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

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

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] 388666 **Revision:** [5] 000

Station(s): [7] LaSalle

Unit No.: [8] 01 & 02

Safety/QA Class: [9] SR

System Code(s): [10] E12, RH

Is this Design Analysis Safeguards Information? [11] 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): [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) — Sean Tanton (Sign Name) — 5/23/12 (Date)

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

Reviewer: [18] Steve Chon (Print Name) — Steve Chon (Sign Name) — 6/6/12 (Date)

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)
External Approver: [20] N/A (Print Name) — (Sign Name) — (Date)

Exelon Reviewer [21] N/A (Print Name) — (Sign Name) — (Date)

Exelon Approver: [22] DAN SCHMIT (Print Name) — DJ Schmit (Sign Name) — 6/6/12 (Date)

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 $hr \cdot ft^2 \cdot °F/BTU$ (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, Total	lbm/hr	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·°F)	215.00
Outside h Factor (Hoff)	0.563555000
Fixed U (BTU/hr·ft²·°F)	0
Fixed Area (ft²)	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 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	1,010
Tube Length (ft)	55.30
Tube Inside Diameter (in)	0.652
Tube Outside Diameter (in)	0.750
Tube Wall K (BTU/hr·ft·°F)	9.40
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	0.000
Bh, Baffle Cut Height (in)	0.000
Ds, Shell Inside Diamter (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

Commonwealth Edison

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

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

Extrapolation Data

Tube Flow (gpm)	7,344.00
Shell Flow (gpm)	6,905.00
Tube Inlet Temp (°F)	107.00
Shell Inlet Temp (°F)	212.00
Input Fouling Factor	0.001470

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3,454,223.04
Tube Mass Flow (lbm/hr)	3,673,832.59
Heat Transferred (BTU/hr)	166,468,480.24
LMTD	58.3
Effective Area (ft²)	10,926.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.26	7.08
Reynold's Number	55,935	69,169
Prandtl Number	2.0490	3.2991
Bulk Visc (lbm/ft·hr)	0.7909	1.2323
Skin Visc (lbm/ft·hr)	0.8775	1.1347
Density (lbm/ft³)	60.3957	61.5557
Cp (BTU/lbm·°F)	1.0032	0.9990
K (BTU/hr·ft·°F)	0.3872	0.3732

Overall Fouling (hr·ft²·°F/BTU)	0.001470
Shell-Side ho (BTU/hr·ft²·°F)	1,128.7
Tube-Side hi (BTU/hr·ft²·°F)	2,079.4
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.8820
U Overall (BTU/hr·ft²·°F)	296.3
Shell Temp In (°F)	212.0
Shell Temp Out (°F)	164.0
Tav Shell (°F)	188.0
Shell Skin Temp (°F)	172.7
Tube Temp In (°F)	107.0
Tube Temp Out (°F)	152.4
Tav Tube (°F)	129.7
Tube Skin Temp (°F)	139.2

** Reynolds Number Outside Range of Equation Applicability

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

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, Total	lbm/hr	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·°F)	215.00
Outside h Factor (Hoff)	0.563555000
Fixed U (BTU/hr·ft²·°F)	0
Fixed Area (ft²)	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 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	1,010
Tube Length (ft)	55.30
Tube Inside Diameter (in)	0.652
Tube Outside Diameter (in)	0.750
Tube Wall K (BTU/hr·ft·°F)	9.40
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	0.000
Bh, Baffle Cut Height (in)	0.000
Ds, Shell Inside Diamter (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

Commonwealth Edison

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		Tube Flow (gpm)	7,344.00
Shell Flow (gpm)		Shell Flow (gpm)	7,122.00
Shell Temp In (°F)		Tube Inlet Temp (°F)	107.00
Shell Temp Out (°F)		Shell Inlet Temp (°F)	121.00
Tube Flow (gpm)			
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		
		U Overall (BTU/hr·ft²·°F)	278.7

Property	Shell-Side	Tube-Side		
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

** Reynolds Number Outside Range of Equation Applicability

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

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

			Last Page No. 1
Analysis No.	97-201		**Revision** A01
EC/ECR No.	EC 352363		**Revision** 0
Title:	Thermal Model of ComEd/LSCS RHR Heat Exchangers 1(2)RHR01A & B		
Station(s)	LaSalle	**Is this Design Analysis Safeguards?**	Yes ☐ No ☒
Unit No.:	Units 1 and 2	**Does this Design Analysis Contain Unverified Assumptions?**	Yes ☐ No ☒
Safety Class	Safety Related		
System Code	E12, RH	ATI/AR#	

Description of Change

This revision clarifies that the required heat removal capability of an RHR HX for the Containment Cooling Mode is now 163.1 MBtu/hr with an RHR service water inlet temperature of 104 deg. F, a maximum fouling factor of 0.00185 hr-ft^2-deg F/Btu, and a 5% tube plugging allowance (ref. Case 3 on page 7 of rev. A00 of this calculation). This heat removal value is to be used as the acceptance criteria in RHR HX thermal performance evaluations. Based on Calculation L-002826 rev. 0, SIL 636 Disposition for LaSalle County Station and New Decay Heat Table, and General Electric Power Uprate Project Task Report 310: Residual Heat Removal System, GE-NE-A1300384-12-01 rev. 0, no change to the Shutdown Cooling Condition (SDC) design heat load acceptance criteria of 41.6 Mbtu/hr is required.

Disposition of Changes (include additional pages as required)

EC 334017 (dated 5-16-02) evaluated the increased cooling water temperature to a new maximum temperature of 104 deg-F. The Design Considerations Summary states in part for the Post LOCA Suppression Pool Temperature Analysis: "Design Analysis No. L-002857, Rev. 0 has been completed to determine the RHR heat exchanger efficiency (expressed as a "K" factor in LaSalle's existing Containment Analysis...) with an increased inlet service water temperature of 104°F at various suppression pool temperatures. After the heat exchanger K factor had been determined, the impact on the LaSalle suppression pool temperature response following a LOCA was evaluated. As detailed within this design analysis, the post LOCA peak suppression pool temperature (193 deg-F) has not increased even with a higher inlet service water temperature of 104°F. The peak suppression pool temperature demonstrated within this design analysis is still well below the suppression pool temperature NPSH limit for the ECCS pumps of 212°F." The increased efficiency implies a higher heat load capability. Based on a review of L-002857: -the credited heat rejection capability is 163.1 MBtu/hr for the CCM case (Table 2 value for Q2). This is the value of Q used to get a 'K factor' of 417. Since we are crediting this heat load capability and this value is higher than 155 Mbtu/hr, this value should be used as the approved acceptance criteria.

	Print Name	Sign Name	Date
Preparer	Dan Schmit	DJSchmit	11/11/04
Reviewer	Terry Martin	[signature]	11/24/04

Method of Review ☒ Detailed Review ☐ Alternate Calculations ☐ Testing

Review Notes:

	Print Name	Sign Name	Date
Approver	W. Hilton	[signature]	11-30-04

(For External Analyses Only)

	Print Name	Sign Name	Date
Exelon Reviewer	NA		
Approver	NA		

DESIGN ANALYSIS NO.: Calc. # 97-201 Major REV Number: A	Minor Rev Number: 00	PAGE NO. 1

[ ] BRAIDWOOD STATION [ ] BYRON STATION [ ] CLINTON STATION [ ] DRESDEN STATION [X] LASALLE CO. STATION [ ] QUAD CITIES STATION Unit: [ ] 0 [X] 1 [X] 2 [ ] 3	DESCRIPTION CODE: (C018) DISCIPLINE CODE: (C011) SYSTEM CODE: (C011)	MØ10 M E12, RH

TITLE: THERMAL MODEL OF COMED/LSCS RHR Heat Exchangers 1(2)RHR01A & B.

[X] Safety Related [ ] Augmented Quality [ ] Non-Safety Related

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	710'		
Software	Proto-HX		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
1E12-B001A	H15
1E12-B001B	H15
2E12-B001A	H15
2E12-B001B	H15

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
~~EC~~ DCP/DCP	EC# 334017	Y
/		
/		
/		
/		
/		
/		

REMARKS: NA

DESIGN ANALYSIS NO. *97-201* **REV: A00 PAGE NO. 2**

Revision Summary (including EC's incorporated): Updated ProtoHX model for 104°F Service Water inlet temperature and calculated Unit 1 and 2 RHR Heat Exchanger thermal margins for different fouling factors and 5% tubes plugged at Containment Cooling and Shutdown Cooling conditions.

Electronic Calculation Data Files: ProtoHX 3.02, e12-b001.phx, 160 KB, 04/19/2002, 10:36am

(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [X] N/A, Per EC#: 334017
(If yes, attach impact review sheet)

Prepared by: Jeff W. VanStrien / Jeff W. VanStrien / 5-1-02
Print / Sign / Date

Reviewed by: Brian L. Davenport / [signature] / 5-08-02
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: N/A **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ 2) ____ / ____ / ____
Print / Sign / Date Print / Sign / Date
3) ____ / ____ / ____ 4) ____ / ____ / ____
Print / Sign / Date Print / Sign / Date

Supplemental Review Results:

Approved by: J. T. Conner / [signature] / 5/14/02
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ____ / ____ / ____
Print / Sign / Date

Approved by: ____ / ____ / ____
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
Tracked By: AT#, EC# etc.)____

ComEd

CALCULATION TABLE OF CONTENTS

CALCULATION NO. *97-201* REV. NO. A00 PAGE NO. 3

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E-FORM

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.

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.

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*ft^2*°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:

$$\frac{Thermal Margin}{Required Heat Load} \times 100\% = \% Thermal Margin$$ [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.

$Q_{phx} = Q_{temp}$ * (Density $_{@temp}$ / Density $_{@\,60\,F}$) [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		

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 $hr*ft^{2}*°F/BTU$ (Ref. 2). For conservatism, this value was doubled to 0.0013 $hr*ft^{2}*°F/BTU$ 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 $hr*ft^{2}*°F/BTU$, 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 $hr*ft^{2}*°F/BTU$ 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.

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 $hr*ft^{2}*°F/BTU$ 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)

Attachment "A"

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

E-FORM

Commonwealth Edison

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

CCM-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
Outlet Temperature	°F	108.80	101.25
Fouling Factor		0.00250	0.00000

Shell Fluid Name	Fresh Water (CASE)
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	
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	1,010 ✓
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
Nss, Number Sealing Strips	0.000

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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

CASE1

Test Data

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

Extrapolation Data

Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	6,905.0
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	212.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-201
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Attachment A
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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.454E+6
Tube Mass Flow (lbm/hr)	3.676E+6
Heat Transferred (BTU/hr)	1.508E+8
LMTD	65.7
Effective Area (ft²)	10,926.6

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	1,136.9
Tube-Side hi (BTU/hr·ft²·°F)	2,027.7
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9268
U Overall (BTU/hr·ft²·°F)	226.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.26	7.07
Reynold's Number	5.677E+04	6.607E+04
Prandtl Number	2.02	3.47
Bulk Visc (lbm/ft·hr)	0.78	1.29
Skin Visc (lbm/ft·hr)	0.85	1.20
Density (lbm/ft³)	60.34	61.64
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	212.0
Shell Temp Out (°F)	168.5
Tav Shell (°F)	190.2
Shell Skin Temp (°F)	177.1
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	145.1
Tav Tube (°F)	124.5
Tube Skin Temp (°F)	133.0

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

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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
Outlet Temperature	°F	108.80	101.25
Fouling Factor		0.00250	0.00000

CAR 1

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	
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	1,010
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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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

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

Extrapolation Data

Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	7,124.0
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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Attachment A
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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.564E+6
Tube Mass Flow (lbm/hr)	3.676E+6
Heat Transferred (BTU/hr)	2.192E+7
LMTD	9.9
Effective Area (ft²)	10,926.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.29	7.04
Reynold's Number	3.292E+04	5.574E+04
Prandtl Number	3.75	4.18
Bulk Visc (lbm/ft·hr)	1.39	1.53
Skin Visc (lbm/ft·hr)	1.42	1.51
Density (lbm/ft³)	61.76	61.90
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	962.4
Tube-Side hi (BTU/hr·ft²·°F)	1,836.6
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9348
U Overall (BTU/hr·ft²·°F)	215.9
Shell Temp In (°F)	120.0
Shell Temp Out (°F)	113.8
Tav Shell (°F)	116.9
Shell Skin Temp (°F)	114.7
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	110.0
Tav Tube (°F)	107.0
Tube Skin Temp (°F)	108.3

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

Attachment "B"

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

E-FORM

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

		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

CASE 2

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	
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
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

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* Fouling Factor input on next page.

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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

CASE 2

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 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)	

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Attachment B
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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)	1,123.8
		Tube-Side hi (BTU/hr·ft²·°F)	1,985.4
Heat Transferred (BTU/hr)	1.779E+8	1/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

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

CASE 2

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	
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
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

* Fouling Factor input on next page.

16:47:30 **PROTO-HX 3.02 by Proto-Power Corporation (SN#663-7371)** 04/15/02

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

<A562

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		
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)	

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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.564E+6	Overall Fouling (hr·ft²·°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
Density (lbm/ft³)	61.77	61.90	Tube Temp Out (°F)	111.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	107.5
K (BTU/hr·ft·°F)	0.37	0.37	Tube Skin Temp (°F)	109.2

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

Attachment "C"

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

E-FORM

Commonwealth Edison

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

CCM-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

CASE 3

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	
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	1,010
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
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page.

16:58:38 **PROTO-HX 3.02 by Proto-Power Corporation (SN#663-7371)** 04/15/02

Commonwealth Edison

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 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)		
Reynold's Number		
Prandtl Number		
Bulk Visc (lbm/ft·hr)		
Skin Visc (lbm/ft·hr)		
Density (lbm/ft³)		
Cp (BTU/lbm·°F)		
K (BTU/hr·ft·°F)		

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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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·ft²·°F)	2,063.8
Heat Transferred (BTU/hr)	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 Overall (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

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

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

CASE 3

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	
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	1,010
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
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page.

Commonwealth Edison

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

Extrapolation Data	
Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	7,124.0
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	120.0
Input Fouling Factor	0.001300*

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.564E+6
Tube Mass Flow (lbm/hr)	3.676E+6
Heat Transferred (BTU/hr)	2.539E+7
LMTD	9.0
Effective Area (ft²)	10,926.6

Overall Fouling (hr·ft²·°F/BTU)	0.001300
Shell-Side ho (BTU/hr·ft²·°F)	960.2
Tube-Side hi (BTU/hr·ft²·°F)	1,842.0
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.8882
U Overall (BTU/hr·ft²·°F)	291.4

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.28	7.04
Reynold's Number	3.277E+04	5.601E+04
Prandtl Number	3.77	4.16
Bulk Visc (lbm/ft·hr)	1.39	1.52
Skin Visc (lbm/ft·hr)	1.43	1.50
Density (lbm/ft³)	61.77	61.90
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.37

Shell Temp In (°F)	120.0
Shell Temp Out (°F)	112.9
Tav Shell (°F)	116.4
Shell Skin Temp (°F)	113.7
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	110.9
Tav Tube (°F)	107.5
Tube Skin Temp (°F)	109.1

** Reynolds Number Outside Range of Equation Applicability
!! 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)

E-FORM

Commonwealth Edison

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

CCM-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 (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	
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 } 5% PLUGGED
Number of Active Tubes	1,010 }
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
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page.

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	
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*

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)	

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Attachment D
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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.454E+6	Overall Fouling (hr·ft²·°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·ft²·°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

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 (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	
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 } 5% PLUGGED
Number of Active Tubes	1,010 }
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
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page.

Commonwealth Edison

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

Extrapolation Data	
Tube Flow (gpm)	7,348.0
Shell Flow (gpm)	7,124.0
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	120.0
Input Fouling Factor	0.001850 X

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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Attachment D
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Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.564E+6
Tube Mass Flow (lbm/hr)	3.676E+6
Heat Transferred (BTU/hr)	2.369E+7
LMTD	9.4
Effective Area (ft²)	10,926.6

Overall Fouling (hr·ft²·°F/BTU)	0.001850
Shell-Side ho (BTU/hr·ft²·°F)	961.3
Tube-Side hi (BTU/hr·ft²·°F)	1,839.3
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9140
U Overall (BTU/hr·ft²·°F)	251.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.28	7.04
Reynold's Number	3.284E+04	5.588E+04
Prandtl Number	3.76	4.17
Bulk Visc (lbm/ft·hr)	1.39	1.53
Skin Visc (lbm/ft·hr)	1.42	1.50
Density (lbm/ft³)	61.76	61.90
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.37

Shell Temp In (°F)	120.0
Shell Temp Out (°F)	113.3
Tav Shell (°F)	116.7
Shell Skin Temp (°F)	114.2
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	110.5
Tav Tube (°F)	107.2
Tube Skin Temp (°F)	108.7

** 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 / 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-HX™ Version 3.02

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Revision History

Revision	Revision Description
A	Original Issue

PROTO-POWER CORPORATION GROTON, CONNECTICUT	CALC NO. 97-201	REV A	PAGE iii OF v
	ORIGINATOR D. Phyfe		DATE 7/16/98
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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.			

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A	Proto-Power Calc. 97-201, Rev. A; Vendor Data Sheet & Drawings	5
B	Proto-Power Calc. 97-201, Rev. A; RHR Process Flow Diagram, 731E966AA Sheets 1 & 3	3
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D	Proto-Power Calc. 97-201, Rev. A; PROTO-HX Calculation Reports for the Fouling Sensitivity	11
E	Proto-Power Calc. 97-201, Rev. A; PROTO-HX Calculation Reports for the Margin Analysis	10
F	Proto-Power Calc. 97-201, Rev. A; PROTO-HX Model of the LaSalle Station RHR Hx.	2
	Number of Attachment Pages:	40
	Total number of pages:	57

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-HX™, Version 3.02, will allow timely analysis of data resulting from the test program.

3.0 DESIGN INPUTS

The PROTO-HX™ 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-HX™ 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 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	1	8.6
Tube Passes per shell	2	8.6

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

$$U-Tube = 2 \cdot L_{Tube} + 30\% \cdot ID_{Shell} \qquad \text{Equation 1}$$

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

$$U-Tube = 2 \cdot 27ft + 0.30 \cdot 51.25\,in \frac{1ft}{12in} = 55.3\,ft$$

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-HX™ 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 5% Plugged: 172	8.6
Tube Side Fluid Type	Service Water (Fresh)	8.6
Tube Side Fouling Factor (Design)	0.002	8.6

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 5% Plugged: 145.3	8.6
Design Q - Service (BTU/hr)	All Tubes: 170,000,000 5% Plugged: 168,000,000	8.6
Design U - Clean (BTU/hr-ft^2-°F)	All Tubes: 563 5% Plugged: 568	8.6
Design U - Service (BTU/hr-ft^2-°F)	All Tubes: 231 5% Plugged: 235	8.6
Shell Velocity (ft/sec)	3.82	8.6
Number of Plugged Tubes	All Tubes: 0 5% Plugged: 53	8.6

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 5% Plugged: 108.8	8.6
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 5% Plugged: 101.25	8.6
Design Q - Service (BTU/hr)	All Tubes: 42,550,000 5% Plugged: 41,600,000	8.6
Design U - Clean (BTU/hr-ft^2-°F)	All Tubes: 463 5% Plugged: 466	8.6

Table 3-5 Shutdown Cooling Performance Detail

Parameter	Value	Reference
Design U - Service (BTU/hr-ft²-°F)	All Tubes: 213 5% Plugged: 215	8.6
Shell Velocity (ft/sec)	3.4	8.6
Number of Plugged Tubes	All Tubes: 0 5% Plugged: 53	8.6

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.

$$\text{Area Ratio} = \frac{\text{Tube OD}}{\text{Tube ID}} \qquad \text{Equation 2}$$

$$f_{total} = f_{shell} + (\text{Area Ratio}) \cdot f_{tube} \qquad \text{Equation 3}$$

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.

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

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

$$f_{total} = f_{tube-side} + f_{shell-side} \quad \text{Equation 5}$$

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-HX™ Version 3.02 with the vendor's specifications for thermal performance under different cooling modes.

4.1. PROTO-HX™ PARAMETER CALCULATION

<u>Minimum Shell Area</u>

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 ft^2.

<u>Outside H Factor (Hoff)</u>

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 ft^2 °F), the Outside H Factor was calculated by PROTO-HX™ to be 0.56355.

4.2. PROTO-HX™ 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-HX™ 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.

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

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.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60°F}} \qquad \text{Equation 7}$$

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

Parameter	Density (lb/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.

6.0 ANALYSIS

6.1. PROTO-HX™ MODEL

Table 6-1compares 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

Parameter	CONTAINMENT COOLING MODE				SHUTDOWN COOLING MODE			
	ALL TUBES		5% PLUGGED		ALL TUBES		5% PLUGGED	
	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-HX™ model. PROTO-HX output reports can be found in Attachment C.

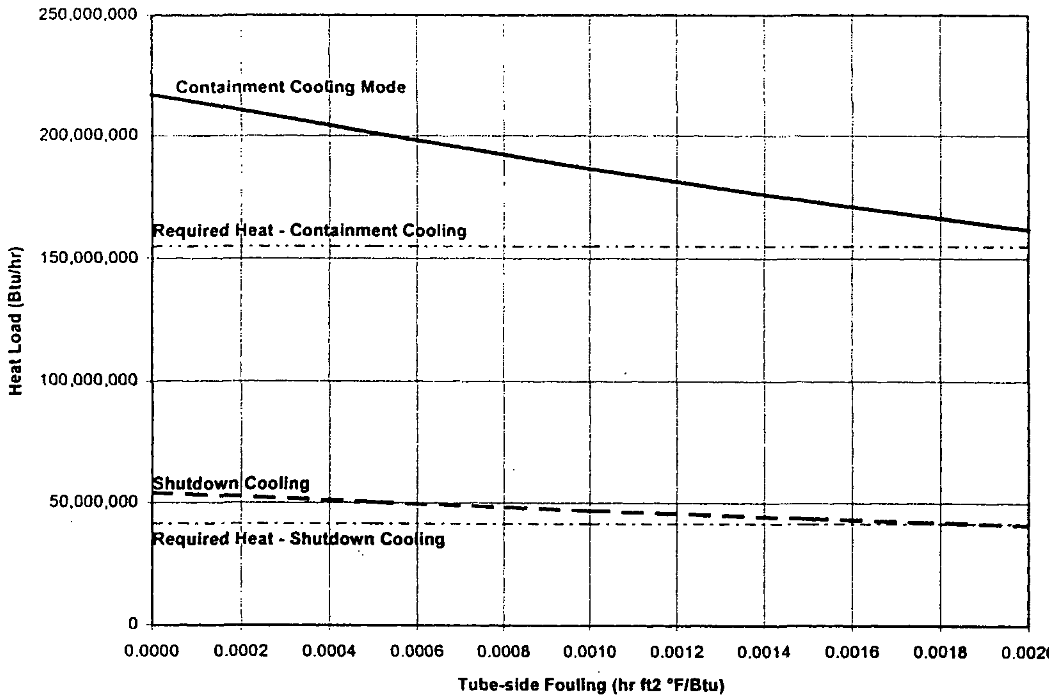
Table 6-2 PROTO-HX Model Correlation

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 ft^2 °F/Btu). The shell-side fouling factor is held constant at the design value of 0.0005 (hr ft^2 °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.

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.

$$\text{Margin} = (\text{Heat Rate}) - (\text{Heat Rate})_{\text{required}} \qquad \text{Equation 8}$$

$$\%\,\text{Margin} = 100 \cdot \frac{\text{Margin}}{(\text{Heat Rate})_{\text{required}}} \qquad \text{Equation 9}$$

Table 6-3 Thermal Margin – Containment Cooling Mode

Parameter	Service (Design Fouling) All Tubes	Service (Design Fouling) 53 Plugs	Clean (0 Fouling) All Tubes	Clean (0 Fouling) 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

Parameter	Service (Design Fouling) All Tubes	Service (Design Fouling) 53 Plugs	Clean (0 Fouling) All Tubes	Clean (0 Fouling) 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-HX™ MODEL

The RHR Hx Model was developed using PROTO-HX™, 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.

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)~~ DJ 8/17/98

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-HX™ 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

18011.4

STRUTHERS WELLS CORPORATION

Heat Exchanger Specification Sheet

ALL TUBES AVAILABLE - SHUTDOWN OPERATING MODE

1		JOB NO.	
2	CUSTOMER GENERAL ELECTRIC COMPANY	REFERENCE NO.	205-AA668
3	ADDRESS San Jose, California	~~XXXXXX~~ NO.	(S.W.) 1-71-04-30971
4	PLANT LOCATION La Salle I & La Salle II	DATE	5/19/71
5	SERVICE OF UNIT Residual Heat Removal Heat Exchs.	ITEM NO.	E12-B001
6	SIZE 52" I.D. x 27' Avg. T.L. TYPE (TEMA) "AEU" (HORIZ.) (VERT.)	~~XXXXXXXXXX~~	Channel Down
7	SURF./UNIT (GROSS) 11,790 (EFF.) 11,500 SHELLS/UNIT One*	SURF./SHELL (GROSS) 11,790 (EFF.) 11,500	
8	* Four (4) Units Reqd	PERFORMANCE OF ONE UNIT	

		SHELL SIDE	TUBE SIDE
9		SHELL SIDE	TUBE SIDE
10	FLUID CIRCULATED	Reactor Water	Service Water
11	TOTAL FLUID ENTERING #/HR	3,725,000 (7450 GPM)	3,700,000 (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 IN °F	120.0	90.0
25	TEMPERATURE OUT °F	108.6	101.5
26	OPERATING PRESSURE PSIG		
27	NO. PASSES PER SHELL	One	Two
28	VELOCITY FT/SEC	3.4 Avg. Long	6.7
29	PRESSURE DROP Max. PSI	8.5	9.0
30	FOULING RESISTANCE (MIN)	.0005	.002
31	HEAT EXCHANGED. BTU/HR 42,550,000	MTD CORRECTED. °F	17.35
32	TRANSFER RATE – SERVICE 213	CLEAN	463
33		CONSTRUCTION OF ONE SHELL (see Shutdown Mode 5% tubes plu	
34	DESIGN PRESSURE PSIG		
35	TEST PRESSURE PSIG		
36	DESIGN TEMPERATURE °F		

37	TUBES NO. O.D. BWG MIN. SMLS. AVG. WLD. LENGTH PITCH	
38	SHELL I.D. O.D.	SHELL COVER (INTEG.)(REMOV.)
39	CHANNEL OR BONNET	CHANNEL COVER
40	TUBESHEET-STATIONARY	TUBESHEET FLOATING
41	BAFFLE-CROSS TYPE	FLOATING HEAD COVER
42	BAFFLES-LONG TYPE	IMPINGEMENT PROTECTION
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 SIDE
49	CODE REQUIREMENTS	TEMA CLASS
50	REMARKS	
51		
52		
53		
54		Proto-Power Calc: 97-201

Attachment: A

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STRUTHERS WELLS CORPORATION

Heat Exchanger Specification Sheet

FIVE PERCENT TUBES PLUGGED- SHUTDOWN OPERATING MODE

	JOB NO.
CUSTOMER GENERAL ELECTRIC COMPANY	REFERENCE NO. 205-AA668
ADDRESS San Jose, California	NO. (S.W.) 1-71-04-30971
PLANT LOCATION La Salle I & La Salle II	DATE 5/19/71
SERVICE OF UNIT Residual Heat Removal Heat Exchs.	ITEM NO. E12-B001
SIZE 52" I.D. x 27' Avg. T.L. TYPE (TEMA) "AEU" (VERT.)	Channel Down
SURF./UNIT (GROSS) 11,790 (EFF.) 11,000 SHELLS/UNIT One *	SURF./SHELL (GROSS) 11,790 (EFF.) 11,000

* Four (4) Units Req'd

PERFORMANCE OF ONE UNIT

		SHELL SIDE	TUBE SIDE
FLUID CIRCULATED		Reactor Water	Service Water
TOTAL FLUID ENTERING	#/HR	3,725,000 (7450 GPM)	3,700,000 (7,400 GPM)
VAPOR			
LIQUID		3,725,000	3,700,000
STEAM			
NON-CONDENSABLES			
FLUID VAPORIZED OR CONDENSED			
STEAM CONDENSED			
SPECIFIC GRAVITY			
VISCOSITY			
MOLECULAR WEIGHT			
SPECIFIC HEAT	BTU/LB °F		
THERMAL CONDUCTIVITY	BTU/HR-FT-°F		
LATENT HEAT	BTU/LB		
TEMPERATURE IN	°F	120.0	90.0
TEMPERATURE OUT	°F	108.8	101.25
OPERATING PRESSURE	PSIG		
NO. PASSES PER SHELL		One	Two
VELOCITY	FT/SEC	3.4 Avg. Long	7.04
PRESSURE DROP Max.	PSI	8.5	10.0
FOULING RESISTANCE	(MIN)	.0005	.002

HEAT EXCHANGED, BTU/HR 41,600,000	MTD CORRECTED, °F 17.6
TRANSFER RATE – SERVICE 215	CLEAN 466

CONSTRUCTION OF ONE SHELL

DESIGN PRESSURE	PSIG	500	150
TEST PRESSURE	PSIG	Per Code	Per Code
DESIGN TEMPERATURE	°F	40 to 480	32 to 480

TUBES 304L S/S (A-249) NO. 1063 U's O.D. 3/4" BWG 18 MIN. WLD. LENGTH *** PITCH 1" Triang.

SHELL C.S. w/304L S/S Clad. I.D. 52"	SHELL COVER C.S. w/304L S/S Clad (INTEG.)
CHANNEL OR BONNET C.S. w/Carbomastic Coating	CHANNEL COVER C.S. w/Carbomastic Coating
TUBESHEET STATIONARY Solid 304L S/S	TUBESHEET FLOATING
BAFFLE-CROSS 304 S/S TYPE Mod. Split Flow	FLOATING HEAD COVER
BAFFLES-LONG TYPE	IMPINGEMENT PROTECTION Yes

TUBE SUPPORTS 304 L S/S - U-Bend Support

TUBE TO TUBE SHEET JOINT Welded & Roller Expanded

GASKETS Metal Jack. Asb.

CONNECTIONS–SHELL SIDE IN 18" OUT 18" RATING W.E.

CHANNEL SIDE IN 18" OUT 18" RATING W.E.

CORROSION ALLOWANCE–SHELL SIDE Per Spec. 21A1686 TUBE SIDE Per Spec. 21A1686

3 CODE REQUIREMENTS Shell Side - Sec. III-C; Tube Side - Sec. III-C TEMA CLASS "C"

REMARKS Performance conditions shown above are based on 53 U-tubes being plugged. *** Approximately 50% of tubes have a straight length of U-Tube equal to 26.5'; 25% have 27' straight length and 25% have straight length of 28'.

SECTION X

100114

STRUTHERS WELLS CORPORATION

Heat Exchanger Specification Sheet

ALL TUBES AVAILABLE - CONTAINMENT COOLING MODE

		JOB NO.	
CUSTOMER	GENERAL ELECTRIC COMPANY	REFERENCE NO.	205-AA668
ADDRESS	San Jose, California	~~XXXXXXXX~~ NO.	(S.W.) 1-71-04-30971
PLANT LOCATION	La Salle I & La Salle II	DATE	5/19/71
SERVICE OF UNIT	Residual Heat Removal Heat Exchs.	ITEM NO.	E12-B001
SIZE	52" I.D. x 27' Avg. T.L. TYPE (TEMA) "AEU" (VERT.)	~~XXXXXXXX~~	Channel Down
SURF./UNIT (GROSS) 11,790 (EFF.) 11,500	SHELLS/UNIT One*	SURF./SHELL	(GROSS) 11,790 (EFF.) 11,500

* Four (4) Units Req'd

PERFORMANCE OF ONE UNIT

	SHELL SIDE	TUBE SIDE
FLUID CIRCULATED	Demin. Water	Service Water
TOTAL FLUID ENTERING #/HR	4,200,000 (8400 GPM)	3,700,000 (7400 GPM)
VAPOR		
LIQUID	4,200,000	3,700,000
STEAM		
NON-CONDENSABLES		
FLUID VAPORIZED OR CONDENSED		
STEAM CONDENSED		
SPECIFIC GRAVITY		
VISCOSITY		
MOLECULAR WEIGHT		
SPECIFIC HEAT BTU/LB °F		
THERMAL CONDUCTIVITY BTU/HR-FT-°F		
LATENT HEAT BTU/LB		
TEMPERATURE IN °F	212.0	100.0
TEMPERATURE OUT °F	171.6	145.9
OPERATING PRESSURE PSIG		
NO. PASSES PER SHELL	One	Two
VELOCITY FT/SEC	3.82 Avg. Long	6.7
PRESSURE DROP Max. PSI	10.0	9.0
FOULING RESISTANCE (MIN)	.0005	.002

HEAT EXCHANGED, BTU/HR	170,000,000	MTD CORRECTED, °F	64.1
TRANSFER RATE – SERVICE	231	CLEAN	563

CONSTRUCTION OF ONE SHELL (See Shutdown Mode 5% tubes)

	SHELL SIDE	TUBE SIDE
DESIGN PRESSURE PSIG		
TEST PRESSURE PSIG		
DESIGN TEMPERATURE °F		

TUBES NO. O.D. BWG MIN. SMLS. AVG. WLD. LENGTH PITCH	
SHELL I.D. O.D.	SHELL COVER (INTEG.)(REMOV.)
CHANNEL OR BONNET	CHANNEL COVER
TUBESHEET-STATIONARY	TUBESHEET FLOATING
BAFFLE-CROSS TYPE	FLOATING HEAD COVER
BAFFLES-LONG TYPE	IMPINGEMENT PROTECTION
TUBE SUPPORTS	
TUBE TO TUBE SHEET JOINT	
GASKETS	
CONNECTIONS–SHELL SIDE IN OUT	RATING
CHANNEL SIDE IN OUT	RATING
CORROSION ALLOWANCE–SHELL SIDE	TUBE SIDE
CODE REQUIREMENTS	TEMA CLASS
REMARKS	

Proto-Power Calc: 97-201

Attachment: A

SECTION X

180114

STRUTHERS WELLS CORPORATION

Heat Exchanger Specification Sheet

FIVE PERCENT TUBES PLUGGED - CONTAINMENT COOLING MODE

	JOB NO.
CUSTOMER GENERAL ELECTRIC COMPANY	REFERENCE NO. 205-AA668
ADDRESS San Jose, California	[illegible] NO. (S.W.) 1-71-04-30971
PLANT LOCATION La Salle I & La Salle II	DATE 5/19/71
SERVICE OF UNIT Residual Heat Removal Heat Exchs.	ITEM NO. E12-B001
SIZE 52" I.D. x 27' Avg. T.L. TYPE (TEMA) "AEU" (HORIZ.)(VERT.)	[illegible] Channel Down
SURF./UNIT (GROSS) 11,790 (EFF.) 11,000 SHELLS/UNIT One*	SURF./SHELL (GROSS) 11,790 (EFF.) 11,000

*Four (4) Units Req'd

PERFORMANCE OF ONE UNIT

		SHELL SIDE	TUBE SIDE
FLUID CIRCULATED		Demin. Water	Service Water
TOTAL FLUID ENTERING	#/HR	4,200,000 (8400 GPM)	3,700,000 (7400 GPM)
VAPOR			
LIQUID		4,200,000	3,700,000
STEAM			
NON-CONDENSABLES			
FLUID VAPORIZED OR CONDENSED			
STEAM CONDENSED			
SPECIFIC GRAVITY			
VISCOSITY			
MOLECULAR WEIGHT			
SPECIFIC HEAT	BTU/LB °F		
THERMAL CONDUCTIVITY	BTU/HR-FT-°F		
LATENT HEAT	BTU/LB		
TEMPERATURE IN	°F	212	100
TEMPERATURE OUT	°F	172	145.3
OPERATING PRESSURE	PSIG		
NO. PASSES PER SHELL		One	Two
VELOCITY	FT/SEC	3.82 Avg. Long	7.04
PRESSURE DROP Max.	PSI	10.0	10.0
FOULING RESISTANCE	(MIN)	.0005	.002

HEAT EXCHANGED, BTU/HR	168,000,000	MTD CORRECTED, °F	65.0
TRANSFER RATE – SERVICE	235	CLEAN	568

CONSTRUCTION OF ONE SHELL (See Shutdown Mode)

		SHELL SIDE	TUBE SIDE
DESIGN PRESSURE	PSIG		
TEST PRESSURE	PSIG		
DESIGN TEMPERATURE	°F		

TUBES NO. O.D. BWG MIN. SMLS. AVG. WLD. LENGTH PITCH

SHELL I.D. O.D.	SHELL COVER (INTEG.)(REMOV.)
CHANNEL OR BONNET	CHANNEL COVER
TUBESHEET-STATIONARY	TUBESHEET FLOATING
BAFFLE-CROSS TYPE	FLOATING HEAD COVER
BAFFLES-LONG TYPE	IMPINGEMENT PROTECTION

TUBE SUPPORTS

TUBE TO TUBE SHEET JOINT

GASKETS

CONNECTIONS–SHELL SIDE IN OUT RATING

CHANNEL SIDE IN OUT RATING

CORROSION ALLOWANCE–SHELL SIDE TUBE SIDE

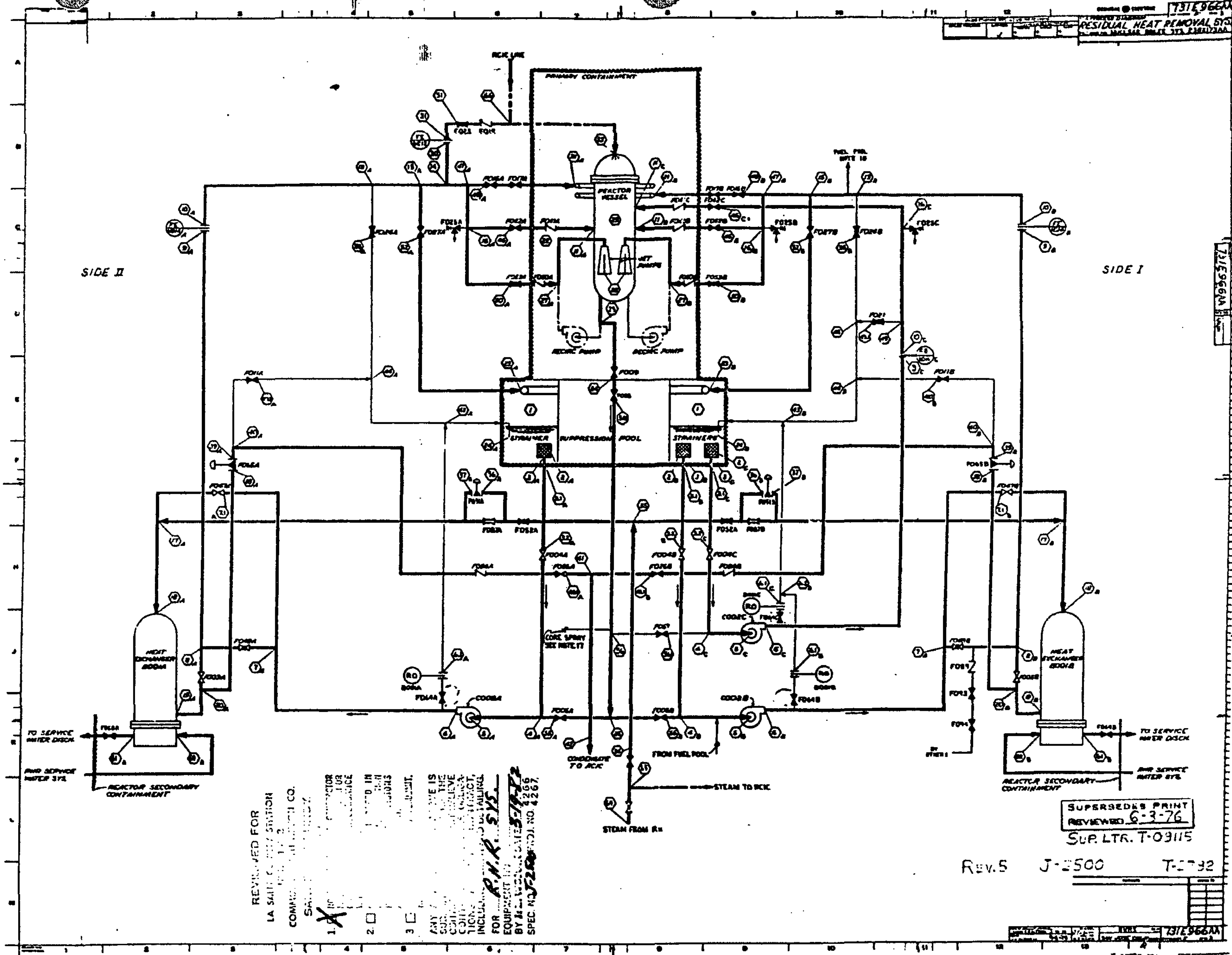
CODE REQUIREMENTS TEMA CLASS

REMARKS Performance conditions are based on 53 U-tubes being plugged.

