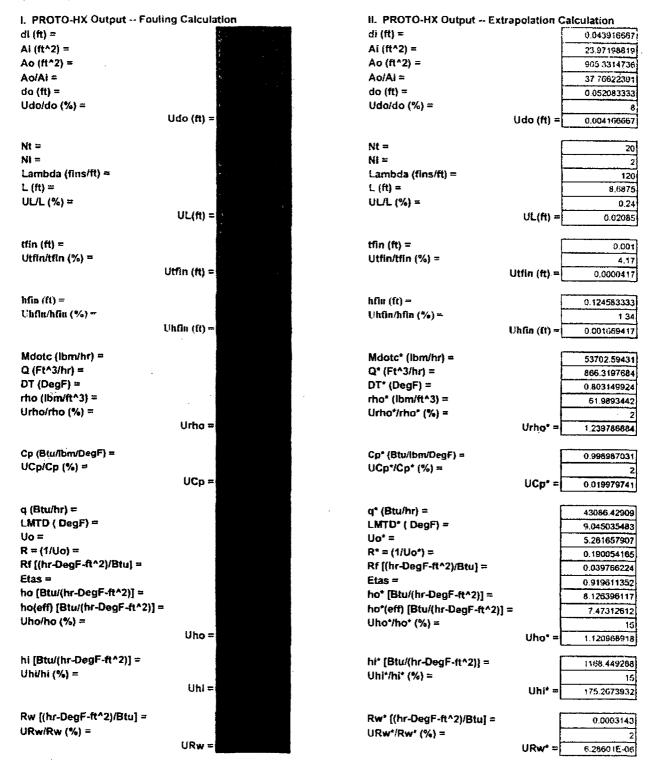


Proto-Power Calc: 97-200

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Proto-Power Calc: 97-200

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1 Analytical Uncertainty in Heat Transfer Surface Area

Ao	Do	Ud	L	UL	tfin	Utfin	hfin	Uhfin	UAo/Ao	UAo
905.33147	0.05208	0.00417	8.68750	0.02085	0.00100	0.00004	0.12458	0 00167	0.04067	36.82236
Derivatives.	-5862.45		104.21		9497.82		16451.97			

2 Analytical Uncertainty in Test Heat Transfer Rate



3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):





4 Analytical Uncertainty in Observed Rf

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	Uho*	hi*	Uhi*	Rw*	URw*	Rf	URf	UR*/R*	UR*
0.19005	7.47313	1.12097	1168.44929	175.26739	0.00031	0.00001	0.03977	0.00000	0.10865	0.02065

6 Analytical Uncertainty in Extrapolated Heat Transfer

q"	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
43086.4291	0.19005	0.02065	905.33147	36.82236	9.04504	0.11601	4998.55238



Proto-Power Calc: 97-200

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	Extrapolated Heat Transfer (Btu/hr)	Calculated Uncertainty (Btu/hr)	(Uq/q)^2
Row1	153749.4783	17805.2066	0.000634
Row2	127832.8305	14810.0984	0.000439
Row3	106416.6914	12333.1813	0.000304
Row4	88680.6339	10280.5788	0.000211
Row5	73965.2057	8576.6630	0.000147
Row6	61737.0435	7160.1351	0.000103
Row7	51562.1547	5981.0379	0.000072
Row8	43086.4291	4998.5524	0.000050

707030.4672 31300.9119 0.044271 qtot SRSS SRSS

Uqtot/qtot = 4.43%



Proto-Power Calc: 97-200

Attachment: J

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	Extrapolated Heat Transfer (Btu/hr)	Calculated Uncertainty (Btu/hr)	(Uq/q)^2
Row1	131195.3801	15103.9427	0.000500
Row2	113794.4455	13105.2568	0.000377
Row3	98799.9660	11381.9018	0.000284
Row4	85856.6718	9893.4811	0.000215
Row5	74666.9011	8606.0900	0.000162
Row6	64980.1137	7491.1472	0.000123
Row7	56584.3908	6524.4468	0.000093
Row8	49299.5662	5685.3828	0.000071

675177.4352 28850.9888 0.042731 qtot SRSS SRSS

Uqtot/qtot = 4.27% (75 gpm case)





Proto-Power Calc: 97-200

Attachment: J

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	Extrapolated Heat Transfer (Btu/hr)	Calculated Uncertainty (Btu/hr)	(Uq/q)^2
Row1	157023.2342	18206.8532	0.000656
Row2	129762.6061	15052.6614	0.000448
Row3	107370.6351	12459.6780	0.000307
Row4	88936.6170	10323.5976	0.000211
Row5	73732.6242	8560.8359	0.000145
Row6	61173.2629	7104.0420	0.000100
Row7	50784.0800	5898.5258	0.000069
Row8	42180.9535	4899.9514	0.000047

710964.0130 31661.4879 0.044533 qtot SRSS SRSS

Uqtot/qtot = 4.45% (115 gpm case)





Proto-Power Calc: 97-200

Attachment: J

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	Extrapolated Heat Transfer (Btu/hr)	Calculated Uncertainty (Btu/hr)	(Uq/q)^2
Row1	179064.4002	22100.0999	0.000887
Row2	142681.0988	17616.1725	0.000564
Row3	113876.2648	14063.8438	0.000359
Row4	91005.7384	11241.8723	0.000230
Row5	72805.1411	8995.1889	0.000147
Row6	58293.7569	7203.3185	0.000094
Row7	46706.6938	5772.1632	0.000061
Row8	37443.1718	4627.7663	0.000039

741876.2658 36200.1472

0.048795

qtot

SRSS

SRSS

Uqtot/qtot =

4.88%

(150 gpm case)



Proto-Power Calc: 97-200

Attachment: J

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Attachment K to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: K

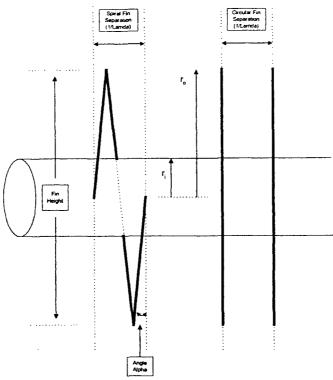
Rev: A Page 1 of 4



COMPARING SPIRAL AND CIRCULAR FINS

Area Calculation

A view of the spiral fin layout as compared to the circular fin layout is provided below. Let angle α represent the angle between the plane of the circular fin and the plane of the spiral fin.



A differential area in the circular fin is given as:

 $dA = rdrd\theta$

The expression for circular fin surface area (times 2 for both sides and disregarding the edge area) taken over a complete traverse of the tube is given as:

$$A_{cf} = 2 \int_{i}^{o} \int_{0}^{2\pi} dr d\theta = 2\pi (r_{o}^{2} - r_{i}^{2})$$

Where:

r_o = the fin outside radius which is one half the fin height
 r_i = the inside fin radius which is the tube outside radius



Proto-Power Calc: 97-200

Attachment: K

Rev: A Page 2 of 4



The spiral fin surface area (times 2 for both sides and disregarding the edge area) can be approximated by the expression:

$$A_{sf} = \left(\frac{1}{\cos \alpha}\right) 2\pi (r_o^2 - r_i^2)$$

The ratio of the two areas becomes:

$$\frac{A_{sf}}{A_{cf}} = \left(\frac{1}{\cos \alpha}\right)$$

Angle α is approximated by the expression:

$$\tan \alpha = \frac{\frac{1}{4}(\text{fin separation})}{r_o} = \frac{1}{4r_o \lambda}$$

$$\alpha = \tan^{-1} \left(\frac{1}{4r_a \lambda} \right)$$

where:

$$\lambda$$
 = fin pitch

Substituting fin height into the expression yields the following:

$$\alpha = \tan^{-1}\left(\frac{2}{4H_f\lambda}\right) = \tan^{-1}\left(\frac{1}{2H_f\lambda}\right)$$

As the angle α goes to zero, the spiral fin area approaches that of the circular fin. It can be seen that for very small fin separations (i.e., high fin pitch) the smaller the resulting angle α .

For the case of the VY cooler fin geometry:

$$\alpha = \tan^{-1} \left(\frac{1}{2H_f \lambda} \right) = \tan^{-1} \left(\frac{1}{2(1.487)(10)} \right) = \tan^{-1} (0.033625) = 1.93^{\circ}$$



Proto-Power Calc: 97-200

Attachment: K

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The resulting area ratio is then:

$$\frac{A_{sf}}{A_{cf}} = \left(\frac{1}{\cos \alpha}\right) = \left(\frac{1}{\cos(1.93^\circ)}\right) = 1.00057$$

This difference is negligible and is bounded by the uncertainty in the analysis presented in Attachment J.

Heat Transfer Coefficient

The fin geometry affects the calculation of the outside heat transfer film coefficient (h_o) for condensing modes of operation. Vertical (circular) fins provide for better condensation heat transfer since the condensate falls away from the fins at a faster rate than if the fin were inclined (i.e., spiral geometry). As shown in the area discussion above, the angular difference between the circular fin geometry and the spriral fin geometry for the VY coils with a fin pitch of 10 fins per inch is very small (i.e., $<2^{\circ}$). The angle of incline, therefore, is deemed to be sufficiently small as to make the difference between circular and spiral fin geometries negligible even for condensing modes of operation. In other words, as far as condensation removal from the fin surfaces is concerned, the 10 fin per inch fin pitch of the VY coils results in a fin orientation that is sufficiently close to vertical as to make differences in condensation heat transfer predictions negligible.