~~Proto-Power Calc. 97-201~~
Attachment: A
Rev: A Page 5 of 5

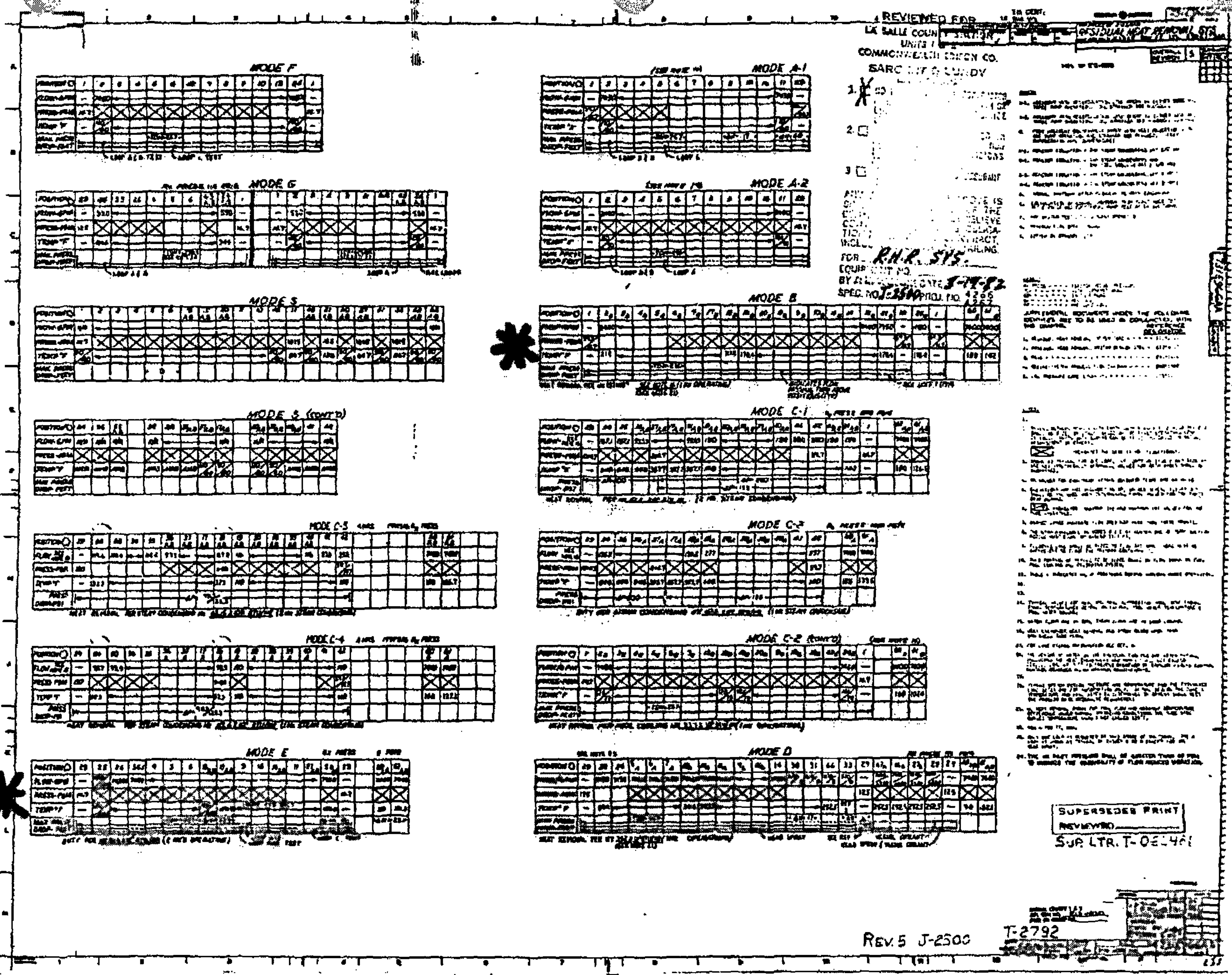
Attachment B to
Proto-Power Calculation
97-201
Revision A

REFERENCE 8.1



Proto-Power Calc: 97-201
Attachment: B
Rev: A Page 2 of 3

REFERENCE 8.1



Proto-Power Calc: 97-201
Attachment: B
Rev: A Page 3 of 3

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

Commonwealth Edison

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

SDC - All Tubes, 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	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	
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
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

3

Commonwealth Edison

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

SDC - 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	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data	
Tube Flow (gpm)	7,396.3
Shell Flow (gpm)	7,446.3
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.725E+6
Tube Mass Flow (lbm/hr)	3.7E+6
Heat Transferred (BTU/hr)	4.251E+7
LMTD	18.5
Effective Area (ft²)	11,500.0

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	977.6
Tube-Side hi (BTU/hr·ft²·°F)	1,666.6
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9328
U Overall (BTU/hr·ft²·°F)	213.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.43	6.72
Reynold's Number	3.354E+04	4.729E+04
Prandtl Number	3.86	4.77
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.67
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.6
Tav Shell (°F)	114.3
Shell Skin Temp (°F)	110.2
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.5
Tav Tube (°F)	95.7
Tube Skin Temp (°F)	98.5

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

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 (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	
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	1,010
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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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

Extrapolation Data	
Tube Flow (gpm)	7,396.3
Shell Flow (gpm)	7,446.3
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.725E+6
Tube Mass Flow (lbm/hr)	3.7E+6
Heat Transferred (BTU/hr)	4.147E+7
LMTD	18.8
Effective Area (ft²)	10,926.6

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	978.0
Tube-Side hi (BTU/hr·ft²·°F)	1,734.7
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9382
U Overall (BTU/hr·ft²·°F)	215.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.43	7.07
Reynold's Number	3.359E+04	4.970E+04
Prandtl Number	3.85	4.78
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.68
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.9
Tav Shell (°F)	114.4
Shell Skin Temp (°F)	110.3
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.2
Tav Tube (°F)	95.6
Tube Skin Temp (°F)	98.3

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

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 (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	
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
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

Commonwealth Edison

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

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	4.2E+6
Tube Mass Flow (lbm/hr)	3.7E+6
Heat Transferred (BTU/hr)	1.7E+8
LMTD	68.8
Effective Area (ft²)	11,500.0

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	1,286.8
Tube-Side hi (BTU/hr·ft²·°F)	1,944.4
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9309
U Overall (BTU/hr·ft²·°F)	230.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.96	6.76
Reynold's Number	6.973E+04	6.230E+04
Prandtl Number	2.00	3.53
Bulk Visc (lbm/ft·hr)	0.77	1.31
Skin Visc (lbm/ft·hr)	0.84	1.20
Density (lbm/ft³)	60.31	61.67
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	212.0
Shell Temp Out (°F)	171.7
Tav Shell (°F)	191.8
Shell Skin Temp (°F)	179.5
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	146.0
Tav Tube (°F)	123.0
Tube Skin Temp (°F)	132.4

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

Commonwealth Edison

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

CCM - 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	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	
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	1,010
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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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

CCM - 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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	4.2E+6
Tube Mass Flow (lbm/hr)	3.7E+6
Heat Transferred (BTU/hr)	1.658E+8
LMTD	69.9
Effective Area (ft²)	10,926.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.97	7.12
Reynold's Number	6.995E+04	6.523E+04
Prandtl Number	1.99	3.55
Bulk Visc (lbm/ft·hr)	0.77	1.32
Skin Visc (lbm/ft·hr)	0.84	1.21
Density (lbm/ft³)	60.30	61.67
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	1,287.9
Tube-Side hi (BTU/hr·ft²·°F)	2,019.7
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9365
U Overall (BTU/hr·ft²·°F)	231.9
Shell Temp In (°F)	212.0
Shell Temp Out (°F)	172.7
Tav Shell (°F)	192.3
Shell Skin Temp (°F)	179.7
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	144.9
Tav Tube (°F)	122.4
Tube Skin Temp (°F)	131.7

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

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

Commonwealth Edison

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

SDC - 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	
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 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)	3.688E+6	Overall Fouling (hr·ft²·°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·ft²·°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

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

Commonwealth Edison

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

SDC - 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	
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·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·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/ft³)	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)	100.3

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

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		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 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)	3.688E+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·ft²·°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/ft³)	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

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

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

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	0.002225

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)			
		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)	0.002225
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/hr)	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)	98.8

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

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

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

Extrapolation Data

Tube Flow (gpm)	7,370.2
Shell Flow (gpm)	7,372.0
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0
Input Fouling Factor	0.002801

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.688E+6
Tube Mass Flow (lbm/hr)	3.687E+6
Heat Transferred (BTU/hr)	4.092E+7
LMTD	18.9
Effective Area (ft²)	11,500.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.40	6.70
Reynold's Number	3.326E+04	4.703E+04
Prandtl Number	3.85	4.78
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.68
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002801
Shell-Side ho (BTU/hr·ft²·°F)	972.4
Tube-Side hi (BTU/hr·ft²·°F)	1,659.7
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9395
U Overall (BTU/hr·ft²·°F)	200.5
Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.9
Tav Shell (°F)	114.4
Shell Skin Temp (°F)	110.6
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.1
Tav Tube (°F)	95.6
Tube Skin Temp (°F)	98.2

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

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	
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 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)	4.031E+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·ft²·°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
Reynold's Number	6.408E+04	6.572E+04	Shell Temp Out (°F)	158.4
Prandtl Number	2.09	3.31	Tav Shell (°F)	185.2
Bulk Visc (lbm/ft·hr)	0.81	1.23	Shell Skin Temp (°F)	165.9
Skin Visc (lbm/ft·hr)	0.92	1.10	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.46	61.56	Tube Temp Out (°F)	159.0
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	129.5
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	143.1

** Reynolds Number Outside Range of Equation Applicability

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

Commonwealth Edison

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	
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 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)	4.031E+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)	139.2

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

Commonwealth Edison

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

CCM - 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

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

Extrapolation Data

Tube Flow (gpm)	7,356.1
Shell Flow (gpm)	8,057.7
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	212.0
Input Fouling Factor	0.001650

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	4.031E+6
Tube Mass Flow (lbm/hr)	3.68E+6
Heat Transferred (BTU/hr)	1.865E+8
LMTD	63.5
Effective Area (ft²)	11,500.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.80	6.73
Reynold's Number	6.568E+04	6.332E+04
Prandtl Number	2.04	3.44
Bulk Visc (lbm/ft·hr)	0.79	1.28
Skin Visc (lbm/ft·hr)	0.87	1.17
Density (lbm/ft³)	60.37	61.63
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.001650
Shell-Side ho (BTU/hr·ft²·°F)	1,244.2
Tube-Side hi (BTU/hr·ft²·°F)	1,961.1
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.8946
U Overall (BTU/hr·ft²·°F)	285.2
Shell Temp In (°F)	212.0
Shell Temp Out (°F)	165.9
Tav Shell (°F)	188.9
Shell Skin Temp (°F)	174.4
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	150.7
Tav Tube (°F)	125.4
Tube Skin Temp (°F)	136.0

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

Commonwealth Edison

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		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	0.002225

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)			
		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)	4.031E+6	Overall Fouling (hr·ft²·°F/BTU)	0.002225
Tube Mass Flow (lbm/hr)	3.68E+6	Shell-Side ho (BTU/hr·ft²·°F)	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·ft²·°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

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

Commonwealth Edison

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 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	0.002801

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)	4.031E+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·°F)	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·ft²·°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)	131.0

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

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

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

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

Extrapolation Data

Tube Flow (gpm)	7,356.1
Shell Flow (gpm)	8,057.7
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	212.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	4.031E+6
Tube Mass Flow (lbm/hr)	3.68E+6
Heat Transferred (BTU/hr)	1.677E+8
LMTD	68.4
Effective Area (ft²)	11,500.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.80	6.73
Reynold's Number	6.668E+04	6.185E+04
Prandtl Number	2.00	3.53
Bulk Visc (lbm/ft·hr)	0.77	1.31
Skin Visc (lbm/ft·hr)	0.84	1.21
Density (lbm/ft³)	60.32	61.67
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	1,253.0
Tube-Side hi (BTU/hr·ft²·°F)	1,934.1
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9286
U Overall (BTU/hr·ft²·°F)	229.4
Shell Temp In (°F)	212.0
Shell Temp Out (°F)	170.5
Tav Shell (°F)	191.3
Shell Skin Temp (°F)	178.7
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	145.6
Tav Tube (°F)	122.8
Tube Skin Temp (°F)	132.2

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

Commonwealth Edison

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

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	4.031E+6
Tube Mass Flow (lbm/hr)	3.68E+6
Heat Transferred (BTU/hr)	1.637E+8
LMTD	69.5
Effective Area (ft²)	10,926.6

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	1,254.1
Tube-Side hi (BTU/hr·ft²·°F)	2,009.1
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9344
U Overall (BTU/hr·ft²·°F)	230.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.80	7.08
Reynold's Number	6.690E+04	6.477E+04
Prandtl Number	2.00	3.55
Bulk Visc (lbm/ft·hr)	0.77	1.32
Skin Visc (lbm/ft·hr)	0.84	1.21
Density (lbm/ft³)	60.31	61.68
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	212.0
Shell Temp Out (°F)	171.5
Tav Shell (°F)	191.8
Shell Skin Temp (°F)	179.0
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	144.5
Tav Tube (°F)	122.3
Tube Skin Temp (°F)	131.4

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

Commonwealth Edison

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

CCM - 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)	7,356.1
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 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)	4.031E+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·°F)	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·ft²·°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)	147.3

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

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	
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 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)		4.031E+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/ft³)	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 Temp (°F)	146.8

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

Commonwealth Edison

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

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

Extrapolation Data

Tube Flow (gpm)	7,370.2
Shell Flow (gpm)	7,372.0
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.688E+6
Tube Mass Flow (lbm/hr)	3.687E+6
Heat Transferred (BTU/hr)	4.233E+7
LMTD	18.5
Effective Area (ft²)	11,500.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.40	6.70
Reynold's Number	3.320E+04	4.713E+04
Prandtl Number	3.86	4.77
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.67
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	971.5
Tube-Side hi (BTU/hr·ft²·°F)	1,661.9
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9322
U Overall (BTU/hr·ft²·°F)	213.4
Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.5
Tav Shell (°F)	114.3
Shell Skin Temp (°F)	110.2
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.5
Tav Tube (°F)	95.7
Tube Skin Temp (°F)	98.5

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

Commonwealth Edison

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

SDC - 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

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

Extrapolation Data

Tube Flow (gpm)	7,370.2
Shell Flow (gpm)	7,372.0
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.688E+6
Tube Mass Flow (lbm/hr)	3.687E+6
Heat Transferred (BTU/hr)	4.131E+7
LMTD	18.8
Effective Area (ft²)	10,926.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.40	7.05
Reynold's Number	3.324E+04	4.952E+04
Prandtl Number	3.86	4.78
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.68
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	971.9
Tube-Side hi (BTU/hr·ft²·°F)	1,729.7
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9376
U Overall (BTU/hr·ft²·°F)	214.6
Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.8
Tav Shell (°F)	114.4
Shell Skin Temp (°F)	110.2
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.2
Tav Tube (°F)	95.6
Tube Skin Temp (°F)	98.3

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

Commonwealth Edison

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

SDC -- Service Margin - 38 Plugs

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	7,370.2
Shell Flow (gpm)	7,372.0
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	120.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	3.688E+6
Tube Mass Flow (lbm/hr)	3.687E+6
Heat Transferred (BTU/hr)	4.16E+7
LMTD	18.7
Effective Area (ft²)	11,088.9

Property	Shell-Side	Tube-Side
Velocity (ft/s)	3.40	6.95
Reynold's Number	3.323E+04	4.882E+04
Prandtl Number	3.86	4.78
Bulk Visc (lbm/ft·hr)	1.42	1.73
Skin Visc (lbm/ft·hr)	1.48	1.68
Density (lbm/ft³)	61.80	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.37	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002500
Shell-Side ho (BTU/hr·ft²·°F)	971.8
Tube-Side hi (BTU/hr·ft²·°F)	1,709.9
1/Wall Resis (BTU/hr·ft²·°F)	2,148.1
LMTD Correction Factor	0.9361
U Overall (BTU/hr·ft²·°F)	214.3
Shell Temp In (°F)	120.0
Shell Temp Out (°F)	108.7
Tav Shell (°F)	114.4
Shell Skin Temp (°F)	110.2
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	101.3
Tav Tube (°F)	95.6
Tube Skin Temp (°F)	98.3

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

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·°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·ft²·°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)	1,686.2
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

Commonwealth Edison

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

SDC - 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	
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·°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·ft²·°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)	102.1

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

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

PROTO-HX™ 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**

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision)		**Last Page No.** [6] 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		
EC/ECR No.: [4]	388666	**Revision:** [5]	000
Station(s): [7]	LaSalle		
Unit No.: [8]	01 & 02		
Safety/QA Class: [9]	SR		
System Code(s): [10]	DG		

Is this Design Analysis Safeguards Information? [11] 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): [14]
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.

	Print Name	Sign Name	Date
Preparer: [16]	Sean Tanton	Sean Tanton	5/1/12

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Steve Chon	Steve Chon	5/16/12

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	NA		
Exelon Reviewer [21]	NA		
Exelon Approver: [22]	DAN SCHMIT	DJ Schmit	5/18/12

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 $hr \cdot ft^2 \cdot °F/BTU$ (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 $hr \cdot ft^2 \cdot °F/BTU$
- 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 $hr \cdot ft^2 \cdot °F/BTU$, 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 $hr \cdot ft^2 \cdot °F/BTU$ 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, Total	lbm/hr	0.00	0.00
Inlet Temperature	°F	190.00	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor	hr·ft²·°F/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·°F)	0
Fixed Area (ft²)	0.00
Performance Factor (% Reduction)	0.00
Heat Exchanger Type	TEMA - E
Total Effective Area per Unit (ft²)	471.23
Area Factor	0.981978184
Area Ratio	0.00000
Number of Shells Per Unit	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)	0.750
Tube Wall K (BTU/hr·ft·°F)	112.00
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	0.000
Bh, Baffle Cut Height (in)	0.000
Ds, Shell Inside Diamter (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

Commonwealth Edison

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

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)	793.98
Shell Flow (gpm)		Shell Flow (gpm)	1,064.50
Shell Temp In (°F)		Tube Inlet Temp (°F)	107.00
Shell Temp Out (°F)		Shell Inlet Temp (°F)	190.00
Tube Flow (gpm)			
Tube Temp In (°F)			
Tube Temp Out (°F)		Input Fouling Factor	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·°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)		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·ft²·°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·ft·°F)	0.3861	0.3694	Tube Skin Temp (°F)	127.9

** Reynolds Number Outside Range of Equation Applicability

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

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
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

Unit: [X] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE:(C018) M010
DISCIPLINE CODE: (C011) M
SYSTEM CODE: (C011) DG

TITLE: THERMAL MODEL OF COMED/LASALLE STATION UNIT 0, 1, AND 2 DIESEL GENERATOR JACKET WATER COOLERS

[X] Safety Related [ ] Augmented Quality [ ] Non-Safety Related

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	710'		
Software	PROTO-HX		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
0DG01A	H15
1DG01A	H15
2DG01A	H15

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
~~EC~~ DCD/DCP	EC# 334017	Y
/		
/		
/		
/		
/		
/		

REMARKS: NA

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 3.02, dg01a.phx, 704 KB, 04/14/2002, 4:01 pm

(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [X] N/A, Per EC#: 334017
(If yes, attach impact review sheet)

Prepared by: Jeff W. VanStrien / Jeff W. VanStrien / 5/9/02
Print Sign Date

Reviewed by: Brian L. Davenport / [signature] / 5/09/02
Print Sign Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: N/A in its entirety.

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ______ / ______ / ______
Print Sign Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ______ / ______ / ______ 2) ______ / ______ / ______
Print Sign Date Print Sign Date

3) ______ / ______ / ______ 4) ______ / ______ / ______
Print Sign Date Print Sign Date

Supplemental Review Results:

Approved by: J. T. Connor / [signature] / 5/14/02
Print Sign Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ______ / ______ / ______
Print Sign Date

Approved by: ______ / ______ / ______
Print Sign Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) ______

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CALCULATION TABLE OF CONTENTS

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E-FORM

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/ft^3 (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.

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*ft^{2}*°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:

$$\frac{ThermalMargin}{RequiredHeatLoad} \times 100\% = \%ThermalMargin \quad \text{[Equation 2]}$$

Case 1

When the service water inlet temperature is increased to 104°F for the same fouling factor (0.002782 hr*ft^{2}*°F/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*ft^{2}*°F/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*ft^{2}*°F/BTU (Ref. 2, page 9). For conservatism, this value was doubled to 0.001068 hr*ft^{2}*°F/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 hr*ft^2*°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*ft^2*°F/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*ft^2*°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)

E-FORM

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS= 104 F @ Design FF

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		0.00278	0.00000

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

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Calculation Report for DG01A - DG Jacket Water Cooler

CSCS= 104 F @ Design FF

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	8.234E+6
LMTD	67.9
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	8.21
Reynold's Number	8.270E+04	6.978E+04
Prandtl Number	2.13	3.86
Bulk Visc (lbm/ft·hr)	0.82	1.42
Skin Visc (lbm/ft·hr)	0.87	1.30
Density (lbm/ft³)	60.52	61.80
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,035.7
Tube-Side hi (BTU/hr·ft²·°F)	2,177.8
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9884
U Overall (BTU/hr·ft²·°F)	260.4
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.6
Tav Shell (°F)	182.3
Shell Skin Temp (°F)	173.6
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	124.7
Tav Tube (°F)	114.4
Tube Skin Temp (°F)	123.7

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

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<u>Attachment "B"</u>

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

E-FORM

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		* 0.00278	0.00000

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page

09:30:07 **PROTO-HX 3.02 by Proto-Power Corporation (SN#663-7371)** 04/12/02

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	190.0
* Input Fouling Factor	0.001068

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-195
Revision No. A00
Attachment B
Page No. B3 of B7

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	1.252E+7
LMTD	58.4
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.001068
Shell-Side ho (BTU/hr·ft²·°F)	2,006.8
Tube-Side hi (BTU/hr·ft²·°F)	2,250.9
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9628
U Overall (BTU/hr·ft²·°F)	472.5

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.98	8.22
Reynold's Number	8.047E+04	7.349E+04
Prandtl Number	2.19	3.64
Bulk Visc (lbm/ft·hr)	0.84	1.35
Skin Visc (lbm/ft·hr)	0.93	1.19
Density (lbm/ft³)	60.61	61.72
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	166.5
Tav Shell (°F)	178.3
Shell Skin Temp (°F)	164.5
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	135.5
Tav Tube (°F)	119.8
Tube Skin Temp (°F)	133.9

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

Attachment “C”

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

E-FORM

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		* 0.00278	0.00000

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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)	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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

*Fouling factor input on next page.

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	190.0
* Input Fouling Factor	0.001068

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-195
Revision No. A00
Attachment C
Page No. C3 of C3

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	1.221E+7
LMTD	59.1
Effective Area (ft²)	448.7

Overall Fouling (hr·ft²·°F/BTU)	0.001068
Shell-Side ho (BTU/hr·ft²·°F)	2,007.6
Tube-Side hi (BTU/hr·ft²·°F)	2,335.8
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9655
U Overall (BTU/hr·ft²·°F)	476.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.98	8.63
Reynold's Number	8.063E+04	7.690E+04
Prandtl Number	2.19	3.66
Bulk Visc (lbm/ft·hr)	0.84	1.36
Skin Visc (lbm/ft·hr)	0.93	1.19
Density (lbm/ft³)	60.61	61.72
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	167.1
Tav Shell (°F)	178.6
Shell Skin Temp (°F)	164.5
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	134.7
Tav Tube (°F)	119.4
Tube Skin Temp (°F)	133.3

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

Attachment "D"

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

E-FORM

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS=104 F@Max. FF, 5% plugged

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		* 0.00278	0.00000

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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)	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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page.

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		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)		* Input Fouling Factor	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·°F/BTU)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-195
Revision No. A00
Attachment D
Page No. D3 of D3

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5	Overall Fouling (hr·ft²·°F/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)	9.032E+6	1/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
Reynold's Number	8.228E+04	7.401E+04
Prandtl Number	2.14	3.82
Bulk Visc (lbm/ft·hr)	0.83	1.41
Skin Visc (lbm/ft·hr)	0.89	1.28
Density (lbm/ft³)	60.54	61.78
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.1
Tav Shell (°F)	181.5
Shell Skin Temp (°F)	171.5
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	126.7
Tav Tube (°F)	115.4
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	[signature] 6/29/98 D. Phyfe	Scott M. Ingalls 6/29/98 S. Ingalls	[signature] 6/30/98 L. Philpot

Revision History

Revision	Revision Description
A	Original Issue

PROTO-POWER CORPORATION GROTON, CONNECTICUT	CALC NO. 97-195	REV A	PAGE iii OF v
	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			

CALCULATION VERIFICATION FORM

REVIEW METHOD:

		N/A
Approach Checked:	☑	☐
Logic Checked:	☑	☐
Arithmetic Checked:	☑	☐
Alternate Method (Attach Brief Summary)	☐	☑
Computer Program Used (Attach Listing)	☐	☑
Other	☐	☑

EXTENT OF VERIFICATION:

- Complete Calculation: ☑
- Revised areas only: ☐
- Other (describe below): ☐

*Errors Detected

Minor Editorial

*Error Resolution

Corrected

*Other Comments

*Extra References Used

*(Attach extra sheets if needed)

CALCULATION FOUND TO BE VALID AND CONCLUSIONS TO BE CORRECT AND REASONABLE:

IDV Signature: Scott M. Ingalls   Initials: SMI

Printed Name: Scott M. Ingalls   Date: 6/29/98

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REVISION HISTORY .... **II**
CALC VERIFICATION SHEET .... **III**
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F	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Calculation Reports for Fouling Sensitivity	6
G	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Calculation Reports for Minimum Service Water Flow	17
H	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Version 3.02 Model	2 (and disk)

Complete Calc (total number of pages) 73

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-HX™, Version 3.02, will allow timely analysis of data resulting from the test program.

3. DESIGN INPUTS

The PROTO-HX™ 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-HX™ 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 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 (ft^2)	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

Table 3-2 Construction Details

Parameter	Value	Reference
Pitch Type	Triangle	8.11

The vendor data sheet shows the effective area as 479 ft^2, however, based on the outside tube diameter and tube length, this value is a gross area (A_{gr}) approximation:

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

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

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

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

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

where:

A_{gr} – Heat Exchanger Gross Area, ft^2

A_{eff} – Heat Exchanger Effective Area, ft^2

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-HX™ 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

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-HX™ Version 3.02 with the manufacturer's specifications for thermal performance.

4.1. PROTO-HX™ 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-HX™ to be 0.490 ft^2.

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-HX™ to be 0.780.

4.2. PROTO-HX™ FLOW RATE INPUTS

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.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60°F}} \quad \text{Equation 3}$$

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-HX™ 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-HX™ 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-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. The PROTO-HX™ 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-HX™ MODEL

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

Table 6-1 Model Benchmark Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft²	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 %

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-HX™ calculations performed with the Standby Jacket Water Cooler model will use the effective area of 471.23 ft^2. This change is made to the PROTO-HX™ 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-HX™ input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HX™ 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 ft^2 °F/Btu for this analysis. The tube-side fouling factor is calculated from the overall fouling found from the PROTO-HX™ iteration process.

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

$$f_{total} = f_{shell} + (\text{Area Ratio}) \cdot f_{tube} \qquad \text{Equation 4}$$

$$\text{Area Ratio} = \frac{\text{Tube OD}}{\text{Tube ID}} \qquad \text{Equation 5}$$

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

From the vendor datasheet the design overall fouling factor is

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

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

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

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

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

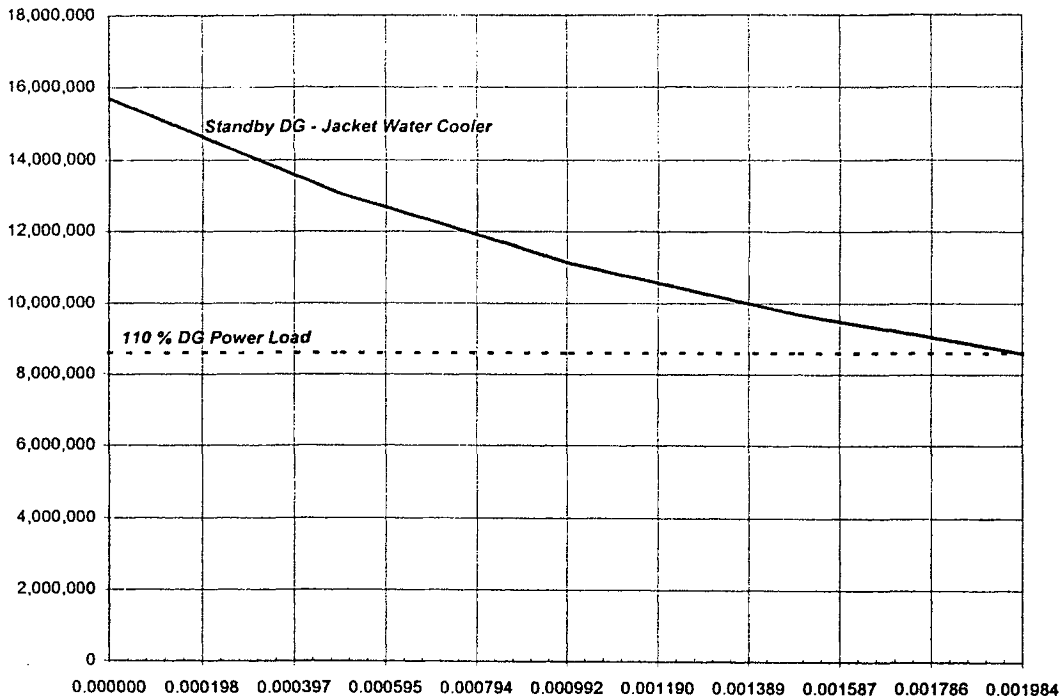
The PROTO-HX™ heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

Attachment E includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HX™ 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 ft^2 °F/Btu) by increments of 0.0005 (hr ft^2 °F/Btu). As in Section 6.2, the shell-side fouling factor is held constant at 0.0005 (hr ft^2 °F/Btu). The PROTO-HX™ Calculation Reports for the fouling sensitivity can be found in Attachment F.

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-HX™ reports can be found in Attachment E.

$$\text{margin} = \text{Heat Rate} - \text{Heat Rate}_{\text{required}} \qquad \text{Equation 6}$$

$$\%\,\text{margin} = 100 \cdot \left(\frac{\text{margin}}{\text{Heat Rate}_{\text{required}}} \right) \qquad \text{Equation 7}$$

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-HX™ flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.12.

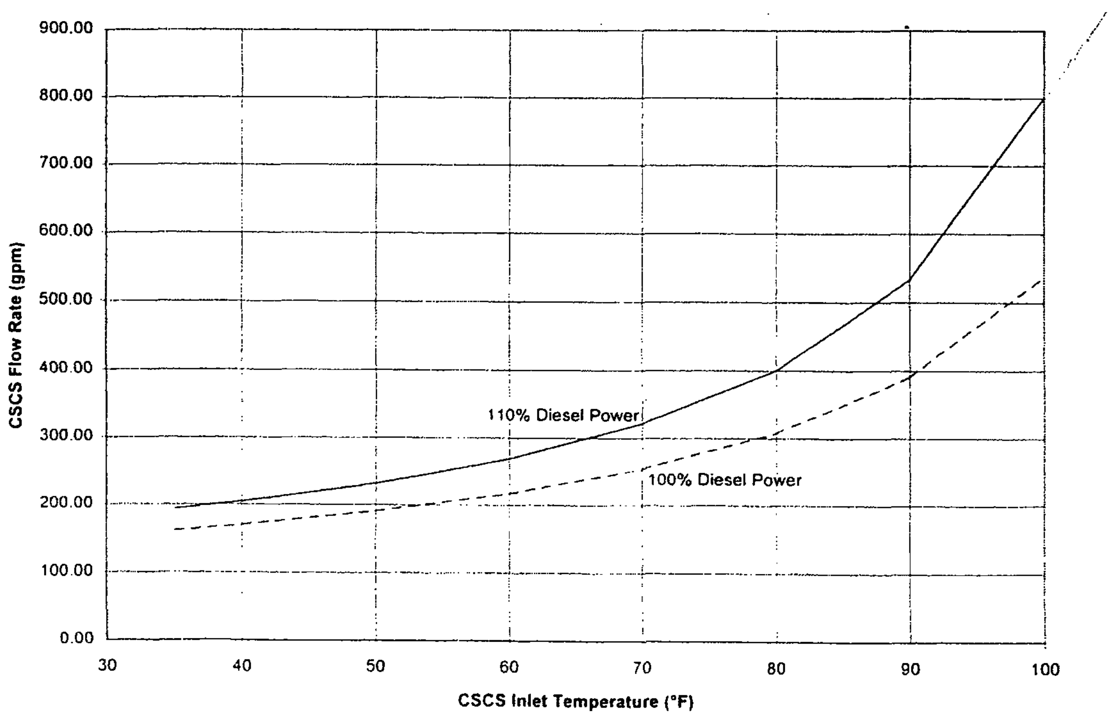
Table 6-5 Minimum CSCS Flow Rate at 100% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft^3)	PROTO-HX™ 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

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

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft³)	PROTO-HX™ 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



7. CONCLUSION

7.1. PROTO-HX™ MODEL

The Standby Jacket Water Cooler model was developed using PROTO-HX™, 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 ft^2 °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.

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

Attachment A to
Proto-Power Calculation
97-197
Revision A

STEWART & STEVENSON

JUN -5

STEWART & STEVENSON SERVICES, INC.

RECIPROCATING ENGINE SALES
8631 EAST FREEWAY
HOUSTON, TEXAS 77029

WE ARE TRANSMITTING 2 PAGE(S) INCLUDING COVER. IF INCOMPLETE, PLEASE CALL, 713/671-6218 OR 713/671-6152

PLEASE DELIVER TO: DATE: 6/4/98

NAME: Duncan Phyfe FROM: Robert E. Mitcham

FIRM: COMED PHONE: 713/671-6137

FAX: 860-446-8292 FAX: 713/671-6127

REF: LaSalle Heat Exchanger Data Sheets

Please find enclosed data sheets you requested

– Robert Mitcham

Proto-Power Calc: 97-195
Attachment: A
Rev: A Page 2 of 3

AMERICAN STANDARD
HEAT TRANSFER DIVISION
BUFFALO, N.Y. 14240

HEAT EXCHANGER SPECIFICATION SHEET

		P.O. NO.	F-68683-77339
CUSTOMER	Stewart & Stevenson for Commonwealth Edison	REFERENCE NO.	HU-974-126 Rev. 1
ADDRESS	LaSalle County Station Units 1 and 2	INQUIRY NO.	June 27, 1975
PLANT LOCATION		DATE	
SERVICE OF UNIT	Jacket Water Cooler	ITEM NO.	01 Alt.
SIZE 15156 CPK	TYPE TEMA AEW* (HORIZ.) (VERT.)	CONNECTED IN	
SQ. FT. SURF./UNIT (GROSS) (EFF.) 479	SHELLS/UNIT One	SQ. FT. SURF./SHELL (GROSS) (EFF.)	479

PERFORMANCE OF ONE UNIT

	SHELL SIDE	TUBE SIDE
FLUID CIRCULATED	Jacket Water	Raw Water
TOTAL FLUID ENTERING	550,000 #/Hr	388,000 #/Hr
VAPOR		
LIQUID	550,000 #/Hr	388,000 #/Hr
STEAM		
NON-CONDENSABLES		
FLUID VAPORIZED OR CONDENSED		
STEAM CONDENSED		
GRAVITY		
VISCOSITY		
MOLECULAR WEIGHT		
SPECIFIC HEAT	BTU/LB-°F	BTU/LB-°F
THERMAL CONDUCTIVITY	BTU/HR-FT-°F	BTU/HR-FT-°F
LATENT HEAT	BTU/LB	BTU/LB
TEMPERATURE IN	190 °F	100 °F
TEMPERATURE OUT	174.4 °F	122.2 °F
OPERATING PRESSURE	PSIG	PSIG
NO. PASSES PER SHELL	One	Two
VELOCITY	5 FT/SEC	8 FT/SEC
PRESSURE DROP	6.1 PSI	6 PSI
FOULING RESISTANCE (MIN.)	.00285 Total	

HEAT EXCHANGED-BTU/HR	8.6×10^6	MTD CORRECTED-°F	70.2
TRANSFER RATE-SERVICE	255.2	CLEAN	

CONSTRUCTION OF ONE SHELL

	SHELL SIDE	TUBE SIDE
DESIGN PRESSURE	150 PSI	150 PSI
TEST PRESSURE	225 PSI	225 PSI
DESIGN TEMPERATURE	300 °F	300 °F

TUBES ARS Copper Alloy 142 No. 188 O.D. 3/4" BWG. 18 LENGTH 156" PITCH 3/4" Tri.

SHELL Steel I.D. O.D. 16"		SHELL COVER	None (INTEG) (REMOV)
CHANNEL	~~XXXXXXXX~~ Muntz	CHANNEL COVER	Steel
TUBESHEET-STATIONARY	Muntz	TUBESHEET-FLOATING	Muntz
BAFFLES-CROSS Steel	TYPE	FLOATING HEAD COVER	
BAFFLES-LONG	TYPE	IMPINGEMENT PROTECTION	No

TUBE SUPPORTS Steel

TUBE TO TUBESHEET JOINT Rolled

GASKETS Comp. Asbestos Packing - Neoprene

CONNECTIONS-SHELL SIDE IN 10" OUT 10" RATING 150# ANSI

CHANNEL SIDE IN 8" OUT 8" RATING 150# ANSI

CORROSION ALLOWANCE-SHELL SIDE 1/16" on C. Steel TUBE SIDE 1/16" on C. Steel

CODE REQUIREMENTS ASME Code III - 3 Stamped TEMA CLASS "C"

WEIGHTS-EACH SHELL 3260 BUNDLE 1860 FULL OF WATER 4410

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)

REMARKS: *Removable Tube Bundle

American Standard P/N 5-046-15-156-001

American Standard Serial No. 8-20005

Proto-Power Calc: 97-195
Attachment: A
Rev: A Page 3 of 3

FORM 180-7 H.Y. REVISED 1-70

JUN 04 '98 19:01

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

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.

REFERENCE 8.7

Name of Bidder: Stewart & Stevenson Services, Inc.

ENGINE-GENERATOR DATA, Cont.	(Insert all data in these columns)		
	BASE BID		ALTERNATE 1
	DIESEL GEN.0	DIESEL GEN. 1A AND 2A	DIESEL GEN. 0,1A AND 2A
(Contractor to furnish complete information 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 (SB111)		
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		

Proto-Power Calc: 97-195
Attachment: B
Rev: A Page 3 of 3

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

5-046-15-156-001

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ. (Horiz. or Vert.) Kind Heat Exch. (Heat Ex.) Vessel No. B-20005-01-1 (Mfrs. Serial No.) (State & State No.) Nat'l Bd. No. 29386 Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ______ Class 3

Items 4–8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length ___ ft. 152.438 in.