Proto-Power Calc: 97-200

Attachment: K

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Attachment L to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: L

Rev: A Page 1 of 6



A Unicom Company

LASALLE STATION FAX TRANSMITTAL

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Proto-Power Calc: 97-200

Attachment: L

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CLEAR DESIGN INF	ORMAT	ION TRANSM	ITTAL
Originating Organization Section: SEB Company: ComEd		NDIT No.: LS Upgrade 0 Page 1 of	2 2
Units: 1	System:	To: Lloyd Philipot, Pro	oto-Power
g and Fins for Cooler 1VY02A			
Engineer Positon	12	77	6/19/98 Date
Engineer	Rift	Flushik	6/19/98 Date
	F	1600	6/19/98
Poskon	Signature	9/	Date
2A cooler by R. Ayer (System Engine	ering) and R. F	Friedrich(Design Engineeni	ng) on 6/19/98.
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ed at ambient conditions with the syst		•	
0.630 +/- 0.05 in. 1.495 +/- 0.02 in. 1.452 +/- 0.02 in. 104.25 +/- 0.25 in.			
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	Originating Organization Section: SEB Company: ComEd Units: 1 //A g and Fins for Cooler 1VY02A Engineer Position Engineer Position DE- Mech. Supv. Position Orea Universified Invening Judgement De-Power for Heat Exchanger Analysis Po-Power for Heat Exchanger Analysis obtained for the 1VY02A room coolered at ambient conditions with the system 1.495 +/- 0.05 in. 1.495 +/- 0.02 in. 1.495 +/- 0.25 in. ents were taken with a calibrated set of	Originating Organization Section: SEB Company: ComEd Units: 1 System: VY g and Fins for Cooler 1VY02A Engineer Position Engineer Position DE- Mech. Supv. Position Toved for Use Univerified Verifica Inheering Judgement Schedu De-Power for Heat Exchanger Analysis Power for Heat Exchanger Analysis Power at the request red at ambient conditions with the system shuldown. Units: 1 System: VY System: VY System: VY De-Mach. Supv. Position Position De-Mach. Supv. Position Position De-Mach. Supv. Positi	Section: SEB Company: ComEd Page 1 of Units: 1 Units: 1 System: VY g and Fins for Cooler 1VY02A Engineer Poston DE- Mech. Supv. Poston DE-Mech. Supv. Poston De-Mech Su

Proto-Power Calc: 97-200

Attachment: L

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	COMED NI	UCLEAR DESIGN INFORM	ATION TRANSMITTAL
	SAFETY-RELATED	Originating Organization	NDIT No.: LS-0835
	NON-SAFETY-RELATED	Section: SEB	Upgrade: 0
)	REGULATORY RELATED	Company ComEd	Page 2 of 2

It is not possible to obtain a measurement for longitudinal tube prich without partial disassembly of the cooler, thus this information is not included in this transmittal. It was, however, verified that successive rows of tubes/fins are offset as shown on page two of Attachment 1 of this NDIT.

Attachments:

Proto-Power Request for Information and Associated Measurements - 2 pages



ComEd - Nuclear Operations Disivion

Proto-Power Calc: 97-200

Attachment: L

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PAGE Z OF Z

Ever format is suitable for design input for the following coil layout dimensions (refer to attached sketch):

do - tube outside diameter

hfin - fin height (outside diameter of circle out by outside fin edge)

ST - transverse tube pitch (the dimension is actually tube center to tube center but the top fin edge to top fin edge dimension shown in sketch should be the same, or top tube edge to top tube edge as well).

SL - longitudinal tube pitch (tube center to tube center but front fin edge to front fin edge to front tube edge to front tube edge to front tube edge to front tube edge will work as well)

-he - finned length of coil (outer fin to outer fin)

Obviously VYOLA is the most important but the info would be good to have for all 4 coolers

Proto-Power Calc: 97-200

Attachment: L

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Attachment M to Proto-Power Calculation 97-200 Revision A

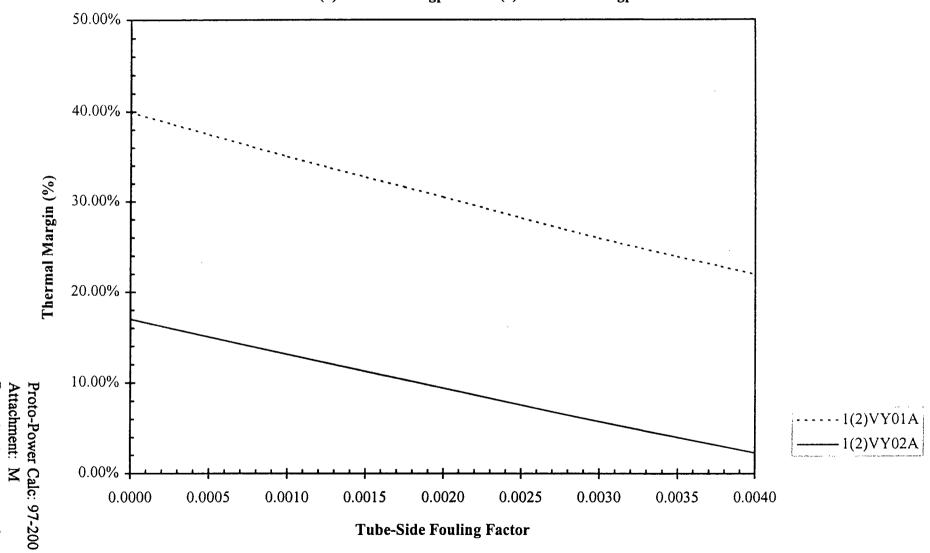
Proto-Power Calc: 97-200

Attachment: M

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Thermal Margin as a function of Tube-Side Fouling 1(2)VY01A at 75 gpm and 1(2)VY02A at 108 gpm



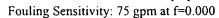
Rev: A

Page

2

Page 1

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils



Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name Tube Fouling Factor		Fresh Water
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration		VY Coolers 01A/02A
	j = EXP[-2.5088 +	-0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft	·°F)	225.00

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.000



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

wet Build Tellip Out (F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	19,289.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315



Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Fouling Sensitivity: 75 gpm at f=0.000



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,279.36	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	107.40	119.41	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ^{2.} °F/BTU)	0.00200000
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	723,937
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	723,937
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,279.36	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	959.48
Inlet Temperature (°F)	148.00	115.28	j Factor	0.0082
Outlet Temperature (°F)	139.38	119.41	Air-Side ho (BTU/hr·ft²-°F)	8.28
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2-°F/BTU)	0.00200000
Average Temp (°F)	143.69	117.34		
Skin Temperature (°F)	121.12	120.72	U Overall (BTU/hr·ft².°F)	6.51
Velocity ***	3,406.37	2.77	Effective Area (ft²)	905.33
Reynold's Number	804**	19,575	LMTD	26.07
Prandtl Number	0.7255	3.7364	Total Heat Transferred (BTU/hr)	153,767
Bulk Visc (lbm/ft·hr)	0.0490	1.3809		
Skin Visc (lbm/ft·hr)		1.3374	Surface Effectiveness (Eta)	0.9182
Density (lbm/ft³)	0.0625	61.7524	Sensible Heat Transferred (BTU/hr)	153,767
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3691	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: M

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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.001

Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	I:aSalle	VY Coolers 01A/02A
i iii comiguration		+ -0.3436 * LOG(Re)]
	j 27ti 2.5000	
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft	∵°F)	225.00
<i>y</i>	,	222.00

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.001



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	19,244.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

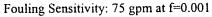
Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,113.07	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	108.73	118.75	Air-Side ho (BTU/hr-ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ^{2.} °F/BTU)	0.02088311
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft²·°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	698,599
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	698,599
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,113.07	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	956.76
Inlet Temperature (°F)	148.00	114.96	j Factor	0.0082
Outlet Temperature (°F)	140.05	118.75	Air-Side ho (BTU/hr·ft².°F)	8.27
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.02088311
Average Temp (°F)	144.03	116.85		
Skin Temperature (°F)	123.30	119.96	U Overall (BTU/hr·ft².°F)	5.79
Velocity ***	3,398.43	2.77	Effective Area (ft²)	905.33
Reynold's Number	802**	19,483	LMTD	26.95
Prandtl Number	0.7255	3.7557	Total Heat Transferred (BTU/hr)	141,344
Bulk Visc (lbm/ft·hr)	0.0490	1.3874		
Skin Visc (lbm/ft·hr)		1.3469	Surface Effectiveness (Eta)	0.9183
Density (lbm/ft³)	0.0624	61.7598	Sensible Heat Transferred (BTU/hr)	141,344
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3690	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability

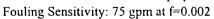


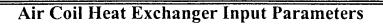
Proto-Power Calc: 97-200

Attachment: M

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





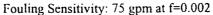
Fluid Quantity, Total 150.00 °F 105.00 °F 105.		Air-Side	Tube-Side
Inlet Wet Bulb Temp	Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Relative Humidity	Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Outlet Dry Bulb Temperature 109.40 °F 115.30 °F Outlet Wet Bulb Temp 84.10 °F Outlet Relative Humidity % Tube Fluid Name Fresh Water Tube Fouling Factor 0.002000 Air-Side Fouling 0.002000 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00	Inlet Wet Bulb Temp	92.00 °F	
Outlet Wet Bulb Temp Outlet Relative Humidity Tube Fluid Name Tube Fouling Factor Air-Side Fouling Design Heat Transfer (BTU/hr) Atmospheric Pressure Sensible Heat Ratio Performance Factor (% Reduction) Heat Exchanger Type Fin Type Fin Configuration Coil Finned Length (in) Fin Pitch (Fins/Inch) Fin Pitch (Fins/Inch) Fin Pitch (Fins/sinch) Fin Typ Thickness (inches) Fin Typ Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Transverse Tube Pitch (in) Transverse Tube Pitch (in) Tube Outside Diameter (in) Transverse Tube Pitch (in) Tube Outside Diameter Tube Pitch (in) Transverse Tube Pitch (in) Transverse Tube Pitch (in) Transverse Tube Pitch (in) Tube Outside Diameters Tube Pitch (in) Transverse Tube Pitch (in)		%	
Outlet Relative Humidity % Tube Fluid Name Fresh Water Tube Fouling Factor 0.002000 Air-Side Fouling 0.0022000 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Roductivity (BTU/hr-ft·°F) 128.000 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1	Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Tube Fluid Name Fresh Water Tube Fouling Factor 0.002000 Air-Side Fouling 0.002000 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.000 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr-ft°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.452 Number of Serpentines 1.000	Outlet Wet Bulb Temp	84.10 °F	
Tube Fouling Factor 0.002000 Air-Side Fouling 0.002000 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr-ft-°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 <t< td=""><td>Outlet Relative Humidity</td><td>%</td><td></td></t<>	Outlet Relative Humidity	%	
Air-Side Fouling 0.002000 Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Active Tubes Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452	Tube Fluid Name		Fresh Water
Design Heat Transfer (BTU/hr) 750,000 Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 10.4250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Tube Fouling Factor		0.002000
Atmospheric Pressure 14.315 Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452	Air-Side Fouling		0.002000
Sensible Heat Ratio 1.00 Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Type Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Design Heat Transfer (BTU/hr)		750,000
Performance Factor (% Reduction) 0.000 Heat Exchanger Type Counter Flow Circular Fins Fin Type Fin Type Circular Fins Circular Fins Fin Configuration LaSalle VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Atmospheric Pressure		14.315
Heat Exchanger TypeCounter Flow Circular FinsFin TypeCircular FinsFin ConfigurationLaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch)Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr-ft- $^{\circ}$ F) 128.000 Fin Tip Thickness (inches)Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 0.0120 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per RowNumber of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 1.500Tube Outside Diameter (in) 0.6250 1.500Longitudinal Tube Pitch (in) 1.500 1.452Number of Serpentines 1.000	Sensible Heat Ratio		1.00
Fin TypeCircular FinsFin ConfigurationLaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr ft °F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Performance Factor (% Reduction)		0.000
Fin ConfigurationLaSalle VY Coolers $01A/02A$ $j = EXP[-2.5088 + -0.3436 * LOG(Re)]$ Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch)Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F)Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches)Circular Fin Height (inches) 0.0120 Circular Fin Height (inches)Number of Coils Per Unit 2 Number of Tube RowsNumber of Tubes Per Row 20.00 Active Tubes Per RowTube Inside Diameter (in) 0.5270 Tube Outside Diameter (in)Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in)Transverse Tube Pitch (in) 1.500 Transverse Tube Pitch (in)Number of Serpentines 1.000	Heat Exchanger Type		Counter Flow
j = EXP[-2.5088 + -0.3436 * LOG(Re)] Coil Finned Length (in) $Fin Pitch (Fins/Inch)$ $Fin Conductivity (BTU/hr·ft·°F)$ $Fin Tonductivity (BTU/hr·ft·°F)$ $Fin Tip Thickness (inches)$ $Fin Root Thickness (inches)$ $Circular Fin Height (inches)$ $Number of Coils Per Unit$ $Number of Tube Rows$ $Number of Tubes Per Row$ $Active Tubes Per Row$ $Tube Inside Diameter (in)$ $Tube Outside Diameter (in)$ $Tube Outside Diameter (in)$ $Transverse Tube Pitch (in)$ $Transverse Tube Pitch (in)$ 1.000 $Number of Serpentines$ 1.000	Fin Type		Circular Fins
Coil Finned Length (in) 104.250 Fin Pitch (Fins/Inch) 10.000 Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) 0.0120 Fin Root Thickness (inches) 0.0120 Circular Fin Height (inches) 1.495 Number of Coils Per Unit 2 Number of Tube Rows 8 Number of Tubes Per Row 20.00 Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Fin Configuration	LaSalle	VY Coolers 01A/02A
Fin Pitch (Fins/Inch) Fin Conductivity (BTU/hr·ft·°F) 128.000 Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Transverse Tube Pitch (in) Number of Serpentines 1.000		j = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Fin Conductivity (BTU/hr·ft·°F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 1.000	Coil Finned Length (in)		104.250
Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 0.0120 0.	Fin Pitch (Fins/Inch)		10.000
Fin Root Thickness (inches) Circular Fin Height (inches) Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 0.0120 20.01 20.01 20.00 0.5270 0.6250 1.500 1.452	Fin Conductivity (BTU/hr·ft·°F)		128.000
Circular Fin Height (inches)1.495Number of Coils Per Unit2Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row20.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Fin Tip Thickness (inches)		0.0120
Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 1.000	Fin Root Thickness (inches)		0.0120
Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row20.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Circular Fin Height (inches)		1.495
Number of Tube Rows8Number of Tubes Per Row20.00Active Tubes Per Row20.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Number of Coils Per Unit		2
Number of Tubes Per Row20.00Active Tubes Per Row20.00Tube Inside Diameter (in)0.5270Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Number of Tube Rows		
Active Tubes Per Row 20.00 Tube Inside Diameter (in) 0.5270 Tube Outside Diameter (in) 0.6250 Longitudinal Tube Pitch (in) 1.500 Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Number of Tubes Per Row		
Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Active Tubes Per Row		
Tube Outside Diameter (in)0.6250Longitudinal Tube Pitch (in)1.500Transverse Tube Pitch (in)1.452Number of Serpentines1.000	Tube Inside Diameter (in)		0.5270
Longitudinal Tube Pitch (in) Transverse Tube Pitch (in) Number of Serpentines 1.000	• •		
Transverse Tube Pitch (in) 1.452 Number of Serpentines 1.000	Longitudinal Tube Pitch (in)		
	Number of Serpentines	N.,	1.000
		·°F)	

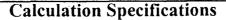
Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

T 1 Pl ()

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	75.00
Air Flow (acfm)	19,202.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: M

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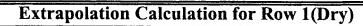


Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.002

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr-ft2.°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	109.96	118.09	Air-Side ho (BTU/hr-ft2.°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ² .°F/BTU)	0.03976622
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	675,177
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	675,177
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,957.87	37,293.47	Tube-Side hi (BTU/hr·ft².ºF)	953.95
Inlet Temperature (°F)	148.00	114.57	j Factor	0.0082
Outlet Temperature (°F)	140.61	118.09	Air-Side ho (BTU/hr·ft².°F)	8.26
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.03976622
Average Temp (°F)	144.30	116.33		
Skin Temperature (°F)	125.07	119.22	U Overall (BTU/hr·ft²-°F)	5.22
Velocity ***	3,391.01	2.77	Effective Area (ft²)	905.33
Reynold's Number	800**	19,386	LMTD	27.78
Prandtl Number	0.7255	3.7764	Total Heat Transferred (BTU/hr)	131,195
Bulk Visc (lbm/ft·hr)	0.0490	1.3943		
Skin Visc (lbm/ft·hr)		1.3564	Surface Effectiveness (Eta)	0.9184
Density (lbm/ft³)	0.0623	61.7676	Sensible Heat Transferred (BTU/hr)	131,195
Cp (BTU/lbm.°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3688	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

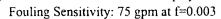
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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.003000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr ft-	°F)	225.00

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.003



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

75.00
19,160.00
100.00
148.0
12.76
0.00
14.315

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils Fouling Sensitivity: 75 gpm at f=0.003



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,802.66	37,293.47	Tube-Side hi (BTU/hr-ft²-°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	111.21	117.53	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft2.°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft2.0F/BTU)	0.05864934
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	651,570
Bulk Visc (lbm/ft·hr)		1		
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	651,570
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,802.66	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	951.56
Inlet Temperature (°F)	148.00	114.25	j Factor	0.0082
Outlet Temperature (°F)	141.09	117.53	Air-Side ho (BTU/hr·ft².°F)	8.25
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU)	0.05864934
Average Temp (°F)	144.55	115.89		
Skin Temperature (°F)	126.60	118.59	U Overall (BTU/hr-ft²-°F)	4.74
Velocity ***	3,383.59	2.77	Effective Area (ft²)	905.33
Reynold's Number	798**	19,303	LMTD	28.49
Prandtl Number	0.7254	3.7942	Total Heat Transferred (BTU/hr)	122,373
Bulk Visc (lbm/ft·hr)	0.0490	1.4003		
Skin Visc (lbm/ft·hr)		1.3646	Surface Effectiveness (Eta)	0.9185
Density (lbm/ft³)	0.0623	61.7743	Sensible Heat Transferred (BTU/hr)	122,373
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3686	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

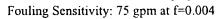
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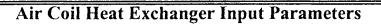
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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.004000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
,		Country Elem
Heat Exchanger Type Fin Type		Counter Flow Circular Fins
Fin Configuration	LaSalla	VY Coolers 01 A/02A
i iii Comiguration		+ -0.3436 * LOG(Re)]
	J - LAI (-2.5000	-0.5450 LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1 000
Tube Wall Conductivity (BTU/hr-ft	·o E)	1.000 225.00
race wan conductivity (B10/III II	1)	223.00

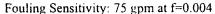
Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

<u> </u>	
Tube Flow (gpm)	75.00
Air Flow (acfm)	19,123.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: M

Rev: A Page 16 of 32



Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.004



17:35:11

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,665.94	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	112.31	116.92	Air-Side ho (BTU/hr ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft².ºF/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ² .°F/BTU)	0.07753245
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft²·°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	630,961
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	630,961
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,665.94	37,293.47	Tube-Side hi (BTU/hr·ft².°F)	948.87
Inlet Temperature (°F)	148.00	113.83	j Factor	0.0082
Outlet Temperature (°F)	141.49	116.92	Air-Side ho (BTU/hr·ft².°F)	8.24
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.07753245
Average Temp (°F)	144.74	115.38		
Skin Temperature (°F)	127.86	117.92	U Overall (BTU/hr·ft².°F)	4.35
Velocity ***	3,377.06	2.77	Effective Area (ft²)	905.33
Reynold's Number	796**	19,208	LMTD	29.23
Prandtl Number	0.7254	3.8149	Total Heat Transferred (BTU/hr)	115,100
Bulk Visc (lbm/ft·hr)	0.0490	1.4073		
Skin Visc (lbm/ft·hr)		1.3733	Surface Effectiveness (Eta)	0.9186
Density (lbm/ft³)	0.0623	61.7819	Sensible Heat Transferred (BTU/hr)	115,100
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3684	Heat to Condensate (BTU/hr)	

^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: M

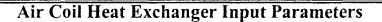
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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.000



	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		2 2 2 2 3 7 7 4 4 4 4 4
Air-Side Fouling		0.002000
D ' II . T C (DWIII)		
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure Sensible Heat Ratio		14.315
		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088]	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
N. I. COURT WITH		
Number of Coils Per Unit Number of Tube Rows		2
Number of Tubes Per Row		8
Active Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr·ft·	PE)	1.000
race wan conductivity (DTO/III.	Γ)	225.00

Proto-Power Calc: 97-200

Attachment: M

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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.000



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

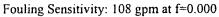
Tube Flow (gpm)	108.00
Air Flow (acfm)	19,347.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,493.69	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	105.73	114.11	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr ft2.°F/BTU)	0.00200000
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	756,011
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	756,011
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,493.69	53,702.59	Tube-Side hi (BTU/hr-ft2.0F)	1,251.72
Inlet Temperature (°F)	148.00	110.69	j Factor	0.0082
Outlet Temperature (°F)	137.73	114.11	Air-Side ho (BTU/hr·ft².°F)	8.29
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr ft2.°F/BTU)	0.00200000
Average Temp (°F)	142.87	112.40		
Skin Temperature (°F)	115.96	115.49	U Overall (BTU/hr·ft².°F)	6.72
Velocity ***	3,416.62	3.98	Effective Area (ft²)	905.33
Reynold's Number	807**	26,863	LMTD	30.16
Prandtl Number	0.7256	3.9391	Total Heat Transferred (BTU/hr)	183,607
Bulk Visc (lbm/ft·hr)	0.0489	1.4490	,	
Skin Visc (lbm/ft·hr)		1.4058	Surface Effectiveness (Eta)	0.9181
Density (lbm/ft³)	0.0626	61.8257	Sensible Heat Transferred (BTU/hr)	183,607
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3674	Heat to Condensate (BTU/hr)	
** Reynolds Number Outside	Pange of Equation	. Applicability	•	

** Reynolds Number Outside Range of Equation Applicability

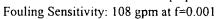


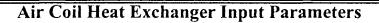
Proto-Power Calc: 97-200

Attachment: M

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.001000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
	j = EXP[-2.5088 +	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft-	°F)	225.00
		_

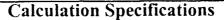
Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.001



Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

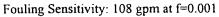
108.00
19,301.00
100.00
148.0
12.76
0.00
14.315

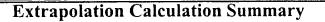
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,323.71	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	107.03	113.64	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft².ºF/BTU 0.00031430)
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU) 0.02088311	
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²) 7,242.65	;
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr) 731,028	,
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)		•	Sensible Heat Transferred (BTU/hr) 731,028	;
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,323.71	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,249.18
Inlet Temperature (°F)	148.00	110.52	j Factor	0.0082
Outlet Temperature (°F)	138.63	113.64	Air-Side ho (BTU/hr·ft².°F)	8.28
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft²-°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².ºF/BTU)	0.02088311
Average Temp (°F)	143.32	112.08		
Skin Temperature (°F)	118.84	114.90	U Overall (BTU/hr·ft ² ·°F)	5.96
Velocity ***	3,408.49	3.98	Effective Area (ft²)	905.33
Reynold's Number	805**	26,780	LMTD	30.98
Prandtl Number	0.7255	3.9527	Total Heat Transferred (BTU/hr)	167,164
Bulk Visc (lbm/ft·hr)	0.0489	1.4535		
Skin Visc (lbm/ft·hr)		1.4139	Surface Effectiveness (Eta)	0.9182
Density (lbm/ft³)	0.0626	61.8302	Sensible Heat Transferred (BTU/hr)	167,164
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3673	Heat to Condensate (BTU/hr)	
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^{**} Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

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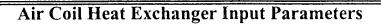
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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000)

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.002



	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr) Atmospheric Pressure Sensible Heat Ratio		750,000 14.315 1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type Fin Type Fin Configuration		Counter Flow Circular Fins VY Coolers 01A/02A + -0.3436 * LOG(Re)]
Coil Finned Length (in) Fin Pitch (Fins/Inch) Fin Conductivity (BTU/hr·ft·°F) Fin Tip Thickness (inches) Fin Root Thickness (inches) Circular Fin Height (inches)		104.250 10.000 128.000 0.0120 0.0120 1.495
Number of Coils Per Unit Number of Tube Rows Number of Tubes Per Row Active Tubes Per Row		2 8 20.00 20.00
Tube Inside Diameter (in) Tube Outside Diameter (in) Longitudinal Tube Pitch (in) Transverse Tube Pitch (in)		0.5270 0.6250 1.500 1.452
Number of Serpentines Tube Wall Conductivity (BTU/hr-ft-	°F)	1.000 225.00

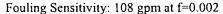
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,258.50
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

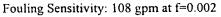
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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	108.29	113.17	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².ºF/BTU 0.00	0031430
Outlet Specific Humidity			Overall Fouling (hr-ft ^{2.} °F/BTU) 0.03	3976622
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	707,030
Bulk Visc (lbm/ft·hr)			•	
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	707,030
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,166.65	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,246.55
Inlet Temperature (°F)	148.00	110.31	j Factor	0.0082
Outlet Temperature (°F)	139.36	113.17	Air-Side ho (BTU/hr-ft2.°F)	8.27
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft².°F/BTU)	0.03976622
Average Temp (°F)	143.68	111.74		
Skin Temperature (°F)	121.18	114.33	U Overall (BTU/hr·ft²·°F)	5.35
Velocity ***	3,400.99	3.98	Effective Area (ft²)	905.33
Reynold's Number	803**	26,688	LMTD	31.73
Prandtl Number	0.7255	3.9675	Total Heat Transferred (BTU/hr)	153,749
Bulk Visc (lbm/ft·hr)	0.0490	1.4585		
Skin Visc (lbm/ft·hr)		1.4217	Surface Effectiveness (Eta)	0.9183
Density (lbm/ft³)	0.0625	61.8352	Sensible Heat Transferred (BTU/hr)	153,749
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3672	Heat to Condensate (BTU/hr)	
			•	

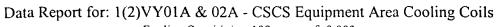
^{**} Reynolds Number Outside Range of Equation Applicability



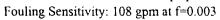
Proto-Power Calc: 97-200

Attachment: M

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Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.003000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
,		
Heat Exchanger Type		Counter Flow
Fin Type		Circular Fins
Fin Configuration		VY Coolers 01A/02A
	J = EXP[-2.5088 -	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
• •		
Number of Serpentines Tube Wall Conductivity (BTU/hr·ft·	.oe)	1.000
rube wan Conductivity (D1 U/nr-n	Г	225.00

Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.003



Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,216.50
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315

Proto-Power Calc: 97-200

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06/22/98

ComEd -- LaSalle

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.003

Ext

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,011.45	53,702.59	Tube-Side hi (BTU/hr-ft2.°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	109.53	112.75	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft².ºF/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft².°F/BTU)	0.05864934
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft².°F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	683,298
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	683,298
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

			'	
	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,011.45	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	1,244.16
Inlet Temperature (°F)	148.00	110.10	j Factor	0.0082
Outlet Temperature (°F)	139.98	112.75	Air-Side ho (BTU/hr·ft².°F)	8.26
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr-ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²-°F/BTU)	0.05864934
Average Temp (°F)	143.99	111.42		
Skin Temperature (°F)	123.15	113.82	U Overall (BTU/hr·ft².°F)	4.86
Velocity ***	3,393.57	3.98	Effective Area (ft²)	905.33
Reynold's Number	801**	26,605	LMTD	32.39
Prandtl Number	0.7255	3.9812	Total Heat Transferred (BTU/hr)	142,406
Bulk Visc (lbm/ft·hr)	0.0490	1.4630		
Skin Visc (lbm/ft·hr)		1.4288	Surface Effectiveness (Eta)	0.9184
Density (lbm/ft³)	0.0624	61.8397	Sensible Heat Transferred (BTU/hr)	142,406
Cp (BTU/lbm.°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3671	Heat to Condensate (BTU/hr)	

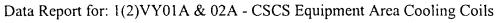
** Reynolds Number Outside Range of Equation Applicability

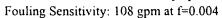


Proto-Power Calc: 97-200

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Air Coil Heat Exchanger Input Parameters

	Air-Side	Tube-Side
Fluid Quantity, Total	21,179.00 acfm	150.00 gpm
Inlet Dry Bulb Temp	150.00 °F	105.00 °F
Inlet Wet Bulb Temp	92.00 °F	
Inlet Relative Humidity	%	
Outlet Dry Bulb Temperature	109.40 °F	115.30 °F
Outlet Wet Bulb Temp	84.10 °F	
Outlet Relative Humidity	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.004000
Air-Side Fouling		0.002000
Design Heat Transfer (BTU/hr)		750,000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1.00
Performance Factor (% Reduction)		0.000
Heat Exchanger Type	•	Counter Flow
Fin Type		Circular Fins
Fin Configuration	LaSalle	VY Coolers 01A/02A
-	$j = EXP[-2.5088 \cdot$	+ -0.3436 * LOG(Re)]
Coil Finned Length (in)		104.250
Fin Pitch (Fins/Inch)		10.000
Fin Conductivity (BTU/hr·ft·°F)		128.000
Fin Tip Thickness (inches)		0.0120
Fin Root Thickness (inches)		0.0120
Circular Fin Height (inches)		1.495
Number of Coils Per Unit		2
Number of Tube Rows		8
Number of Tubes Per Row		20.00
Active Tubes Per Row		20.00
Tube Inside Diameter (in)		0.5270
Tube Outside Diameter (in)		0.6250
Longitudinal Tube Pitch (in)		1.500
Transverse Tube Pitch (in)		1.452
Number of Serpentines		1.000
Tube Wall Conductivity (BTU/hr-ft-c	'F)	225.00
	- ,	223.00

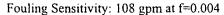
Proto-Power Calc: 97-200

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils





Calculation Specifications

Constant Inlet Temperature Method Was Used Extrapolation Was to User Specified Conditions Design Fouling Factors Were Used

Test Data

Data Date

Air Flow (acfm)

Air Dry Bulb Temp In (°F)

Air Dry Bulb Temp Out (°F)

Relative Humidity In (%)

Relative Humidity Out (%)

Wet Bulb Temp In (°F)

Wet Bulb Temp Out (°F)