5. Seams: Long SML'S H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ______ T.S. ______ (b) Material ______ T.S. ______

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

7. Jacket Closure ______ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ______ Charpy Impact ______ ft-lb ~~Pneumatic~~ Hydrostatic or ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 in. (Subject to press.) Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 ~~inches or~~ gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell~~ CHANNEL: Material SML'S STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length ___ ft. 14.000 in.

12. Seams: Long SML'S (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL. SA285-C T.S. 55,000 (b) Material ______ T.S. ______ (c) Material ______ T.S. ______

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (b) ______ (c) ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ______ Charpy Impact ______ ft-lb ~~Pneumatic~~ Hydrostatic or ~~Combination~~ Test Pressure 225 psi

[1] If Postweld Heat-Treated

[2] List other internal or external pressures with coincident temperature when applicable.

Proto-Power Calc: 97-195

Attachment: C

Rev: A Page 2 of 7

100-371 NB 15938

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______

16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Dia. or Size	Type	Material	Thickness	Reinforcement Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106 B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106 B	.277	—	WELDED

17. Inspection Openings: Manholes, No. ______ Size ______ Location ______
Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.

Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL

Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850

Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/ 1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner — R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

J. A. Thomas
Inspector's Signature

Commissions NB 7710
National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19__

______
Inspector's Signature

Commissions ______
National Board, State, Province and No.

Printed in U.S.A. (7/71) This form (E38) is obtainable from the ASME, 345 E. 47th St., New York, N.Y. 10017

5-046-15-156-001

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES ; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ (Horiz. or Vert.), Kind Heat Exch. (Tank, Separator, Heat Ex.) Vessel No. 8-20005-01-2 (Mfrs. Serial No.) (State & State No.) Nat'l Bd. No. 29387 Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ______ Class 3

Items 4–8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length ___ ft. 152.438 in.

5. Seams: Long SML'S H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ______ T.S. ______ (b) Material ______ T.S. ______

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

7. Jacket Closure ______ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ______ Charpy Impact ______ ft-lb. Pneumatic / Hydrostatic or / ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary, Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 (Subject to press.) in. Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating, Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB 111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 inches or gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell~~ CHANNEL: Material SML'S STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length ___ ft. 14.000 in.

12. Seams: Long SML'S (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL. SA285-C T.S. 55,000 (b) Material ______ T.S. ______ (c) Material ______ T.S. ______

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (b) ______ (c) ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ______ Charpy Impact ______ ft-lb. Pneumatic / Hydrostatic or / Combination Test Pressure 225 psi

[1] If Postweld Heat-Treated
[2] List other internal or external pressures with coincident temperature when applicable.

NB#29387

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______

16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Dia. or Size	Type	Material	Thickness	Reinforcement, Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106 B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106 B	.277	—	WELDED

17. Inspection Openings: Manholes, No. ______ Size ______ Location ______
Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.

Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL

Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850

Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner - R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

J. A. Thomas Inspector's Signature Commissions NB 7710 National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19 ______

______ Inspector's Signature Commissions ______ National Board, State, Province and No.

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ. (Horiz. or Vert.) Kind Heat Exch. (Heat Ex.) Vessel No. 8-20005-01-9 (Mfrs. serial No.) Nat'l Bd. No. 29388 (State & State No.) Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ______ Class 3

Items 4–8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length ___ ft. 152.438 in.

5. Seams: Long SMLS H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ______ T.S. ______ (b) Material ______ T.S. ______

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

7. Jacket Closure ______ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ______ Charpy Impact ______ ft-lb Pneumatic Hydrostatic or ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 (Subject to press.) in. Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 inches or gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell:~~ CHANNEL: Material SMLS STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length 14.000 ft. ___ in.

12. Seams: Long SMLS (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL. SA285-C T.S. 55,000 (b) Material ______ T.S. ______ (c) Material ______ T.S. ______

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (b) ______ (c) ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ______ Charpy Impact ______ ft-lb Pneumatic Hydrostatic or ~~Combination~~ Test Pressure 225

[1] If Postweld Heat-Treated

[2] List other internal or external pressures with coincident temperature when applicable.

NB# 29388

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______

16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Dia. or Size	Type	Material	Thickness	Reinforcement, Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106 B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106 B	.277	—	WELDED

17. Inspection Manholes, No. ______ Size ______ Location ______
Openings: Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.

Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL

Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850

Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner — R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

L. A. Thomas
Inspector's Signature

Commissions NB 7710
National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19 ______

______
Inspector's Signature

Commissions ______
National Board, State, Province and No.

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

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

l. 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 Design Bases

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

2. diesel-generator cooler (division 1 and 2 only) - 800 gpm

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

Proto-Power Calc: 97-195
Attachment: D
Rev: A Page 2 of 5

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 1E. 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 approximately 7.8 x 10^6 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.

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 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 diesel-generator 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

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	8.6×10^6 btu/hr
Diesel-generator set cooling requirement	7.8×10^6 btu/hr

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

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

Vendor Data Sheet - BENCHMARK

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

VENDOR DATA SHEET GIVES TOTAL FOULING • THEREFORE, SHELL-SIDE IS SET TO TOTAL FOULING AND TUBE-SIDE FOULING IS SET TO Ø.

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	479.00
Area Factor	0.998169790
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

PROTO-HX CALCULATED VALUE @ BENCHMARK CONDITIONS. (Empirical Factor for Outside h)

DATA SHEET AREA (EFFECTIVE)

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

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

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.5E+5
Tube Mass Flow (lbm/hr)	3.88E+5
Heat Transferred (BTU/hr)	8.589E+6
LMTD	71.1
Effective Area (ft²)	479.0

COMPARED TO VENDOR DATA SHEET

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.15	8.00
Reynold's Number	8.537E+04	6.589E+04
Prandtl Number	2.13	4.00
Bulk Visc (lbm/ft·hr)	0.82	1.47
Skin Visc (lbm/ft·hr)	0.87	1.33
Density (lbm/ft³)	60.53	61.85
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002850
Shell-Side ho (BTU/hr·ft²·°F)	2,075.6
Tube-Side hi (BTU/hr·ft²·°F)	2,100.5
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9886
U Overall (BTU/hr·ft²·°F)	255.2
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.4
Tav Shell (°F)	182.2
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	122.2
Tav Tube (°F)	111.1
Tube Skin Temp (°F)	121.0

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

Commonwealth Edison

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
Outlet Temperature	°F	174.40	122.20
Fouling Factor		0.00285	0.00000

VENDOR DATA SHEET 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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

CALCULATED IN SECTION 3.2

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

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

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

Extrapolation Data

Tube Flow (gpm)	775.6
Shell Flow (gpm)	1,099.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.5E+5
Tube Mass Flow (lbm/hr)	3.88E+5
Heat Transferred (BTU/hr)	8.481E+6
LMTD	71.3
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.15	8.00
Reynold's Number	8.543E+04	6.580E+04
Prandtl Number	2.13	4.00
Bulk Visc (lbm/ft·hr)	0.82	1.47
Skin Visc (lbm/ft·hr)	0.87	1.34
Density (lbm/ft³)	60.52	61.85
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002850
Shell-Side ho (BTU/hr·ft²·°F)	2,076.0
Tube-Side hi (BTU/hr·ft²·°F)	2,099.0
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9889
U Overall (BTU/hr·ft²·°F)	255.2
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.6
Tav Shell (°F)	182.3
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	121.9
Tav Tube (°F)	110.9
Tube Skin Temp (°F)	120.9

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

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 (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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

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

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	8.484E+6
LMTD	71.3
Effective Area (ft²)	471.2

LESS THAN REF. COND. REQUIRED HEATRATE

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	8.20
Reynold's Number	8.257E+04	6.728E+04
Prandtl Number	2.14	4.01
Bulk Visc (lbm/ft·hr)	0.82	1.47
Skin Visc (lbm/ft·hr)	0.88	1.34
Density (lbm/ft³)	60.53	61.85
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002850
Shell-Side ho (BTU/hr·ft²·°F)	2,034.1
Tube-Side hi (BTU/hr·ft²·°F)	2,138.0
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9889
U Overall (BTU/hr·ft²·°F)	255.2
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.1
Tav Shell (°F)	182.1
Shell Skin Temp (°F)	173.1
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	121.4
Tav Tube (°F)	110.7
Tube Skin Temp (°F)	120.5

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

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
Outlet Temperature	°F	174.40	122.20
Fouling Factor		0.00285	0.00000

FOULING INPUT MODE USED IN FOLLOWING CALCULATION

Shell Fluid Name	Fresh Water
Tube Fluid Name	Fresh Water
Design Heat Transfer (BTU/hr)	8,600,000
Design Heat Trans Coeff (BTU/hr·ft^2·°F)	255.20
Emprical Factor for Outside h	0.780339000
Performance Factor (% Reduction)	0.00
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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	
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·°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·ft²·°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)	25,594.8
LMTD	71.1	LMTD Correction Factor	0.9885
Effective Area (ft²)	471.2		
		U Overall (BTU/hr·ft²·°F)	259.7

REFERENCE HEAT RATE (→ 8.6E+6)

ADJUSTED OVERALL FOULING FACTOR (→ 0.002782)

Property	Shell-Side	Tube-Side		
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/ft³)	60.53	61.85	Tube Temp Out (°F)	121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	120.8

** Reynolds Number Outside Range of Equation Applicability

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

Commonwealth Edison

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	100.00
Outlet Temperature	°F	174.40	122.20
Fouling Factor		0.00278	0.00000

REDUCED OVERALL FOULING SECTION 6.2

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

ADJUSTED AREA SECTION 3.2

12:31:13 **PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)** 06/29/98

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-HX MODEL

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

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)		
Reynold's Number		
Prandtl Number		
Bulk Visc (lbm/ft·hr)		
Skin Visc (lbm/ft·hr)		
Density (lbm/ft³)		
Cp (BTU/lbm·°F)		
K (BTU/hr·ft·°F)		

Shell Temp In (°F)
Shell Temp Out (°F)
Tav Shell (°F)
Shell Skin Temp (°F)
Tube Temp In (°F)
Tube Temp Out (°F)
Tav Tube (°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)	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)	25,594.8
LMTD	71.1	LMTD Correction Factor	0.9885
Effective Area (ft²)	471.2		
		U Overall (BTU/hr·ft²·°F)	259.7

ADJUSTED FOULING

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	8.20
Reynold's Number	8.251E+04	6.738E+04
Prandtl Number	2.14	4.01
Bulk Visc (lbm/ft·hr)	0.82	1.47
Skin Visc (lbm/ft·hr)	0.88	1.34
Density (lbm/ft³)	60.53	61.85
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.9
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	121.6
Tav Tube (°F)	110.8
Tube Skin Temp (°F)	120.8

Proto-Power Calc: 97-195
Attachment: E
Rev: A Page 11 of 13

** Reynolds Number Outside Range of Equation Applicability

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

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		0.00278	0.00000

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
Heat Exchanger Type	TEMA-E
Effective Area (ft^2)	471.23
Area Factor	0.981978184
Area Ratio	
Number of Shells per Unit	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 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
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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 — Ø FOULING 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·°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·°F/BTU)	0.000000
Tube Mass Flow (lbm/hr)	3.978E+5	Shell-Side ho (BTU/hr·ft²·°F)	1,957.5
		Tube-Side hi (BTU/hr·ft²·°F)	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·ft²·°F)	955.9

CLEAN HEAT RATE → 1.885E+7; "CLEAN" → 0.000000

Property	Shell-Side	Tube-Side		
Velocity (ft/s)	4.97	8.22	Shell Temp In (°F)	190.0
Reynold's Number	7.721E+04	7.626E+04	Shell Temp Out (°F)	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)	148.6
Skin Visc (lbm/ft·hr)	1.05	1.07	Tube Temp In (°F)	100.0
Density (lbm/ft³)	60.74	61.65	Tube Temp Out (°F)	147.4
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	123.7
K (BTU/hr·ft·°F)	0.38	0.37	Tube Skin Temp (°F)	146.8

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

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

Commonwealth Edison

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·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·ft²·°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·°F)	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·ft²·°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 Temp (°F)	138.0

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

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

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0
Input Fouling Factor	0.001075

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	1.304E+7
LMTD	61.3
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.001075
Shell-Side ho (BTU/hr·ft²·°F)	2,003.3
Tube-Side hi (BTU/hr·ft²·°F)	2,216.1
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9633
U Overall (BTU/hr·ft²·°F)	469.0

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.98	8.21
Reynold's Number	8.020E+04	7.118E+04
Prandtl Number	2.20	3.77
Bulk Visc (lbm/ft·hr)	0.85	1.39
Skin Visc (lbm/ft·hr)	0.94	1.21
Density (lbm/ft³)	60.62	61.77
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	165.6
Tav Shell (°F)	177.8
Shell Skin Temp (°F)	163.4
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	132.8
Tav Tube (°F)	116.4
Tube Skin Temp (°F)	131.4

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

Tube-side Fouling = 0.0010

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data	
Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0
Input Fouling Factor	0.001650

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	1.112E+7
LMTD	65.5
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.001650
Shell-Side ho (BTU/hr·ft²·°F)	2,016.5
Tube-Side hi (BTU/hr·ft²·°F)	2,183.2
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9770
U Overall (BTU/hr·ft²·°F)	368.8

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.98	8.20
Reynold's Number	8.120E+04	6.953E+04
Prandtl Number	2.17	3.87
Bulk Visc (lbm/ft·hr)	0.84	1.43
Skin Visc (lbm/ft·hr)	0.91	1.27
Density (lbm/ft³)	60.58	61.80
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	169.2
Tav Shell (°F)	179.6
Shell Skin Temp (°F)	167.6
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	128.0
Tav Tube (°F)	114.0
Tube Skin Temp (°F)	126.7

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

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

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	9.683E+6
LMTD	68.7
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002225
Shell-Side ho (BTU/hr·ft²·°F)	2,026.2
Tube-Side hi (BTU/hr·ft²·°F)	2,158.6
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9842
U Overall (BTU/hr·ft²·°F)	303.9

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	8.20
Reynold's Number	8.194E+04	6.830E+04
Prandtl Number	2.15	3.95
Bulk Visc (lbm/ft·hr)	0.83	1.45
Skin Visc (lbm/ft·hr)	0.89	1.31
Density (lbm/ft³)	60.55	61.83
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	171.9
Tav Shell (°F)	180.9
Shell Skin Temp (°F)	170.6
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	124.4
Tav Tube (°F)	112.2
Tube Skin Temp (°F)	123.3

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

Tube-side Fouling = 0.001984 (LIMIT)

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	0.002782

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·ft²·°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)	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		
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/ft³)	60.53	61.85	Tube Temp Out (°F)	121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	120.8

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

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 35°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	193.5
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	35.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	9.68E+4
Heat Transferred (BTU/hr)	8.6E+6
LMTD	98.1
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	1.98
Reynold's Number	8.251E+04	1.155E+04
Prandtl Number	2.14	5.90
Bulk Visc (lbm/ft·hr)	0.82	2.09
Skin Visc (lbm/ft·hr)	0.88	1.39
Density (lbm/ft³)	60.53	62.22
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.35

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,032.2
Tube-Side hi (BTU/hr·ft²·°F)	599.1
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9740
U Overall (BTU/hr·ft²·°F)	191.1
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.3
Tube Temp In (°F)	35.0
Tube Temp Out (°F)	123.9
Tav Tube (°F)	79.4
Tube Skin Temp (°F)	117.0

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 40°F

Calculation Specifications

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

Test Data

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.024E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	96.0
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	2.10
Reynold's Number	8.251E+04	1.261E+04
Prandtl Number	2.14	5.70
Bulk Visc (lbm/ft·hr)	0.82	2.02
Skin Visc (lbm/ft·hr)	0.88	1.38
Density (lbm/ft³)	60.53	62.20
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,032.3
Tube-Side hi (BTU/hr·ft²·°F)	634.9
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9744
U Overall (BTU/hr·ft²·°F)	195.1
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.3
Tube Temp In (°F)	40.0
Tube Temp Out (°F)	124.0
Tav Tube (°F)	82.0
Tube Skin Temp (°F)	117.3

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 50°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	232.2
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	50.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.162E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	91.9
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	2.38
Reynold's Number	8.251E+04	1.520E+04
Prandtl Number	2.14	5.33
Bulk Visc (lbm/ft·hr)	0.82	1.91
Skin Visc (lbm/ft·hr)	0.88	1.37
Density (lbm/ft³)	60.53	62.15
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,032.5
Tube-Side hi (BTU/hr·ft²·°F)	719.6
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9756
U Overall (BTU/hr·ft²·°F)	203.6
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.4
Tube Temp In (°F)	50.0
Tube Temp Out (°F)	124.1
Tav Tube (°F)	87.0
Tube Skin Temp (°F)	117.9

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 60°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.346E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	87.8
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	2.76
Reynold's Number	8.251E+04	1.865E+04
Prandtl Number	2.14	5.00
Bulk Visc (lbm/ft·hr)	0.82	1.80
Skin Visc (lbm/ft·hr)	0.88	1.37
Density (lbm/ft³)	60.53	62.09
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,032.7
Tube-Side hi (BTU/hr·ft²·°F)	828.7
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9770
U Overall (BTU/hr·ft²·°F)	212.7
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.5
Tube Temp In (°F)	60.0
Tube Temp Out (°F)	123.9
Tav Tube (°F)	92.0
Tube Skin Temp (°F)	118.5

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 70°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	321.0
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	70.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.606E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	83.7
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	3.30
Reynold's Number	8.251E+04	2.348E+04
Prandtl Number	2.14	4.71
Bulk Visc (lbm/ft·hr)	0.82	1.71
Skin Visc (lbm/ft·hr)	0.88	1.36
Density (lbm/ft³)	60.53	62.03
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,032.8
Tube-Side hi (BTU/hr·ft²·°F)	975.6
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9790
U Overall (BTU/hr·ft²·°F)	222.6
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.6
Tube Temp In (°F)	70.0
Tube Temp Out (°F)	123.6
Tav Tube (°F)	96.8
Tube Skin Temp (°F)	119.2

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 80°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.997E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	79.6
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,033.0
Tube-Side hi (BTU/hr·ft²·°F)	1,186.3
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9814
U Overall (BTU/hr·ft²·°F)	233.5

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	4.11
Reynold's Number	8.251E+04	3.075E+04
Prandtl Number	2.14	4.45
Bulk Visc (lbm/ft·hr)	0.82	1.62
Skin Visc (lbm/ft·hr)	0.88	1.35
Density (lbm/ft³)	60.53	61.97
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.7
Tube Temp In (°F)	80.0
Tube Temp Out (°F)	123.1
Tav Tube (°F)	101.5
Tube Skin Temp (°F)	119.8

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

09:00:52 **PROTO-HX 3.02 by Proto-Power Corporation (SN#PHX-0000)** 06/29/98

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 90°F

Calculation Specifications

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

Test Data

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

Extrapolation Data	
Tube Flow (gpm)	530.9
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	90.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	2.656E+5
Heat Transferred (BTU/hr)	8.6E+6
LMTD	75.4
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,033.2
Tube-Side hi (BTU/hr·ft²·°F)	1,519.8
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9845
U Overall (BTU/hr·ft²·°F)	245.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	5.47
Reynold's Number	8.251E+04	4.293E+04
Prandtl Number	2.14	4.22
Bulk Visc (lbm/ft·hr)	0.82	1.54
Skin Visc (lbm/ft·hr)	0.88	1.34
Density (lbm/ft³)	60.53	61.91
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	173.9
Tav Shell (°F)	181.9
Shell Skin Temp (°F)	172.8
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	122.4
Tav Tube (°F)	106.2
Tube Skin Temp (°F)	120.3

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 100°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)	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·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·ft²·°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)	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		
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/ft³)	60.53	61.85	Tube Temp Out (°F)	121.6
Cp (BTU/lbm·°F)	1.00	1.00	Tav Tube (°F)	110.8
K (BTU/hr·ft·°F)	0.39	0.37	Tube Skin Temp (°F)	120.8

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 35°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	161.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	35.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	8.059E+4
Heat Transferred (BTU/hr)	7.8E+6
LMTD	93.3
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,037.1
Tube-Side hi (BTU/hr·ft²·°F)	531.4
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9713
U Overall (BTU/hr·ft²·°F)	182.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	1.65
Reynold's Number	8.292E+04	1.010E+04
Prandtl Number	2.13	5.59
Bulk Visc (lbm/ft·hr)	0.82	1.99
Skin Visc (lbm/ft·hr)	0.87	1.31
Density (lbm/ft³)	60.52	62.18
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.8
Tube Temp In (°F)	35.0
Tube Temp Out (°F)	131.8
Tav Tube (°F)	83.4
Tube Skin Temp (°F)	122.7

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 40°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data	
Tube Flow (gpm)	169.8
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	40.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	8.492E+4
Heat Transferred (BTU/hr)	7.8E+6
LMTD	91.4
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,037.2
Tube-Side hi (BTU/hr·ft²·°F)	561.0
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9716
U Overall (BTU/hr·ft²·°F)	186.5

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	1.74
Reynold's Number	8.292E+04	1.097E+04
Prandtl Number	2.13	5.40
Bulk Visc (lbm/ft·hr)	0.82	1.93
Skin Visc (lbm/ft·hr)	0.87	1.31
Density (lbm/ft³)	60.52	62.16
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.8
Tube Temp In (°F)	40.0
Tube Temp Out (°F)	131.9
Tav Tube (°F)	86.0
Tube Skin Temp (°F)	122.9

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 50°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	9.527E+4
Heat Transferred (BTU/hr)	7.8E+6
LMTD	87.5
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,037.4
Tube-Side hi (BTU/hr·ft²·°F)	629.9
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9726
U Overall (BTU/hr·ft²·°F)	194.6

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	1.96
Reynold's Number	8.292E+04	1.305E+04
Prandtl Number	2.13	5.06
Bulk Visc (lbm/ft·hr)	0.82	1.82
Skin Visc (lbm/ft·hr)	0.87	1.30
Density (lbm/ft³)	60.52	62.10
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.9
Tube Temp In (°F)	50.0
Tube Temp Out (°F)	131.9
Tav Tube (°F)	91.0
Tube Skin Temp (°F)	123.6

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 60°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.088E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	83.6
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,037.6
Tube-Side hi (BTU/hr·ft²·°F)	716.3
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9739
U Overall (BTU/hr·ft²·°F)	203.3

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	2.24
Reynold's Number	8.292E+04	1.575E+04
Prandtl Number	2.13	4.76
Bulk Visc (lbm/ft·hr)	0.82	1.72
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	62.05
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	174.0
Tube Temp In (°F)	60.0
Tube Temp Out (°F)	131.8
Tav Tube (°F)	95.9
Tube Skin Temp (°F)	124.2

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 70°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	254.2
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	70.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.272E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	79.7
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	2.62
Reynold's Number	8.292E+04	1.940E+04
Prandtl Number	2.13	4.50
Bulk Visc (lbm/ft·hr)	0.82	1.63
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	61.99
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,037.8
Tube-Side hi (BTU/hr·ft²·°F)	829.2
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9757
U Overall (BTU/hr·ft²·°F)	212.8
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	174.1
Tube Temp In (°F)	70.0
Tube Temp Out (°F)	131.4
Tav Tube (°F)	100.7
Tube Skin Temp (°F)	124.9

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 80°F

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data	
Tube Flow (gpm)	307.0
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	80.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.536E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	75.8
Effective Area (ft²)	471.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	3.16
Reynold's Number	8.292E+04	2.462E+04
Prandtl Number	2.13	4.26
Bulk Visc (lbm/ft·hr)	0.82	1.56
Skin Visc (lbm/ft·hr)	0.87	1.28
Density (lbm/ft³)	60.52	61.92
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,038.0
Tube-Side hi (BTU/hr·ft²·°F)	984.2
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9779
U Overall (BTU/hr·ft²·°F)	223.2
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	174.2
Tube Temp In (°F)	80.0
Tube Temp Out (°F)	130.8
Tav Tube (°F)	105.4
Tube Skin Temp (°F)	125.6

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 90°F

Calculation Specifications

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

Test Data

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.947E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	71.9
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,038.2
Tube-Side hi (BTU/hr·ft²·°F)	1,213.3
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9808
U Overall (BTU/hr·ft²·°F)	234.8

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	4.01
Reynold's Number	8.292E+04	3.273E+04
Prandtl Number	2.13	4.04
Bulk Visc (lbm/ft·hr)	0.82	1.48
Skin Visc (lbm/ft·hr)	0.87	1.27
Density (lbm/ft³)	60.52	61.86
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	174.3
Tube Temp In (°F)	90.0
Tube Temp Out (°F)	130.1
Tav Tube (°F)	110.1
Tube Skin Temp (°F)	126.2

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

Commonwealth Edison

Calculation Report for DG01A - DG Jacket Water Cooler

CSCS = 100°F

Calculation Specifications

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

Test Data

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

Extrapolation Data	
Tube Flow (gpm)	534.5
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	2.674E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	67.8
Effective Area (ft²)	471.2

Overall Fouling (hr·ft²·°F/BTU)	0.002782
Shell-Side ho (BTU/hr·ft²·°F)	2,038.4
Tube-Side hi (BTU/hr·ft²·°F)	1,592.6
1/Wall Resis (BTU/hr·ft²·°F)	25,594.8
LMTD Correction Factor	0.9844
U Overall (BTU/hr·ft²·°F)	247.9

Property	Shell-Side	Tube-Side
Velocity (ft/s)	4.99	5.52
Reynold's Number	8.292E+04	4.701E+04
Prandtl Number	2.13	3.85
Bulk Visc (lbm/ft·hr)	0.82	1.42
Skin Visc (lbm/ft·hr)	0.87	1.27
Density (lbm/ft³)	60.52	61.79
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	174.4
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	129.2
Tav Tube (°F)	114.6
Tube Skin Temp (°F)	126.8

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

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

PROTO-HX™ 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**

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

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

EC/ECR No.: [4] 388666 **Revision:** [5] 000

Station(s): [7] LaSalle

Unit No.: [8] 01 & 02

Safety/QA Class: [9] SR

System Code(s): [10] HP, DG, E22

Is this Design Analysis Safeguards Information? [11] 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): [14]
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] Sean Tarton (Print Name) Sean Tarton (Sign Name) 5/18/12 (Date)

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

Reviewer: [18] Steve Chon (Print Name) Steve Chon (Sign Name) 5/18/12 (Date)

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

External Approver: [20] NA (Print Name) (Sign Name) (Date)

Exelon Reviewer [21] NA (Print Name) (Sign Name) (Date)

Exelon Approver: [22] DAN SCHMIT (Print Name) D Schmit (Sign Name) 5/18/12 (Date)

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·ft^2·°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·ft^2·°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·ft^2·°F/BTU and 0.00196 hr·ft^2·°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·ft^2·°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·ft^2·°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·ft^2·°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·ft^2·°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 $hr \cdot ft^2 \cdot °F/BTU$ (2 pgs)

B. Data Report for 1(2)E22-S001 at 550 gpm with FF = 0.00196 $hr \cdot ft^2 \cdot °F/BTU$ (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·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·°F)	241.70
Outside h Factor (Hoff)	0.633693000
Fixed U (BTU/hr·ft²·°F)	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	0.00000
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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

Extrapolation Data	
Tube Flow (gpm)	645.10
Shell Flow (gpm)	1,064.50
Tube Inlet Temp (°F)	107.00
Shell Inlet Temp (°F)	190.00
Input Fouling Factor	0.002230

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	532,515.63
Tube Mass Flow (lbm/hr)	322,710.98
Heat Transferred (BTU/hr)	7,916,590.94
LMTD	63.2
Effective Area (ft²)	463.7

Overall Fouling (hr·ft²·°F/BTU)	0.002230
Shell-Side ho (BTU/hr·ft²·°F)	1,891.2
Tube-Side hi (BTU/hr·ft²·°F)	1,408.2
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9847
U Overall (BTU/hr·ft²·°F)	274.4

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.37
Reynold's Number	77,252	32,323
Prandtl Number	2.1276	3.6616
Bulk Visc (lbm/ft·hr)	0.8197	1.3556
Skin Visc (lbm/ft·hr)	0.8730	1.1913
Density (lbm/ft³)	60.5172	61.7228
Cp (BTU/lbm·°F)	1.0025	0.9988
K (BTU/hr·ft·°F)	0.3862	0.3698

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.2
Tav Shell (°F)	182.6
Shell Skin Temp (°F)	173.4
Tube Temp In (°F)	107.0
Tube Temp Out (°F)	131.6
Tav Tube (°F)	119.3
Tube Skin Temp (°F)	133.5

** Reynolds Number Outside Range of Equation Applicability

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

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·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·°F)	241.70
Outside h Factor (Hoff)	0.633693000
Fixed U (BTU/hr·ft²·°F)	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	0.00000
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Commonwealth Edison

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

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

Extrapolation Data

Tube Flow (gpm)	545.90
Shell Flow (gpm)	1,064.50
Tube Inlet Temp (°F)	107.00
Shell Inlet Temp (°F)	190.00
Input Fouling Factor	0.001960

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	532,515.63
Tube Mass Flow (lbm/hr)	273,086.22
Heat Transferred (BTU/hr)	7,936,128.27
LMTD	60.7
Effective Area (ft²)	463.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	3.70
Reynold's Number	77,243	27,941
Prandtl Number	2.1278	3.5771
Bulk Visc (lbm/ft·hr)	0.8198	1.3270
Skin Visc (lbm/ft·hr)	0.8737	1.1487
Density (lbm/ft³)	60.5176	61.6875
Cp (BTU/lbm·°F)	1.0025	0.9988
K (BTU/hr·ft·°F)	0.3862	0.3705

Overall Fouling (hr·ft²·°F/BTU)	0.001960
Shell-Side ho (BTU/hr·ft²·°F)	1,890.9
Tube-Side hi (BTU/hr·ft²·°F)	1,248.7
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9802
U Overall (BTU/hr·ft²·°F)	287.5
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.1
Tav Shell (°F)	182.6
Shell Skin Temp (°F)	173.3
Tube Temp In (°F)	107.0
Tube Temp Out (°F)	136.1
Tav Tube (°F)	121.5
Tube Skin Temp (°F)	137.8

** Reynolds Number Outside Range of Equation Applicability

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

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision)		**Last Page No.** [6]	1
Analysis No.: [1]	97-197	**Revision:** [2]	A03
Title: [3]	Thermal Model of ComEd / LaSalle Station HPCS Diesel Generator Jacket Water Coolers		
EC/ECR No.: [4]	EC 384525	**Revision:** [5]	000
Station(s): [7]	LaSalle		
Unit No.: [8]	02		
Safety/QA Class: [9]	SR		
System Code(s): [10]	HP, E22, DG		

Is this Design Analysis Safeguards Information? [11] 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): [14]

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.

	Print Name	Sign Name	Date
Preparer: [16]	Sean Tanton	Sean Tanton	3/20/12

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Matthew Cosenza	[signature]	3/20/12

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	N/A	N/A	N/A
Exelon Reviewer [21]	N/A	N/A	N/A
Exelon Approver: [22]	Dan Schmit	D Schmit	3/28/12

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision) | **Last Page No.** [6] Attachment A, pg A2

Analysis No.: [1] 97-197 **Revision:** [2] A02

Title: [3] Thermal Model of ComEd / LaSalle Station HPCS Diesel Generator Jacket Water Coolers

EC/ECR No.: [4] 370853 **Revision:** [5] 000

Station(s): [7] LaSalle
Unit No.: [8] 01
Safety/QA Class: [9] SR
System Code(s): [10] HP, E22, DG

Is this Design Analysis Safeguards Information? [11] 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): [14]
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 revision determines if the revised flows are acceptable and can remove the required amount of heat for the heat exchangers.

This revision only applies to Unit 1. The flows shown for Unit 2 remain valid and are not impacted by this revision.

Disposition of Changes: [15]
Attachment A shows that a sufficient heat transfer rate can be achieved by reducing the fouling factor to 0.00196 hr*ft^2*°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*ft^2*°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. System engineering has agreed to accept more stringent criteria for the cleanliness of the 1E22-S001 cooler. Therefore, the changes to the flows are acceptable and can remove the required amount of heat.

	Print Name	Sign Name	Date
Preparer: [16]	Sean Tanton	Sean Tanton	5/24/11

Method of Review: [17] Detailed Review ☒ Alternate Calculations ☐ Testing ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Matthew Cosenza	Matt C	05/24/2011

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	N/A	N/A	N/A
Exelon Reviewer [21]	N/A	N/A	N/A
Exelon Approver: [22]	Dan Schmit	DJSchmit	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 flow[1] = 550 gpm (Ref. 2)
Plugging allowance = 1% (4 tubes) (Ref. 1)
Tubeside inlet water temperature = 104 °F (Ref. 1)
Overall fouling factor[2] = 0.00223 hr*ft^2*°F/BTU (Ref. 1)
Design heat load[3] = 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*ft^2*°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*ft^2*°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)

Assumptions:
There are no assumptions associated with this revision.

References:
1. 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*ft^2*°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*ft^2*°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)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

546.26 gpm Tube Flow, 104 F Tube Temp, 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 Data	
Data Date		Tube Flow (gpm)	546.26
Shell Flow (gpm)		Shell Flow (gpm)	1,064.50
Shell Temp In (°F)		Tube Inlet Temp (°F)	104.00
Shell Temp Out (°F)		Shell Inlet Temp (°F)	190.00
Tube Flow (gpm)			
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·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)	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
		Tube-Side hi (BTU/hr·ft²·°F)	1,235.3
Heat Transferred (BTU/hr)	8,206,590.75	1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD	63.0	LMTD Correction Factor	0.9803
Effective Area (ft²)	463.7		
		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)	136.0

** Reynolds Number Outside Range of Equation Applicability

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

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·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·°F)	241.70
Outside h Factor (Hoff)	0.633693000
Fixed U (BTU/hr·ft²·°F)	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	0.00000
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (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 Generator Jacket Water Coolers		
EC/ECR No.: [4]	EC 366846	**Revision:** [5]	0
Station(s): [7]	LaSalle		
Unit No.: [8]	1 and 2		
Safety/QA Class: [9]	SR		
System Code(s): [10]	E22		

Is this Design Analysis Safeguards Information? [11] Yes ☐ No ☒ If yes, see SY-AA-101-106

Does this Design Analysis contain Unverified Assumptions? [12] Yes ☐ No ☒ If yes, ATI/AR#: ______

This Design Analysis SUPERCEDES: [13] **NA** **in its entirety.**

Description of Changes (list affected pages): [14]

- Revised pg. 2/12 of Rev. A to add new Reference 8.12 to Table 3-1
- Added Reference 8.12 to references list on page 12 of 12 of Rev. A
- Replaced pgs. 3 and 4 of Attachment B in Rev. A, UFSAR Section 9.5.5.1.1 Rev. 0, with new pg. 3, UFSAR Section 9.5.5.1.1 from pending approved UFSAR Change LUCR-0082 for Rev. 17 of the UFSAR
- Added new Ref. 8.12 (pg. PTD-7 from Specification J-2544 Amd. 2) to Attachment B as page 4

Verified no UFSAR change to the 650 gpm minimum cooling water flow value shown on Attachment B pg. 2/5 of Rev. A (UFSAR Section 9.2.1.1.1 a. 3) has occurred over time.

Disposition of Changes: [15]

This revision updates an included UFSAR section reference with the latest approved UFSAR information, and provides an additional reference for the basis of the heat load from the DG cooler. This revision also addresses A/R (Issue Report) No. 628211 and associated assignment 02.

Based on diesel generator nameplate data obtained by the System Manager, the Div. 3 diesel is from the same manufacturer, is the same model number, and has the same rated output as the Div. 1 and 2 DGs. Technical proposal heat balance data for the Div. 1 and 2 DGs, submitted by the supplier (see Ref. 8.12 in Attachment B, pg. PTD-7 from Purchase Specification J-2544 Amendment 2), shows that the energy absorbed by the cooling water at rated load and design ambient conditions is 2284 kW, which converts to 7.8E+06 Btu/hr, as stated in the UFSAR and used in previous revisions of the calculation.

	Print Name	Sign Name	Date
Preparer: [16]	Dan Schmit	D J Schmit	8/03/07

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Sean Tarton	Sean Tarton	8/9/07

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	NA		
Exelon Reviewer [21]	NA		
Exelon Approver: [22]	Bill Hilton	B. Hilton	8-10-07

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
Heat Exchanger Type	TEMA - E	8.7, 8.8
Number of Shells per unit	1	8.7
Total Effective Area per unit (ft^2)	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

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-HX™ 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

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

104

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 10^6 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 low-pressure expansion tank, an AMOT temperature regulating valve, a

Approved pending
UFSAR Change LUCR-0082.

REFERENCE 8.12

Proposal Technical Data for
Diesel Engine-Generator Sets, Cont.

La Salle County Station - Units 1 and 2

J-2544
Amd. 2, 01-27-78

Name of Bidder: Steward & Stevenson Services, Inc.

ENGINE-GENERATOR DATA, Cont.	(Insert all data in these columns)			
	BASE BID		ALTERNATE 1	
	DIESEL GEN. 0	DIESEL GEN. 1A AND 2A	DIESEL GEN. 0, 1A AND 2A	
k. WK^2 value of all rotating parts..............($lb\text{-}ft^2$)	34,690			
l. Is base frame stress relieved after fabrication but before machining.......	no			
m. Vibration Dampers:				
(1) Type..................	None required or recommended			
(2) Number.................	N/A			
n. Full load speed.....(r/min)	900			
o. 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 × 10³ Btu/hr·kW	= 7.8×10⁶ Btu/h	
(3) Energy dissipated in exhaust gases......(kW)	2,689			
(4) Energy lost to ambient by radiation and convection............(kW)	260			
p. Environmental Data:				
(1) Maximum ambient temperature for continuous operation..........(°F)	104°			Amd. 2
(2) Minimum ambient temperature for continuous operation..........(°F)	30°			Amd. 2
(3) Generator losses to ambient at rated load and design ambient.(kW)	98			

*Note: 2,600 kW at 90°F Ambient (This would derate 4% in 40°C - 104°F)

125

:2

Calc. 97-197 R. A01
Attach. B
Pg. 4/5

LASALLE CALCULATION

EDITORIAL – COMMENT TO CALCULATION

Affecting Calculation No.: 97-197	Rev: A00	For Reference	Page No. 1 of 1

The use of this form shall be limited to document corrections of editorial nature. Return to Sylvia Venecia

	Print	Sign	Date
Prepared by:	Sylvia F-Venecia	[signature]	6/3/02
Reviewed by:			
Approved by:			

Description of Correction:

1) Pages 3 thru 6, A1, B1 & C1 are on forms with the ComEd logo, which are not the most current forms.

(Per J.T. Conner on 5/28/02. OK to Process. In the future the most current forms will be used.)

When these comments are incorporated, return this form with the revised calculation.

Incorporated on Calc Rev.	By:	Date:

DESIGN ANALYSIS NO.: Calc. # 97-197 **PAGE NO. 1**
Major REV Number: A **Minor Rev Number: 00**

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

Unit: [ ] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE: (C018) M010
DISCIPLINE CODE: (C011) M
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**

ATTRIBUTES (C016)

TYPE	VALUE	TYPE	VALUE
Elevation	710' 0"		
Software	PROTO-HX		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
1E22-S001	H15
2E22-S001	H15

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
~~EC~~/DCP	EC# 334017	Y
/		
/		
/		
/		
/		
/		

REMARKS: NA

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, 192 KB, 04/14/2002, 5:04pm

(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [X] N/A, Per EC#: 334017
(If yes, attach impact review sheet)

Prepared by: Jeff W. VanStrien / Jeff W. VanStrien / 5-9-02
Print / Sign / Date

Reviewed by: Brian L. Davenport / B.L. Davenport / 5-9-02
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: N/A **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] **Additional Review** [ ] **Special Review Team**

Additional Reviewer or Special Review Team Leader: ____ / ____ / ____
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ____ / ____ / ____ 2) ____ / ____ / ____
Print / Sign / Date / Print / Sign / Date

3) ____ / ____ / ____ 4) ____ / ____ / ____
Print / Sign / Date / Print / Sign / Date

Supplemental Review Results:

Approved by: J.T. Conner / [signature] / 5/14/02
Print / Sign / Date

External Design Analysis Review **(Attachment 3 Attached)**

Reviewed by: ____ / ____ / ____
Print / Sign / Date

Approved by: ____ / ____ / ____
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] **Yes** **[X] No**
Tracked By: AT#, EC# etc.) ____

ComEd

NES-G-14.01
Effective Date:
04/14/00

CALCULATION TABLE OF CONTENTS

CALCULATION NO. *97-197* **REV. NO. A00 PAGE NO. 3**

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E-FORM

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/ft^3 (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.