Atmospheric Pressure

Tube Flow (gpm)

Tube Temp In (°F)

Tube Temp Out (°F)

Condensate Temperature (°F)

Extrapolation Data

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,177.00
Tube Inlet Temp (°F)	100.00
Air Inlet Temp (°F)	148.0
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure	14.315



Proto-Power Calc: 97-200

Attachment: M

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.004



Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,865.48	53,702.59	Tube-Side hi (BTU/hr·ft².°F)	
Inlet Temperature (°F)	148.00	100.00	j Factor	
Outlet Temperature (°F)	110.71	112.33	Air-Side ho (BTU/hr·ft².°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr-ft².°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr-ft ² .°F/BTU)	0.07753245
Average Temp (°F)				
Skin Temperature (°F)			U Overall (BTU/hr·ft ^{2.} °F)	
Velocity ***			Effective Area (ft²)	7,242.65
Reynold's Number			LMTD	
Prandtl Number			Total Heat Transferred (BTU/hr)	660,999
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	660,999
Cp (BTU/lbm·°F)			Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)			Heat to Condensate (BTU/hr)	



Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,865.48	53,702.59	Tube-Side hi (BTU/hr·ft²·°F)	1,241.70
Inlet Temperature (°F)	148.00	109.85	j Factor	0.0082
Outlet Temperature (°F)	140.51	112.33	Air-Side ho (BTU/hr·ft².°F)	8.25
Inlet Specific Humidity	0.0203		Tube Wall Resistance (hr·ft².°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr-ft2.°F/BTU)	0.07753245
Average Temp (°F)	144.25	111.09		
Skin Temperature (°F)	124.81	113.33	U Overall (BTU/hr·ft².°F)	4.44
Velocity ***	3,386.59	3.98	Effective Area (ft²)	905.33
Reynold's Number	799**	26,517	LMTD	33.01
Prandtl Number	0.7255	3.9957	Total Heat Transferred (BTU/hr)	132,834
Bulk Visc (lbm/ft·hr)	0.0490	1.4679	· · · · · ·	
Skin Visc (lbm/ft·hr)		1.4357	Surface Effectiveness (Eta)	0.9185
Density (lbm/ft³)	0.0624	61.8445	Sensible Heat Transferred (BTU/hr)	132,834
Cp (BTU/lbm·°F)	0.2402	0.9988	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0162	0.3669	Heat to Condensate (BTU/hr)	
			•	

** Reynolds Number Outside Range of Equation Applicability



Proto-Power Calc: 97-200

Attachment: M

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Attachment N to Proto-Power Calculation 97-200 Revision A

Proto-Power Calc: 97-200

Attachment: N

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Proto-HX Model Database



Saved on attached disk as:

Name:

vy-0102a.phx

Size:

1,146,880 bytes

Date:

6/24/98

Time:

2:25:30 pm





Proto-Power Calc: 97-200

Attachment: N

Rev: A Page 2 of 2

PROTO-POWER CORPORATION CALCULATION TITLE SHEET

CLIENT:

Commonwealth Edison / LaSalle County Station

PROJECT:

COMED / LaSalle Station GL 89-13 Program

CALCULATION TITLE:

Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2

Diesel Generator Jacket Water Coolers

CALCULATION NO.:

97-195

FILE NO.:

31-003

COMPUTER CODE & VERSION (if applicable): PROTO-HX ver 3.02

REV	TOTAL NO. OF PAGES	ORIGINATOR/DATE	VERIFIER/DATE	APPROVAL/DATE
A	73	D. Phyfe	S. Ingalls	L. Philpot 430/95

Page i of v



Form No.: <u>P1050101</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

Ref.: P&I 5-1

PROTO-POWER CORPORATION	CALC NO. 97-195	REV A	PAGE ii OF V
GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/29/98
	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
TITLE Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

Revision History

Revision	Revision Description
A	Original Issue



Form No.: <u>P1050102</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/29/98
	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		89-13 Program
Thermal Model of COMED / LaSalle St	ation Unit 0, 1, and 2 Diesel	Generator J	acket Water Coolers

CALCULATION VERIFICATION FORM

	,		EXTENT OF VERIFICA	ATION:	
Approach Checked:	I	N/A 🔲	Complete Calculation:	d	
Logic Checked: Arithmetic Checked:	岩	N/A 🗍 N/A 🗍	Revised areas only:	П	
Alternate Method		N/A ☑	·		
(Attach Brief Summary) Computer Program Used		N/A	Other (describe below):		
(Attach Listing) Other		N/A		_	
*Errors Detected			*Error Resolution		
Minor Editional			Cornecked		
*O41					
*Other Comments					
*Other Comments					
*Other Comments					
*Other Comments					
*Other Comments					
*Other Comments *Extra References Used					
*Extra References Used	E VALID A	AND CONCLUSI	IONS TO BE CORRECT AND F	REASONABL	E:
*Extra References Used *(Attach extra sheets if needed) CALCULATION FOUND TO B	E VALID A	AND CONCLUSI	IONS TO BE CORRECT AND F		E:
*Extra References Used *(Attach extra sheets if needed)	E VALID A	AND CONCLUSI	IONS TO BE CORRECT AND F	REASONABL Initials:	E:



Form No.: <u>PI050103</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

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	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
TITLE Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

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Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

LIST OF ATTACHMENTS				
<u>Attachment</u>	Subject Matter	Total Pages		
A	Proto-Power Calc. 97-195, Rev. A;	3		
	Vendor Supplied Hx. Information			
В	Proto-Power Calc. 97-195, Rev. A;	3		
	Sargent & Lundy Specification J-2544			
C	Proto-Power Calc. 97-195, Rev. A;	7		
	Form N-1 Manufacturer's Data Report for Nuclear Vessels			
D	Proto-Power Calc. 97-195, Rev. A;	5		
	LaSalle Station UFSAR Sections: 9.2.1.1.1, 9.5.5.1.1, FSAR Q40.92			
E	Proto-Power Calc. 97-195, Rev. A;	13		
	PROTO-HX TM Calculation Reports and Model Data Sheets			
F	Proto-Power Calc. 97-195, Rev. A;	6		
	PROTO-HX™ Calculation Reports for Fouling Sensitivity			
G	Proto-Power Calc. 97-195, Rev. A;	17		
	PROTO-HX™ Calculation Reports for Minimum Service Water Flow			
Н	Proto-Power Calc. 97-195, Rev. A;	2		
	PROTO-HX™ Version 3.02 Model	(and disk)		

Complete Calc (total number of pages)



Form No.: <u>P1050104</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

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	GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/29/98
)		VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIE	NT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers				

1. PURPOSE

The purpose of this calculation is to develop a thermal performance analysis model for the Commonwealth Edison (ComEd) LaSalle Station, Standby Diesel Generator heat exchanger. This model is to be used for the analysis of heat exchanger thermal performance test data as part of the LaSalle Station heat exchanger testing program.

Once developed, the model is used to evaluate the thermal margin of the heat exchanger at the LaSalle Station Reference Conditions as currently defined in the LaSalle design and licensing basis.

The thermal performance model documented in this calculation has been created and used with PROTO-HX, Version 3.02. The model can be used with previous versions of PROTO-HX and produce identical results as long as the following restrictions are upheld:

- Versions prior to version 3.02 will not calculate a negative fouling factor when calculating the fouling factor based on test data.
- Shell and tube heat exchangers analyzed in Version 3.0 or earlier must have a tube-side Reynolds Number greater than 10,000 (i.e., fully developed turbulent flow).

Current limitations of use for PROTO-HX are established by the limits on fluid properties included within the software. Fluid properties contained within PROTO-HX are currently limited to the following temperature ranges:

Water (fresh and salt): 32-500°F

2. BACKGROUND

LaSalle Station is in the process of implementing a heat exchanger thermal performance monitoring program in response to the requirements of NRC Generic Letter 89-13 (Reference 8.2). Development of an analytical model in PROTO-HXTM, Version 3.02, will allow timely analysis of data resulting from the test program.

3. DESIGN INPUTS

The PROTO-HXTM program was developed and validated in accordance with Proto-Power's Nuclear Software Quality Assurance Program (SQAP). This program meets the requirements of 10CFR50 Appendix B, 10CFR21, and ANSI NQA-1, and was developed in accordance with the guidelines and standards contained in ANSI/IEEE Standard 730/1984 and ANSI NQA-2b-1991. PROTO-HXTM Version 3.02 was verified and approved for use as documented in Reference 8.10.

The design inputs for this calculation consist of the heat exchanger design basis requirement (Section 3.1), construction details (Section 3.2), and performance specifications (Section 3.3) provided by the Hx manufacturer data sheets or design documents as referenced. Construction



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GROTON, CONNECTICUT	ORIGINATOR D. Phyfe		DATE 6/29/98
	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIENT COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		
Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

details give the necessary information for model construction while performance specifications provided by the manufacturer are used to benchmark the model.

Thermal performance of the Standby diesel generator heat exchanger is assessed in this calculation at the LaSalle Station Reference Conditions of Section 3.1 with all tubes active at 100% and 110% of rated load. No tube plugging margin is considered.

3.1. LASALLE STATION REFERENCE CONDITIONS

Table 3-1 describes the performance requirement of the jacket water cooler. These conditions ensure that the engine operating temperature range will not be exceeded.