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*ft^{2}*°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:

$$\frac{ThermalMargin}{RequiredHeatLoad} \times 100\% = \%ThermalMargin \qquad \text{[Equation 2]}$$

Case 1

When the service water inlet temperature is increased to 104°F for the same fouling factor (0.002732 hr*ft^{2}*°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*ft^{2}*°F/BTU (Ref. 2). For conservatism, this value was doubled to 0.00223 hr*ft^{2}*°F/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].

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 $hr*ft^{2}*°F/BTU$) 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 $hr*ft^{2}*°F/BTU$ 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)

E-FORM

Attachment "A"

Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ Design Fouling)

E-FORM

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		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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

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

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

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

Extrapolation Data

Tube Flow (gpm)	646.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-197
Revision No. A00
Attachment A
Page No. A3 of A3

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	7.474E+6
LMTD	67.3
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.34
Reynold's Number	7.746E+04	3.095E+04
Prandtl Number	2.12	3.81
Bulk Visc (lbm/ft·hr)	0.82	1.41
Skin Visc (lbm/ft·hr)	0.87	1.24
Density (lbm/ft³)	60.51	61.78
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,894.1
Tube-Side hi (BTU/hr·ft²·°F)	1,372.6
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9880
U Overall (BTU/hr·ft²·°F)	240.0
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	176.0
Tav Shell (°F)	183.0
Shell Skin Temp (°F)	174.5
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	127.2
Tav Tube (°F)	115.6
Tube Skin Temp (°F)	129.2

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

Attachment "B"

Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ 2X Max. Tested FF)

E-FORM

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		* 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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

* Fouling Factor input on next page

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)	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)		* Input Fouling Factor	0.002230

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Calculation No. 97-197
Revision No. A00
Attachment B
Page No. B3 of B3

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	8.237E+6
LMTD	65.4
Effective Area (ft²)	468.2

Overall Fouling (hr·ft²·°F/BTU)	0.002230
Shell-Side ho (BTU/hr·ft²·°F)	1,889.3
Tube-Side hi (BTU/hr·ft²·°F)	1,383.0
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9845
U Overall (BTU/hr·ft²·°F)	273.3

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.34
Reynold's Number	7.709E+04	3.130E+04
Prandtl Number	2.13	3.76
Bulk Visc (lbm/ft·hr)	0.82	1.39
Skin Visc (lbm/ft·hr)	0.88	1.21
Density (lbm/ft³)	60.52	61.76
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.6
Tav Shell (°F)	182.3
Shell Skin Temp (°F)	172.8
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	129.5
Tav Tube (°F)	116.8
Tube Skin Temp (°F)	131.7

** Reynolds Number Outside Range of Equation Applicability

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

Attachment "C"

Proto-Hx Calc. Report for DG01B
(CSCS=104 F @ 2X Max. Tested FF, w\ 1% plugged)

E-FORM

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=104 F@ 2X NDIT FF, 1% plug

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	*	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	TEMA-E
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	416
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

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Page No. C2 of C3

* fouling factor input on next page.

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

Extrapolation Data	
Tube Flow (gpm)	646.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	104.0
Shell Inlet Temp (°F)	190.0
* Input Fouling Factor	0.002230

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

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Attachment C
Page No. C3 of C3

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	8.189E+6
LMTD	65.5
Effective Area (ft²)	463.7

Overall Fouling (hr·ft²·°F/BTU)	0.002230
Shell-Side ho (BTU/hr·ft²·°F)	1,889.4
Tube-Side hi (BTU/hr·ft²·°F)	1,393.0
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9848
U Overall (BTU/hr·ft²·°F)	273.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.38
Reynold's Number	7.712E+04	3.158E+04
Prandtl Number	2.13	3.76
Bulk Visc (lbm/ft·hr)	0.82	1.39
Skin Visc (lbm/ft·hr)	0.88	1.21
Density (lbm/ft³)	60.52	61.76
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.7
Tav Shell (°F)	182.3
Shell Skin Temp (°F)	172.8
Tube Temp In (°F)	104.0
Tube Temp Out (°F)	129.4
Tav Tube (°F)	116.7
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

REV	TOTAL NO. OF PAGES	ORIGINATOR/DATE	VERIFIER/DATE	APPROVAL/DATE
A	58	[signature] 6/26/98 D. Phyfe	[signature] 6/26/98 S. Ingalls	[signature] 6/30/98 L. Philpot

Revision History

Revision	Revision Description
A	Original Issue

PROTO-POWER CORPORATION GROTON, CONNECTICUT	CALC NO. 97-197	REV A	PAGE III OF V
	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.			

CALCULATION VERIFICATION FORM

REVIEW METHOD:

Approach Checked:	☒	N/A ☐
Logic Checked:	☒	N/A ☐
Arithmetic Checked:	☒	N/A ☐
Alternate Method (Attach Brief Summary)	☐	N/A ☒
Computer Program Used (Attach Listing)	☐	N/A ☒
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
ProtoHX Density effects need to be accounted for	Section Added to discuss ρ and PROTOHX Runs re-run.

*Other Comments

None

*Extra References Used

*(Attach extra sheets if needed)

CALCULATION FOUND TO BE VALID AND CONCLUSIONS TO BE CORRECT AND REASONABLE:

IDV Signature: Scott M. Ingalls Initials: SMI

Printed Name: Scott M. Ingalls Date: 6/26/98

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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.			

LIST OF ATTACHMENTS

Attachment	Subject Matter	Total Pages
A	Proto-Power Calc. 97-197, Rev. A; Vendor Data Sheet & Drawings	4
B	Proto-Power Calc. 97-197, Rev. A; LaSalle Station UFSAR Section: 9.5.5.1.1, and FSAR Q40.92	5
C	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
E	Proto-Power Calc. 97-197, Rev. A; PROTO-HX™ Calculation Reports for Minimum Service Water Flow	10
F	Proto-Power Calc. 97-197, Rev. A; PROTO-HX™ Version 3.02 Model	2 (and disk)
	Number of Attachment Pages:	41
	Complete Calc (total number of pages)	58

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-HX™, Version 3.02, will allow timely analysis of data resulting from the test program.

3.0 DESIGN INPUTS

The PROTO-HX™ 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-HX™ 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 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	1	8.7
Total Effective Area per unit (ft^2)	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

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:

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

$$A_{gr} = 420 \cdot 7\,ft \cdot \pi \cdot \left(\frac{0.625\,in}{12\,in/ft} \right) = 481.056\,ft^2$$

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

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

$$A_{eff} = 420 \cdot \left(7\,ft - \frac{(1.in + 1.25\,in)}{12\,in/ft} \right) \cdot \pi \cdot \left(\frac{0.625\,in}{12\,in/ft} \right) = 468.171\,ft^2$$

where:

A_{gr} – Heat Exchanger Gross Area, ft^2

A_{eff} – Heat Exchanger Effective Area, ft^2

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-HX™ 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

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-ft^2-°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-HX™ Version 3.02 with the vendor's specifications for thermal performance.

4.1. PROTO-HX™ 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-HX™ to be 0.438 ft^2.

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-HX™ 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.

4.2. PROTO-HX™ FLOW RATE INPUTS

When the volumetric flow rates are entered into PROTO-HX™ they are converted to mass flow rates based on a set temperature of 60°F. 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.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60°F}} \qquad \text{Equation 3}$$

Table 4-1 PROTO-HX™ Flow Rate Inputs

Parameter	Density (lb/ft^3)	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-HX™ 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-HX™ 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-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. The PROTO-HX™ 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.

6.0 ANALYSIS

6.1. PROTO-HX™ MODEL

Table 6-1 shows the PROTO-HX™ benchmarking of the Jacket Water Cooler for the HPCS Diesel Generator. The PROTO-HX™ 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-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 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-HX™ calculations performed with the HPCS Jacket Water Cooler model will use the effective area of 468.17 ft^2. This change is made to the PROTO-HX™ 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-HX™ input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HX™ runs for the limited fouling factor case, see Attachment C.

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-HX™ iteration process. The area ratio is used to convert the overall fouling factor to a tube-side and shell-side fouling factor

$$f_{total} = f_{shell} + (\text{Area Ratio}) \cdot f_{tube} \qquad \text{Equation 4}$$

$$\text{Area Ratio} = \frac{\text{Tube OD}}{\text{Tube ID}} \qquad \text{Equation 5}$$

$$\text{Area Ratio} = \frac{0.625\,\text{in}}{0.541\,\text{in}} = 1.15527$$

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 :

$$f_{adjusted} = 0.002732\, {}^{\text{hr ft}^2\,°\text{F}}\!/_{\text{Btu}}$$

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

$$f_{tube} = \frac{(f_{adjusted} - f_{shell})}{\text{Area Ratio}} = \frac{(0.002732 - 0.0005)^{hr\,ft^2\,°F/Btu}}{1.15527} = 0.001932^{hr\,ft^2\,°F}/_{Btu}$$

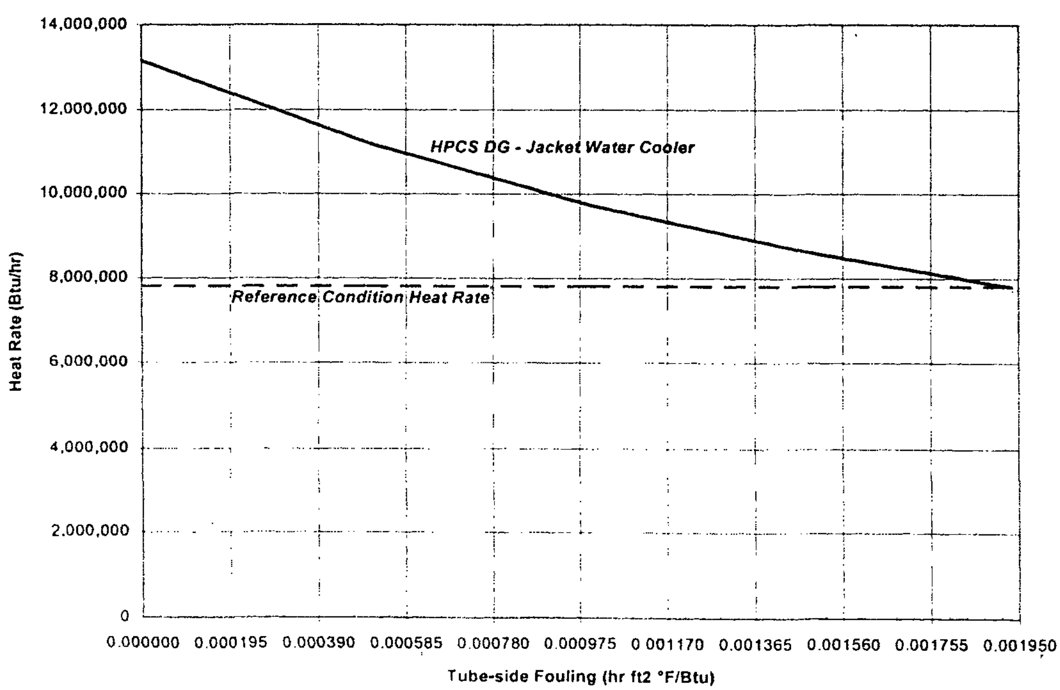
The PROTO-HX™ heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

Attachment C includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HX™ 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 ft^2 °F/Btu) by increments of 0.0005 (hr ft^2 °F/Btu). The shell-side fouling factor is held constant at the design value of 0.0005 (hr ft^2 °F/Btu). The PROTO-HX™ Calculation Reports for the fouling sensitivity can be found in Attachment D

Figure 6-1 Tube-side Fouling Sensitivity



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-HX™ reports can be found in Attachment C.

$$\text{margin} = \text{Heat Rate} - \text{Heat Rate}_{\text{required}} \qquad \text{Equation 6}$$

$$\%\,\text{margin} = 100 \cdot \left(\frac{\text{margin}}{\text{Heat Rate}_{\text{required}}} \right) \qquad \text{Equation 7}$$

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

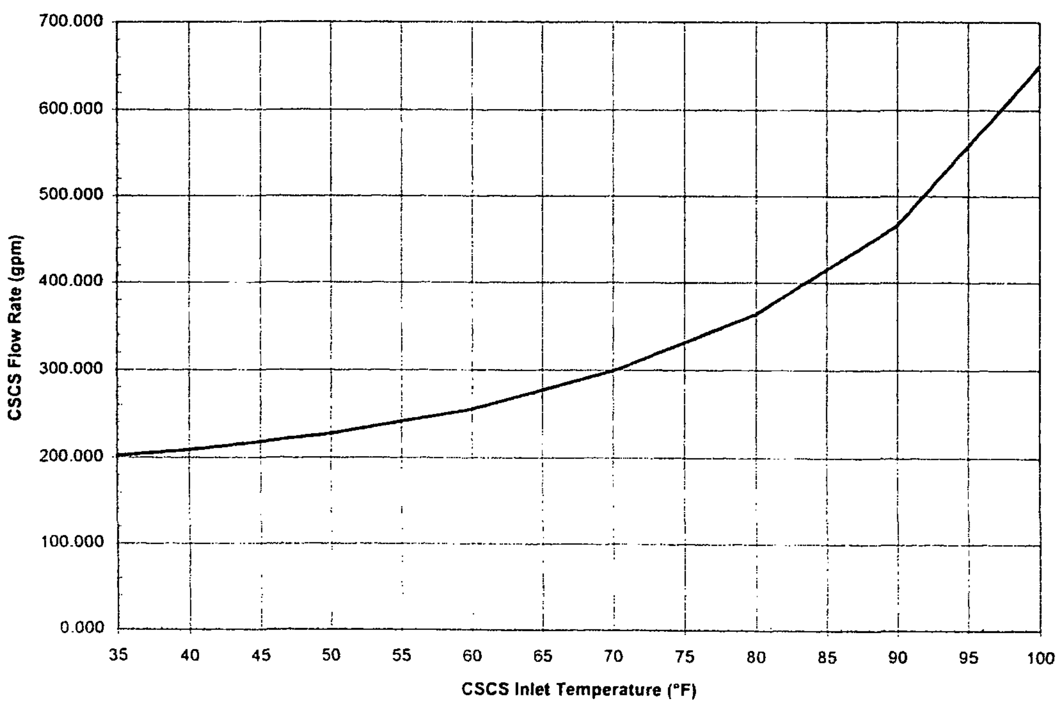
The minimum service water flow rate for the adjusted design fouling condition is calculated with the shell-side inlet temperature at 190°F and a flow rate of 1,100 gpm. Iterating using the service water flow rate and inlet temperature, the minimum acceptable flow rate is found for each inlet temperature (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-HX™ flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.11.

Table 6-5 Minimum Required CSCS Flow Rate

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft^3)	PROTO-HX™ 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



7.0 CONCLUSION

7.1. PROTO-HX™ MODEL

The HPCS Jacket Water Cooler model was developed using PROTO-HX™, 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 ft^2 °F/Btu. This overall fouling factor is broken down into a 0.001932 and 0.0005 hr ft^2 °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.

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-HX™ 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

REFERENCE 8.6

O & H MANUFACTURING COMPANY
Houston, Texas

RECEIVED
OCT 11 1974
ENGINEERING DEPT.

EXCHANGER SPECIFICATION SHEET

CUSTOMER	Stewart & Stevenson Services	REFERENCE NO.	F-64546-50583
ADDRESS	Houston, Texas	INQUIRY NO.	G.E. APED
PLANT LOCATION		DATE	April 3, 1974
SERVICE OF UNIT	Jacket Water Cooler	ITEM NO.	
SIZE	AE-1807-2521	O & H DRAWING NO.	6980
GROSS SURFACE PER UNIT	482	O & H JOB NO.	62015

Rev. B 9/26/74: Added fouling factors

PERFORMANCE OF UNIT

	SHELL SIDE		TUBE SIDE	
FLUID CIRCULATED	Jacket Water		Raw Water	
TOTAL FLUID ENTERING				
VAPOR				
LIQUID	1,100 GPM		800 GPM	
STEAM				
NON-CONDENSABLES				
FLUID VAPORIZED OR CONDENSED				
STEAM CONDENSED				
GRAVITY				
VISCOSITY				
MOLECULAR WEIGHT				
SPECIFIC HEAT		BTU/LB/°F		BTU/LB/°F
LATENT HEAT - VAPORS		BTU/LB/°F		BTU/LB/°F
TEMPERATURE IN	190	°F	100	°F
TEMPERATURE OUT	175	°F	121	°F
OPERATING PRESSURE		PSI		PSI
NUMBER OF PASSES PER SHELL	1		2	
VELOCITY	5.6	FT/SEC	5.3	FT/SEC
PRESSURE DROP	6.5	PSI	3.7	PSI
FOULING RESISTANCE	.0005		.002	

HEAT EXCHANGED 8,505,000 BTU/HR M.T.D. (CORRECTED) 73

TRANSFER RATE - SERVICE 241.7 EFF. SURFACE/UNIT 482 ← * Eff. Area

CONSTRUCTION

	SHELL SIDE		TUBE SIDE	
DESIGN PRESSURE	150	PSI	150	PSI
TEST PRESSURE	225	PSI	225	PSI
DESIGN TEMPERATURE	300	°F	300	°F

TUBES Admiralty NO. 420 O.D. 5/8" BWG. 18 LENGTH 7' PITCH 3/4

SHELL C. S. I.D. O.D. 18"

SHELL COVER FLOATING HEAD COVER

CHANNEL C.S. CHANNEL COVER

TUBE SHEETS STATIONARY Naval Brass FLOATING Naval Brass

BAFFLES-CROSS Brass TYPE Segmental

BAFFLES-LONG TYPE

TUBE SUPPORTS GASKETS Asbestos

CONNECTIONS-SHELL IN 4" OUT 4" RATING 150# PSI RFSO

-CHANNEL IN 6" OUT 6" RATING 150# PSI RFSO

CORROSION ALLOWANCE - SHELL SIDE TUBE SIDE

CODE REQUIREMENTS ASME Section VIII Code Stamp TEMA CLASS C

WEIGHTS-EACH SHELL FULL OF WATER 3650# ; DRY 2800#

NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) OR (X.R.)

REMARKS: 9/26/74: Copy to Mr. Bill Phillips, Mr. Bob Evans
10/10/74: Original to Mr. W. C. Philipp

Form #103

NOTE: THIS DRAWING/DATA NOT RELEASED FOR MANUFACTURE OR REVIEW UNLESS SIGNED OFF BELOW

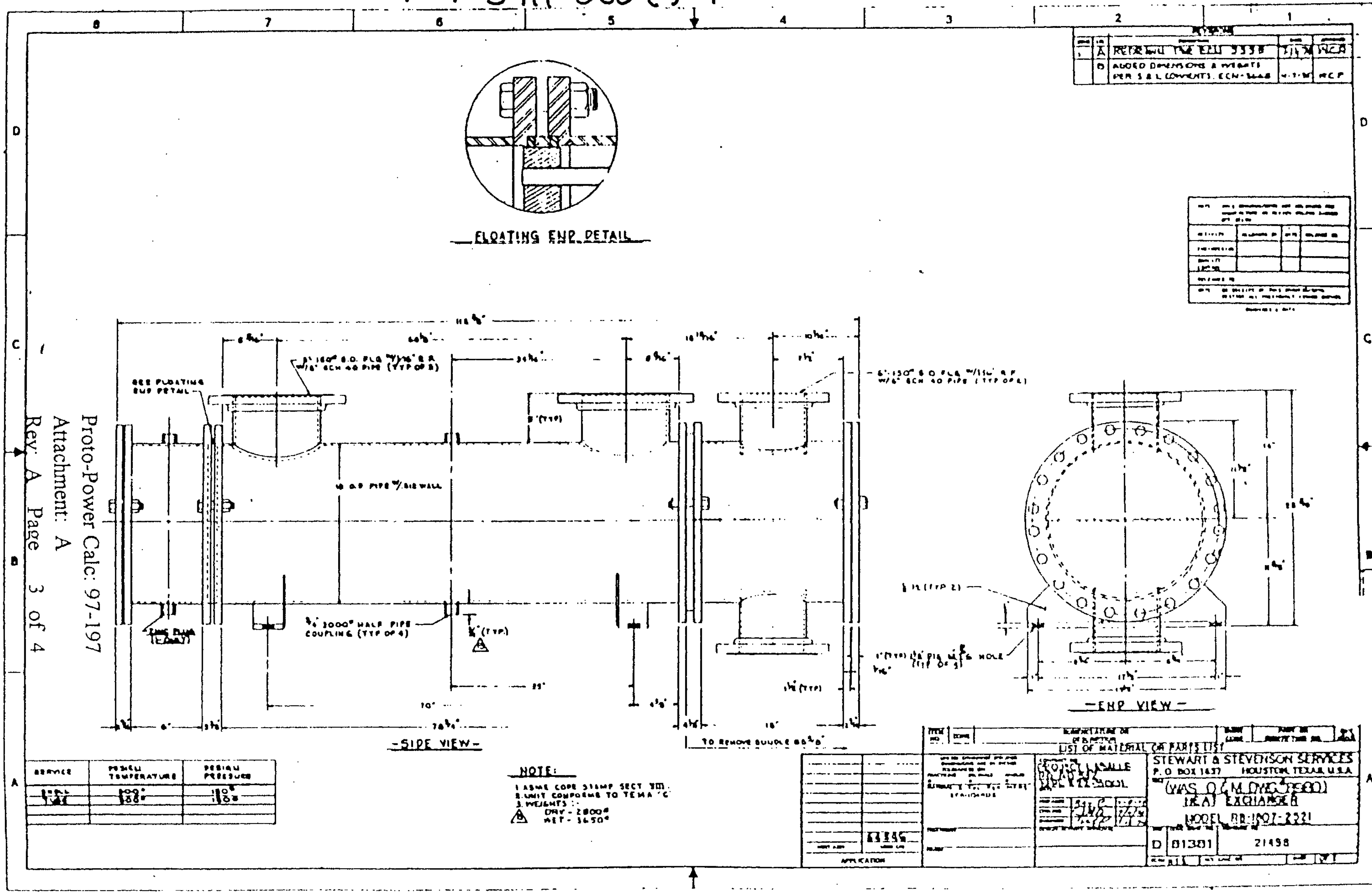
ACTIVITY	RELEASED BY	DATE	RELEASE NO.
ENGINEERING			
QUALITY CONTROL			
RELEASED TO			

NOTE: ON RECEIPT OF THIS DRAWING/DATA DESTROY ALL PREVIOUSLY ISSUED COPIES

CPB

HPCS

VPF-3411-080 (1)-1

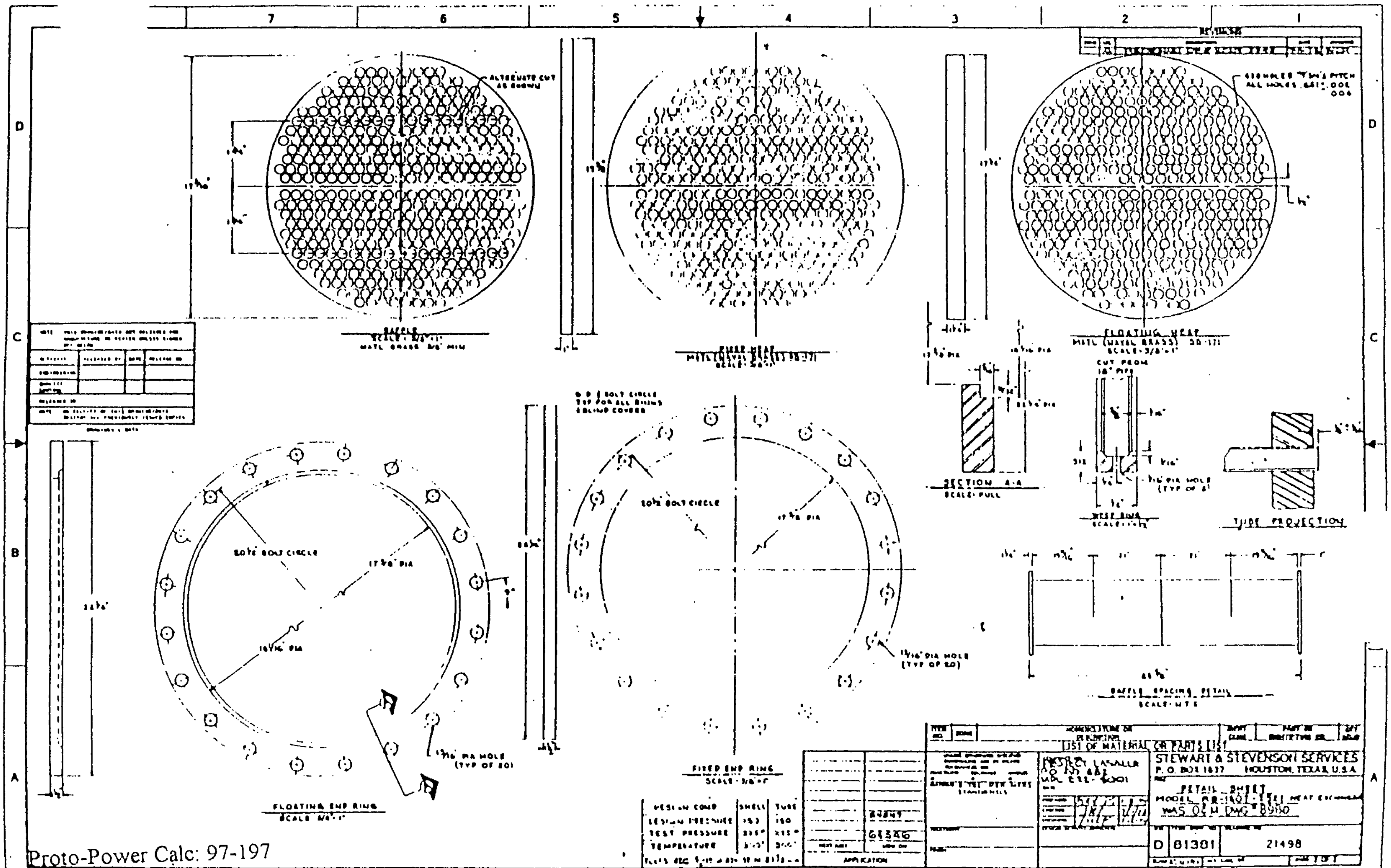


Proto-Power Calc: 97-197
Attachment: A
Rev: A Page 3 of 4

REFERENCE 8.7

VPF-3411-080(2)-1

HPCS



REFERENCE 8.8

Proto-Power Calc: 97-197
Attachment: A
Rev: A Page 4 of 4

Attachment B to Proto-Power Calculation 97-197 Revision A

REFERENCE 8.1

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

l. 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 Design Bases

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

2. diesel-generator cooler (division 1 and 2 only) - 800 gpm

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

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Attachment: B
Rev: A Page 2 of 5

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 1E. 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

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Attachment: B
Rev: A Page 3 of 5

approximately 7.8 x 10^6 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.

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 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 diesel-generator 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

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	8.6×10^6 btu/hr
Diesel-generator set cooling requirement	7.8×10^6 btu/hr

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

Attachment C to
Proto-Power Calculation
97-197
Revision A

Commonwealth Edison
Calculation Report for DG01B - LSCS - HPCS DG Hx.
Vendor Data - BENCHMARK

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		0.00050	0.00200

VENDOR DATA SHEET VALUES

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	TEMA-E
Effective Area (ft^2)	482.00
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 (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

PROTO-HX CALCULATED @BENCHMARK CONDITIONS (Emprical Factor for Outside h)

VENDOR DATA SHEET VALUE (Effective Area)

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Vendor Data - BENCHMARK

Calculation Specifications

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

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

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

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	8.277E+6
LMTD	71.8
Effective Area (ft²)	482.0

COMPARE TO VENDOR DATA SHEET

Overall Fouling (hr·ft²·°F/BTU)	0.002811
Shell-Side ho (BTU/hr·ft²·°F)	1,889.7
Tube-Side hi (BTU/hr·ft²·°F)	1,576.5
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9895
U Overall (BTU/hr·ft²·°F)	241.7

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	5.33
Reynold's Number	7.707E+04	3.620E+04
Prandtl Number	2.13	4.03
Bulk Visc (lbm/ft·hr)	0.82	1.48
Skin Visc (lbm/ft·hr)	0.88	1.31
Density (lbm/ft³)	60.53	61.85
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.5
Tav Shell (°F)	182.2
Shell Skin Temp (°F)	173.1
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	120.8
Tav Tube (°F)	110.4
Tube Skin Temp (°F)	123.1

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Design Conditions - Adjusted Eff. Area

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		0.00050	0.00200

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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

CALCULATED IN SECTION 3.2

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

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

Extrapolation Data

Tube Flow (gpm)	795.3
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.978E+5
Heat Transferred (BTU/hr)	8.089E+6
LMTD	72.2
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	5.33
Reynold's Number	7.717E+04	3.612E+04
Prandtl Number	2.13	4.04
Bulk Visc (lbm/ft·hr)	0.82	1.48
Skin Visc (lbm/ft·hr)	0.87	1.31
Density (lbm/ft³)	60.52	61.86
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002811
Shell-Side ho (BTU/hr·ft²·°F)	1,890.3
Tube-Side hi (BTU/hr·ft²·°F)	1,574.7
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9901
U Overall (BTU/hr·ft²·°F)	241.7
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	174.8
Tav Shell (°F)	182.4
Shell Skin Temp (°F)	173.2
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	120.4
Tav Tube (°F)	110.2
Tube Skin Temp (°F)	123.0

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

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	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	0.616913000
Performance Factor (% Reduction)	0.00
Heat Exchanger Type	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

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

Test Data

Test Data	
Data Date	
Shell Flow (gpm)	
Shell Temp In (°F)	
Shell Temp Out (°F)	
Tube Flow (gpm)	
Tube Temp In (°F)	
Tube Temp Out (°F)	

Extrapolation Data

Extrapolation Data	
Tube Flow (gpm)	650.0
Shell Flow (gpm)	1,100.0
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.503E+5
Tube Mass Flow (lbm/hr)	3.252E+5
Heat Transferred (BTU/hr)	7.718E+6
LMTD	71.0
Effective Area (ft²)	468.2

LOWER THAN LSCS REF. CONDITION REQUIRED.

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.77	4.36
Reynold's Number	8.005E+04	3.003E+04
Prandtl Number	2.12	3.96
Bulk Visc (lbm/ft·hr)	0.82	1.46
Skin Visc (lbm/ft·hr)	0.87	1.27
Density (lbm/ft³)	60.51	61.83
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002811
Shell-Side ho (BTU/hr·ft²·°F)	1,880.7
Tube-Side hi (BTU/hr·ft²·°F)	1,354.4
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9890
U Overall (BTU/hr·ft²·°F)	234.7
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	176.0
Tav Shell (°F)	183.0
Shell Skin Temp (°F)	174.1
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	123.8
Tav Tube (°F)	111.9
Tube Skin Temp (°F)	126.1

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

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		0.00050	0.00200

VENDOR VALUES NOT USED IN FOLLOWING CALCULATION

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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

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

Commonwealth Edison

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 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		
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)	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

MEETS REFERENCE HEAT RATE

ADJUSTED OVERALL FOULING FACTOR

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

** Reynolds Number Outside Range of Equation Applicability

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

Commonwealth Edison

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 TUBE-SIDE FOULING SECTION 6.2
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 (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			TEMA-E	ADJUSTED AREA SECTION 3.2
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 Baffle and Shell (in)			0.000	
Ltb, Diametral difference between Tube and Baffle (in)			0.000	
Nss, Number Sealing Strips			0.000	

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 REDUCED TUBE-SIDE FOULING.

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·°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)	0.002732
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

DESIGN "ADJUSTED" OVERALL FOULING FACTOR

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

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

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		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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CLEAN - FINAL MODEL

Calculation Specifications

Constant Inlet Temperature Method Was Used

Extrapolation Was to User Specified Conditions

Fouling Was Input by User — ØFOULING 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·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

MAXIMUM HEAT RATE

"CLEAN"

Shell Mass Flow (lbm/hr)	5.325E+5	Overall Fouling (hr·ft²·°F/BTU)	$\boxed{0.000000}$
Tube Mass Flow (lbm/hr)	3.232E+5	Shell-Side ho (BTU/hr·ft²·°F)	1,839.7
		Tube-Side hi (BTU/hr·ft²·°F)	1,455.3
Heat Transferred (BTU/hr)	$\boxed{1.542E+7}$	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

** Reynolds Number Outside Range of Equation Applicability

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

Attachment D to
Proto-Power Calculation
97-197
Revision A

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		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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

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

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

Extrapolation Data

Tube Flow (gpm)	646.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0
Input Fouling Factor	0.000500

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	1.316E+7
LMTD	56.9
Effective Area (ft²)	468.2

Overall Fouling (hr·ft²·°F/BTU)	0.000500
Shell-Side ho (BTU/hr·ft²·°F)	1,856.7
Tube-Side hi (BTU/hr·ft²·°F)	1,423.4
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9458
U Overall (BTU/hr·ft²·°F)	522.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.57	4.34
Reynold's Number	7.471E+04	3.240E+04
Prandtl Number	2.20	3.62
Bulk Visc (lbm/ft·hr)	0.85	1.34
Skin Visc (lbm/ft·hr)	0.95	1.09
Density (lbm/ft³)	60.63	61.71
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	165.3
Tav Shell (°F)	177.7
Shell Skin Temp (°F)	161.6
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	140.8
Tav Tube (°F)	120.4
Tube Skin Temp (°F)	144.7

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

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)	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	0.001078

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·ft²·°F/BTU)	0.001078
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)	137.9

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Tube--side Fouling = 0.0010

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	646.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0
Input Fouling Factor	0.001655

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	9.727E+6
LMTD	65.6
Effective Area (ft²)	468.2

Overall Fouling (hr·ft²·°F/BTU)	0.001655
Shell-Side ho (BTU/hr·ft²·°F)	1,879.8
Tube-Side hi (BTU/hr·ft²·°F)	1,376.2
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9784
U Overall (BTU/hr·ft²·°F)	323.5

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.34
Reynold's Number	7.637E+04	3.080E+04
Prandtl Number	2.15	3.83
Bulk Visc (lbm/ft·hr)	0.83	1.41
Skin Visc (lbm/ft·hr)	0.90	1.20
Density (lbm/ft³)	60.56	61.79
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	171.8
Tav Shell (°F)	180.9
Shell Skin Temp (°F)	169.6
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	130.1
Tav Tube (°F)	115.1
Tube Skin Temp (°F)	132.9

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

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)	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	0.002233

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·ft²·°F/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·°F)	1,360.6
Heat Transferred (BTU/hr)	8.59E+6	1/Wall Resis (BTU/hr·ft²·°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)	129.2

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

Tube--side Fouling = 0.001932 (LIMIT)

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	646.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	100.0
Shell Inlet Temp (°F)	190.0
Input Fouling Factor	0.002732

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	3.232E+5
Heat Transferred (BTU/hr)	7.801E+6
LMTD	70.5
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	4.33
Reynold's Number	7.731E+04	2.991E+04
Prandtl Number	2.13	3.95
Bulk Visc (lbm/ft·hr)	0.82	1.45
Skin Visc (lbm/ft·hr)	0.87	1.27
Density (lbm/ft³)	60.52	61.83
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.37

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,892.1
Tube-Side hi (BTU/hr·ft²·°F)	1,349.8
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9881
U Overall (BTU/hr·ft²·°F)	239.2
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.8
Tube Temp In (°F)	100.0
Tube Temp Out (°F)	124.2
Tav Tube (°F)	112.1
Tube Skin Temp (°F)	126.5

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

Attachment E to Proto-Power Calculation 97-197 Revision A

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		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	TEMA-E
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 Baffle and Shell (in)	0.000
Ltb, Diametral difference between Tube and Baffle (in)	0.000
Nss, Number Sealing Strips	0.000

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=35°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	202.4
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	35.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.012E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	106.1
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	1.35
Reynold's Number	7.731E+04	6.041E+03
Prandtl Number	2.13	6.41
Bulk Visc (lbm/ft·hr)	0.82	2.25
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	62.27
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.35

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,891.5
Tube-Side hi (BTU/hr·ft²·°F)	393.5
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9829
U Overall (BTU/hr·ft²·°F)	159.7
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	35.0
Tube Temp Out (°F)	112.0
Tav Tube (°F)	73.5
Tube Skin Temp (°F)	124.7

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=40°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	209.1
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	40.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.046E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	102.5
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	1.39
Reynold's Number	7.731E+04	6.552E+03
Prandtl Number	2.13	6.08
Bulk Visc (lbm/ft·hr)	0.82	2.15
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	62.24
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.35

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,891.5
Tube-Side hi (BTU/hr·ft²·°F)	425.1
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9822
U Overall (BTU/hr·ft²·°F)	165.5
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	40.0
Tube Temp Out (°F)	114.6
Tav Tube (°F)	77.3
Tube Skin Temp (°F)	124.7

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=50°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	227.4
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	50.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.138E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	95.9
Effective Area (ft²)	468.2

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,891.5
Tube-Side hi (BTU/hr·ft²·°F)	497.6
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9813
U Overall (BTU/hr·ft²·°F)	177.1

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	1.52
Reynold's Number	7.731E+04	7.772E+03
Prandtl Number	2.13	5.52
Bulk Visc (lbm/ft·hr)	0.82	1.97
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	62.17
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	50.0
Tube Temp Out (°F)	118.6
Tav Tube (°F)	84.3
Tube Skin Temp (°F)	124.8

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=60°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	255.0
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	60.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

U Overall (BTU/hr·ft²·°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)	

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

Shell Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.276E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	90.1
Effective Area (ft²)	468.2

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,891.6
Tube-Side hi (BTU/hr·ft²·°F)	583.3
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9812
U Overall (BTU/hr·ft²·°F)	188.5

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	1.70
Reynold's Number	7.731E+04	9.385E+03
Prandtl Number	2.13	5.09
Bulk Visc (lbm/ft·hr)	0.82	1.83
Skin Visc (lbm/ft·hr)	0.87	1.29
Density (lbm/ft³)	60.52	62.11
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.5
Tube Temp In (°F)	60.0
Tube Temp Out (°F)	121.2
Tav Tube (°F)	90.6
Tube Skin Temp (°F)	125.0

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=70°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)	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·°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)	0.002732
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

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=80°F

Calculation Specifications

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

Test Data

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

Extrapolation Data

Tube Flow (gpm)	362.9
Shell Flow (gpm)	1,064.5
Tube Inlet Temp (°F)	80.0
Shell Inlet Temp (°F)	190.0

Fouling Calculation Results

Shell Mass Flow (lbm/hr)	
Tube Mass Flow (lbm/hr)	
Heat Transferred (BTU/hr)	
LMTD	
Effective Area (ft²)	

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

U Overall (BTU/hr·ft²·°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 Temp In (°F)	
Shell Temp Out (°F)	
Tav Shell (°F)	
Shell Skin Temp (°F)	
Tube Temp In (°F)	
Tube Temp Out (°F)	
Tav Tube (°F)	
Tube Skin Temp (°F)	

Extrapolation Calculation Results

Shell Mass Flow (lbm/hr)	5.325E+5
Tube Mass Flow (lbm/hr)	1.815E+5
Heat Transferred (BTU/hr)	7.8E+6
LMTD	80.4
Effective Area (ft²)	468.2

Property	Shell-Side	Tube-Side
Velocity (ft/s)	5.58	2.43
Reynold's Number	7.731E+04	1.507E+04
Prandtl Number	2.13	4.45
Bulk Visc (lbm/ft·hr)	0.82	1.62
Skin Visc (lbm/ft·hr)	0.87	1.28
Density (lbm/ft³)	60.52	61.98
Cp (BTU/lbm·°F)	1.00	1.00
K (BTU/hr·ft·°F)	0.39	0.36

Overall Fouling (hr·ft²·°F/BTU)	0.002732
Shell-Side ho (BTU/hr·ft²·°F)	1,891.8
Tube-Side hi (BTU/hr·ft²·°F)	814.6
1/Wall Resis (BTU/hr·ft²·°F)	15,431.0
LMTD Correction Factor	0.9835
U Overall (BTU/hr·ft²·°F)	210.8
Shell Temp In (°F)	190.0
Shell Temp Out (°F)	175.4
Tav Shell (°F)	182.7
Shell Skin Temp (°F)	173.6
Tube Temp In (°F)	80.0
Tube Temp Out (°F)	123.0
Tav Tube (°F)	101.5
Tube Skin Temp (°F)	125.8

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=90°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)	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)			
		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)	0.002732
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)	126.2

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

Commonwealth Edison

Calculation Report for DG01B - LSCS - HPCS DG Hx.