Table 3-1 LaSalle Station Reference Conditions

Parameter	Value	Reference
Heat Load at 100% power/110% power (BTU/hr)	7,800,000 / 8,600,000	8.1, 8.4
Shell-Side Flow Rate (gpm)	1,100	8.4
Shell-Side Inlet Temperature (°F)	190	8.4
Tube-Side Flow Rate (gpm)	800	8.1, 8.4
Tube-Side Inlet Temperature (°F)	100	8.1

3.2. CONSTRUCTION DETAILS

Table 3-2 Construction Details

Parameter	Value	Reference
Heat Exchanger Type	AEW	8.11
Total Effective Area per unit (ft²)	479	8.11
Number of Shells per unit	ı	8.11
Shell Velocity (ft/sec)	5	8.11
Tube Passes per shell	2	8.11
U-Tubes (yes or no)	No	8.11
Total Number of Tubes	188	8.11
Tube Length (ft)	13	8.11
Tube Inside Diameter (in)	0.652 (18 BWG)	8.11
Tube Outside Diameter (in)	0.750	8.11
Stationary Tubesheet Thickness (in)	0.938	8.3
Floating Tubesheet Thickness (in)	1.875	8.3
Tube Wall Conductivity (BTU/hr-ft-°F)	112 (Arsenical Cooper)	8.9, (8.11)
Tube Pitch (in)	0.750	8.11

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	VERIFIED BY S. Ingalls		JOB NO. 31-003
CLIEST COMED / LaSalle County Station	PROJECT COMED / LaSalle Station GL 89-13 Program		89-13 Program
TITLE Thermal Model of COMED / LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers			

Table 3-2 Construction Details

Parameter	Value	Reference
Pitch Type	Triangle	8.11

The vendor data sheet shows the effective area as 479 $\rm ft^2$, however, based on the outside tube diameter and tube length, this value is a gross area ($A_{\rm gr}$) approximation:

$$A_{gr} = (number of tubes) \cdot (L_{tube}) \cdot (tube outside circ.)$$

Equation 1

$$A_{gr} = 188 \cdot 13 \,\text{ft} \cdot \pi \cdot \left(\frac{0.750 \,\text{in}}{12 \,\text{in/ft}} \right) = 479.878 \,\text{ft}^2$$

The effective area (A_{eff}) can be approximated as follows:

$$A_{eff} = (number of tubes) \cdot (L_{tube} - T_{fixed} - T_{floating}) \cdot (tube outside circ.)$$

Equation 2

$$A_{eff} = 188 \cdot \left(13 \, \text{ft} - \frac{\left(0.938 \, \text{in} + 1.875 \, \text{in}\right)}{12 \, \text{in/ft}}\right) \cdot \pi \cdot \left(\frac{0.750 \, \text{in}}{12 \, \text{in/ft}}\right) = 471.2251 \, \text{ft}^2$$

where:

A_{gr} – Heat Exchanger Gross Area, st²

A_{eff} – Heat Exchanger Effective Area, ft²

L_{tube} - Tube Length, ft

T_{fixed} - Fixed End Tubesheet Thickness, ft (0.938" per Reference 8.3)

T_{floating} - Floating End Tubesheet Thickness, ft (1.875" per Reference 8.3)

The data sheet value for the effective area will be used in the model benchmarking process. However, for PROTO-HXTM runs of the Standby heat exchanger model the above calculated effective area will be used.

3.3. Performance Details

Table 3-3 Performance Details

Parameter	Value	Reference	
Shell Side Fluid Type	Jacket Water (Fresh)	8.11	
Total Fouling Factor (Design)	0.00285	8.11	
Shell Side Fluid Flow Rate (lb/hr)	550,000	8.11	
Shell Side Inlet Temperature (°F)	190	8.11	
Shell Side Outlet Temperature (°F)	174.4	8.11	
Tube Side Fluid Type	Service Water (Fresh)	8.1/8.7	

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Table 3-3 Performance Details

Parameter	Value	Reference
Tube Side Fluid Flow Rate (lb/hr)	388,000	8.11
Tube Side Inlet Temperature (°F)	100	8.11
Tube Side Outlet Temperature (°F)	122.2	8.11
Hx. Design Q - Service (BTU/hr)	8,600,000	8.11
Hx. Design U - Service (BTU/hr-ft²-°F)	255.2	8.11

4. APPROACH

This calculation utilizes plant/vendor fabrication specifications provided in Attachment (A) to develop a thermal performance prediction model for the LaSalle Station Unit 0, 1, and 2 Diesel Generator Jacket Water Coolers. The calculation then benchmarks the model by comparing the heat transfer rate calculated by PROTO-HXTM Version 3.02 with the manufacturer's specifications for thermal performance.

4.1. PROTO-HXTM PARAMETER CALCULATION

Minimum Shell Area

The minimum shell area is calculated using either the shell side velocity or a shell geometry. The preferred method of calculation is using the shell side velocity. Reference 8.11 gives the shell side velocity to be 5 ft/sec at a flow rate of 1100 gpm. Based on this velocity and flow rate the minimum shell side area is calculated by PROTO-HXTM to be 0.490 ft².

Outside H Factor (Hoff)

The Outside H Factor is a multiplier, with value less then 1.0, used to reduce the ideal shell side film heat transfer coefficient. The Outside H Factor accounts for inefficiency in the heat exchanger. Using the back calculation method, based on the design overall heat transfer coefficient, the Outside H Factor was calculated by PROTO-HXTM to be 0.780.

4.2. PROTO-HXTM FLOW RATE INPUTS

Volumetric flow rates are converted to mass flow rates based on a set temperature of 60°F in PROTO-HXTM. Therefore, the actual PROTO-HXTM inputs have to be adjusted to give the correct mass flow rate. The PROTO-HXTM input is adjusted using the ratio of the actual water density and the density of water at 60°F.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60^{\circ}F}}$$

Equation 3



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Table 4-1 PROTO-HX™ Flow Rate Inputs

Parameter	Density (lb/ft³)	Actual Flow (gpm)	PROTO-HX™	Input (gpm)
Tube-side, 100°F	61.994 (8.12)	800	795.25	
Shell-side, 190°F	60.349 (8.12)	1,100	1,064.495	
PROTO-HX™, 60°F	62:364 (8.12)			

4.3. PROTO-HXTM EXTRAPOLATION METHOD

All calculations performed for this calculation are based on a constant cold inlet temperature. This allows the comparison of the heat transfer, outlet temperatures, log mean temperature difference (LMTD), and overall heat transfer coefficient. There is no comparison of the overall heat transfer coefficient in the design case since PROTO-HXTM used the data sheet value of the overall heat transfer coefficient to calculate the shell side film heat transfer coefficient.

5. ASSUMPTIONS

5.1. The vendor data sheet (Reference 8.11) is considered an accurate reflection of the vendor's expectation for the heat exchanger's outside film heat transfer coefficient. Therefore, the benchmarking of the PROTO-HXTM model to the vendor data sheet will ensure that the PROTO-HXTM calculated outside film heat transfer coefficient is consistent with the vendor's expectation. The PROTO-HXTM model is benchmarked with the vendor data sheet effective area. However, calculations performed with the model use the effective area determined in Section 3.2. Future validation of this assumption is not required.

6. ANALYSIS

6.1. PROTO-HXTM MODEL

Table 6-1 shows the PROTO-HXTM benchmarking of the Jacket Water Cooler for the Standby Diesel Generator. The PROTO-HXTM reports can be found in Attachment E.

Table 6-1 Model Benchmark Correlation

Parameter	PROTO-HXTM	Data Sheet	Percent Difference
Effective Area, ft ²	479	479	0.00 %
Shell Side Outlet Temp, °F	174.4	174.4	0.00 %
Tube Side Outlet Temp, ^e F	122.2	122.2	0.00 %
Heat Transferred, BTU/hr	8,589,000	8,600,000	-0.13 %
Corrected LMTD	70.3	70.2	0.14 %

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Table 6-2 shows the PROTO-HXTM results for the heat exchanger design conditions using the corrected effective area, Section 3.2. The PROTO-HXTM reports can be found in Attachment E.

Table 6-2 Model Design Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft ²	471.2	479	-1.63 %
Shell Side Outlet Temp, °F	174.6	174.4	0.11 %
Tube Side Outlet Temp, °F	121.9	122.2	-0.25 %
Heat Transferred, BTU/hr	8,481,000	8,600,000	-1.38 %
Corrected LMTD	70.5	70.2	0.43 %

All PROTO-HXTM calculations performed with the Standby Jacket Water Cooler model will use the effective area of 471.23 ft². This change is made to the PROTO-HXTM heat exchanger data sheet as shown in Attachment E.

6.2. HEAT EXCHANGER FOULING FACTOR LIMIT

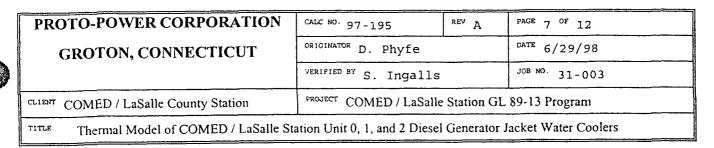
In order for the jacket water cooler to meet the Reference Conditions (Table 3-1) the fouling must be limited from the values listed on the vendor's data sheet (Reference 8.11). The overall fouling factor limit was determined by iterating on the overall fouling factor, a PROTO-HXTM input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HXTM runs for the limited fouling factor case, see Attachment E.

Table 6-3 Fouling Factor Limit

Parameter	Design Fouling	Limited Fouling
Overall Fouling Factor	0.00285	0.002782
Overall Heat Transfer Coefficient	255.2	259.7
Heat Transfer Rate	8,484,000	8,600,000
Required Heat Transfer Rate	8,600,000	8,600,000
Thermal Margin	-116,000	0.0
% Thermal Margin	1.35 %	0.00 %

The limitations on the fouling factor are placed on the tube-side fouling factor, since the tube-side is the most controllable via periodic tube-side cleaning. To be consistent with the HPCS Diesel the shell-side fouling factor will be set to 0.0005 hr ft² °F/Btu for this analysis. The tube-side fouling factor is calculated from the overall fouling found from the PROTO-HXTM iteration process.





The area ratio is used to convert the overall fouling factor to a tube-side and shell-side fouling factor

$$f_{total} = f_{shell} + (Area Ratio) \cdot f_{tube}$$

Equation 4

Area Ratio =
$$\frac{\text{Tube OD}}{\text{Tube ID}}$$

Equation 5

Area Ratio =
$$\frac{0.750 \,\text{in}}{0.652 \,\text{in}} = 1.150$$

From the vendor datasheet the design overall fouling factor is

$$f_{\text{Total}} = 0.002850 \, \text{hr ft}^2 \, \text{°F} / \text{Btu}$$

From the PROTO - HX iteration the adjusted overall fouling factor is found:

$$f_{adjusted} = 0.002782 \frac{hr ft^2}{Btu}$$

From the new overall fouling factor the new tube - side fouling factor is calculated:

$$f_{\text{tube}} = \frac{\left(f_{\text{adjusted}} - f_{\text{shell}}\right)}{\text{Area Ratio}} = \frac{\left(0.002782 - 0.0005\right)^{\text{hr ft}^2 \circ \text{F}}}{1.150} = 0.001984^{\text{hr ft}^2 \circ \text{F}}$$

The PROTO-HX[™] heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

Attachment E includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HXTM data sheet.