CSCS=100°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)	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·°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)	0.002732
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

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

Attachment F to
Proto-Power Calculation
97-197
Revision A

PROTO-HX™ 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**

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

Title: [3] VY Cooler Thermal Performance Model – 1(2)VY01A and 1(2)VY02A

EC/ECR No.: [4] 388666 **Revision:** [5] 000

Station(s): [7] LaSalle
Unit No.: [8] 01 & 02
Safety/QA Class: [9] SR
System Code(s): [10] VY

Is this Design Analysis Safeguards Information? [11] 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): [14]
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.

Preparer: [16] Sean Tanton (Print Name) Sean Tanton (Sign Name) 5/3/12 (Date)

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐
Reviewer: [18] Steve Chon (Print Name) Steve Chon (Sign Name) 5/7/12 (Date)
Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)
External Approver: [20] N/A (Print Name) (Sign Name) (Date)
Exelon Reviewer [21] N/A (Print Name) (Sign Name) (Date)

Exelon Approver: [22] DAN SCHMIT (Print Name) DJ Schmit (Sign Name) 5/18/12 (Date)

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 $hr\cdot ft^2\cdot °F/BTU$ (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 $hr\cdot ft^2\cdot °F/BTU$
- 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·ft^2·°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·ft^2·°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·ft^2·°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 ≤ 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)

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 gpm
Mass Flow	0.00 lbm/hr	0.00 lbm/hr
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 Water
Tube-Side Fouling	0.001500
Air-Side Fouling	0.000000
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 Flow
Fin Type	Circular Fins
Configuration (for Air-Side h)	LaSalle VY Coolers 01A/02A
	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)	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 Conductivity (BTU/hr·ft·°F)	225.00

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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

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 (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)	18,098.00
Tube Inlet Temp (°F)	107.00
Air Inlet Temp (°F)	148.00
Inlet Relative Humidity (%)	12.76
Inlet Wet Bulb Temp (°F)	0.00
Atmospheric Pressure (psia)	14.315

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,878.21	37,240.41
Inlet Temperature (°F)	148.00	107.00
Outlet Temperature (°F)	114.50	122.05
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
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)	560,505
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,878.21	37,240.41
Inlet Temperature (°F)	148.00	118.98
Outlet Temperature (°F)	141.17	122.05
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	144.58	120.5178
Skin Temperature (°F)	126.85	123.0132
Velocity ***	3,364.26	2.9125
Reynold's Number	793**	21,205
Prandtl Number	0.7254	3.6151
Bulk Visc (lbm/ft·hr)	0.0490	1.3399
Skin Visc (lbm/ft·hr)	0.0000	1.3091
Density (lbm/ft³)	0.0623	61.7036
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3702
Relative Humidity In (%)	12.76	
Relative Humidity Out (%)	15.16	

Tube-Side hi (BTU/hr·ft²·°F)	1,013.40
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.22
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.56
Effective Area (ft²)	860.06
LMTD	23.88
Total Heat Transferred (BTU/hr)	114,284
Surface Effectiveness (Eta)	0.9188
Sensible Heat Transferred (BTU/hr)	114,284
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	141.17	116.36
Outlet Temperature (°F)	135.35	118.98
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	138.26	117.6724
Skin Temperature (°F)	123.10	119.8303
Velocity ***	3,364.26	2.9105
Reynold's Number	799**	20,641
Prandtl Number	0.7260	3.7235
Bulk Visc (lbm/ft·hr)	0.0486	1.3765
Skin Visc (lbm/ft·hr)	0.0000	1.3486
Density (lbm/ft³)	0.0629	61.7474
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3692
Relative Humidity In (%)	15.16	
Relative Humidity Out (%)	17.62	

Tube-Side hi (BTU/hr·ft²·°F)	998.60
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.54
Effective Area (ft²)	860.06
LMTD	20.43
Total Heat Transferred (BTU/hr)	97,394
Surface Effectiveness (Eta)	0.9190
Sensible Heat Transferred (BTU/hr)	97,394
Latent Heat Transferred (BTU/hr)	
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)	66,878.21	37,240.41
Inlet Temperature (°F)	135.35	114.13
Outlet Temperature (°F)	130.38	116.36
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	132.86	115.2463
Skin Temperature (°F)	119.90	117.1108
Velocity ***	3,364.26	2.9087
Reynold's Number	805**	20,164
Prandtl Number	0.7264	3.8202
Bulk Visc (lbm/ft·hr)	0.0483	1.4091
Skin Visc (lbm/ft·hr)	0.0000	1.3839
Density (lbm/ft³)	0.0634	61.7839
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3684
Relative Humidity In (%)	17.62	
Relative Humidity Out (%)	20.10	

Tube-Side hi (BTU/hr·ft²·°F)	985.92
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.17
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.53
Effective Area (ft²)	860.06
LMTD	17.48
Total Heat Transferred (BTU/hr)	83,087
Surface Effectiveness (Eta)	0.9192
Sensible Heat Transferred (BTU/hr)	83,087
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,878.21	37,240.41
Inlet Temperature (°F)	130.38	112.22
Outlet Temperature (°F)	126.14	114.13
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	128.26	113.1757
Skin Temperature (°F)	117.17	114.7854
Velocity ***	3,364.26	2.9073
Reynold's Number	810**	19,760
Prandtl Number	0.7268	3.9061
Bulk Visc (lbm/ft·hr)	0.0480	1.4379
Skin Visc (lbm/ft·hr)	0.0000	1.4154
Density (lbm/ft³)	0.0639	61.8144
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3677
Relative Humidity In (%)	20.10	
Relative Humidity Out (%)	22.52	

Tube-Side hi (BTU/hr·ft²·°F)	975.07
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.51
Effective Area (ft²)	860.06
LMTD	14.97
Total Heat Transferred (BTU/hr)	70,945
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	70,945
Latent Heat Transferred (BTU/hr)	
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)	66,878.21	37,240.41
Inlet Temperature (°F)	126.14	110.59
Outlet Temperature (°F)	122.52	112.22
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	124.33	111.4071
Skin Temperature (°F)	114.83	112.7959
Velocity ***	3,364.26	2.9061
Reynold's Number	814**	19,417
Prandtl Number	0.7271	3.9819
Bulk Visc (lbm/ft·hr)	0.0478	1.4633
Skin Visc (lbm/ft·hr)	0.0000	1.4433
Density (lbm/ft³)	0.0643	61.8400
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3670
Relative Humidity In (%)	22.52	
Relative Humidity Out (%)	24.87	

Tube-Side hi (BTU/hr·ft²·°F)	965.76
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.13
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.50
Effective Area (ft²)	860.06
LMTD	12.82
Total Heat Transferred (BTU/hr)	60,626
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	60,626
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,878.21	37,240.41
Inlet Temperature (°F)	122.52	109.20
Outlet Temperature (°F)	119.42	110.59
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	120.97	109.8952
Skin Temperature (°F)	112.83	111.0927
Velocity ***	3,364.26	2.9051
Reynold's Number	818**	19,126
Prandtl Number	0.7273	4.0486
Bulk Visc (lbm/ft·hr)	0.0475	1.4856
Skin Visc (lbm/ft·hr)	0.0000	1.4679
Density (lbm/ft³)	0.0646	61.8615
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0157	0.3665
Relative Humidity In (%)	24.87	
Relative Humidity Out (%)	27.10	

Tube-Side hi (BTU/hr·ft²·°F)	957.79
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.12
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.49
Effective Area (ft²)	860.06
LMTD	10.99
Total Heat Transferred (BTU/hr)	51,842
Surface Effectiveness (Eta)	0.9197
Sensible Heat Transferred (BTU/hr)	51,842
Latent Heat Transferred (BTU/hr)	
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)	66,878.21	37,240.41
Inlet Temperature (°F)	119.42	108.01
Outlet Temperature (°F)	116.77	109.20
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	118.09	108.6021
Skin Temperature (°F)	111.12	109.6340
Velocity ***	3,364.26	2.9042
Reynold's Number	821**	18,878
Prandtl Number	0.7275	4.1072
Bulk Visc (lbm/ft·hr)	0.0474	1.5051
Skin Visc (lbm/ft·hr)	0.0000	1.4895
Density (lbm/ft³)	0.0649	61.8797
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0156	0.3660
Relative Humidity In (%)	27.10	
Relative Humidity Out (%)	29.18	

Tube-Side hi (BTU/hr·ft²·°F)	950.95
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.11
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.48
Effective Area (ft²)	860.06
LMTD	9.42
Total Heat Transferred (BTU/hr)	44,357
Surface Effectiveness (Eta)	0.9198
Sensible Heat Transferred (BTU/hr)	44,357
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	116.77	106.99
Outlet Temperature (°F)	114.50	108.01
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	115.63	107.4955
Skin Temperature (°F)	109.66	108.3843
Velocity ***	3,364.26	2.9035
Reynold's Number	824**	18,666
Prandtl Number	0.7277	4.1584
Bulk Visc (lbm/ft·hr)	0.0472	1.5221
Skin Visc (lbm/ft·hr)	0.0000	1.5084
Density (lbm/ft³)	0.0652	61.8950
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3656
Relative Humidity In (%)	29.18	
Relative Humidity Out (%)	31.12	

Tube-Side hi (BTU/hr·ft²·°F)	945.09
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.09
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.47
Effective Area (ft²)	860.06
LMTD	8.08
Total Heat Transferred (BTU/hr)	37,971
Surface Effectiveness (Eta)	0.9199
Sensible Heat Transferred (BTU/hr)	37,971
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Formulas from Section 6.7 for iteration process to determine inlet 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	psia	
			Rv =	85.778	(ft-lbf)/(lbm-R)	
			Ra =	53.352	(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	

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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

	Air-Side		Tube-Side	
Flow	21,179.00	acfm	150.00	gpm
Mass Flow	0.00	lbm/hr	0.00	lbm/hr
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 Water
Tube-Side Fouling	0.001500
Air-Side Fouling	0.000000
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 Flow
Fin Type	Circular Fins
Configuration (for Air-Side h)	LaSalle VY Coolers 01A/02A
	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)	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 Conductivity (BTU/hr·ft·°F)	225.00

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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

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 (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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,113.67	53,626.19
Inlet Temperature (°F)	153.00	107.00
Outlet Temperature (°F)	114.36	119.71
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
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)	681,320
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,113.67	53,626.19
Inlet Temperature (°F)	153.00	116.88
Outlet Temperature (°F)	144.40	119.71
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	148.70	118.2967
Skin Temperature (°F)	125.88	120.7965
Velocity ***	3,527.02	4.1917
Reynold's Number	827**	29,901
Prandtl Number	0.7250	3.6993
Bulk Visc (lbm/ft·hr)	0.0493	1.3683
Skin Visc (lbm/ft·hr)	0.0000	1.3364
Density (lbm/ft³)	0.0617	61.7379
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0163	0.3695
Relative Humidity In (%)	12.76	
Relative Humidity Out (%)	15.80	

Tube-Side hi (BTU/hr·ft²·°F)	1,341.67
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.49
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.84
Effective Area (ft²)	860.06
LMTD	30.19
Total Heat Transferred (BTU/hr)	151,661
Surface Effectiveness (Eta)	0.9164
Sensible Heat Transferred (BTU/hr)	151,661
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	144.40	114.55
Outlet Temperature (°F)	137.31	116.88
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	140.86	115.7147
Skin Temperature (°F)	121.99	117.8022
Velocity ***	3,527.02	4.1891
Reynold's Number	835**	29,168
Prandtl Number	0.7258	3.8012
Bulk Visc (lbm/ft·hr)	0.0488	1.4027
Skin Visc (lbm/ft·hr)	0.0000	1.3748
Density (lbm/ft³)	0.0624	61.7769
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3686
Relative Humidity In (%)	15.80	
Relative Humidity Out (%)	18.94	

Tube-Side hi (BTU/hr·ft²·°F)	1,323.45
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.46
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.82
Effective Area (ft²)	860.06
LMTD	24.96
Total Heat Transferred (BTU/hr)	124,935
Surface Effectiveness (Eta)	0.9167
Sensible Heat Transferred (BTU/hr)	124,935
Latent Heat Transferred (BTU/hr)	
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)	70,113.67	53,626.19
Inlet Temperature (°F)	137.31	112.62
Outlet Temperature (°F)	131.47	114.55
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	134.39	113.5865
Skin Temperature (°F)	118.78	115.3281
Velocity ***	3,527.02	4.1869
Reynold's Number	842**	28,569
Prandtl Number	0.7263	3.8888
Bulk Visc (lbm/ft·hr)	0.0484	1.4321
Skin Visc (lbm/ft·hr)	0.0000	1.4080
Density (lbm/ft³)	0.0630	61.8084
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3678
Relative Humidity In (%)	18.94	
Relative Humidity Out (%)	22.09	

Tube-Side hi (BTU/hr·ft²·°F)	1,308.37
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.43
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.80
Effective Area (ft²)	860.06
LMTD	20.66
Total Heat Transferred (BTU/hr)	103,055
Surface Effectiveness (Eta)	0.9169
Sensible Heat Transferred (BTU/hr)	103,055
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,113.67	53,626.19
Inlet Temperature (°F)	131.47	111.04
Outlet Temperature (°F)	126.64	112.62
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	129.06	111.8301
Skin Temperature (°F)	116.14	113.2821
Velocity ***	3,527.02	4.1852
Reynold's Number	848**	28,078
Prandtl Number	0.7268	3.9635
Bulk Visc (lbm/ft·hr)	0.0481	1.4571
Skin Visc (lbm/ft·hr)	0.0000	1.4364
Density (lbm/ft³)	0.0636	61.8339
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3672
Relative Humidity In (%)	22.09	
Relative Humidity Out (%)	25.14	

Tube-Side hi (BTU/hr·ft²·°F)	1,295.89
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.41
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.78
Effective Area (ft²)	860.06
LMTD	17.11
Total Heat Transferred (BTU/hr)	85,102
Surface Effectiveness (Eta)	0.9171
Sensible Heat Transferred (BTU/hr)	85,102
Latent Heat Transferred (BTU/hr)	
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)	70,113.67	53,626.19
Inlet Temperature (°F)	126.64	109.72
Outlet Temperature (°F)	122.66	111.04
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	124.65	110.3790
Skin Temperature (°F)	113.95	111.5888
Velocity ***	3,527.02	4.1838
Reynold's Number	853**	27,675
Prandtl Number	0.7271	4.0271
Bulk Visc (lbm/ft·hr)	0.0478	1.4784
Skin Visc (lbm/ft·hr)	0.0000	1.4606
Density (lbm/ft³)	0.0640	61.8546
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3667
Relative Humidity In (%)	25.14	
Relative Humidity Out (%)	28.03	

Tube-Side hi (BTU/hr·ft²·°F)	1,285.54
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.39
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.77
Effective Area (ft²)	860.06
LMTD	14.17
Total Heat Transferred (BTU/hr)	70,341
Surface Effectiveness (Eta)	0.9173
Sensible Heat Transferred (BTU/hr)	70,341
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	122.66	108.64
Outlet Temperature (°F)	119.36	109.72
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	121.01	109.1793
Skin Temperature (°F)	112.14	110.1867
Velocity ***	3,527.02	4.1826
Reynold's Number	857**	27,343
Prandtl Number	0.7273	4.0809
Bulk Visc (lbm/ft·hr)	0.0475	1.4963
Skin Visc (lbm/ft·hr)	0.0000	1.4812
Density (lbm/ft³)	0.0644	61.8716
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0157	0.3662
Relative Humidity In (%)	28.03	
Relative Humidity Out (%)	30.71	

Tube-Side hi (BTU/hr·ft²·°F)	1,276.97
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.37
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.76
Effective Area (ft²)	860.06
LMTD	11.74
Total Heat Transferred (BTU/hr)	58,184
Surface Effectiveness (Eta)	0.9174
Sensible Heat Transferred (BTU/hr)	58,184
Latent Heat Transferred (BTU/hr)	
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)	70,113.67	53,626.19
Inlet Temperature (°F)	119.36	107.74
Outlet Temperature (°F)	116.63	108.64
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	117.99	108.1866
Skin Temperature (°F)	110.64	109.0251
Velocity ***	3,527.02	4.1817
Reynold's Number	861**	27,069
Prandtl Number	0.7275	4.1263
Bulk Visc (lbm/ft·hr)	0.0474	1.5115
Skin Visc (lbm/ft·hr)	0.0000	1.4987
Density (lbm/ft³)	0.0647	61.8854
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0156	0.3659
Relative Humidity In (%)	30.71	
Relative Humidity Out (%)	33.15	

Tube-Side hi (BTU/hr·ft²·°F)	1,269.86
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.36
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.75
Effective Area (ft²)	860.06
LMTD	9.74
Total Heat Transferred (BTU/hr)	48,159
Surface Effectiveness (Eta)	0.9175
Sensible Heat Transferred (BTU/hr)	48,159
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	116.63	106.99
Outlet Temperature (°F)	114.36	107.74
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	115.49	107.3648
Skin Temperature (°F)	109.40	108.0624
Velocity ***	3,527.02	4.1809
Reynold's Number	864**	26,843
Prandtl Number	0.7277	4.1645
Bulk Visc (lbm/ft·hr)	0.0472	1.5242
Skin Visc (lbm/ft·hr)	0.0000	1.5134
Density (lbm/ft³)	0.0649	61.8968
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3656
Relative Humidity In (%)	33.15	
Relative Humidity Out (%)	35.34	

Tube-Side hi (BTU/hr·ft²·°F)	1,263.97
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.35
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.74
Effective Area (ft²)	860.06
LMTD	8.07
Total Heat Transferred (BTU/hr)	39,883
Surface Effectiveness (Eta)	0.9176
Sensible Heat Transferred (BTU/hr)	39,883
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Formulas from Section 6.7 for iteration process to determine inlet airflow for extrapolation conditions					
Total P:	P =			14.315	psia
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	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)) =			0.064908	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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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	21,179.00	acfm	150.00	gpm
Mass Flow	0.00	lbm/hr	0.00	lbm/hr
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 Water
Tube-Side Fouling	0.001500
Air-Side Fouling	0.000000
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 Flow
Fin Type	Circular Fins
Configuration (for Air-Side h)	LaSalle VY Coolers 01A/02A 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)	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 Conductivity (BTU/hr·ft·°F)	225.00

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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

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 (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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,245.05	78,453.13
Inlet Temperature (°F)	153.00	107.00
Outlet Temperature (°F)	113.28	115.98
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
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)	701,741
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,245.05	78,453.13
Inlet Temperature (°F)	153.00	113.82
Outlet Temperature (°F)	143.40	115.98
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	148.20	114.9014
Skin Temperature (°F)	122.69	117.0014
Velocity ***	3,533.63	6.1272
Reynold's Number	829**	42,337
Prandtl Number	0.7251	3.8343
Bulk Visc (lbm/ft·hr)	0.0492	1.4138
Skin Visc (lbm/ft·hr)	0.0000	1.3854
Density (lbm/ft³)	0.0618	61.7890
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0163	0.3683
Relative Humidity In (%)	12.76	
Relative Humidity Out (%)	16.21	

Tube-Side hi (BTU/hr·ft²·°F)	1,786.84
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.50
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.97
Effective Area (ft²)	860.06
LMTD	33.06
Total Heat Transferred (BTU/hr)	169,688
Surface Effectiveness (Eta)	0.9163
Sensible Heat Transferred (BTU/hr)	169,688
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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·ft²·°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·ft²·°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			

** Reynolds Number Outside Range of Equation Applicability

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		
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)	
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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 4(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,245.05	78,453.13	Tube-Side hi (BTU/hr·ft²·°F)	1,740.68
Inlet Temperature (°F)	129.65	109.62	j Factor	0.0080
Outlet Temperature (°F)	124.78	110.72	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)	127.21	110.1699		
Skin Temperature (°F)	114.15	111.2629	U Overall (BTU/hr·ft²·°F)	5.91
Velocity ***	3,533.63	6.1204	Effective Area (ft²)	860.06
Reynold's Number	852**	40,403	LMTD	16.92
Prandtl Number	0.7269	4.0364	Total Heat Transferred (BTU/hr)	86,054
Bulk Visc (lbm/ft·hr)	0.0479	1.4815		
Skin Visc (lbm/ft·hr)	0.0000	1.4654	Surface Effectiveness (Eta)	0.9171
Density (lbm/ft³)	0.0638	61.8576	Sensible Heat Transferred (BTU/hr)	86,054
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·ft²·°F/BTU)	0.02832467
Average Temp (°F)	122.83	109.1819		
Skin Temperature (°F)	112.37	110.0604	U Overall (BTU/hr·ft²·°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			

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,245.05	78,453.13
Inlet Temperature (°F)	120.88	108.04
Outlet Temperature (°F)	117.77	108.74
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	119.33	108.3920
Skin Temperature (°F)	110.94	109.0979
Velocity ***	3,533.63	6.1180
Reynold's Number	861**	39,684
Prandtl Number	0.7275	4.1168
Bulk Visc (lbm/ft·hr)	0.0474	1.5083
Skin Visc (lbm/ft·hr)	0.0000	1.4976
Density (lbm/ft³)	0.0645	61.8826
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0157	0.3660
Relative Humidity In (%)	29.44	
Relative Humidity Out (%)	32.10	

Tube-Side hi (BTU/hr·ft²·°F)	1,723.23
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.38
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.89
Effective Area (ft²)	860.06
LMTD	10.86
Total Heat Transferred (BTU/hr)	55,019
Surface Effectiveness (Eta)	0.9174
Sensible Heat Transferred (BTU/hr)	55,019
Latent Heat Transferred (BTU/hr)	
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)	70,245.05	78,453.13
Inlet Temperature (°F)	117.77	107.48
Outlet Temperature (°F)	115.28	108.04
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	116.52	107.7600
Skin Temperature (°F)	109.80	108.3270
Velocity ***	3,533.63	6.1171
Reynold's Number	864**	39,430
Prandtl Number	0.7276	4.1460
Bulk Visc (lbm/ft·hr)	0.0473	1.5180
Skin Visc (lbm/ft·hr)	0.0000	1.5093
Density (lbm/ft³)	0.0648	61.8914
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3657
Relative Humidity In (%)	32.10	
Relative Humidity Out (%)	34.44	

Tube-Side hi (BTU/hr·ft²·°F)	1,717.01
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.36
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.88
Effective Area (ft²)	860.06
LMTD	8.70
Total Heat Transferred (BTU/hr)	44,037
Surface Effectiveness (Eta)	0.9175
Sensible Heat Transferred (BTU/hr)	44,037
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,245.05	78,453.13
Inlet Temperature (°F)	115.28	107.03
Outlet Temperature (°F)	113.28	107.48
Inlet Specific Humidity	0.023032	
Outlet Specific Humidity	0.023032	
Average Temp (°F)	114.28	107.2540
Skin Temperature (°F)	108.89	107.7094
Velocity ***	3,533.63	6.1164
Reynold's Number	867**	39,226
Prandtl Number	0.7278	4.1697
Bulk Visc (lbm/ft·hr)	0.0471	1.5259
Skin Visc (lbm/ft·hr)	0.0000	1.5188
Density (lbm/ft³)	0.0650	61.8983
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3655
Relative Humidity In (%)	34.44	
Relative Humidity Out (%)	36.45	

Tube-Side hi (BTU/hr·ft²·°F)	1,712.02
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.35
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.88
Effective Area (ft²)	860.06
LMTD	6.98
Total Heat Transferred (BTU/hr)	35,265
Surface Effectiveness (Eta)	0.9176
Sensible Heat Transferred (BTU/hr)	35,265
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Formulas from Section 6.7 for iteration process to determine inlet airflow for extrapolation conditions					
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

Design Analysis (Minor Revision)		**Last Page No.** [6]	1
Analysis No.: [1]	97-200	**Revision:** [2]	A04
Title: [3]	VY Cooler Thermal Performance Model – 1(2)VY01A and 1(2)VY02A		
EC/ECR No.: [4]	384525	**Revision:** [5]	000

Station(s): [7] LaSalle
Unit No.: [8] 02
Safety/QA Class: [9] SR
System Code(s): [10] HP, E22, DG, VY

Is this Design Analysis Safeguards Information? [11] 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): [14]
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.

	Print Name	Sign Name	Date
Preparer: [16]	Sean Tanton	Sean Tanton	3/20/12

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Matthew Cosenza	[signature]	3/20/12

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	N/A	N/A	N/A
Exelon Reviewer [21]	N/A	N/A	N/A
Exelon Approver: [22]	Dan Schmit	DJ Schmit	3/28/12

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

Design Analysis (Minor Revision) — **Last Page No.:** [6] 1

Analysis No.: [1] 97-200 — **Revision:** [2] A03

Title: [3] VY Cooler Thermal Performance Model – 1(2)VY01A and 1(2)VY02A

EC/ECR No.: [4] 370853 — **Revision:** [5] 000

Station(s): [7] LaSalle

Unit No.: [8] 01

Safety/QA Class: [9] SR

System Code(s): [10] HP, E22, DG

Is this Design Analysis Safeguards Information? [11] 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): [14]
To recover available margin in Division III of the CSCS, EC 370853 revises the flows of the 1VY02A cooler. To recover margin, 100 gpm will be diverted from the 1E22-S001 cooler. Of this 100 gpm, 50 gpm will be returned to the 1E22-C001 pump, while the other 50 gpm will be given to the 1VY02A cooler. This minor revision documents the change in flow.

Note that this analysis covers the 1(2)VY02A and the 1(2)VY01A coolers. This revision only applies to Div. 3, Unit 1 (1VY02A cooler). The flows shown for the remaining coolers are not impacted by this revision.

Disposition of Changes: [15]
The minimum flow required to remove the design heat load of 646,235 Btu/hr has not changed. Because the flow through the coolers is increasing by 50 gpm, the heat transfer will be greater and the previous scenarios that have been run in this calculation will remain bounding. The increase in flow will not increase the velocity of the water through the tubes to a point that would exceed the limits established in ER-AA-340-2000. Therefore, the additional 50 gpm is acceptable.

	Print Name	Sign Name	Date
Preparer: [16]	Sean Tanton	Sean Tanton	5/31/11

Method of Review: [17] **Detailed Review** ☒ **Alternate Calculations** ☐ **Testing** ☐

	Print Name	Sign Name	Date
Reviewer: [18]	Matthew Cosenza	Matthew Cosenza	6/1/11

Review Notes: [19] Independent review ☒ Peer review ☐

(For External Analyses Only)

	Print Name	Sign Name	Date
External Approver: [20]	N/A	N/A	N/A
Exelon Reviewer: [21]	N/A	N/A	N/A
Exelon Approver: [22]	Dan Schmit	D Schmit	6/1/11

ATTACHMENT 2
Design Analysis Minor Revision Cover Sheet

+ Plus Att A Page A1 - A7
Att B Page B1-B7

Analysis No.	97-200	**Last Page No.** 3	
		Revision	A02
EC/ECR No.	356225	**Revision**	0
Title:	VY Cooler Thermal Performance Model - 1(2)VY01A and 1(2)VY02A		

Station(s)	LaSalle	**Is 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

This minor revision reduces the amount of air flow required into the 1(2)VY01A coolers by 5%, and determines a new maximum fouling factor at this reduced air flow.The 1(2)VY02A coolers were not changed.

Disposition of Changes (include additional pages as required)

See attached sheets. The change is acceptable.

	Print Name	Sign Name	Date
Preparer	Terry Martin	[signature]	7/6/05
Reviewer	DAN SCHMIT	[signature]	7/6/05

Method of Review ☑ Detailed Review ☐ Alternate Calculations ☐ Testing

Review Notes:

	Print Name	Sign Name	Date
Approver	W. Hilton	[signature]	7-6-05

(For External Analyses Only)

	Print Name	Sign Name	Date
Exelon Reviewer			
Approver			

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*ft^2*°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.

Inputs:
The design inputs consist of Reference 1 listed below.

Assumptions:
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*ft^2*°F/BTU, and a 5% tube plugging allowance, 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*ft^2*°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*ft^2*°F/BTU), a 5% tube plugging allowance, and a 5% reduction in air flow rate. The maximum fouling factor is 0.07593245 hr*ft^2*°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)

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06-09-2005 14:41:20 **PROTO-HX 4.01 by Proto-Power Corporation (SN#PHX-0000)**

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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	0.00	lbm/hr	0.00	lbm/hr
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 Water
Tube-Side Fouling	0.001500
Air-Side Fouling	0.000000
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 Flow
Fin Type	Circular Fins
Configuration (for Air-Side h)	LaSalle VY Coolers 01A/02A
	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)	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 Conductivity (BTU/hr·ft·°F)	225.00

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Att A
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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

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 (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

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AH A
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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

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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 Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	67,203.40	37,264.79
Inlet Temperature (°F)	148.00	104.00
Outlet Temperature (°F)	112.12	120.20
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
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)	603,150
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	67,203.40	37,264.79
Inlet Temperature (°F)	148.00	116.90
Outlet Temperature (°F)	140.70	120.20
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	144.35	118.5507
Skin Temperature (°F)	125.37	121.2532
Velocity ***	3,380.62	2.9130
Reynold's Number	797**	20,828
Prandtl Number	0.7255	3.6895
Bulk Visc (lbm/ft·hr)	0.0490	1.3650
Skin Visc (lbm/ft·hr)	0.0000	1.3307
Density (lbm/ft³)	0.0623	61.7340
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3695
Relative Humidity In (%)	12.76	
Relative Humidity Out (%)	15.34	

Tube-Side hi (BTU/hr·ft²·°F)	1,004.28
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.24
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.57
Effective Area (ft²)	860.06
LMTD	25.60
Total Heat Transferred (BTU/hr)	122,664
Surface Effectiveness (Eta)	0.9186
Sensible Heat Transferred (BTU/hr)	122,664
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

97-200 Rev A.
Att A
Page A3

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	140.70	114.09
Outlet Temperature (°F)	134.48	116.90
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	137.59	115.4974
Skin Temperature (°F)	121.35	117.8395
Velocity ***	3,380.62	2.9108
Reynold's Number	804**	20,226
Prandtl Number	0.7261	3.8100
Bulk Visc (lbm/ft·hr)	0.0486	1.4056
Skin Visc (lbm/ft·hr)	0.0000	1.3743
Density (lbm/ft³)	0.0630	61.7801
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3685
Relative Humidity In (%)	15.34	
Relative Humidity Out (%)	18.03	

Tube-Side hi (BTU/hr·ft²·°F)	988.35
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.21
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.55
Effective Area (ft²)	860.06
LMTD	21.93
Total Heat Transferred (BTU/hr)	104,623
Surface Effectiveness (Eta)	0.9188
Sensible Heat Transferred (BTU/hr)	104,623
Latent Heat Transferred (BTU/hr)	
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)	67,203.40	37,264.79
Inlet Temperature (°F)	134.48	111.69
Outlet Temperature (°F)	129.17	114.09
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	131.82	112.8918
Skin Temperature (°F)	117.92	114.9196
Velocity ***	3,380.62	2.9090
Reynold's Number	810**	19,718
Prandtl Number	0.7265	3.9181
Bulk Visc (lbm/ft·hr)	0.0482	1.4419
Skin Visc (lbm/ft·hr)	0.0000	1.4136
Density (lbm/ft³)	0.0636	61.8185
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3676
Relative Humidity In (%)	18.03	
Relative Humidity Out (%)	20.76	

Tube-Side hi (BTU/hr·ft²·°F)	974.69
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.53
Effective Area (ft²)	860.06
LMTD	18.79
Total Heat Transferred (BTU/hr)	89,336
Surface Effectiveness (Eta)	0.9191
Sensible Heat Transferred (BTU/hr)	89,336
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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)	0.00031430
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²·°F/BTU)	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/ft³)	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 (BTU/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			

** 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

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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
Inlet Temperature (°F)	120.74	106.38
Outlet Temperature (°F)	117.41	107.89
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	119.08	107.1344
Skin Temperature (°F)	110.32	108.4442
Velocity ***	3.380.62	2.9052
Reynold's Number	824**	18,610
Prandtl Number	0.7275	4.1753
Bulk Visc (lbm/ft·hr)	0.0474	1.5278
Skin Visc (lbm/ft·hr)	0.0000	1.5075
Density (lbm/ft³)	0.0649	61.9000
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3655
Relative Humidity In (%)	26.12	
Relative Humidity Out (%)	28.66	

Tube-Side hi (BTU/hr·ft²·°F)	944.29
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.48
Effective Area (ft²)	860.06
LMTD	11.85
Total Heat Transferred (BTU/hr)	55,913
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	55,913
Latent Heat Transferred (BTU/hr)	
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)	67,203.40	37,264.79
Inlet Temperature (°F)	117.41	105.10
Outlet Temperature (°F)	114.56	106.38
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	115.99	105.7400
Skin Temperature (°F)	108.48	106.8708
Velocity ***	3.380.62	2.9043
Reynold's Number	827**	18,345
Prandtl Number	0.7277	4.2417
Bulk Visc (lbm/ft·hr)	0.0472	1.5498
Skin Visc (lbm/ft·hr)	0.0000	1.5319
Density (lbm/ft³)	0.0652	61.9190
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3650
Relative Humidity In (%)	28.66	
Relative Humidity Out (%)	31.06	

Tube-Side hi (BTU/hr·ft²·°F)	936.89
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.12
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.47
Effective Area (ft²)	860.06
LMTD	10.17
Total Heat Transferred (BTU/hr)	47,894
Surface Effectiveness (Eta)	0.9197
Sensible Heat Transferred (BTU/hr)	47,894
Latent Heat Transferred (BTU/hr)	
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

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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
Inlet Temperature (°F)	114.56	103.99
Outlet Temperature (°F)	112.12	105.10
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	113.34	104.5452
Skin Temperature (°F)	106.90	105.5210
Velocity ***	3.380.62	2.9035
Reynold's Number	830**	18,119
Prandtl Number	0.7278	4.3000
Bulk Visc (lbm/ft·hr)	0.0471	1.5692
Skin Visc (lbm/ft·hr)	0.0000	1.5534
Density (lbm/ft³)	0.0655	61.9351
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3645
Relative Humidity In (%)	31.06	
Relative Humidity Out (%)	33.30	

Tube-Side hi (BTU/hr·ft²·°F)	930.53
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.11
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.47
Effective Area (ft²)	860.06
LMTD	8.73
Total Heat Transferred (BTU/hr)	41,047
Surface Effectiveness (Eta)	0.9198
Sensible Heat Transferred (BTU/hr)	41,047
Latent Heat Transferred (BTU/hr)	
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

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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/hr
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 Water
Tube-Side Fouling	0.004000
Air-Side Fouling	0.000400
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 Flow
Fin Type	Circular Fins
Configuration (for Air-Side h)	LaSalle VY Coolers 01A/02A
	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)	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 Conductivity (BTU/hr·ft·°F)	225.00

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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

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 (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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*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	148.00	104.00
Outlet Temperature (°F)	114.87	118.87
Inlet Specific Humidity		
Outlet Specific Humidity		

Tube-Side hi (BTU/hr·ft²·°F)	0.00
j Factor	0.0000
Air-Side ho (BTU/hr·ft²·°F)	0.00
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
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)	553,584
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,793.22	37,264.79
Inlet Temperature (°F)	148.00	116.10
Outlet Temperature (°F)	141.83	118.87
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	144.91	117.4817
Skin Temperature (°F)	128.95	119.7606
Velocity ***	3.359.98	2.9122
Reynold's Number	792**	20,617
Prandtl Number	0.7254	3.7310
Bulk Visc (lbm/ft·hr)	0.0490	1.3790
Skin Visc (lbm/ft·hr)	0.0000	1.3495
Density (lbm/ft³)	0.0622	61.7503
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3692
Relative Humidity In (%)	12.76	
Relative Humidity Out (%)	14.91	

Tube-Side hi (BTU/hr·ft²·°F)	998.32
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.21
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.07593245
U Overall (BTU/hr·ft²·°F)	4.39
Effective Area (ft²)	860.06
LMTD	27.30
Total Heat Transferred (BTU/hr)	103,117
Surface Effectiveness (Eta)	0.9189
Sensible Heat Transferred (BTU/hr)	103,117
Latent Heat Transferred (BTU/hr)	
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

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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)	984.79
Inlet Temperature (°F)	141.83	113.66	j Factor	0.0082
Outlet Temperature (°F)	136.39	116.10	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)	0.07593245
Average Temp (°F)	139.11	114.8760		
Skin Temperature (°F)	125.00	116.9114	U Overall (BTU/hr·ft²·°F)	4.38
Velocity ***	3,359.98	2.9104	Effective Area (ft²)	860.06
Reynold's Number	798**	20,105	LMTD	24.12
Prandtl Number	0.7259	3.8354	Total Heat Transferred (BTU/hr)	90,846
Bulk Visc (lbm/ft·hr)	0.0487	1.4142		
Skin Visc (lbm/ft·hr)	0.0000	1.3866	Surface Effectiveness (Eta)	0.9191
Density (lbm/ft³)	0.0628	61.7894	Sensible Heat Transferred (BTU/hr)	90,846
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)	
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			

** 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

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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 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,793.22	37,264.79
Inlet Temperature (°F)	131.60	109.61
Outlet Temperature (°F)	127.37	111.50
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	129.48	110.5551
Skin Temperature (°F)	118.47	112.1747
Velocity ***	3.359.98	2.9074
Reynold's Number	808**	19,265
Prandtl Number	0.7267	4.0193
Bulk Visc (lbm/ft·hr)	0.0481	1.4758
Skin Visc (lbm/ft·hr)	0.0000	1.4522
Density (lbm/ft³)	0.0638	61.8521
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3667
Relative Humidity In (%)	19.46	
Relative Humidity Out (%)	21.79	

Tube-Side hi (BTU/hr·ft²·°F)	962.23
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.07593245
U Overall (BTU/hr·ft²·°F)	4.36
Effective Area (ft²)	860.06
LMTD	18.84
Total Heat Transferred (BTU/hr)	70,636
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	70,636
Latent Heat Transferred (BTU/hr)	
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)	66,793.22	37,264.79
Inlet Temperature (°F)	127.37	107.93
Outlet Temperature (°F)	123.64	109.61
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	125.51	108.7689
Skin Temperature (°F)	115.76	110.2121
Velocity ***	3.359.98	2.9062
Reynold's Number	812**	18,922
Prandtl Number	0.7270	4.0995
Bulk Visc (lbm/ft·hr)	0.0478	1.5026
Skin Visc (lbm/ft·hr)	0.0000	1.4809
Density (lbm/ft³)	0.0642	61.8773
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3661
Relative Humidity In (%)	21.79	
Relative Humidity Out (%)	24.11	

Tube-Side hi (BTU/hr·ft²·°F)	952.85
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.13
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.07593245
U Overall (BTU/hr·ft²·°F)	4.35
Effective Area (ft²)	860.06
LMTD	16.66
Total Heat Transferred (BTU/hr)	62,333
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	62,333
Latent Heat Transferred (BTU/hr)	
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

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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 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·ft²·°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 (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 (%)	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 (BTU/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			

** Reynolds Number Outside Range of Equation Applicability

97-200 Rev A02
Att B
Page B6

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	66,793.22	37,264.79
Inlet Temperature (°F)	117.44	103.99
Outlet Temperature (°F)	114.87	105.15
Inlet Specific Humidity	0.020268	
Outlet Specific Humidity	0.020268	
Average Temp (°F)	116.15	104.5707
Skin Temperature (°F)	109.41	105.5885
Velocity ***	3.359.98	2.9036
Reynold's Number	822**	18,123
Prandtl Number	0.7277	4.2987
Bulk Visc (lbm/ft·hr)	0.0472	1.5688
Skin Visc (lbm/ft·hr)	0.0000	1.5523
Density (lbm/ft³)	0.0651	61.9348
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3645
Relative Humidity In (%)	28.64	
Relative Humidity Out (%)	30.79	

Tube-Side hi (BTU/hr·ft²·°F)	930.72
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.09
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.07593245
U Overall (BTU/hr·ft²·°F)	4.33
Effective Area (ft²)	860.06
LMTD	11.53
Total Heat Transferred (BTU/hr)	42,938
Surface Effectiveness (Eta)	0.9199
Sensible Heat Transferred (BTU/hr)	42,938
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

97-200 Rev A02
Att B
Page B7 of B7 Final

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

DESIGN ANALYSIS NO.: Calc. #97-200 **PAGE NO.** 1
Major REV Number: A **Minor Rev Number:** 01

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

Unit: [ ] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE: (C018) M10
DISCIPLINE CODE: (C011) M
SYSTEM CODE: (C011) 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	VALUE	TYPE	VALUE
Elevation	694'		
Software	PROTO-HX		

COMPONENT EPN: (C014 Panel)

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

EPN	TYPE	Type/Sub	Document Number	Input (Y/N)
1VY01A	H15	DCD/ EVAL	EC#337494	Y
2VY01A	H15	/		
1VY02A	H15	/		
2VY02A	H15	/		
		/		
		/		
		/		

REMARKS:

DESIGN ANALYSIS NO. 97-200 **REV:** A01 **PAGE NO.** 2

Revision Summary (including EC's incorporated): evaluated issues associated with 1) the impact of an error "flag" message on the printouts of Proto-Hx, which states that the Air Side Reynolds number is outside the range of equation applicability. 2) the "Data Report" output for the air coolers indicates a LOG (base 10) in the Fin Configuration equation for the Colburn 'j' factor, however the equation in the body of this calculation shows this as the natural log (Ln). The calc. has been evaluated to be acceptable as-is.