6.3. FOULING SENSITIVITY

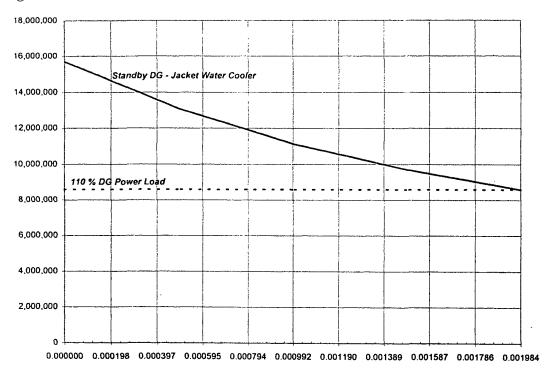
The fouling sensitivity of the jacket water cooler is shown in Figure 6-1. The fouling sensitivity was developed at 800 gpm CSCS flow, 100°F CSCS inlet temperature, 1100 gpm jacket water flow, and 190°F jacket water inlet temperature. The tube-side fouling factor was varied from 0.0000 to 0.001984 (hr ft² °F/Btu) by increments of 0.0005 (hr ft² °F/Btu). As in Section 6.2, the shell-side fouling factor is held constant at 0.0005 (hr ft² °F/Btu). The PROTO-HXTM Calculation Reports for the fouling sensitivity can be found in Attachment F.



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Figure 6-1



6.4. THERMAL MARGIN ASSESSMENT

The clean thermal margin is assessed by a comparison of the reference condition performance requirements to the heat exchanger performance capability with a zero (0) fouling factor. Using a zero (0) fouling factor shows the maximum available performance of the heat exchanger. Likewise, the service thermal margin is assessed by comparing the reference condition performance requirements to the heat exchanger performance capability with the design fouling factor.

The margin is calculated directly and as a percentage compared to the required heat rate to perform the component's safety function. The PROTO-HXTM reports can be found in Attachment E.

margin=Heat Rate - Heat Rate required

Equation 6

$$\% \text{ margin} = 100 \cdot \left(\frac{\text{margin}}{\text{Heat Rate}_{\text{required}}} \right)$$

Equation 7

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Table 6-4 Thermal Margin

Parameter	Service (Design Fouling)	Clean (0 Fouling)
Overall Heat Transfer Coefficient	259.7	955.9
Heat Transfer Rate	8,600,000	18,850,000
Required Heat Transfer Rate	8,600,000	8,600,000
Thermal Margin	0.0	10,250,000
% Thermal Margin	0.00 %	119.19 %

6.5. MINIMUM SERVICE WATER FLOW RATE

The minimum service water flow rate for the adjusted design fouling condition is calculated with the shell-side inlet temperature at 190°F and a flow rate of 1,100 gpm. Iterating using the service water flow rate and inlet temperature, the minimum acceptable flow rate is found for each inlet temperature (Attachment G). The heat load for each iteration must be equal to or slightly above the required heat load of 7,800,000 BTU/hr and 8,600,000 BTU/hr, the diesel heat load at 100% and 110% power, respectively (Reference 8.1). Figure 6-2 shows the results of this iteration process.

The results of the model iterations are summarized in Table 6-5 and Table 6-6 along with Figure 6-2. Density corrections of the PROTO-HXTM flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.12.

Table 6-5 Minimum CSCS Flow Rate at 100% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HX TM Input Flow Rate (gpm)	Density Corrected Flow Rate (gpm)
35	62.41903	161.1	161.0
40	62.42184	169.8	169.6
50	62.40595	190.5	190.3
60	62.36445	217.5	217.5
70	62.30034	254.2	254.5
80	62.21603	307.0	307.7
90	62.11349	389.3	390.9
100	61.99437	534.5	537.7



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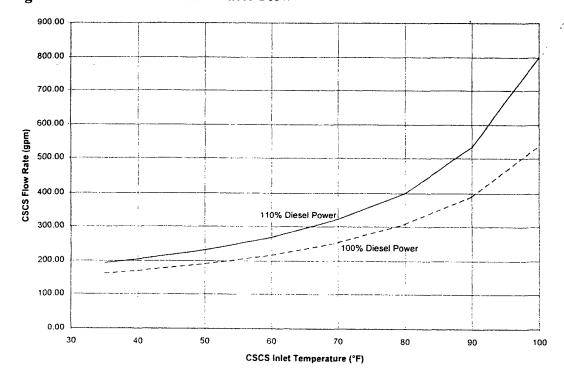
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Table 6-6 Minimum CSCS Flow Rate at 110% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HX TM Input Flow Rate (gpm)	Density Corrected Flow Rate (gpm)
35	62.41903	193.5	193.3
40	62.42184	204.8	204.6
50	62.40595	232.2	232.1
60	62.36445	269.1	269.1
70	62.30034	321.0	321.3
80	62.21603	399.3	400.3
90	62.11349	530.9	533.1
100	61.99437	795.3	800.0



Figure 6-2 Minimum Service Water Flow





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7. CONCLUSION

7.1. PROTO-HXTM MODEL

The Standby Jacket Water Cooler model was developed using PROTO-HXTM, Version 3.02. The model was benchmarked to the vendor data sheet. The benchmark model correlation to the vendor data sheet is -0.13 %. The benchmark model is for reference only based on the non-conservative approximation of heat exchanger effective area as discussed in Section 3.2 and Assumption 5.1. Calculations performed with the Standby Jacket Water Cooler model are to use the effective area developed in Section 3.2.

This model should be considered suitable for use in the analysis of thermal performance test data.

The model database is saved under file name dg01a.phx, with a file size of 640 KB, and a file date and time of 6/29/98 at 1:50:34 PM. The saved database is set up to run the Reference Conditions with design fouling factor selected, the design fouling factor is a shell-side fouling of 0.002782. The database file is included as Attachment H.

7.2. HEAT EXCHANGER FOULING FACTOR LIMIT

For the Standby Diesel Generator Jacket Water Cooler to provide adequate heat removal at the specified LaSalle Station Reference Conditions the overall fouling factor must be equal to or less than 0.002782 hr ft² °F/Btu. This overall fouling factor is entered in the model as the shell-side design fouling factor.

7.3. FOULING SENSITIVITY

Given a constant shell-side fouling at the model design value, the sensitivity of the jacket water cooler to tube-side fouling effects is shown on Figure 6-1.

7.4. THERMAL MARGIN ASSESSMENT

Assuming the adjusted heat exchanger effective area and maximum overall fouling factor, the clean and service available thermal margins are 119.19 % and 0.00 % respectively.

7.5. MINIMUM SERVICE WATER FLOW RATE

As shown in Figure 6-2 the service water flow can be throttled down to account for lower service water inlet temperature conditions. The heat exchanger can remove the design heat load for the diesel at 100% (7,800,000 BTU/hr) and 110% (8,600,000 BTU/hr) rated power, by reducing service water flow rates as the service water temperature decreases.



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8. REFERENCES

- 8.1. LaSalle Station UFSAR, Sections: 9.2.1.1.1, 9.5.5.1.1 (Attachment D)
- 8.2. NRC Generic Letter 89-13
- 8.3. The National Board of Boiler and Pressure Vessel Inspectors, Form N-1 Manufacturers' Data Report for nuclear Vessels (Attachment C)
- 8.4. LaSalle Station FSAR Q40.92 (Attachment D)
- 8.5. Stewart & Stevens Vendor Manual, VM J-152 through VM J-157
- 8.6. LaSalle Station Drawing, D-22079
- 8.7. Sargent and Lundy Specification J-2544 (Selected Pages, Attachment B)
- 8.8. Not used
- 8.9. Standard of the Tubular Exchanger Manufacturers Association
- 8.10. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HX[™] Version 3.02 Software Validation and Verification Report (SVVR) SQA No. SVVR-93948-02, Revision F, dated 2/17/98
- 8.11. American Standard Heat Exchanger Data Sheet for the LaSalle Station Standby Diesel Generator Jacket Water Coolers. (Attachment A)
- 8.12. Proto-Power Calculation 93-048, "Fluid Properties Fresh Water Range 32°F to 500°F", Rev. A





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Attachment A to Proto-Power Calculation 97-197 Revision A

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Proto-Power Calc: 97-195

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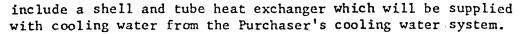
Attachment B to Proto-Power Calculation 97-195 Revision A

Proto-Power Calc: 97-195

Attachment: B

Rev: A Page 1 of 3

REFERENCE 8.7



- b. The closed cooling water system pump shall be of the centrifugal type and shall be driven by the engine.
- c. The shell and the tube heat exchanger shall be of the capacity required for 110 percent of rated power with a fouling factor of 0.0005 on shell side and .002 on the tube side. The heat exchanger shall be in accordance with the requirements of ITEM A, TEMA (Tube Exchanger Manufacturers' Association) Class C and the ASME Code Section III. The type bundle shall be removable without removing shell from its mounting. The tubes shall be 5/8 inch minimum and be of admiralty metal.
- .d. The circulating water system shall be provided with controls which will sense and maintain optimum jacket water temperature.
 - e. Cooling water supply for the heat exchangers will be at a maximum inlet temperature of 100°F and a minimum of 32°F. The coolers shall be designed for a 150 psig water working pressure and tested at a hydraulic pressure of 225 psig.

F. Starting System

- a. Each engine shall be equipped with an independent pneumatic starting system complete with all valves, integral piping, controls, etc.
- b. The reliability of the starting system is paramount and no compromise of the starting capability shall be made with other basic requirements of the equipment design. Any special devices or auxiliaries required to insure successful starting shall be provided, except any equipment of an experimental type will be unacceptable. Contractor shall describe in his proposal what occurances are possible to preclude successful starting, and what remedies would be necessary that are not already provided for in the equipment design.
- c. The compressed air starting system shall consist of two redundant sets of equipment, each completely independent of the other for successful operation. A cross-connecting line with a normally closed valve shall be provided between sets. The accumulator furnished with each set of equipment shall have the capacity for a minimum of three normal cranking cycles in rapid succession without the use of its air compressor. Each accumulator shall be furnished with a shut-off cock, pressure gauge drain valve, safety valve, and sensing element for low pressure alarm.

 Proto-Power Calc: 97-195

Attachment: B

Proposal Technical Data for Diesel Engine-Generator Sets, Cont. La Salle County Station ~ Units 1 and 2

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REFERENCE 8.7

NGINE-GENERATOR DATA, Cont.	(Insert all	data in these	columns)
į	BASE	BID	ALTERNATE 1
		DIESEL GEN.	DIESEL GEN.
	DIESEL GEN.O	1A AND 2A	O, la AND 2A
Contractor to furnish complete infor- ation for starting system furnished)	·		
E. Engine Cooling System:			
a. Cooling system capacity.(gal)	545		
b. Pipe size for cooling water connections(in)	8	·	
c. Heat exchanger dimensions:			
(1) Length(in)	179.5		
(2) Diam(in)	16"		
(3) Height(in)	19.5"		
d. Quantity of cooling water at rated load, required at 80°F(gal/min)	550		
at 95°F(gal/min)	750		
at 100°F(gal/min)	840		
e. Tube material	Arsenical Copper (SB1	11)	
f. Diameter and thickness of tubes(in)	3/4" x 18 BWG		
g. Total tube cooling surface (ft ²)	479		
h. Water box material	Carbon Steel		
	Weights: 3050 lbs Dry 4350 lbs Wet		

PTD-15

Proto-Power Calc: 97-195

Attachment: B

Rev: A Page 3 of 3

Attachment C to **Proto-Power Calculation** 97-195 **Revision A**

Form No.: <u>PI050104</u> Rev.: <u>10</u> Date: <u>10/21/97</u>

Proto-Power Calc: 97-195

Attachment: C

Rev: A Page 1 of 7 Ref.: <u>P&I 5-1</u>

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS. As required by the Provisions of the ASME Code Rules.

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2. Manufactured for _	STEW	ART:	STE	VENSO	N SERV	uces_;	HOUSTO	N. TEXA
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(b)							-	
If removable, balti	s u scd	(Materia)	, Spec. No.	T.S., NIZO, N	umber)	Oiber føsten	ing (Describe	or attach chotch)
							,	
7. Jacket Closure		(Descrit	** ** 06**	<u> </u>	ic. If her give d	imensione, des	relie or shotch	
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LIPHENESSES

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13. Balaty Valve Outle	ini Number_	Si	Le venne e e e e e e e e e e e e e e e e	Lucation			····
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TUBEINFOUT	2_8	-150# ASI	A PIPE FRG	.5A106 B	277		WELDE
17. Inspection Manhole Openings: Handho Threads	les, No	Size	Location				
18. Supports: Skitt							TO SHEL
*, ***		Brief description	of service for whi	th recel was design			
Design information or Stress analysis repur Design specifications Stress analysis repur	n lile a AMEA t on lile at NA t contilled by E t contilled by M	CER PICAN ST E AFPLIG L J MA PE PAPAL	THECATION OF STATE TO SEE STATE TO SEE STATE TO SEE SEE SEE SEE SEE SEE SEE SEE SEE SE	F DESIGN 9NS. DIV. B FCTION III Prof. Br	CLASS Sone, State LLL	VE 55 B Reg. No. 1	<u> </u>
We certify they the cion of the ASME Code, Date	i/ 15.7	Signida.	TRANSPER_DI\ (Menulucturer	ision of K	R. Warne	Office	er, Q.C.
i, the understand, had no province of New York have inspected the pres	ding a volid as OTK sure vessel des	CDARD HEAT	by the National Me IMDETMENS Mu Aufacturer's Data S	VISION Protection of Matter and Protection Casualty	y Go.	Chicago,	for the State

personal injury or properly demage or a loss of any kind secsing from or connected with this, inspection, rest

National Huard, State, Province and No.

CERTIFICATE OF FIE	JD ASSEMBLY	INSPECTION
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By_signing this certificate neither the Inspectur nor his employer makes ony waventy, expressed or implied, concerning the pressure described in this Manufacturer's Data Report. Furthermore, nather the Inspector nor his employer shall be liable in any manner

f, the undersigned, halding a valid commission issued by the National Mand of Batler and Pressure Vessel Inspeciers and/or the State and employed by ______ ond employed by ve compared the statements in this Manufactureds Data Pepor, with the described pressure vessel and state that parts referred to as

heen inspected by me and that to the heat of ay knowledge and belief the manufacturer has constructed and assembled this pressure vassel in proordince with the ASME Code, Section lift. The described vessel was imported and subjected to a hydrostatic test and/or Preumetic Test of _______psi.

By signing this certificate neither the inspector nor his employer makes any werranty, expressed or implied, concerning the pressure

vessel described in this Monufacturer's Data Report, Furthermore, neither the inspector nor his employer shall be lishic in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection, 117, - tolder

Date ______19____1 frapertor's Signature

Nettmal Board, State, Province and No.

Printed in 33.8. A. (7/71)

Cade, Section III.

This form (E3f) is obtainable from the ASME, 345 E. 47th St., New York, N.Y. 10017

Proto-Power Calc: 97-195

Attachment: C

3 of 7 Rev: A Page

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS An required by the Provincian of the ASME Code Rulen

	ASSETTATION	C 2.4 11C	ADD USA						-
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Type_HORIZ			•						•
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This form (E38) is obtainable from the ARME, 145 E. 47th Re., New York, N.Y. 18017 Proto-Power Calc: 97-195

Attachment: C

Rev: A Page 5 of 7

FORM N-1 MANUFACTURERS' DATA REPORT FOR NUCLEAR VESSELS An required by the Provisions of the ASME Code Rules.

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us 4-8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers. SML 5.5T.
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Hender (a) Haterial A285-CT.S. 55,000 (b) Haterial T.S. (c) Material T.S.
Comm Knuchlo Kilipitesi Conical Homisphorical Plaj Bids to Progs, w Lametian Thickness Hadius Radius Katio Apex Angla Kadius Djametes (Convex ou Conseguit)
(a) #
(b) Channel
(c) Floating
ALLOYETL SAIRS BT
If companie batta med fail? 5,000 4/2-16/by
(Motorial, Spie, No., Fr. 5., Sice, Number) Drap weight Premittele (Vesoribe or sturk sketch)
Charpy Impact it-ib Hydrostatic of } Test Design pressure 150 pol at 300 of at temp, of of. Combination } Pressure P25 and
Design presente 1312 pol st. SUO F et temp, of F. Combination Presente F.S.
Canada Company
Charpy Impact 150 pol at 300 of at temp, of 0. Combination 1. Co

FORN N-1 (back)

)	liens below to be completed for all vessels where applicable.
	15. Safety Valve Ourlets: Number Size Location
	SHELL IN COUT & 10-150-ASA PIPE (FIG. SAIGE 307 - WELDET
	TUBEINGOUT 2 8"-150#ASA PIPEGRG. SAISOB 277 - WELDEL
	17. Inspection Manholes, No. Size Location Locat
	18. Supports: Skire NO Lugs Legs Other CRADLES Attached WALDED TO SHEU 19. Remarks: JACKET WATER COOLER.
[(Brief description of service for which vessel was designed) CERTIFICATION OF DESIGN
	Design information on the a ANIERICAN STP. HEAT SRANS. DIV. BUFFALO NY. Tuess analysis report on the st NOT APPLICABLE TO SECTION III CLASS & NESSEL
1	Dealen appelition contilled by R. J. MAZZA Prof. Eng. State 64 Noc. No. 62-21854
1	Ricese analysis report contified by MOT MAPLICAELE Prof. Eng. State Reg. No.
ı	We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASMIT/Code, Section III. AMERICAN STANDARD HEAT Output (Manufacturer) R. R. Warner - Habands, Q.C.
(Certificate of authorization Expires. AUGUST 4. 1978 Certificate of Authorization No. 1164
	CERTIFICATE OF SHOP INSPECTION VESSEL MADE BYATERICAN STANDARD EEAT TEARSTER DIVISION of Buffelo, New York L. the understand, holding a valid commission issued by the National Board of Buffer and Pressure Vessel Inspectors and/or the State or Province of New York and amployed by Lumbermens Matual Casualty Co. Chicago, Tilinois
.,	have inspected the pressure vessel described in this Manufacturer's Data Report on Alexand Alexand Alexand Alexand Alexand and etails that to the best of my knowledge and belief, the Manufacturer has constructed this pressure exical in accordance with the ASME Code, Section III. My signing this contribute melther the inspector nor his employer makes any warranty, expressed or implied, concerning the pressure resoluted in this Manufacturer's Data Report. Furthermore, neither the inspector nor his employer chall be liable in only minner for any personal injury or properly demage or a lune of any kind or sing from or connected with this inspection.
	Date Editable 26 19 76 NB 7710 Inspector's Signature Commissions National Buard, State, Province and No.
ſ	CURTIFICATE OF FIELD ASSEMBLY INSPECTION
	I, the undersigned, holding a valid commission issued by the National Hazed of Boiler and Pressure Vascei [nepectors and/or the State
	or Province of
	deta lisma
	By signing this certife at neither the inspectur nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Reput. Furthermore, neither the inspector one his employer shall be liable in any manner for any personal injury or properly damage as a loss of any blind arising from or connected with this inspection.
	Completions
Į,	Printed in U.S.A. (7/71) This form (E38) is obtainable from the ASUR, 348 R. (318) St., New York, N.Y. (4017) Attachment: C
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