Electronic Calculation Data Files: Proto-Hx (This data is same as previous minor revision; no computer runs were performed for this minor revision)

(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [x] N/A, Per EC#:_337494________
(If yes, attach impact review sheet)

Prepared by: __B._L. Davenport __________ / [signature] / 6-06-02
Print / Sign / Date

Reviewed by: __D. J. Schmit__________ / [signature] / 6/10/02
Print / Sign / Date

Method of Review: [✓] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: ____________N/A____________ **in its entirety.**

Supplemental Review Required? [ ] Yes [ ] No

[ ] **Additional Review** [ ] **Special Review Team**

Additional Reviewer or Special Review Team Leader: ________ / ________ / ________
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1)______ / ______ / ______ 2)______ / ______ / ______
Print / Sign / Date Print / Sign / Date

3)______ / ______ / ______ 4)______ / ______ / ______
Print / Sign / Date Print / Sign / Date

Supplemental Review Results:

Approved by: J. T. Conner / [signature] / 6/10/02
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ______________ / ______________ / ______________
Print / Sign / Date

Approved by: ______________ / ______________ / ______________
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
Tracked By: AT#, EC# etc.)______________________

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 ANALYSIS 97-200, REV. A01
ATTACHMENT A PAGE A1 OF A1

PROTO-POWER CORPORATION
A Utility Engineering Subsidiary

15 THAMES STREET
GROTON, CT 06340
PH: 860.440.9725
FX: 860.440.8292
www.protopower.com

SEAG Number

02-000086

MEMORANDUM

File No. 908SOF/050119/M02001

To: Brian Davenport

From: Joseph G. Fayan

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:baj

CC: Joseph G. Fayan
Job File

LASALLE CALCULATION

EDITORIAL – COMMENT TO CALCULATION

Affecting Calculation No.: 97-200	Rev: A00	For Reference	Page No. 1 of 1

The use of this form shall be limited to document corrections of editorial nature. Return to Sylvia Venecia

	Print	Sign	Date
Prepared by:	Sylvia F. Venecia	[signature]	6/6/02
Reviewed by:			
Approved by:			

Description of Correction:

1) Pages 3 thru 7, A1, B1 + C1 are on forms with the ComEd logo which are not the most current forms.

Per J.T. Conner on 5/28/02 OK to Process. In the future the most current forms will be used.

When these comments are incorporated, return this form with the revised calculation.

Incorporated on Calc Rev.	By:	Date:

DESIGN ANALYSIS NO.: Calc. # 97-200 PAGE NO. 1
Major REV Number: A Minor Rev Number: 00

[ ] BRAIDWOOD STATION
[ ] BYRON STATION
[ ] CLINTON STATION
[ ] DRESDEN STATION
[X] LASALLE CO. STATION
[ ] QUAD CITIES STATION

Unit: [ ] 0 [X] 1 [X] 2 [ ] 3

DESCRIPTION CODE:(C018) M010
DISCIPLINE CODE: (C011) M
SYSTEM CODE: (C011) 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	VALUE	TYPE	VALUE
Elevation	694'		
Software	Proto-HX		

COMPONENT EPN: (C014 Panel)

EPN	TYPE
1VY01A	H15
2VY01A	H15
1VY02A	H15
2VY02A	H15

DOCUMENT NUMBERS: (C012 Panel) (Design Analyses References)

Type/Sub	Document Number	Input (Y/N)
~~EC~~ DCP/DCP	EC# 334017	Y
/		
/		
/		
/		
/		
/		

REMARKS: NA

DESIGN ANALYSIS NO. *97-200* **REV: A00 PAGE NO. 2**

Revision Summary (including EC's incorporated): Updated ProtoHX model for 104°F Service Water inlet temperature and calculated thermal margins with the design fouling factor and 5% tubes plugged for the Unit 1 and 2 A RHR Pump Room Coolers (1/2VY01A) and HPCS Pump Room Coolers (1/2VY02A).

Electronic Calculation Data Files: ProtoHX 3.02, vy-0102a.phx, 1152 KB, 11/02/2001, 2:14 am

(Program Name, Version, File Name extension/size/date/hour/min)

Design impact review completed? [ ] Yes [X] N/A, Per EC#: 334017
(If yes, attach impact review sheet)

Prepared by: Jeff W. VanStrien / [signature] / 5-7-02
Print / Sign / Date

Reviewed by: Brian L. Davenport / [signature] / 5-10-02
Print / Sign / Date

Method of Review: [X] Detailed [ ] Alternate [ ] Test

This Design Analysis supersedes: N/A **in its entirety.**

Supplemental Review Required? [ ] Yes [X] No

[ ] Additional Review [ ] Special Review Team

Additional Reviewer or Special Review Team Leader: ______ / ______ / ______
Print / Sign / Date

Special Review Team: (N/A for Additional Review)

Reviewers: 1) ______ / ______ / ______ 2) ______ / ______ / ______
Print / Sign / Date / Print / Sign / Date

3) ______ / ______ / ______ 4) ______ / ______ / ______
Print / Sign / Date / Print / Sign / Date

Supplemental Review Results:

Approved by: J. T. [illegible] / [signature] / 5/14/02
Print / Sign / Date

External Design Analysis Review (Attachment 3 Attached)

Reviewed by: ______ / ______ / ______
Print / Sign / Date

Approved by: ______ / ______ / ______
Print / Sign / Date

Do any ASSUMPTIONS / ENGINEERING JUDGEMENTS require later verification? [ ] Yes [X] No
Tracked By: AT#, EC# etc.) ______

ComEd

NES-G-14.01
Effective Date:
04/14/00

CALCULATION TABLE OF CONTENTS

CALCULATION NO. *97-200* REV. NO. A00 PAGE NO. 3

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2.0 METHODOLOGY AND ACCEPTANCE CRITERIA	4	
3.0 ASSUMPTIONS / ENGINEERING JUDGEMENTS	4	
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Attachment "A" – Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A (CSCS=104°F @ Design Fouling)	A1 to A17	
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	

E-FORM

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".

E-FORM

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*ft^2*°F/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:

$$\frac{ThermalMargin}{RequiredHeatLoad} \times 100\% = \%ThermalMargin \qquad \text{[Equation 2]}$$

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*ft^2*°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%

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*ft^{2}*°F/BTU and 5% plugged [Attachment B].

Cooler	Limiting Flow Rate (gpm)	$Q_{required}$ (BTU/hr)	$Q_{available}$ (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*ft^{2}*°F/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*ft^{2}*°F/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.

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*ft^2*°F/BTU). The maximum allowable overall fouling factor for the 1(2)VY01A coolers is 0.0949 hr*ft^2*°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*ft^2*°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)

E-FORM

Attachment "A"

Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A
(CSCS=104°F @ Design Fouling)

E-FORM

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY01 @ 104 F, DESIGN FF

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 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

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)	19,120.00
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

VY01 @ 104 F, DESIGN FF

Extrapolation Calculation Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	148.00	104.00
Outlet Temperature (°F)	112.40	120.93
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)		
K (BTU/hr·ft·°F)		

Tube-Side hi (BTU/hr·ft²·°F)	
j Factor	
Air-Side ho (BTU/hr·ft²·°F)	
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	
Effective Area (ft²)	7,242.65
LMTD	
Total Heat Transferred (BTU/hr)	629,279
Surface Effectiveness (Eta)	
Sensible Heat Transferred (BTU/hr)	629,279
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 1(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	148.00	117.56
Outlet Temperature (°F)	140.90	120.93
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	144.45	119.24
Skin Temperature (°F)	125.98	121.97
Velocity ***	3,376.53	2.77
Reynold's Number	796**	19,916
Prandtl Number	0.7254	3.6630
Bulk Visc (lbm/ft·hr)	0.0490	1.3561
Skin Visc (lbm/ft·hr)		1.3218
Density (lbm/ft³)	0.0623	61.7233
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3698

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	967.24
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.24
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.55
Effective Area (ft²)	905.33
LMTD	25.01
Total Heat Transferred (BTU/hr)	125,565
Surface Effectiveness (Eta)	0.9186
Sensible Heat Transferred (BTU/hr)	125,565
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	140.90	114.66
Outlet Temperature (°F)	134.79	117.56
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	137.84	116.11
Skin Temperature (°F)	121.93	118.49
Velocity ***	3,376.53	2.77
Reynold's Number	803**	19,327
Prandtl Number	0.7260	3.7855
Bulk Visc (lbm/ft·hr)	0.0486	1.3974
Skin Visc (lbm/ft·hr)		1.3658
Density (lbm/ft³)	0.0630	61.7710
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3687

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	951.58
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.21
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.52
Effective Area (ft²)	905.33
LMTD	21.57
Total Heat Transferred (BTU/hr)	107,856
Surface Effectiveness (Eta)	0.9189
Sensible Heat Transferred (BTU/hr)	107,856
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	134.79	112.17
Outlet Temperature (°F)	129.55	114.66
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	132.17	113.41
Skin Temperature (°F)	118.45	115.49
Velocity ***	3,376.53	2.76
Reynold's Number	809**	18,827
Prandtl Number	0.7265	3.8961
Bulk Visc (lbm/ft·hr)	0.0483	1.4346
Skin Visc (lbm/ft·hr)		1.4057
Density (lbm/ft³)	0.0635	61.8109
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3678

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	938.05
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.18
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.50
Effective Area (ft²)	905.33
LMTD	18.61
Total Heat Transferred (BTU/hr)	92,745
Surface Effectiveness (Eta)	0.9191
Sensible Heat Transferred (BTU/hr)	92,745
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

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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
Inlet Temperature (°F)	129.55	110.02
Outlet Temperature (°F)	125.03	112.17
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	127.29	111.09
Skin Temperature (°F)	115.45	112.90
Velocity ***	3,376.53	2.76
Reynold's Number	814**	18,399
Prandtl Number	0.7269	3.9956
Bulk Visc (lbm/ft·hr)	0.0479	1.4679
Skin Visc (lbm/ft·hr)		1.4417
Density (lbm/ft³)	0.0640	61.8445
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3669

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	926.37
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.16
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.49
Effective Area (ft²)	905.33
LMTD	16.07
Total Heat Transferred (BTU/hr)	79,826
Surface Effectiveness (Eta)	0.9193
Sensible Heat Transferred (BTU/hr)	79,826
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	125.03	108.17
Outlet Temperature (°F)	121.14	110.02
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	123.08	109.10
Skin Temperature (°F)	112.87	110.67
Velocity ***	3,376.53	2.76
Reynold's Number	818**	18,034
Prandtl Number	0.7272	4.0846
Bulk Visc (lbm/ft·hr)	0.0477	1.4976
Skin Visc (lbm/ft·hr)		1.4740
Density (lbm/ft³)	0.0644	61.8727
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3662

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	916.28
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.47
Effective Area (ft²)	905.33
LMTD	13.88
Total Heat Transferred (BTU/hr)	68,762
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	68,762
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	121.14	106.58
Outlet Temperature (°F)	117.79	108.17
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	119.46	107.38
Skin Temperature (°F)	110.64	108.75
Velocity ***	3,376.53	2.76
Reynold's Number	822**	17,722
Prandtl Number	0.7274	4.1639
Bulk Visc (lbm/ft·hr)	0.0474	1.5240
Skin Visc (lbm/ft·hr)		1.5028
Density (lbm/ft³)	0.0648	61.8966
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	907.56
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.13
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.46
Effective Area (ft²)	905.33
LMTD	11.99
Total Heat Transferred (BTU/hr)	59,274
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	59,274
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	117.79	105.21
Outlet Temperature (°F)	114.89	106.58
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	116.34	105.89
Skin Temperature (°F)	108.72	107.09
Velocity ***	3,376.53	2.76
Reynold's Number	826**	17,454
Prandtl Number	0.7276	4.2343
Bulk Visc (lbm/ft·hr)	0.0473	1.5474
Skin Visc (lbm/ft·hr)		1.5285
Density (lbm/ft³)	0.0651	61.9169
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3650

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	900.01
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.12
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.45
Effective Area (ft²)	905.33
LMTD	10.37
Total Heat Transferred (BTU/hr)	51,127
Surface Effectiveness (Eta)	0.9197
Sensible Heat Transferred (BTU/hr)	51,127
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,654.85	37,262.20
Inlet Temperature (°F)	114.89	104.02
Outlet Temperature (°F)	112.40	105.21
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	113.64	104.61
Skin Temperature (°F)	107.06	105.65
Velocity ***	3,376.53	2.76
Reynold's Number	829**	17,224
Prandtl Number	0.7278	4.2966
Bulk Visc (lbm/ft·hr)	0.0471	1.5680
Skin Visc (lbm/ft·hr)		1.5513
Density (lbm/ft³)	0.0654	61.9342
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3646

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	893.49
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.11
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.44
Effective Area (ft²)	905.33
LMTD	8.96
Total Heat Transferred (BTU/hr)	44,124
Surface Effectiveness (Eta)	0.9198
Sensible Heat Transferred (BTU/hr)	44,124
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Inlet Air Flowrate Calculator - 1(2)VY01A

Total P:	P=		14.315	psia	Inlet Air Flow
Dry Bulb T OUT:	T=		112.4	F	19120 acfm
Specific Hum.:	W =		0.020274		
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875	psia	
		Rv =	85.778	(ft-lbf)/(lbm-R)	
		Ra =	53.352	(ft-lbf)/(lbm-R)	
Dry Air P:	Pa = P - Pv =		13.86313	psia	
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0654	lbm/ft^3	
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575	lbm/ft^3	
Dry Bulb T IN:	T=		148	F	
Outlet Air Flow:	V =		18000	cfm	

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF

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 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

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)	19,173.00
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

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·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)	143.82	114.91		
Skin Temperature (°F)	122.08	117.36	U Overall (BTU/hr·ft²·°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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	139.65	111.26
Outlet Temperature (°F)	132.79	113.53
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	136.22	112.39
Skin Temperature (°F)	118.31	114.44
Velocity ***	3,385.89	3.98
Reynold's Number	807**	26,839
Prandtl Number	0.7262	3.9393
Bulk Visc (lbm/ft·hr)	0.0485	1.4490
Skin Visc (lbm/ft·hr)		1.4202
Density (lbm/ft³)	0.0632	61.8258
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3674

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,249.06
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.22
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.67
Effective Area (ft²)	905.33
LMTD	23.65
Total Heat Transferred (BTU/hr)	121,509
Surface Effectiveness (Eta)	0.9188
Sensible Heat Transferred (BTU/hr)	121,509
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,850.70	53,657.57
Inlet Temperature (°F)	132.79	109.40
Outlet Temperature (°F)	127.16	111.26
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	129.97	110.33
Skin Temperature (°F)	115.21	112.03
Velocity ***	3,385.89	3.98
Reynold's Number	813**	26,293
Prandtl Number	0.7267	4.0293
Bulk Visc (lbm/ft·hr)	0.0481	1.4791
Skin Visc (lbm/ft·hr)		1.4543
Density (lbm/ft³)	0.0638	61.8554
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3667

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,234.94
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.66
Effective Area (ft²)	905.33
LMTD	19.50
Total Heat Transferred (BTU/hr)	99,875
Surface Effectiveness (Eta)	0.9190
Sensible Heat Transferred (BTU/hr)	99,875
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

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·°F/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)	

** 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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,850.70	53,657.57
Inlet Temperature (°F)	118.70	105.56
Outlet Temperature (°F)	115.55	106.60
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.13	106.08
Skin Temperature (°F)	108.83	107.05
Velocity ***	3,385.89	3.97
Reynold's Number	827**	25,182
Prandtl Number	0.7276	4.2254
Bulk Visc (lbm/ft·hr)	0.0473	1.5444
Skin Visc (lbm/ft·hr)		1.5291
Density (lbm/ft³)	0.0651	61.9144
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3651

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,205.71
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.62
Effective Area (ft²)	905.33
LMTD	10.97
Total Heat Transferred (BTU/hr)	55,792
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	55,792
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,850.70	53,657.57
Inlet Temperature (°F)	115.55	104.70
Outlet Temperature (°F)	112.96	105.56
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	114.26	105.13
Skin Temperature (°F)	107.40	105.94
Velocity ***	3,385.89	3.97
Reynold's Number	830**	24,935
Prandtl Number	0.7278	4.2713
Bulk Visc (lbm/ft·hr)	0.0471	1.5597
Skin Visc (lbm/ft·hr)		1.5467
Density (lbm/ft³)	0.0654	61.9273
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3647

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,199.14
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.12
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.61
Effective Area (ft²)	905.33
LMTD	9.06
Total Heat Transferred (BTU/hr)	46,015
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	46,015
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,850.70	53,657.57
Inlet Temperature (°F)	112.96	103.99
Outlet Temperature (°F)	110.81	104.70
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	111.89	104.35
Skin Temperature (°F)	106.22	105.01
Velocity ***	3,385.89	3.97
Reynold's Number	833**	24,733
Prandtl Number	0.7279	4.3099
Bulk Visc (lbm/ft·hr)	0.0470	1.5725
Skin Visc (lbm/ft·hr)		1.5615
Density (lbm/ft³)	0.0656	61.9378
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3644

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,193.72
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.11
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.60
Effective Area (ft²)	905.33
LMTD	7.49
Total Heat Transferred (BTU/hr)	37,972
Surface Effectiveness (Eta)	0.9197
Sensible Heat Transferred (BTU/hr)	37,972
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Inlet Air Flowrate Calculator - 1(2)VY02A

Total P:	P=		14.315 psia	Inlet Air Flow
Dry Bulb T OUT:	T=		110.81 F	19173 acfm
Specific Hum.:	W =		0.020274	
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875 psia	
		Rv =	85.778 (ft-lbf)/(lbm-R)	
		Ra =	53.352 (ft-lbf)/(lbm-R)	
Dry Air P:	Pa = P - Pv =		13.86313 psia	
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0656 lbm/ft^3	
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575 lbm/ft^3	
Dry Bulb T IN:	T=		148 F	
Outlet Air Flow:	V =		18000 cfm	

Attachment "B"

Proto-Hx Calc. Report for 1(2)VY01A & 1(2)VY02A
(CSCS=104°F @ Design FF, 5% Plugged)

E-FORM

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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	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	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 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)	19,113.00
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

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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
Inlet Temperature (°F)	148.00	104.00
Outlet Temperature (°F)	112.62	120.76
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)		
K (BTU/hr·ft·°F)		

Tube-Side hi (BTU/hr·ft²·°F)	
j Factor	
Air-Side ho (BTU/hr·ft²·°F)	
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	
Effective Area (ft²)	6,880.52
LMTD	
Total Heat Transferred (BTU/hr)	625,070
Surface Effectiveness (Eta)	
Sensible Heat Transferred (BTU/hr)	625,070
Latent Heat Transferred (BTU/hr)	
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
Inlet Temperature (°F)	148.00	117.44
Outlet Temperature (°F)	141.01	120.76
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	144.50	119.10
Skin Temperature (°F)	125.96	121.81
Velocity ***	3,552.94	2.91
Reynold's Number	838**	20,935
Prandtl Number	0.7254	3.6685
Bulk Visc (lbm/ft·hr)	0.0490	1.3580
Skin Visc (lbm/ft·hr)		1.3238
Density (lbm/ft³)	0.0623	61.7256
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3697

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,007.00
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.52
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.70
Effective Area (ft²)	860.06
LMTD	25.22
Total Heat Transferred (BTU/hr)	123,549
Surface Effectiveness (Eta)	0.9162
Sensible Heat Transferred (BTU/hr)	123,549
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	141.01	114.58
Outlet Temperature (°F)	134.98	117.44
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	137.99	116.01
Skin Temperature (°F)	121.96	118.38
Velocity ***	3,552.94	2.91
Reynold's Number	845**	20,325
Prandtl Number	0.7260	3.7895
Bulk Visc (lbm/ft·hr)	0.0486	1.3987
Skin Visc (lbm/ft·hr)		1.3672
Density (lbm/ft³)	0.0629	61.7725
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3687

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	990.92
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.49
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.67
Effective Area (ft²)	860.06
LMTD	21.82
Total Heat Transferred (BTU/hr)	106,500
Surface Effectiveness (Eta)	0.9164
Sensible Heat Transferred (BTU/hr)	106,500
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	134.98	112.11
Outlet Temperature (°F)	129.78	114.58
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	132.38	113.34
Skin Temperature (°F)	118.50	115.42
Velocity ***	3,552.94	2.91
Reynold's Number	851**	19,804
Prandtl Number	0.7265	3.8991
Bulk Visc (lbm/ft·hr)	0.0483	1.4355
Skin Visc (lbm/ft·hr)		1.4067
Density (lbm/ft³)	0.0635	61.8119
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3677

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	976.99
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.46
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.65
Effective Area (ft²)	860.06
LMTD	18.90
Total Heat Transferred (BTU/hr)	91,897
Surface Effectiveness (Eta)	0.9166
Sensible Heat Transferred (BTU/hr)	91,897
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	129.78	109.98
Outlet Temperature (°F)	125.29	112.11
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	127.53	111.04
Skin Temperature (°F)	115.52	112.86
Velocity ***	3,552.94	2.91
Reynold's Number	856**	19,358
Prandtl Number	0.7269	3.9979
Bulk Visc (lbm/ft·hr)	0.0480	1.4686
Skin Visc (lbm/ft·hr)		1.4424
Density (lbm/ft³)	0.0640	61.8452
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3669

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	964.92
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.44
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.64
Effective Area (ft²)	860.06
LMTD	16.37
Total Heat Transferred (BTU/hr)	79,368
Surface Effectiveness (Eta)	0.9168
Sensible Heat Transferred (BTU/hr)	79,368
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	125.29	108.13
Outlet Temperature (°F)	121.40	109.98
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	123.34	109.05
Skin Temperature (°F)	112.94	110.64
Velocity ***	3,552.94	2.91
Reynold's Number	861**	18,975
Prandtl Number	0.7272	4.0866
Bulk Visc (lbm/ft·hr)	0.0477	1.4982
Skin Visc (lbm/ft·hr)		1.4745
Density (lbm/ft³)	0.0644	61.8733
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3662

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	954.45
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.42
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.62
Effective Area (ft²)	860.06
LMTD	14.19
Total Heat Transferred (BTU/hr)	68,601
Surface Effectiveness (Eta)	0.9170
Sensible Heat Transferred (BTU/hr)	68,601
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	121.40	106.54
Outlet Temperature (°F)	118.05	108.13
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	119.72	107.33
Skin Temperature (°F)	110.71	108.72
Velocity ***	3,552.94	2.91
Reynold's Number	865**	18,646
Prandtl Number	0.7274	4.1659
Bulk Visc (lbm/ft·hr)	0.0475	1.5246
Skin Visc (lbm/ft·hr)		1.5033
Density (lbm/ft³)	0.0648	61.8972
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	945.37
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.41
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.61
Effective Area (ft²)	860.06
LMTD	12.30
Total Heat Transferred (BTU/hr)	59,336
Surface Effectiveness (Eta)	0.9171
Sensible Heat Transferred (BTU/hr)	59,336
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	118.05	105.16
Outlet Temperature (°F)	115.14	106.54
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	116.59	105.85
Skin Temperature (°F)	108.78	107.06
Velocity ***	3,552.94	2.90
Reynold's Number	869**	18,364
Prandtl Number	0.7276	4.2365
Bulk Visc (lbm/ft·hr)	0.0473	1.5481
Skin Visc (lbm/ft·hr)		1.5290
Density (lbm/ft³)	0.0651	61.9176
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3650

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	937.50
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.39
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.60
Effective Area (ft²)	860.06
LMTD	10.67
Total Heat Transferred (BTU/hr)	51,352
Surface Effectiveness (Eta)	0.9172
Sensible Heat Transferred (BTU/hr)	51,352
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,628.98	37,262.20
Inlet Temperature (°F)	115.14	103.96
Outlet Temperature (°F)	112.62	105.16
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	113.88	104.56
Skin Temperature (°F)	107.11	105.62
Velocity ***	3,552.94	2.90
Reynold's Number	872**	18,120
Prandtl Number	0.7278	4.2992
Bulk Visc (lbm/ft·hr)	0.0471	1.5689
Skin Visc (lbm/ft·hr)		1.5518
Density (lbm/ft³)	0.0654	61.9349
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3645

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	930.67
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.38
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.59
Effective Area (ft²)	860.06
LMTD	9.25
Total Heat Transferred (BTU/hr)	44,466
Surface Effectiveness (Eta)	0.9173
Sensible Heat Transferred (BTU/hr)	44,466
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Inlet Air Flowrate Calculator - 1(2)VY01A

Total P:	P=		14.315 psia	Inlet Air Flow
Dry Bulb T OUT:	T=		112.62 F	19113 acfm
Specific Hum.:	W =		0.020274	
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875 psia	
		Rv =	85.778 (ft-lbf)/(lbm-R)	
		Ra =	53.352 (ft-lbf)/(lbm-R)	
Dry Air P:	Pa = P - Pv =		13.86313 psia	
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0654 lbm/ft^3	
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575 lbm/ft^3	
Dry Bulb T IN:	T=		148 F	
Outlet Air Flow:	V =		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 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 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 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)	19,164.00
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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF, 5% PLUG

Extrapolation Calculation Summary

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	148.00	104.00
Outlet Temperature (°F)	111.10	116.20
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)		
K (BTU/hr·ft·°F)		

Tube-Side hi (BTU/hr·ft²·°F)	
j Factor	
Air-Side ho (BTU/hr·ft²·°F)	
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	
Effective Area (ft²)	6,880.52
LMTD	
Total Heat Transferred (BTU/hr)	653,739
Surface Effectiveness (Eta)	
Sensible Heat Transferred (BTU/hr)	653,739
Latent Heat Transferred (BTU/hr)	
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
Inlet Temperature (°F)	148.00	113.50
Outlet Temperature (°F)	139.81	116.20
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	143.90	114.85
Skin Temperature (°F)	122.15	117.28
Velocity ***	3,562.42	4.19
Reynold's Number	841**	28,941
Prandtl Number	0.7255	3.8364
Bulk Visc (lbm/ft·hr)	0.0490	1.4145
Skin Visc (lbm/ft·hr)		1.3817
Density (lbm/ft³)	0.0624	61.7897
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0162	0.3683

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,318.81
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.53
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.85
Effective Area (ft²)	860.06
LMTD	28.85
Total Heat Transferred (BTU/hr)	145,141
Surface Effectiveness (Eta)	0.9161
Sensible Heat Transferred (BTU/hr)	145,141
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

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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
Inlet Temperature (°F)	139.81	111.26
Outlet Temperature (°F)	133.05	113.50
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	136.43	112.38
Skin Temperature (°F)	118.43	114.41
Velocity ***	3,562.42	4.19
Reynold's Number	849**	28,248
Prandtl Number	0.7262	3.9400
Bulk Visc (lbm/ft·hr)	0.0485	1.4493
Skin Visc (lbm/ft·hr)		1.4206
Density (lbm/ft³)	0.0631	61.8260
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3674

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,301.27
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.50
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.83
Effective Area (ft²)	860.06
LMTD	23.88
Total Heat Transferred (BTU/hr)	119,696
Surface Effectiveness (Eta)	0.9163
Sensible Heat Transferred (BTU/hr)	119,696
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	133.05	109.42
Outlet Temperature (°F)	127.47	111.26
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	130.26	110.34
Skin Temperature (°F)	115.35	112.04
Velocity ***	3,562.42	4.19
Reynold's Number	855**	27,680
Prandtl Number	0.7267	4.0288
Bulk Visc (lbm/ft·hr)	0.0481	1.4790
Skin Visc (lbm/ft·hr)		1.4541
Density (lbm/ft³)	0.0637	61.8552
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3667

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,286.74
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.47
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.81
Effective Area (ft²)	860.06
LMTD	19.78
Total Heat Transferred (BTU/hr)	98,838
Surface Effectiveness (Eta)	0.9166
Sensible Heat Transferred (BTU/hr)	98,838
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ 104 F, DESIGN FF, 5% PLUG

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	127.47	107.89
Outlet Temperature (°F)	122.86	109.42
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	125.17	108.65
Skin Temperature (°F)	112.81	110.07
Velocity ***	3,562.42	4.18
Reynold's Number	861**	27,214
Prandtl Number	0.7270	4.1047
Bulk Visc (lbm/ft·hr)	0.0478	1.5043
Skin Visc (lbm/ft·hr)		1.4829
Density (lbm/ft³)	0.0642	61.8789
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3661

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,274.71
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.45
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.79
Effective Area (ft²)	860.06
LMTD	16.40
Total Heat Transferred (BTU/hr)	81,701
Surface Effectiveness (Eta)	0.9168
Sensible Heat Transferred (BTU/hr)	81,701
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	122.86	106.63
Outlet Temperature (°F)	119.04	107.89
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	120.95	107.26
Skin Temperature (°F)	110.71	108.44
Velocity ***	3,562.42	4.18
Reynold's Number	866**	26,831
Prandtl Number	0.7273	4.1693
Bulk Visc (lbm/ft·hr)	0.0475	1.5258
Skin Visc (lbm/ft·hr)		1.5075
Density (lbm/ft³)	0.0647	61.8982
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3655

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,264.72
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.43
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.78
Effective Area (ft²)	860.06
LMTD	13.59
Total Heat Transferred (BTU/hr)	67,596
Surface Effectiveness (Eta)	0.9169
Sensible Heat Transferred (BTU/hr)	67,596
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	119.04	105.59
Outlet Temperature (°F)	115.88	106.63
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.46	106.11
Skin Temperature (°F)	108.97	107.09
Velocity ***	3,562.42	4.18
Reynold's Number	870**	26,515
Prandtl Number	0.7276	4.2239
Bulk Visc (lbm/ft·hr)	0.0473	1.5440
Skin Visc (lbm/ft·hr)		1.5284
Density (lbm/ft³)	0.0650	61.9140
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3651

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,256.44
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.41
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.77
Effective Area (ft²)	860.06
LMTD	11.28
Total Heat Transferred (BTU/hr)	55,967
Surface Effectiveness (Eta)	0.9171
Sensible Heat Transferred (BTU/hr)	55,967
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	115.88	104.72
Outlet Temperature (°F)	113.27	105.59
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	114.58	105.15
Skin Temperature (°F)	107.53	105.97
Velocity ***	3,562.42	4.18
Reynold's Number	873**	26,255
Prandtl Number	0.7278	4.2701
Bulk Visc (lbm/ft·hr)	0.0471	1.5593
Skin Visc (lbm/ft·hr)		1.5461
Density (lbm/ft³)	0.0653	61.9269
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3648

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,249.57
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.40
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.76
Effective Area (ft²)	860.06
LMTD	9.36
Total Heat Transferred (BTU/hr)	46,367
Surface Effectiveness (Eta)	0.9172
Sensible Heat Transferred (BTU/hr)	46,367
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²). Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,817.44	53,657.57
Inlet Temperature (°F)	113.27	104.01
Outlet Temperature (°F)	111.10	104.72
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	112.18	104.36
Skin Temperature (°F)	106.34	105.05
Velocity ***	3,562.42	4.18
Reynold's Number	876**	26,039
Prandtl Number	0.7279	4.3090
Bulk Visc (lbm/ft·hr)	0.0470	1.5722
Skin Visc (lbm/ft·hr)		1.5610
Density (lbm/ft³)	0.0656	61.9375
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3645

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,243.87
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.39
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.75
Effective Area (ft²)	860.06
LMTD	7.76
Total Heat Transferred (BTU/hr)	38,433
Surface Effectiveness (Eta)	0.9173
Sensible Heat Transferred (BTU/hr)	38,433
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

Inlet Air Flowrate Calculator - 1(2)VY02A

Total P:	P=		14.315 psia	Inlet Air Flow	
Dry Bulb T OUT:	T=		111.1 F	19164 acfm	
Specific Hum.:	W =		0.020274		
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875 psia		
		Rv =	85.778 (ft-lbf)/(lbm-R)		
		Ra =	53.352 (ft-lbf)/(lbm-R)		
Dry Air P:	Pa = P - Pv =		13.86313 psia		
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0656 lbm/ft^3		
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575 lbm/ft^3		
Dry Bulb T IN:	T=		148 F		
Outlet Air Flow:	V =		18000 cfm		

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

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY01 @ MAX FF, w\ 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	0.005000
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)	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 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)	18,982.00
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

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)	998.47
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)	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²·°F/BTU)	0.09491556
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)	860.06
Reynold's Number	831**	20,630	LMTD	27.55
Prandtl Number	0.7254	3.7281	Total Heat Transferred (BTU/hr)	97,604
Bulk Visc (lbm/ft·hr)	0.0491	1.3780		
Skin Visc (lbm/ft·hr)		1.3501	Surface Effectiveness (Eta)	0.9165
Density (lbm/ft³)	0.0622	61.7492	Sensible Heat Transferred (BTU/hr)	97,604
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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	142.44	113.89
Outlet Temperature (°F)	137.45	116.24
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	139.94	115.07
Skin Temperature (°F)	126.76	117.03
Velocity ***	3,528.59	2.91
Reynold's Number	837**	20,141
Prandtl Number	0.7259	3.8275
Bulk Visc (lbm/ft·hr)	0.0487	1.4115
Skin Visc (lbm/ft·hr)		1.3851
Density (lbm/ft³)	0.0627	61.7865
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3683

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	985.60
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.46
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.11
Effective Area (ft²)	860.06
LMTD	24.78
Total Heat Transferred (BTU/hr)	87,561
Surface Effectiveness (Eta)	0.9167
Sensible Heat Transferred (BTU/hr)	87,561
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,144.89	37,262.20
Inlet Temperature (°F)	137.45	111.78
Outlet Temperature (°F)	132.97	113.89
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	135.21	112.84
Skin Temperature (°F)	123.35	114.61
Velocity ***	3,528.59	2.91
Reynold's Number	842**	19,705
Prandtl Number	0.7263	3.9205
Bulk Visc (lbm/ft·hr)	0.0484	1.4427
Skin Visc (lbm/ft·hr)		1.4178
Density (lbm/ft³)	0.0632	61.8193
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3676

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	974.02
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.44
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.10
Effective Area (ft²)	860.06
LMTD	22.28
Total Heat Transferred (BTU/hr)	78,587
Surface Effectiveness (Eta)	0.9169
Sensible Heat Transferred (BTU/hr)	78,587
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,144.89	37,262.20
Inlet Temperature (°F)	132.97	109.88
Outlet Temperature (°F)	128.95	111.78
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	130.96	110.83
Skin Temperature (°F)	120.29	112.45
Velocity ***	3,528.59	2.91
Reynold's Number	846**	19,317
Prandtl Number	0.7266	4.0071
Bulk Visc (lbm/ft·hr)	0.0482	1.4717
Skin Visc (lbm/ft·hr)		1.4483
Density (lbm/ft³)	0.0636	61.8482
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3668

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	963.58
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.42
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.09
Effective Area (ft²)	860.06
LMTD	20.05
Total Heat Transferred (BTU/hr)	70,561
Surface Effectiveness (Eta)	0.9170
Sensible Heat Transferred (BTU/hr)	70,561
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,144.89	37,262.20
Inlet Temperature (°F)	128.95	108.18
Outlet Temperature (°F)	125.34	109.88
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	127.14	109.03
Skin Temperature (°F)	117.54	110.50
Velocity ***	3,528.59	2.91
Reynold's Number	851**	18,971
Prandtl Number	0.7269	4.0875
Bulk Visc (lbm/ft·hr)	0.0479	1.4986
Skin Visc (lbm/ft·hr)		1.4766
Density (lbm/ft³)	0.0640	61.8736
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3662

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	954.18
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.40
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.09
Effective Area (ft²)	860.06
LMTD	18.04
Total Heat Transferred (BTU/hr)	63,378
Surface Effectiveness (Eta)	0.9172
Sensible Heat Transferred (BTU/hr)	63,378
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	125.34	106.65
Outlet Temperature (°F)	122.09	108.18
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	123.71	107.42
Skin Temperature (°F)	115.07	108.74
Velocity ***	3,528.59	2.91
Reynold's Number	855**	18,662
Prandtl Number	0.7272	4.1621
Bulk Visc (lbm/ft·hr)	0.0477	1.5234
Skin Visc (lbm/ft·hr)		1.5029
Density (lbm/ft³)	0.0643	61.8961
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0158	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	945.71
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.39
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.08
Effective Area (ft²)	860.06
LMTD	16.23
Total Heat Transferred (BTU/hr)	56,946
Surface Effectiveness (Eta)	0.9173
Sensible Heat Transferred (BTU/hr)	56,946
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,144.89	37,262.20
Inlet Temperature (°F)	122.09	105.28
Outlet Temperature (°F)	119.17	106.65
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	120.63	105.96
Skin Temperature (°F)	112.86	107.17
Velocity ***	3,528.59	2.90
Reynold's Number	858**	18,386
Prandtl Number	0.7274	4.2309
Bulk Visc (lbm/ft·hr)	0.0475	1.5463
Skin Visc (lbm/ft·hr)		1.5273
Density (lbm/ft³)	0.0647	61.9160
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3651

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	938.08
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.37
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.07
Effective Area (ft²)	860.06
LMTD	14.61
Total Heat Transferred (BTU/hr)	51,182
Surface Effectiveness (Eta)	0.9174
Sensible Heat Transferred (BTU/hr)	51,182
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

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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

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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
Inlet Temperature (°F)	119.17	104.04
Outlet Temperature (°F)	116.55	105.28
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.86	104.66
Skin Temperature (°F)	110.86	105.75
Velocity ***	3,528.59	2.90
Reynold's Number	861**	18,138
Prandtl Number	0.7276	4.2944
Bulk Visc (lbm/ft·hr)	0.0473	1.5673
Skin Visc (lbm/ft·hr)		1.5497
Density (lbm/ft³)	0.0650	61.9336
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3646

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	931.21
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.36
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.09491556
U Overall (BTU/hr·ft²·°F)	4.07
Effective Area (ft²)	860.06
LMTD	13.15
Total Heat Transferred (BTU/hr)	46,015
Surface Effectiveness (Eta)	0.9175
Sensible Heat Transferred (BTU/hr)	46,015
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²). Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Inlet Air Flowrate Calculator - 1(2)VY01A

Total P:	P=		14.315	psia	Inlet Air Flow
Dry Bulb T OUT:	T=		116.55	F	18982 acfm
Specific Hum.:	W =		0.020274		
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875	psia	
		Rv =	85.778	(ft-lbf)/(lbm-R)	
		Ra =	53.352	(ft-lbf)/(lbm-R)	
Dry Air P:	Pa = P - Pv =		13.86313	psia	
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0649	lbm/ft^3	
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575	lbm/ft^3	
Dry Bulb T IN:	T=		148	F	
Outlet Air Flow:	V =		18000	cfm	

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

VY02 @ CSCS=104 F, ROOM T=150 F

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 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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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

Tube Flow (gpm)	108.00
Air Flow (acfm)	19,162.00
Tube Inlet Temp (°F)	104.00
Air Inlet Temp (°F)	150.0
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

VY02 @ CSCS=104 F, ROOM T=150 F

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	70,460.57	53,657.57	Tube-Side hi (BTU/hr·ft²·°F)	
Inlet Temperature (°F)	150.00	104.00	j Factor	
Outlet Temperature (°F)	111.14	116.85	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)	686,379
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	686,379
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)	70,460.57	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·ft²·°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)	

** 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

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,460.57	53,657.57
Inlet Temperature (°F)	141.26	111.60
Outlet Temperature (°F)	134.08	113.97
Inlet Specific Humidity	0.0213	
Outlet Specific Humidity	0.0213	
Average Temp (°F)	137.67	112.78
Skin Temperature (°F)	118.95	114.91
Velocity ***	3,367.24	3.98
Reynold's Number	801**	26,943
Prandtl Number	0.7260	3.9226
Bulk Visc (lbm/ft·hr)	0.0486	1.4434
Skin Visc (lbm/ft·hr)		1.4137
Density (lbm/ft³)	0.0629	61.8201
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3675

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,251.77
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.66
Effective Area (ft²)	905.33
LMTD	24.70
Total Heat Transferred (BTU/hr)	126,678
Surface Effectiveness (Eta)	0.9190
Sensible Heat Transferred (BTU/hr)	126,678
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,460.57	53,657.57
Inlet Temperature (°F)	134.08	109.66
Outlet Temperature (°F)	128.19	111.60
Inlet Specific Humidity	0.0213	
Outlet Specific Humidity	0.0213	
Average Temp (°F)	131.14	110.63
Skin Temperature (°F)	115.71	112.40
Velocity ***	3,367.24	3.98
Reynold's Number	808**	26,373
Prandtl Number	0.7266	4.0159
Bulk Visc (lbm/ft·hr)	0.0482	1.4746
Skin Visc (lbm/ft·hr)		1.4490
Density (lbm/ft³)	0.0636	61.8510
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3668

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,237.05
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.17
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.65
Effective Area (ft²)	905.33
LMTD	20.36
Total Heat Transferred (BTU/hr)	104,043
Surface Effectiveness (Eta)	0.9193
Sensible Heat Transferred (BTU/hr)	104,043
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T. Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	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·ft²·°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

Extrapolation Calculation for Row 5(Dry)

	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·ft²·°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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec): Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,460.57	53,657.57
Inlet Temperature (°F)	119.36	105.67
Outlet Temperature (°F)	116.08	106.75
Inlet Specific Humidity	0.0213	
Outlet Specific Humidity	0.0213	
Average Temp (°F)	117.72	106.21
Skin Temperature (°F)	109.07	107.22
Velocity ***	3,367.24	3.97
Reynold's Number	822**	25,215
Prandtl Number	0.7276	4.2192
Bulk Visc (lbm/ft·hr)	0.0473	1.5424
Skin Visc (lbm/ft·hr)		1.5264
Density (lbm/ft³)	0.0649	61.9126
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3651

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,206.63
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.11
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.61
Effective Area (ft²)	905.33
LMTD	11.43
Total Heat Transferred (BTU/hr)	58,002
Surface Effectiveness (Eta)	0.9198
Sensible Heat Transferred (BTU/hr)	58,002
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,460.57	53,657.57
Inlet Temperature (°F)	116.08	104.78
Outlet Temperature (°F)	113.37	105.67
Inlet Specific Humidity	0.0213	
Outlet Specific Humidity	0.0213	
Average Temp (°F)	114.73	105.22
Skin Temperature (°F)	107.58	106.06
Velocity ***	3,367.24	3.97
Reynold's Number	825**	24,959
Prandtl Number	0.7278	4.2668
Bulk Visc (lbm/ft·hr)	0.0471	1.5582
Skin Visc (lbm/ft·hr)		1.5447
Density (lbm/ft³)	0.0652	61.9260
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3648

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,199.81
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.10
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.60
Effective Area (ft²)	905.33
LMTD	9.43
Total Heat Transferred (BTU/hr)	47,809
Surface Effectiveness (Eta)	0.9199
Sensible Heat Transferred (BTU/hr)	47,809
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

ComEd -- LaSalle

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
Inlet Temperature (°F)	113.37	104.04
Outlet Temperature (°F)	111.14	104.78
Inlet Specific Humidity	0.0213	
Outlet Specific Humidity	0.0213	
Average Temp (°F)	112.26	104.41
Skin Temperature (°F)	106.36	105.10
Velocity ***	3,367.24	3.97
Reynold's Number	828**	24,749
Prandtl Number	0.7279	4.3068
Bulk Visc (lbm/ft·hr)	0.0470	1.5714
Skin Visc (lbm/ft·hr)		1.5601
Density (lbm/ft³)	0.0655	61.9369
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3645

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,194.18
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.09
Tube Wall Resistance (hr·ft²·°F/BTU)	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.59
Effective Area (ft²)	905.33
LMTD	7.79
Total Heat Transferred (BTU/hr)	39,429
Surface Effectiveness (Eta)	0.9200
Sensible Heat Transferred (BTU/hr)	39,429
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²). Tube Fluid Velocity (ft/sec): Air Density at Inlet T, Other Properties at Average T

Inlet Air Flowrate Calculator - 1(2)VY02A

Total P:	P=		14.315 psia	Inlet Air Flow	
Dry Bulb T OUT:	T=		111.14 F	19162 acfm	
Specific Hum.:	W =		0.020274		
H2O Vap P:	Pv = (W*Rv*P)/(Ra+(W*Rv) =		0.451875 psia		
		Rv =	85.778 (ft-lbf)/(lbm-R)		
		Ra =	53.352 (ft-lbf)/(lbm-R)		
Dry Air P:	Pa = P - Pv =		13.86313 psia		
Dry Air rho OUT:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.0656 lbm/ft^3		
Dry Air rho IN:	rho a = (144/Ra)*(Pa/(459.67+T) =		0.061575 lbm/ft^3		
Dry Bulb T IN:	T=		148 F		
Outlet Air Flow:	V =		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
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Revision History

Revision	Revision Description
A	Original Issue

PROTO-POWER CORPORATION GROTON, CONNECTICUT	CALC NO. 97-200	REV A	PAGE iii OF vi
	ORIGINATOR L. Philpot		DATE 6/24/98
	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			

CALCULATION VERIFICATION FORM

REVIEW METHOD:

Approach Checked:	☑	N/A ☐
Logic Checked:	☑	N/A ☐
Arithmetic Checked:	☑	N/A ☐
Alternate Method (Attach Brief Summary)	☐	N/A ☑
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Other	☐	N/A ☑

EXTENT OF VERIFICATION:

Complete Calculation:	☑
Revised areas only:	☐
Other (describe below):	☐

*Errors Detected

1) Section 7.3: Bounding Uncertainty is not used.

2) Clarification suggested in Section 7.4

*Error Resolution

1) Uncertainty of 4.5% used instead of 4.3%.

2) Last 2 sentences in Section 7.4 added to clarify issue of analytical uncertainty.

*Other Comments

*Extra References Used

*(Attach extra sheets if needed)

CALCULATION FOUND TO BE VALID AND CONCLUSIONS TO BE CORRECT AND REASONABLE:

IDV Signature: [signature] Initials: MA

Printed Name: MERID ABOYE Date: 6/24/98

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Complete Calculation (total number of pages): 205

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 re-balancing 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-HX™, 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.

3. DESIGN INPUTS

The thermal performance model is developed using PROTO-HX™, Version 3.01. PROTO-HX™ 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-HX™ 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 (Table1), 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

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

Table 3: Construction Details

Parameter	Value	Reference[1]
Heat Exchanger Type and relative direction of Tube-side 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.

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-HX™ 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-HX™ "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

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

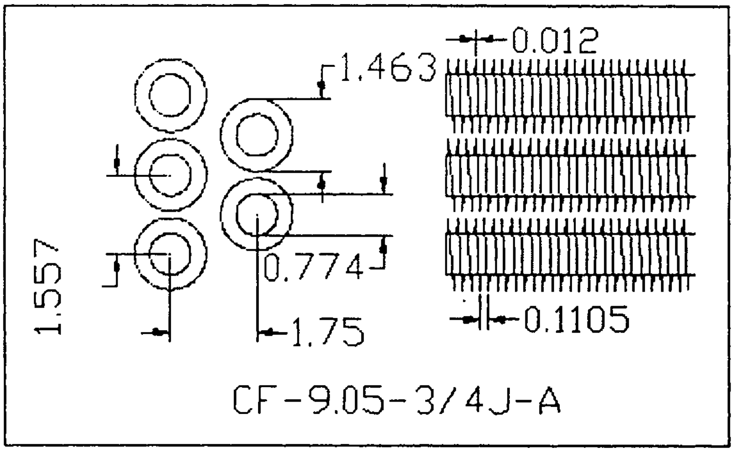
The longitudinal tube pitch is not directly available from the coil data sheet or Reference 20. It can be estimated based on the geometry of the coil. Per Reference (7), the coil stack depth is 12.00 inches. Dividing the stack depth evenly between 8 tube rows yields a longitudinal (horizontal) tube pitch 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.

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-HX™ 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-HX™ 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-HX™ 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-HX™ input. The only input requiring adjustment is the specified air-side flow rate of 17,330 *scfm*. PROTO-HX™ requires air-side flow rate to be given at actual inlet air conditions (units of *acfm*).

The correction of *scfm* to *acfm* is made as follows (holding mass flow rate constant for the defining case):

$$\dot{m} = (\text{scfm}) \times (\rho_{std}) \times \left(\frac{60\,\text{min}}{1\,\text{hr}}\right) = (\text{acfm}) \times (\rho_{actual}) \times \left(\frac{60\,\text{min}}{1\,\text{hr}}\right) \qquad \text{Equation (1)}$$

where:

$\dot{m}$ = mass flow (lbm/hr)

scfm = volumetric flow rate at standard conditions (ft^3/min)

ρ_{std} = standard density of 0.075 lbm/ft^3

acfm = volumetric flow rate at specified (non-standard) conditions (ft^3/min)

ρ_{actual} = density of dry air at specified inlet temperature and humidity (lbm/ft^3)

Rearranging terms yields the following correction factor for converting scfm to inlet acfm:

$$(\text{acfm}) = (\text{scfm}) \times \frac{(\rho_{std})}{(\rho_{actual})} \qquad \text{Equation (2)}$$

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:

$$(\rho_{actual}) = (\text{scfm}) \times \frac{(\rho_{std})}{(\text{acfm})} = (17{,}330) \times \frac{0.07500}{18{,}000} = 0.0722\ \text{lbm}/\text{ft}^3$$

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 held constant until a dry air density of 0.0722 lbm/ft^3 is reached. The result of the iterative process is as follows:

<u>Given per Reference (13)</u>
Dry Bulb Temperature: 70.00°F
Relative Humidity: 40.00 %

<u>Derived above</u>
Dry Air Density: 0.0722 lbm/ft^3

<u>Derived per Attachment H</u>
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:

<u>Given per Reference (7)</u>
Dry Bulb Temperature: 150.00°F
Wet Bulb Temperature: 92.00°F

<u>Derived above</u>
Atmospheric Pressure: 14.315 psia

<u>Derived per Attachment H</u>
Relative Humidity: 12.18 %
Specific Humidity: 0.02034 lbmv/lbma

Dry Air Pressure:	13.8617 psia
Vapor Pressure:	0.4533 psia
Dry Air Density:	**0.06137 lbm/ft^3**
Vapor Density:	0.001248 lbm/ft^3

The actual volumetric flow rate at vendor specified inlet conditions is then calculated as:

$$(\text{acfm}) = (\text{scfm}) \times \frac{(\rho_{std})}{(\rho_{actual})} = (17{,}330) \times \frac{0.07500}{0.06137} = 21{,}179 \ \text{ft}^3/\text{min}$$

Summary of PROTO-HX™ 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-HX™ 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.

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) (in^2)

A_1 = Frontal Area (Section 3.3.8) (in^2)

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_a (a dimensionless parameter), is given by:

$$Pr_a = \frac{c_{pa}\ \mu_a}{k_a} \qquad \text{Equation (3)}$$

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:

$$M_a = \frac{60\,\rho_a Q_a}{N_C} \qquad \text{Equation (4)}$$

The bulk-stream mass flux, G (lb_m/ hr-ft^2), is:

$$G = \frac{144\,M_a}{A_{MIN}} \qquad \text{Equation (5)}$$

The Colburn j-factor is defined in terms of the Stanton Number, St_a, as:

$$j = St_a\ Pr_a^{2/3} = \left(\frac{h_o}{G\ c_{pa}}\right) Pr_a^{2/3} \qquad \text{Equation (6)}$$

Therefore, the outside heat transfer coefficient, h_o (Btu/hr-ft^2-°F), may be defined in terms of the j-factor:

$$h_o = \frac{j\ G\ c_{pa}}{Pr_a^{2/3}} \qquad \text{Equation (7)}$$

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):

$$j = f(Re_a) \qquad where:\ Re_a = \frac{G\ D_H}{\mu_a} \qquad \text{Equation (8)}$$

The standard air-side configuration for coil type CF-9.05-3/4 J-A, provided in PROTO-HX™'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 j-Factor

Reynolds Number	Colburn j-Factor (Standard)	Colburn j-Factor (Custom)
1000	0.009	0.00758
8000	0.0044	0.00371

$$j = e^{[-2.5088 - 0.3436 * Ln(Re)]} \qquad \text{Equation (9)}$$

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-HX™ "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

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-HX™.

<u>**Air-Side Pressure**</u>

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:

Elevation (feet above sea level)	**Pressure (psia)**	
682	14.337	Reference (16)
738	14.308	Reference (16)
698	14.329	Interpolation between above points at VY elevation

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 (inwg)	**Water Density (lbm/ft^{3})**	**Coil Pressure (psig)**	**Atm Pressure (psia)**	**Coil Pressure (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-HX™ 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-HX™ 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;

- 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:

$$(cfm_{in}) = (cfm_{out}) \times \frac{(\rho_{out})}{(\rho_{in})} = (18{,}000) \times \frac{(0.06631929)}{(0.061575103)} = 19{,}387 \text{ (Fan Temperature = 104.53)}$$

Service:

$$(cfm_{in}) = (cfm_{out}) \times \frac{(\rho_{out})}{(\rho_{in})} = (18{,}000) \times \frac{(0.06609320)}{(0.061575103)} = 19{,}321 \text{ (Fan Temperature = 106.46)}$$

<u>Summary of PROTO-HX™ Inputs for Extrapolation to Reference Conditions</u>

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-HX™ inputs for these conditions are as follows:

Tube-Side Flow Rate	150 gpm
Tube-Side Inlet Temperature	100°F
Air-Side Flow Rate	(varies with temperature)
Air-Side Inlet Temperature -- Dry Bulb	148°F
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-HX™ 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:

$$\text{Margin (BTU / hr)} = q_{available} - q_{required} \quad \text{Equation (10)}$$

$$\text{Margin (\%)} = \left(\frac{q_{available} - q_{required}}{q_{required}} \right) \times 100 \quad \text{Equation (11)}$$

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-HX™ library. The results of this initial benchmarking case are presented in Table 5. The PROTO-HX™ 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-HX™ 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)

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-HX™ 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

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-HX™ 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

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-HX™ extrapolated heat transfer rate ranges from ± 4.27 to ± 4.88% for the ranges of cooling water flow evaluated. An uncertainty of ± 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
1(2)VY02A	108 gpm	646,235	707,030	9.41	4.05

7.4 Fouling Sensitivity Analysis

The results of the fouling sensitivity analysis are included in Tables 11 and 12. The PROTO-HX™ 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%

8. CONCLUSIONS

A model for the LaSalle County Station Units 1 & 2 NW and SW Cubicle Area Coolers was developed using PROTO-HX™ 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-HX™ has provided high confidence in the thermal margins defined by the model for all cases.

The model database is saved under file name vy-0102a.phx, with a file size of 1,146,880 bytes, and a file date and time of 6/24/98 at 2:25:30 pm. The saved database is set up to run the 108 gpm case with adjusted design fouling factors of 0.002 air-side and 0.002 tube-side. The database file is included as Attachment N.

9. REFERENCES

1. Heat Exchanger Thermal Performance Modeling Software Program PROTO-HX™ 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)

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

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: 1×10^7 rads gamma (integrated)

Pressure: -0.4 inch W.G.

1(2)VY01A
1(2)VY02A

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).

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 Reference 5

4. RHR pump seal cooler ('A' and 'B' RHR pumps only) - 20 gpm

5. LPCS pump motor cooling coil - 4 gpm

6. northwest cubicle area cooling coil - 150 gpm

7. southwest cubicle area cooling coil - 150 gpm

8. northeast cubicle area cooling coil - 200 gpm

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.

e. 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.

f. Design of system piping and components is based on a 40-year life. 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
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INDIVIDUAL CO[illegible]					PERFO[illegible]					[illegible]TA (TOTAL FOR BOTH COILS)								
TUBE FACE	ROWS	CIRCUIT-ING	FACE AREA (SQ.FT.)	MARK FOR	SCFM	ENT. AIR TEMP (°F) DB/WB	LVG. AIR TEMP (°F) DB/WB	ENT. WATER TEMP (°F)	LVG. WATER TEMP (°F)	WATER GPM	TOTAL HEAT TRANSFER (BTU/HR)(10^6)	AIR SIDE PRESS. DROP (IN. H2O)	TUBE SIDE PRESS. DROP (FT. OF H2O)	DESIGN PRESSURE (PSIG)	DESIGN TEMP. (F°)	COIL QTY. PER UNIT	SHIPP[illegible] WGT (LBS) PER COIL	O[illegible]RATING WGT (LBS) PER COIL
20	8	FULL	21.4	1VY01A, 1VY02A 2VY01A, 2VY02A	17330	150./92.	109.4/84.1	105.0	115.3	150.	.75	.42	27.0	250	200	2	875	1025

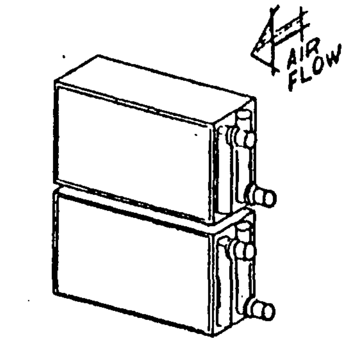
MATERIAL SPECIFICATIONS

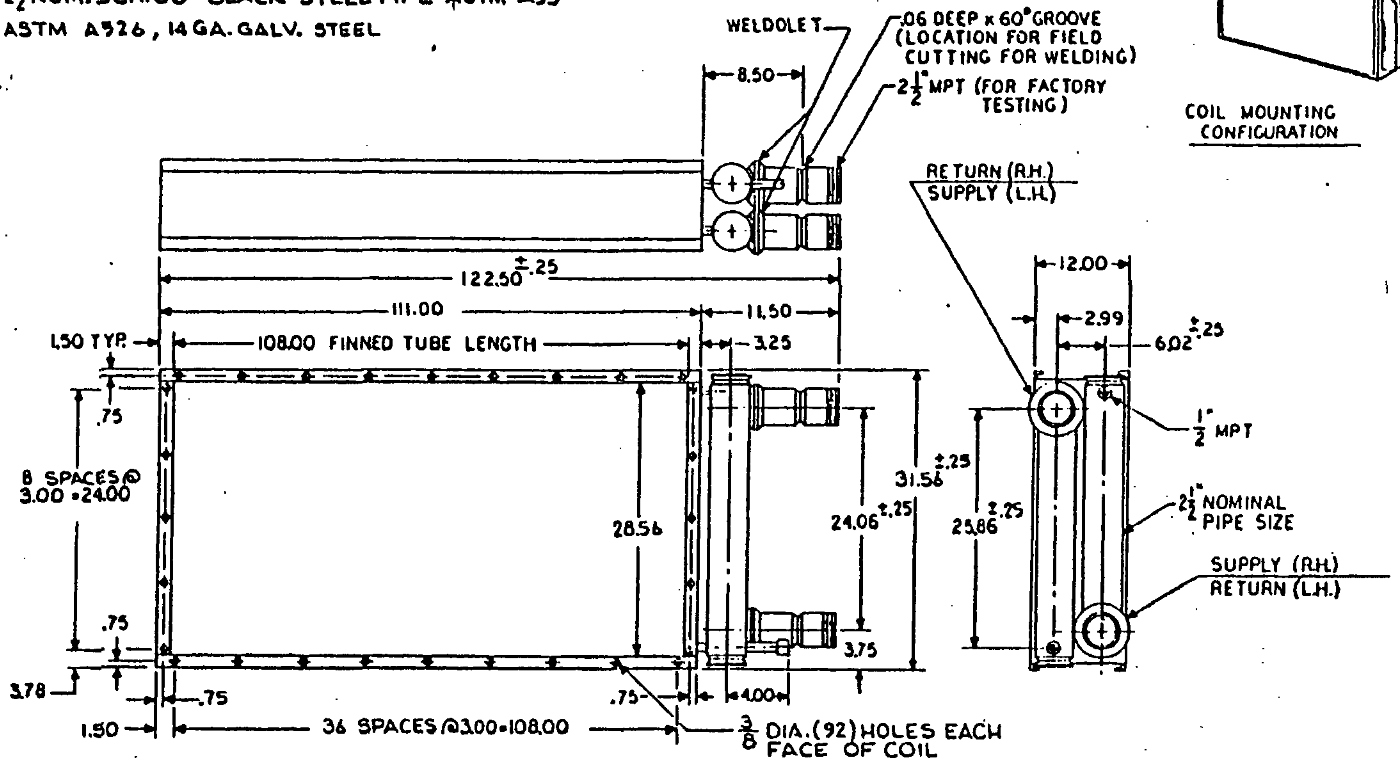
TUBES - 5/8 O.D. ASME SB75 COPPER, .049 WALL THICKNESS.

FINS - ASTM B209 ALUM. 0.012 IN. THK. SPIRAL TYPE MECHANICAL BOND, 10.0 FINS/INCH.

HEADERS - 2 1/2" NOM. SCH. 80 BLACK STEEL PIPE ASTM A53

CASING - ASTM A526, 14 GA. GALV. STEEL





Reference 7

Proto-Power Calc: 97-200
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GENERAL TOLERANCES
DECIMALS ±.12
UNLESS OTHERWISE SPECIFIED
DIMENSIONS IN INCHES

JOB NAME LASALLE COUNTY POWER STATION-UNIT #1/2
JOB LOCATION SENECA, ILLINOIS
BUYER COMMONWEALTH EDISON COMPANY
BUYER NO. 194871 CARRIER NO. 690002059
DIMENSIONS CERTIFIED BY [signature] DATE 7-21-76

DRAWN BY	THOMSON	6-17-76
CH'KD BY	RDB	7-21-76

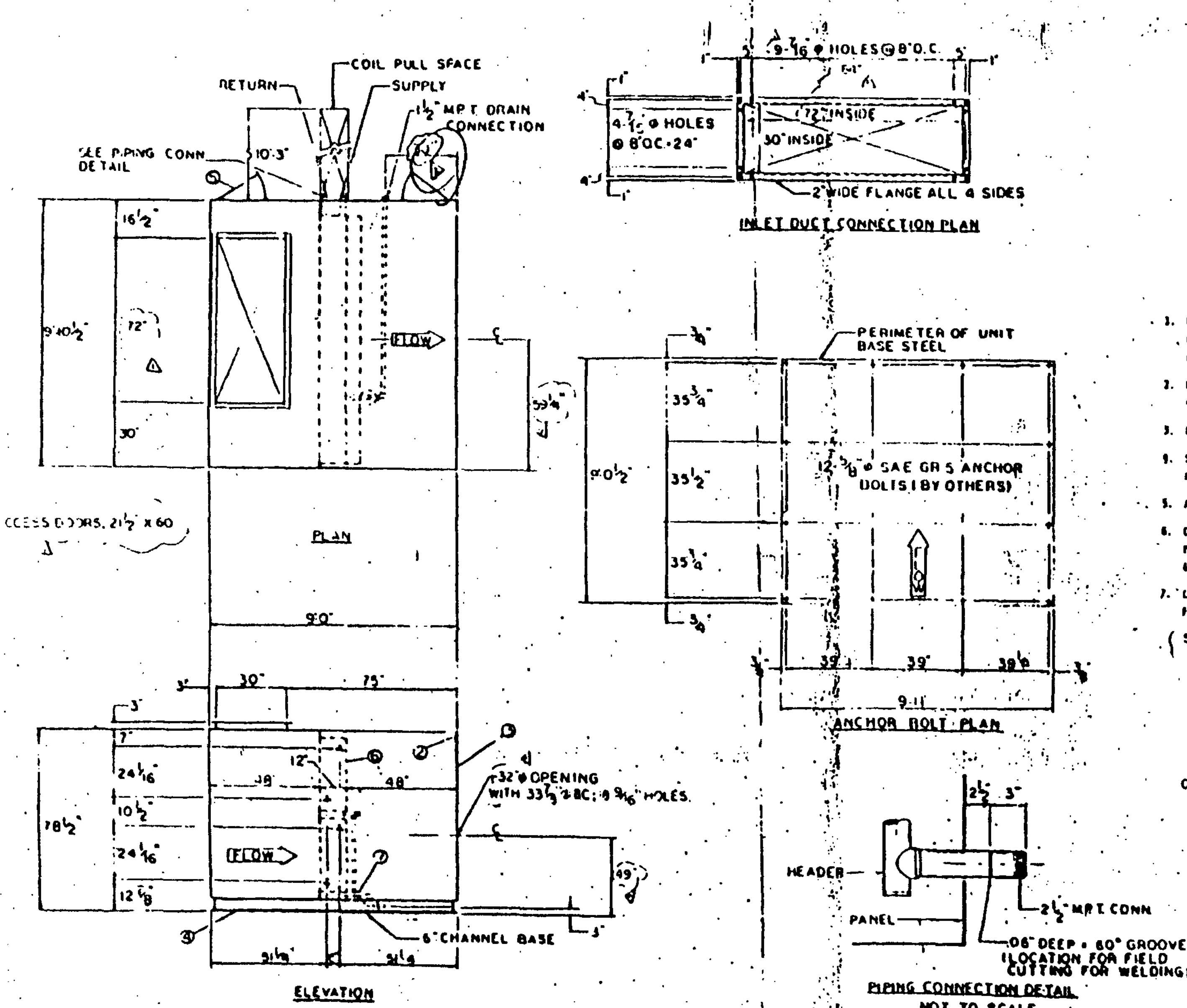
DATE | SUPERSEDES

CSCS EQUIPMENT AREA COOLING COILS

EQUIPMENT NO.(S) 1VY01A, 1VY02A 2VY01A, 2VY02A

DWG. NO. 28SW404543

REV.



BILL OF MATERIALS

1. UNIT COOLER DESIGNED TO COOL 37,330 SCFM FROM 150/92°F TO [illegible] USING 150 GPM OF WATER FROM 105°F TO 115.1°F COMPLETE WITH THE FOLLOWING CONSTRUCTION AND EQUIPMENT. FACTORY ORDER NO. 8-36513-130.
2. GROUP OF INTERNAL STRUCTURAL FRAMING (SPEC. 2). FACTORY ORDER NO. 8-00513-130A.
3. GROUP OF ENCLOSURE PANELS (SPEC. 3). FACTORY ORDER NO. 8-00513-130B.
4. STRUCTURAL STEEL BASE WITH LIFTING LUGS (SPEC. 3). FACTORY ORDER NO. 8-00513-130C.
5. ACCESS DOORS (SPEC. 4). FACTORY ORDER NO. 8-00513-130D.
6. COOLING COILS [illegible] FULL CIRCUIT RATED [illegible] AIR PRESSURE DROP 0.42 IN. WATER, WATER PRESSURE DROP [illegible] WATER (SPEC. 6 & 6A). FACTORY ORDER NO. 8-00513-130E.
7. COOLING COIL DRIP PANS CONSTRUCTED FROM 16 GA. [illegible] STAINLESS STEEL. FACTORY ORDER NO. 8-00513-130F.

SARGENT & LUNDY SPEC. J2582

SAFETY RELATED

SEE DWG 2505-1-6 FOR MAT'L SPEC'S

SHIPPING WEIGHT 5150#
OPERATING WEIGHT 5450#

LEFT HAND UNIT
ALL DIMENSIONS ± ⅛"

GRAPHIC SCALE

Reference 11

LASALLE COUNTY POWER STA. UNITS 1&2
SENECA, ILL.
COMMONWEALTH EDISON CO.

DATE	SUPERSEDES		CSCS EQUIPMENT AREA AIR HANDLEING UNIT UNIT NO. 1VY01A		
5-4-77	BBC-100-9	REV 1	BCOA / DATE	BAHNSON DWG. NO. 2605-11	DRAWN BY / CHECKED BY
					BBC-100-9

Proto-Power Calc: 97-200
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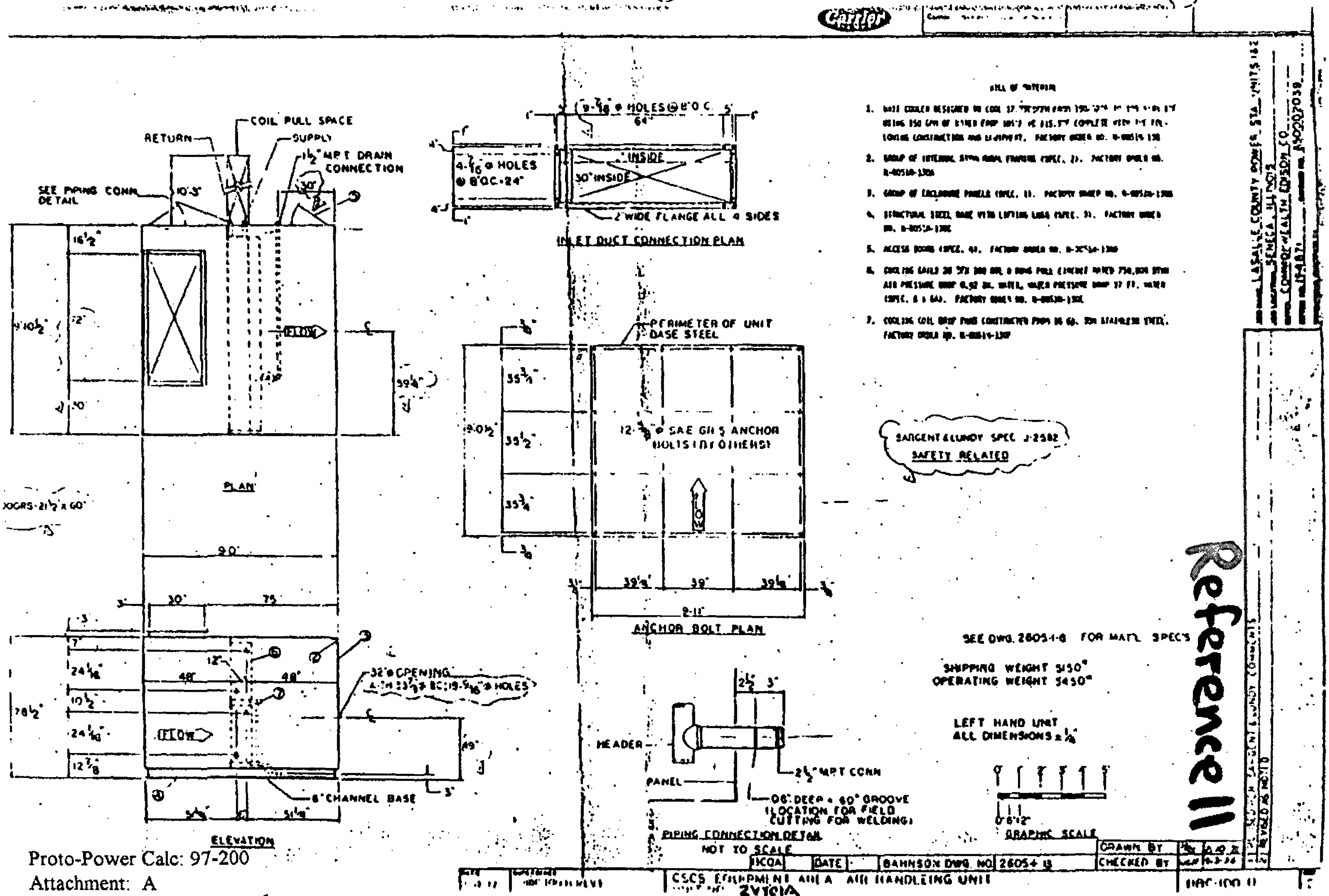

Proto-Power Calc: 97-200
Attachment: A
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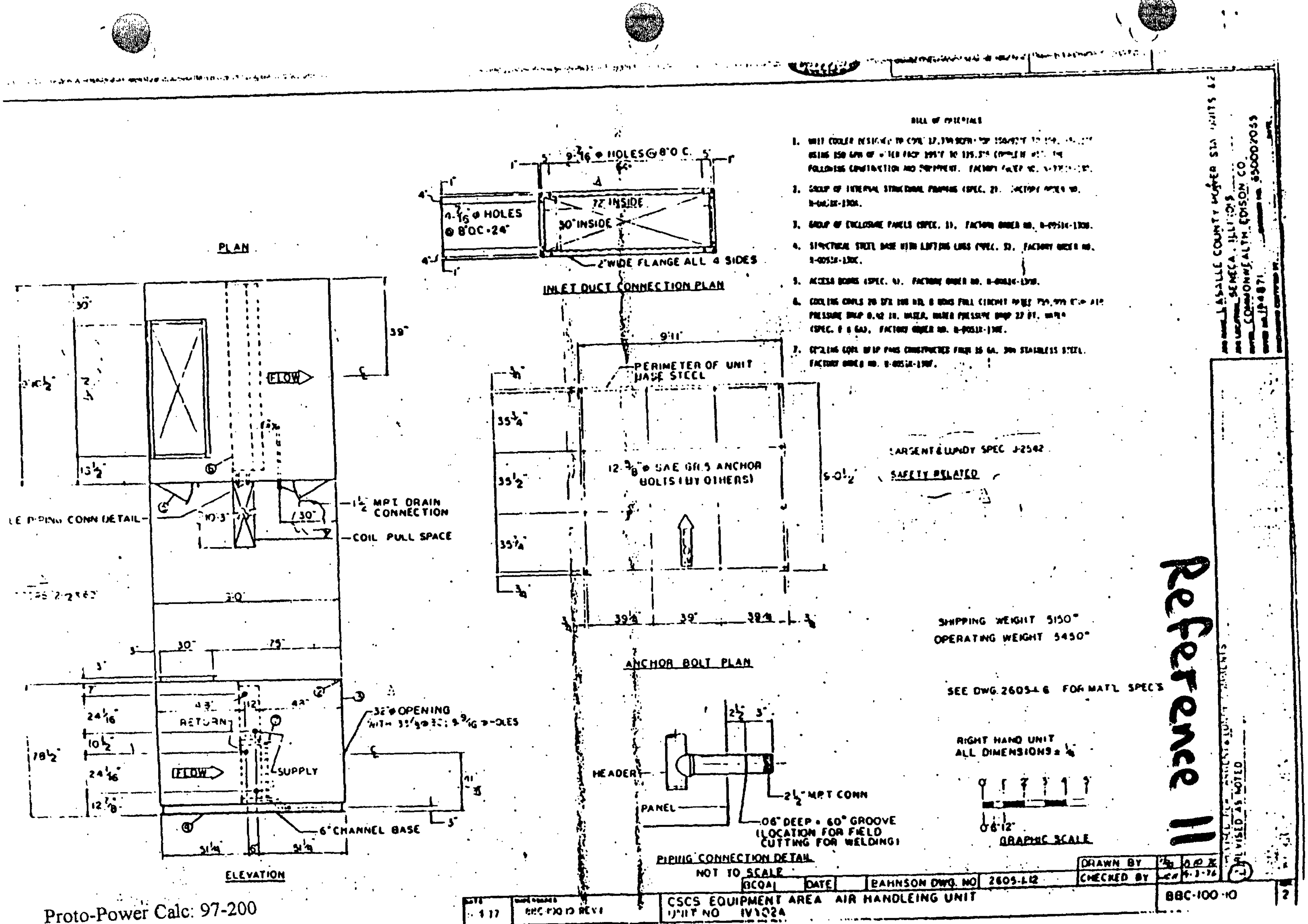

Proto-Power Calc: 97-200
Attachment: A
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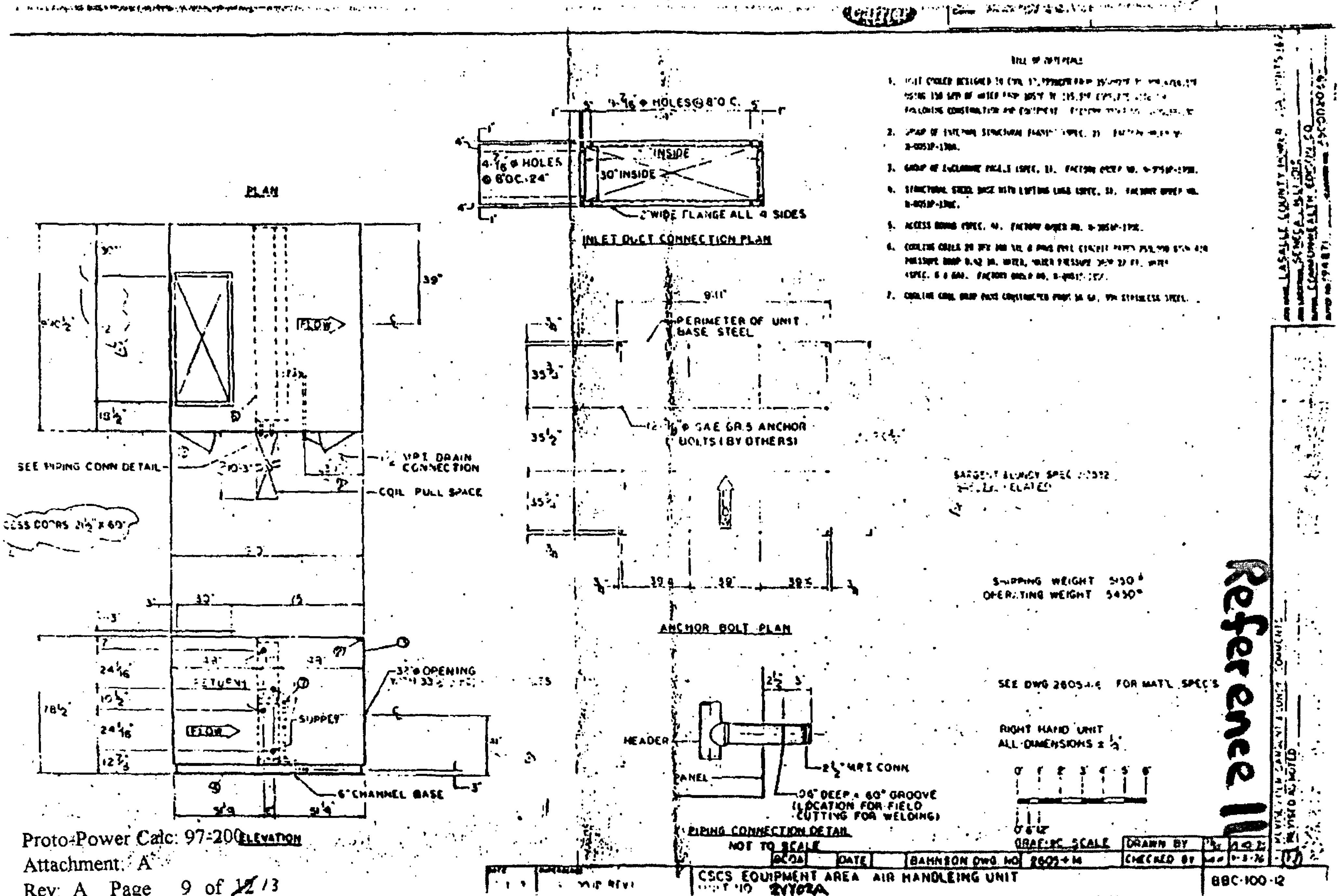

Proto-Power Calc: 97-200

Attachment: A

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FJF 6/23/98

GENERAL QUALITY ASSURANCE PROCEDURE

SARGENT & LUNDY ENGINEERS CHICAGO

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

REV	DATE	PREPARER	APPROVER	PURPOSE OF ISSUE
1	1-16-75	P. N. Mehrotra	W. C. Brown	Issue to CECO for bids.

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	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............	OVC02AA OVC02AB	OVE01AA OVE01AB	1VP03AA 1VP03AB 2VP03AA 2VP03AB	1VY01A 1VY02A 2VY01A 2VY02A	1VY03A 2VY03A	1VY04A 2VY04A	
	Safety related or Nonsafety related (SR or NSR)..........	SR	SR	NSR	SR and ASME III	SR and ASME III	SR and ASME III	
403.	PERFORMANCE DATA (HEAT EXCHANGE COIL CABINETS)							
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	Add.1
b.	Entering Air Wet Bulb......(°F)	63.1	63.2	92	____	____	____	Add.1
c.	Leaving Air Dry Bulb.......(°F)	54.3	54.9	65	110	110	110	Add.1
d.	Leaving Air Wet Bulb.......(°F)	52.8	53.2	63	____	____	____	Add.1
e.	Actual Air Quantity at 70°F, 40% RH and Site Elevation ....(ft^3/min)	26340	31300	50000	18000	26400	28500	
f.	Standard Air Quantity at .075 lb/ft^3............(Std ft^3/min)	25380	30100	48150	17330	25420	27450	
g.	Cooling Medium................	R-22	R-22	Chilled Water	Water	Water	Water	
h.	Evaporator Refrigerant Tempera-ture......................(°F)	42	42	____	____	____	____	Add.1
i.	Entering Water Temperature.(°F)	____	____	46	105.	105.	105.	
j.	Maximum Water Quantity(gal/min)	____	____	1200	150.	220.	240	
k.	Minimum Total Heat Exchange Capacity ....(Btu/h)	797,000	936,000	6.55×10^6	748,700	1.1×10^6	1.19×10^6	
l.	Minimum Sensible Heat Exchange Capacity ....(Btu/h)	725,000	847,000	3.63×10^6	748,700	1.1×10^6	1.19×10^6	
m.	Maximum Coil Face Velocity ....(ft/min)	600	600	600	700	700	700	

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Reference 13

Table 1A Heating and Wind Design Conditions—United States

							Heating DB		Extreme Wind Speed			Coldest Month WS/MDB				MWS/MWD to DB				Annual Extreme Daily			
												0.4%		1%		99.6%		0.4%		Mean DB		StdD DB	
Station	WMO#	Lat.	Long.	Elev. ft	StdP psia	Dates	99.6%	99%	1%	2.5%	5%	WS	MDB	WS	MDB	MWS	PWD	MWS	PWD	Max	Min	Max	Min
West Palm Beach	722030	26.68	80.12	20	14.685	6193	43	47	24	21	19	24	69	21	70	9	320	12	110	94	35	2.0	5.0
GEORGIA																							
Albany	722160	31.53	84.18	194	14.593	8293	27	30	19	17	15	19	50	18	50	4	360	9	250	100	17	2.2	7.2
Athens	723110	33.95	83.32	810	14.270	6193	20	25	19	17	15	20	40	15	40	10	290	9	270	95	11	3.5	6.6
Atlanta	722190	33.65	84.42	1033	14.155	6193	18	24	22	19	17	23	37	21	36	12	320	9	300	96	9	3.5	7.3
Augusta	722180	33.37	81.97	148	14.617	6193	21	25	20	18	15	21	45	19	46	5	290	9	250	100	13	3.7	5.6
Brunswick	722137	31.15	81.38	20	14.685	8293	30	34	18	17	16	19	49	18	49	8	350	10	250	98	22	2.5	7.7
Columbus, Fort Benning	722250	32.33	85.00	233	14.572	8293	23	27	16	13	11	17	46	15	46	3	320	5	240	100	14	2.9	6.7
Columbus, Metro Airport	722255	32.52	84.93	397	14.436	6193	23	27	17	15	14	18	44	16	46	7	310	9	310	99	14	2.3	6.1
Macon	722170	32.70	83.65	361	14.505	6193	23	27	19	17	15	20	46	18	45	7	320	9	270	100	14	2.7	6.4
Marietta, Dobbins AFB	722270	33.92	84.52	1070	14.136	8293	21	26	18	16	13	20	35	18	38	9	340	6	300	97	12	3.6	6.7
Rome	723200	34.35	85.17	643	14.357	8293	15	21	14	12	10	14	42	13	42	5	340	6	270	98	4	3.8	7.0
Savannah	722070	32.13	81.20	49	14.669	6193	26	29	20	17	15	23	49	19	49	7	270	9	270	95	18	3.0	5.4
Valdosta, Moody AFB	747810	30.97	83.20	233	14.572	8293	30	34	15	13	12	16	53	14	52	4	360	5	300	99	21	2.5	7.6
Valdosta, Regional Airport	722166	30.78	83.28	203	14.588	8293	28	31	17	15	14	18	55	16	56	4	340	8	300	99	17	3.2	7.7
Waycross	722130	31.25	82.40	151	14.615	8293	29	32	16	14	12	16	52	14	52	4	250	7	240	95	21	7	7.6
HAWAII																							
Ewa, Barbers Point NAS	911780	21.32	158.07	49	14.609	8293	59	61	20	18	16	22	73	19	75	5	40	11	60	93	35	1.6	21.4
Hilo	912850	19.72	155.07	36	14.676	6193	61	63	19	16	14	21	76	18	76	7	230	12	110	88	58	1.6	1.8
Honolulu	911820	21.35	157.93	16	14.687	6193	61	63	23	21	20	23	74	21	75	5	320	15	60	91	58	1.9	2.2
Kahului	911900	20.90	156.43	66	14.661	6193	59	61	27	25	24	32	76	28	76	6	160	19	50	92	54	1.5	4.5
Kaneohe, MCAS	911760	21.45	157.77	10	14.690	8293	67	68	20	18	17	21	74	19	74	7	190	10	70	88	40	1.4	29.0
Lihue	911650	21.98	159.35	148	14.617	6193	60	62	26	24	21	25	73	23	73	8	270	14	60	87	57	1.4	3.0
Molokai	911860	21.15	157.10	449	14.458	8293	60	61	24	22	21	22	74	21	74	4	70	13	60	92	43	4	22.0
IDAHO																							
Boise	726810	43.57	116.22	2867	13.235	6193	2	9	24	21	18	22	37	19	37	6	130	11	320	103	−4	2.7	9.1
Burley	725867	42.55	113.77	4150	12.621	8293	−5	2	23	21	19	23	30	22	28	7	60	8	280	98	−11	4	8.5
Idaho Falls	725785	43.52	112.07	4741	12.346	8293	−12	−6	27	23	21	28	32	23	29	7	360	12	180	96	−20	3.6	9.0
Lewiston	727830	46.38	117.02	1437	13.948	8293	6	15	20	17	14	24	38	20	40	5	280	7	310	103	3	2.7	9.9
Mountain Home, AFB	726815	43.05	115.87	2995	13.173	8293	0	5	23	21	18	23	33	21	31	2	90	8	350	105	−6	3.2	8.5
Mullan	727836	47.47	115.80	3317	13.017	8293	−1	7	10	10	9	11	18	9	21	2	10	4	10	92	−7	2	7.9
Pocatello	725780	42.92	112.60	4478	12.468	6193	−7	0	29	25	23	30	36	27	36	6	50	11	250	98	−15	2.3	9.1
ILLINOIS																							
Belleville, Scott AFB	724338	38.55	89.85	453	14.457	8293	3	10	21	18	15	23	32	20	31	7	360	7	190	100	−3	3.1	7.2
Chicago, Meigs Field	725340	41.78	87.75	623	14.367	8293	−4	3	23	22	19	26	17	23	30	12	240	13	220	97	−10	3.2	8.1
Chicago, O'Hare Int'l A	725300	41.98	87.90	673	14.342	6193	−6	−1	26	23	21	27	24	23	23	10	270	12	230	96	−12	2.8	6.5
Decatur	725316	39.83	88.87	682	14.337	8293	−2	3	24	22	20	27	24	24	27	13	310	12	210	99	−10	5.8	[illegible]
Glenview, NAS	725306	42.08	87.82	653	14.352	8293	−3	4	22	19	17	23	17	20	25	11	250	10	240	98	−10	3.1	7.7
Marseilles	744600	41.37	88.68	738	14.308	8293	−5	1	26	22	20	28	18	25	21	12	290	10	250	96	−11	4	5.9
Moline/Davenport IA	725440	41.45	90.52	594	14.383	6193	−8	−3	26	23	20	28	16	24	18	9	290	12	200	97	−14	2.7	6.0
Peoria	725320	40.67	89.68	663	14.347	6193	−6	−1	25	22	20	26	16	23	19	9	290	11	180	96	−12	3.3	6.1
Quincy	724396	39.95	91.20	768	14.292	8293	−4	2	26	23	20	28	23	24	22	12	330	12	210	97	−10	3.6	[illegible]
Rockford	725430	42.20	89.10	741	14.306	6193	−10	−4	26	23	21	26	18	23	20	9	290	13	200	95	−16	3.1	5.5
Springfield	724390	39.85	89.67	614	14.373	6193	−4	2	25	23	21	27	25	24	27	10	270	12	230	97	−11	2.8	5.5
West Chicago	725305	41.92	88.25	758	14.297	8293	−7	0	23	21	19	25	13	23	20	11	290	11	240	96	−14	3.2	7.7
INDIANA																							
Evansville	724320	38.05	87.53	387	14.491	6193	3	9	22	19	17	22	33	20	34	7	320	9	240	97	−4	2.7	8.5
Fort Wayne	725330	41.00	85.20	827	14.262	6193	−4	2	25	23	20	27	19	24	22	10	250	12	230	95	−11	3.6	5.2
Indianapolis	724380	39.73	86.27	807	14.272	6193	−3	3	24	21	19	25	26	22	27	8	230	11	230	94	−10	2.8	6.8
Lafayette, Purdue Univ	724386	40.42	86.93	607	14.376	8293	−5	3	22	20	18	24	26	22	27	9	270	12	220	97	−11	3.8	7.7
Peru, Grissom AFB	725335	40.65	86.15	810	14.270	8293	−3	4	24	21	18	29	20	24	22	11	270	9	210	96	−8	3.8	7.4
South Bend	725350	41.70	86.32	774	14.289	6193	−2	3	25	23	20	26	22	23	23	13	230	12	230	95	−10	3.3	5.8
Terre Haute	724373	39.45	87.32	584	14.388	8293	−3	5	23	20	18	23	31	21	32	8	150	11	230	96	−10	3.2	7.9
IOWA																							
Burlington	725455	40.78	91.13	699	14.328	8293	−4	1	21	19	17	24	12	21	18	9	310	11	200	98	10	4	6.8
Cedar Rapids	725450	41.88	91.70	869	14.240	8293	−11	−5	25	22	20	29	12	26	14	10	300	11	180	96	−15	3.6	5.4
Des Moines	725460	41.53	93.65	965	14.190	6193	−9	−4	27	24	21	28	14	24	19	11	320	12	180	98	−15	3.4	5.1
Fort Dodge	725490	42.55	94.18	1165	14.087	8293	−13	−7	27	23	21	29	10	26	10	11	340	11	190	96	−17	4.9	4.9
Lamoni	725466	40.62	93.95	1122	14.109	8293	−6	0	19	17	15	21	23	19	20	7	320	9	230	99	−12	4.3	6.8
Mason City	725485	43.15	93.33	1214	14.062	6193	−15	−10	27	23	22	30	9	27	12	12	300	14	200	97	−23	3.6	11.4
Ottumwa	725465	41.10	92.45	846	14.251	8293	−5	0	29	26	23	31	20	28	24	13	320	15	200	98	−12	4	6.8
Sioux City	725570	42.40	96.38	1102	14.119	6193	−11	−6	29	25	22	31	14	28	16	11	320	14	180	99	−18	3.6	4.7
Spencer	726500	43.17	95.15	1339	13.998	8293	−16	−13	24	22	20	25	13	23	13	10	300	12	180	99	−20	6.3	4.0
Waterloo	725480	42.55	92.40	879	14.234	6193	−14	−9	27	24	22	29	10	25	13	9	300	13	180	96	−20	3.5	5.9
KANSAS																							
Concordia	724580	39.55	97.65	1483	13.925	8293	−4	3	28	25	22	28	32	25	32	13	360	16	10	104	−8	4	9.4
Dodge City	724510	37.77	99.97	2592	13.370	6193	0	6	30	27	24	31	31	27	32	13	10	17	200	104	−6	2.8	5.6
Ft Riley, Marshall AAF	724550	39.05	96.77	1066	14.138	8293	−2	5	21	18	16	20	39	18	37	5	350	9	180	104	−5	3.1	9.0
Garden City	724515	37.93	100.72	2890	13.224	8293	−3	4	30	26	23	29	32	25	34	12	360	16	190	104	−9	2.7	6.5
Goodland	724650	39.37	101.70	3688	12.840	6193	−3	2	32	28	24	31	27	27	30	12	270	13	180	102	−11	2.9	6.6

WMO# = World Meteorological Organization number; Lat = latitude; Long. = longitude; Elev = elevation, ft; StdP = standard pressure at station elevation, psia; DB = dry-bulb temperature, °F; WS = wind speed, mph

Reference 16

Table 3 Properties of Solids

Material Description	Specific Heat, Btu/lb-°F	Density, lb/ft³	Thermal Conductivity, Btu/h-ft-°F	Emissivity Ratio	Emissivity Surface Condition
Aluminum (alloy 1100)	0.214[h]	171[u]	128[v]	0.09[n]	Commercial sheet
				0.20[n]	Heavily oxidized
Aluminum bronze (76% Cu, 22% Zn, 2% Al)	0.09[v]	517[v]	58[v]		
Asbestos: Fiber	0.25[h]	150[v]	0.097[u]		
Insulation	0.20[l]	36[h]	0.092[h]	0.93[h]	"Paper"
Ashes, wood	0.20[l]	40[h]	0.041[h] (122)		
Asphalt	0.22[h]	132[h]	0.43[h]		
Bakelite	0.35[h]	81[u]	9.7[u]		
Bell metal	0.086[l] (122)				
Bismuth tin	0.040[*]		37.6[*]		
Brick, building	0.2[h]	123[u]	0.4[h]	0.93[*]	
Brass: Red (85% Cu, 15% Zn)	0.09[u]	548[u]	87[u]	0.030[h]	Highly polished
Yellow (65% Cu, 35% Zn)	0.09[u]	519[u]	69[u]	0.033[h]	Highly polished
Bronze	0.104[l]	530[l]	17[d] (32)		
Cadmium	0.055[a]	540[l]	53.7[h]	0.02[u]	
Carbon (gas retort)	0.17[a]		0.20[h] (2)	0.81[a]	
Cardboard			0.04[h]		
Cellulose	0.32[h]	3.4[l]	0.033[l]		
Cement (portland clinker)	0.16[h]	120[l]	0.017[l]		
Chalk	0.215[l]	143[l]	0.48[*]	0.34[*]	About 250°F
Charcoal (wood)	0.20[l]	15[a]	0.03[a] (392)		
Chrome brick	0.17[h]	200[h]	0.67[h]		
Clay	0.22[h]	63[f]			
Coal	0.3[h]	90[f]	0.098[f] (32)		
Coal tars	0.35[h] (104)	75[h]	0.07[h]		
Coke (petroleum, powdered)	0.36[h] (752)	62[h]	0.55[h] (752)		
Concrete (stone)	0.156[h] (392)	144[h]	0.54[h]		
Copper (electrolytic)	0.092[u]	556[u]	227[u]	0.072[n]	Commercial, shiny
Cork (granulated)	0.485[l]	5.4[l]	0.028[l] (23)		
Cotton (fiber)	0.319[u]	95[u]	0.024[u]		
Cryolite ($AlF_3 \cdot 3NaF$)	0.253[h]	181[h]			
Diamond	0.147[h]	151[l]	27[l]		
Earth (dry and packed)		95[l]	0.037[*]	0.41[*]	
Felt		20.6[h]	0.03[h]		
Fireclay brick	0.198[h] (212)	112[l]	0.58[h] (392)	0.75[n]	At 1832°F
Fluorspar (CaF_2)	0.21[h]	199[v]	0.63[v]		
German silver (nickel silver)	0.09[u]	545[u]	19[u]	0.135[n]	Polished
Glass: Crown (soda-lime)	0.18[h]	154[u]	0.59[l] (200)	0.94[n]	Smooth
Flint (lead)	0.117[h]	267[u]	0.79[f]		
Heat-resistant	0.20[h]	139[l]	0.59[l] (200)		
"Wool"	0.157[h]	3.25[f]	0.022[l]		
Gold	0.0312[u]	1208[u]	172[l]	0.02[n]	Highly polished
Graphite: Powder	0.165[*]		0.106[*]		
Impervious	0.16[u]	117[u]	75[u]	0.75[n]	
Gypsum	0.259[h]	78[h]	0.25[h]	0.903[h]	On a smooth plate
Hemp (fiber)	0.323[u]	93[u]			
Ice: 32°F	0.487[l]	57.5[h]	1.3[h]	0.95[*]	
−4°F	0.465[l]		1.41[*]		
Iron: Cast	0.12[v] (212)	450[h]	27.6[h] (129)	0.435[h]	Freshly turned
Wrought		485[h]	34.9[h]	0.94[h]	Dull, oxidized
Lead	0.0309[u]	707[u]	20.1[u]	0.28[n]	Gray, oxidized
Leather (sole)		62.4[h]	0.092[h]		
Limestone	0.217[h]	103[h]	0.54[h]	0.36[*] to 0.90	At 145 to 380°F
Linen			0.05[h]		
Litharge (lead monoxide)	0.055[h]	490[h]			
Magnesia: Powdered	0.234[h] (212)	49.7[h]	0.35[h] (117)		
Light carbonate		13[h]	0.034[h]		
Magnesite brick	0.222[h] (212)	158[h]	2.2[h] (400)		
Magnesium	0.241[h]	108[u]	91[u]	0.55[u]	Oxidized
Marble	0.21[h]	162[h]	1.5[h]	0.931[h]	Light gray, polished
Nickel, polished	0.105[u]	555[u]	34.4[u]	0.045[n]	Electroplated
Paints: White lacquer				0.80[n]	
White enamel				0.91[n]	On rough plate
Black lacquer				0.80[n]	
Black shellac		63[u]	0.15[u]	0.91[n]	"Matte" finish
Flat black lacquer				0.96[n]	
Aluminum lacquer				0.39[n]	On rough plate

*Data source unknown.

Notes: 1. Values are for room temperature unless otherwise noted in parentheses

2. Superscript letters indicate data source from the section on References.

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Attachment B to
Proto-Power Calculation
97-200
Revision A

LA SALLE COUNTY STATION
HEAT EXCHANGER
(WATER TO AIR)
DATABASE

EQUIPMENT NUMBER/ NAME	INSPECT DATE	BASE	PHOT	PHOTO STORAGE LOCATION	GENERAL APPEARANCE	TUBE CONDITION	FINS CONDITION	DEFECTS	CORRECTIVE ACTIONS RECOMMENDED	ACTUAL
1VY01C "A" RHR AREA COOLER	09/15/92	N	Y	BTN/XAPSHOT HX#1	VERY CLEAN. NO DEBRIS.	NO DAMAGE OR LEAKS FOUND.	CLEAN NO DEBRIS. A FEW FINS BENT.	NONE.	NONE NEEDED.	N/A

VY01A - Cooler
VY01C - Cooler Fan

Proto-Power Calc: 97-200
Attachment: B
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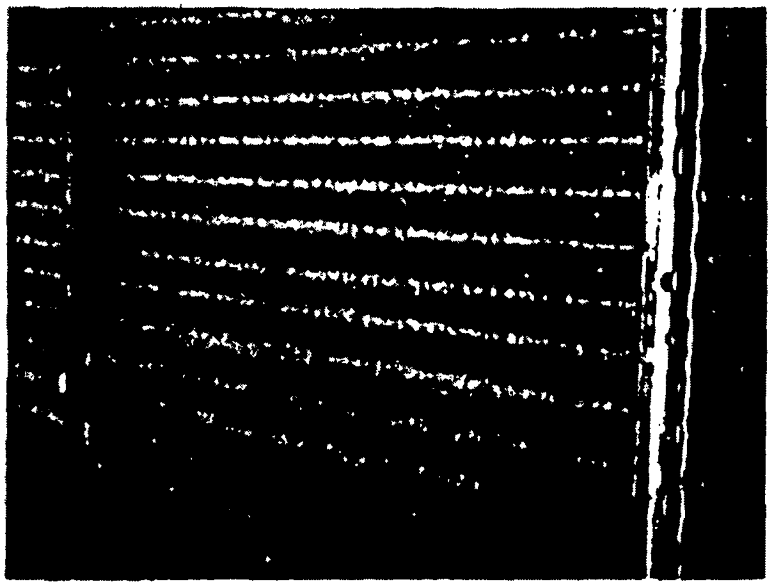
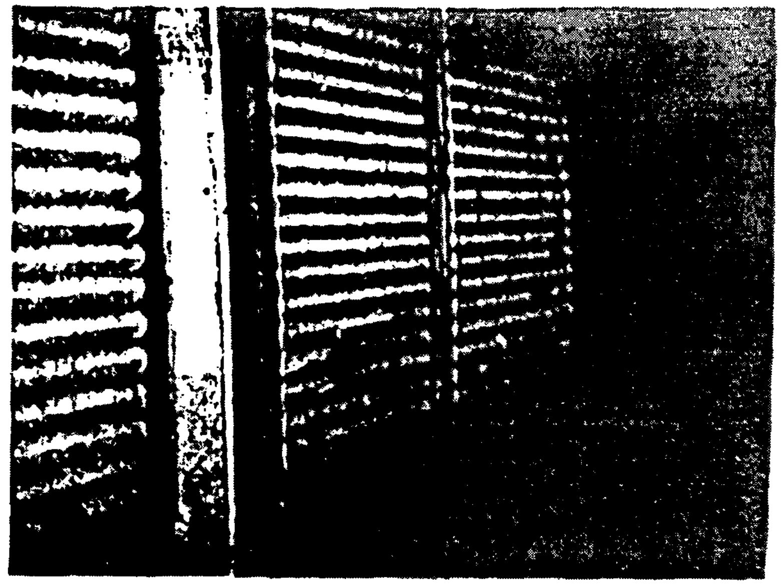


1VY01C OUTLET SIDE 9/15/92



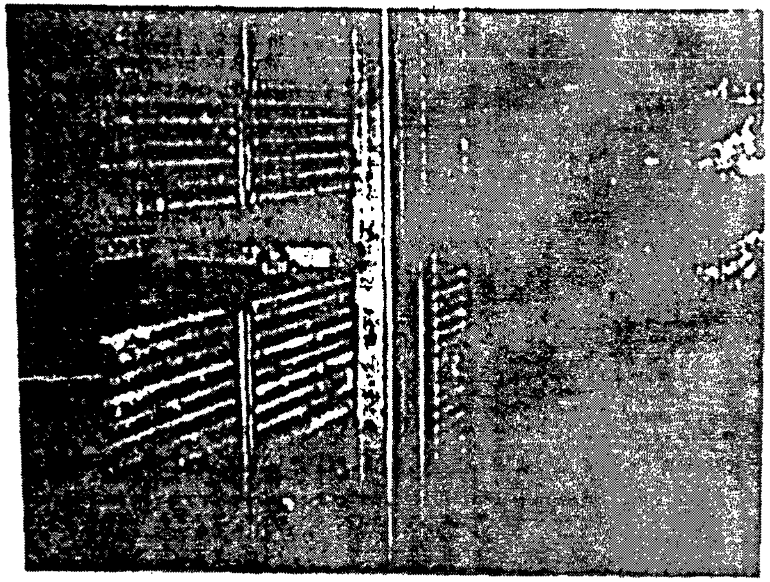
1VY01C INLET SIDE 9/15/92

LA SALLE COUNTY STATION
HEAT EXCHANGER
(WATER TO AIR)
DATABASE

EQUIPMENT NUMBER/ NAME	INSPECT DATE	BASE	PHOT	PHOTO STORAGE LOCATION	GENERAL APPEARANCE	TUBE CONDITION	FINS CONDITION	DEFECTS	CORRECTIVE ACTIONS RECOMMENDED	CORRECTIVE ACTIONS ACTUAL
1VY02C HPCS AREA COOLER	09/01/92	N	Y	BTN / XAPSHOT HX#1	VERY CLEAN. NO DEBRIS FOUND.	CLEAN. NO DAMAGE NOTICED.	JUST A FEW FINS BENT. GENERAL CONDITION IS VERY CLEAN.	NONE.	NONE.	N/A

VY02A - Cooler
VY02C - Cooler Fan

1VY02C INLET SIDE 9/1/92



1VY02C OUTLET SIDE 9/1/92

Photo-Power Calc.
Attachment: B
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Attachment C to
Proto-Power Calculation
97-200
Revision A

ComEd -- LaSalle

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Initial Benchmark Case -- Standard Coil

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	CF-9.05-3/4J A
	j = EXP[-2.3333 + -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·°F)	225.00

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

ComEd -- LaSalle

Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Initial Benchmark Case -- Standard 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)	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)	

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)	1,639.65
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·°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²·°F/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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	140.10	110.78
Outlet Temperature (°F)	132.32	112.82
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	136.21	111.80
Skin Temperature (°F)	118.38	113.70
Velocity ***	3,598.07	5.52
Reynold's Number	857**	37,051
Prandtl Number	0.7262	3.9648
Bulk Visc (lbm/ft·hr)	0.0485	1.4576
Skin Visc (lbm/ft·hr)		1.4304
Density (lbm/ft³)	0.0632	61.8343
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3672

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,618.86
j Factor	0.0095
Air-Side ho (BTU/hr·ft²·°F)	10.15
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.69
Effective Area (ft²)	937.90
LMTD	24.20
Total Heat Transferred (BTU/hr)	151,828
Surface Effectiveness (Eta)	0.9020
Sensible Heat Transferred (BTU/hr)	151,828
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	132.32	109.17
Outlet Temperature (°F)	126.20	110.78
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	129.26	109.98
Skin Temperature (°F)	115.17	111.49
Velocity ***	3,598.07	5.52
Reynold's Number	865**	36,382
Prandtl Number	0.7267	4.0450
Bulk Visc (lbm/ft·hr)	0.0481	1.4844
Skin Visc (lbm/ft·hr)		1.4620
Density (lbm/ft³)	0.0639	61.8603
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3665

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,602.43
j Factor	0.0095
Air-Side ho (BTU/hr·ft²·°F)	10.12
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.67
Effective Area (ft²)	937.90
LMTD	19.11
Total Heat Transferred (BTU/hr)	119,548
Surface Effectiveness (Eta)	0.9024
Sensible Heat Transferred (BTU/hr)	119,548
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	126.20	107.91
Outlet Temperature (°F)	121.37	109.17
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	123.78	108.54
Skin Temperature (°F)	112.65	109.74
Velocity ***	3,598.07	5.52
Reynold's Number	871**	35,858
Prandtl Number	0.7271	4.1100
Bulk Visc (lbm/ft·hr)	0.0477	1.5061
Skin Visc (lbm/ft·hr)		1.4878
Density (lbm/ft³)	0.0644	61.8805
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3660

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,589.45
j Factor	0.0094
Air-Side ho (BTU/hr·ft²·°F)	10.09
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.65
Effective Area (ft²)	937.90
LMTD	15.11
Total Heat Transferred (BTU/hr)	94,256
Surface Effectiveness (Eta)	0.9026
Sensible Heat Transferred (BTU/hr)	94,256
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	121.37	106.91
Outlet Temperature (°F)	117.55	107.91
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	119.46	107.41
Skin Temperature (°F)	110.65	108.36
Velocity ***	3,598.07	5.52
Reynold's Number	876**	35,447
Prandtl Number	0.7274	4.1625
Bulk Visc (lbm/ft·hr)	0.0474	1.5235
Skin Visc (lbm/ft·hr)		1.5087
Density (lbm/ft³)	0.0648	61.8962
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,579.19
j Factor	0.0094
Air-Side ho (BTU/hr·ft²·°F)	10.07
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.64
Effective Area (ft²)	937.90
LMTD	11.95
Total Heat Transferred (BTU/hr)	74,393
Surface Effectiveness (Eta)	0.9028
Sensible Heat Transferred (BTU/hr)	74,393
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	117.55	106.12
Outlet Temperature (°F)	114.54	106.91
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	116.05	106.51
Skin Temperature (°F)	109.08	107.27
Velocity ***	3,598.07	5.52
Reynold's Number	880**	35,123
Prandtl Number	0.7277	4.2047
Bulk Visc (lbm/ft·hr)	0.0472	1.5376
Skin Visc (lbm/ft·hr)		1.5256
Density (lbm/ft³)	0.0652	61.9085
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3653

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,571.08
j Factor	0.0094
Air-Side ho (BTU/hr·ft²·°F)	10.05
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.63
Effective Area (ft²)	937.90
LMTD	9.45
Total Heat Transferred (BTU/hr)	58,765
Surface Effectiveness (Eta)	0.9029
Sensible Heat Transferred (BTU/hr)	58,765
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	114.54	105.49
Outlet Temperature (°F)	112.16	106.12
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	113.35	105.81
Skin Temperature (°F)	107.84	106.41
Velocity ***	3,598.07	5.52
Reynold's Number	884**	34,868
Prandtl Number	0.7278	4.2386
Bulk Visc (lbm/ft·hr)	0.0471	1.5488
Skin Visc (lbm/ft·hr)		1.5392
Density (lbm/ft³)	0.0654	61.9181
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3650

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,564.65
j Factor	0.0094
Air-Side ho (BTU/hr·ft²·°F)	10.03
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.62
Effective Area (ft²)	937.90
LMTD	7.48
Total Heat Transferred (BTU/hr)	46,450
Surface Effectiveness (Eta)	0.9031
Sensible Heat Transferred (BTU/hr)	46,450
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	112.16	105.00
Outlet Temperature (°F)	110.28	105.49
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	111.22	105.25
Skin Temperature (°F)	106.86	105.72
Velocity ***	3,598.07	5.52
Reynold's Number	886**	34,667
Prandtl Number	0.7280	4.2656
Bulk Visc (lbm/ft·hr)	0.0469	1.5578
Skin Visc (lbm/ft·hr)		1.5501
Density (lbm/ft³)	0.0657	61.9257
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3648

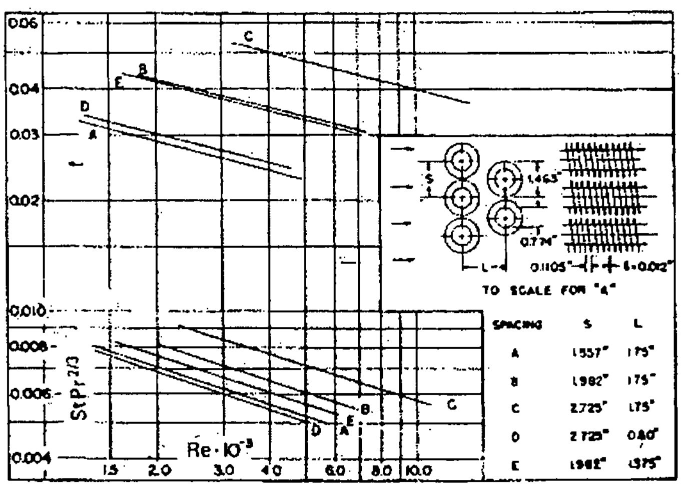
** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,559.57
j Factor	0.0094
Air-Side ho (BTU/hr·ft²·°F)	10.02
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°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)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment D to
Proto-Power Calculation
97-200
Revision A

Fig. 10-89 Finned circular tubes, surface CF-9.05-3/4J. *(Data of Jameson.)*



Tube outside diameter = 0.774 in = 19.66×10^{-3} 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

	A	*B*	*C*	*D*	*E*
Flow passage hydraulic diameter, $4r_h$ =	0.01681	0.02685	0.0445	0.01587	0.02108 ft
=	5.131×10^{-3}	8.179×10^{-3}	13.59×10^{-3}	4.846×10^{-3}	6.426×10^{-3} m
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 ft^2/ft^3
=	354	279	203	443	354 m^2/m^3

Note: Minimum free-flow area in all cases occurs in the spaces transverse to the flow, except for *D*, in which the minimum area is in the diagonals.

Proto-Power Calc: 97-200
Attachment: D
Rev: A Page 2 of 2

Attachment E to
Proto-Power Calculation
97-200
Revision A

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark Case -- Custom Coil

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 VY Coolers 01A/02A j = EXP[-2.5088 + -0.3436 * 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

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

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·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)	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)	

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)	1,637.56
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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	140.99	110.84
Outlet Temperature (°F)	133.73	112.75
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	137.36	111.79
Skin Temperature (°F)	117.93	113.57
Velocity ***	3,598.07	5.52
Reynold's Number	856**	37,048
Prandtl Number	0.7261	3.9651
Bulk Visc (lbm/ft·hr)	0.0486	1.4577
Skin Visc (lbm/ft·hr)		1.4323
Density (lbm/ft³)	0.0631	61.8344
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3672

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,618.52
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.56
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.95
Effective Area (ft²)	937.90
LMTD	25.39
Total Heat Transferred (BTU/hr)	141,802
Surface Effectiveness (Eta)	0.9158
Sensible Heat Transferred (BTU/hr)	141,802
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	133.73	109.30
Outlet Temperature (°F)	127.86	110.84
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	130.79	110.07
Skin Temperature (°F)	115.04	111.52
Velocity ***	3,598.07	5.52
Reynold's Number	863**	36,416
Prandtl Number	0.7266	4.0408
Bulk Visc (lbm/ft·hr)	0.0482	1.4830
Skin Visc (lbm/ft·hr)		1.4616
Density (lbm/ft³)	0.0637	61.8590
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3666

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,603.09
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.53
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.94
Effective Area (ft²)	937.90
LMTD	20.58
Total Heat Transferred (BTU/hr)	114,578
Surface Effectiveness (Eta)	0.9161
Sensible Heat Transferred (BTU/hr)	114,578
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	127.86	108.06
Outlet Temperature (°F)	123.11	109.30
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	125.48	108.68
Skin Temperature (°F)	112.71	109.86
Velocity ***	3,598.07	5.52
Reynold's Number	869**	35,909
Prandtl Number	0.7270	4.1037
Bulk Visc (lbm/ft·hr)	0.0478	1.5039
Skin Visc (lbm/ft·hr)		1.4861
Density (lbm/ft³)	0.0642	61.8786
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3661

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,590.59
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.50
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.92
Effective Area (ft²)	937.90
LMTD	16.69
Total Heat Transferred (BTU/hr)	92,686
Surface Effectiveness (Eta)	0.9163
Sensible Heat Transferred (BTU/hr)	92,686
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	123.11	107.05
Outlet Temperature (°F)	119.26	108.06
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	121.18	107.55
Skin Temperature (°F)	110.82	108.51
Velocity ***	3,598.07	5.52
Reynold's Number	874**	35,499
Prandtl Number	0.7273	4.1558
Bulk Visc (lbm/ft·hr)	0.0476	1.5213
Skin Visc (lbm/ft·hr)		1.5065
Density (lbm/ft³)	0.0646	61.8943
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,580.44
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.48
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.91
Effective Area (ft²)	937.90
LMTD	13.54
Total Heat Transferred (BTU/hr)	75,047
Surface Effectiveness (Eta)	0.9164
Sensible Heat Transferred (BTU/hr)	75,047
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	119.26	106.23
Outlet Temperature (°F)	116.14	107.05
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.70	106.64
Skin Temperature (°F)	109.29	107.42
Velocity ***	3,598.07	5.52
Reynold's Number	878**	35,169
Prandtl Number	0.7276	4.1987
Bulk Visc (lbm/ft·hr)	0.0473	1.5356
Skin Visc (lbm/ft·hr)		1.5233
Density (lbm/ft³)	0.0650	61.9068
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3653

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,572.22
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.47
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.90
Effective Area (ft²)	937.90
LMTD	10.99
Total Heat Transferred (BTU/hr)	60,810
Surface Effectiveness (Eta)	0.9166
Sensible Heat Transferred (BTU/hr)	60,810
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	116.14	105.57
Outlet Temperature (°F)	113.62	106.23
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	114.88	105.90
Skin Temperature (°F)	108.05	106.54
Velocity ***	3,598.07	5.52
Reynold's Number	882**	34,902
Prandtl Number	0.7277	4.2341
Bulk Visc (lbm/ft·hr)	0.0472	1.5473
Skin Visc (lbm/ft·hr)		1.5372
Density (lbm/ft³)	0.0653	61.9169
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3650

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,565.54
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.46
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.89
Effective Area (ft²)	937.90
LMTD	8.92
Total Heat Transferred (BTU/hr)	49,305
Surface Effectiveness (Eta)	0.9167
Sensible Heat Transferred (BTU/hr)	49,305
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	113.62	105.03
Outlet Temperature (°F)	111.57	105.57
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	112.59	105.30
Skin Temperature (°F)	107.05	105.82
Velocity ***	3,598.07	5.52
Reynold's Number	885**	34,686
Prandtl Number	0.7279	4.2631
Bulk Visc (lbm/ft·hr)	0.0470	1.5569
Skin Visc (lbm/ft·hr)		1.5486
Density (lbm/ft³)	0.0655	61.9250
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3648

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,560.11
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.45
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.89
Effective Area (ft²)	937.90
LMTD	7.24
Total Heat Transferred (BTU/hr)	39,996
Surface Effectiveness (Eta)	0.9168
Sensible Heat Transferred (BTU/hr)	39,996
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 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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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Final Benchmark - Effective Coil Length

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

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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	0.00031430
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)	746,297
Bulk Visc (lbm/ft·hr)				
Skin Visc (lbm/ft·hr)			Surface Effectiveness (Eta)	
Density (lbm/ft³)			Sensible Heat Transferred (BTU/hr)	746,297
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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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)	

** 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·ft²·°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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	128.10	108.04
Outlet Temperature (°F)	123.37	109.28
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	125.73	108.66
Skin Temperature (°F)	112.82	109.88
Velocity ***	3,727.50	5.52
Reynold's Number	900**	35,901
Prandtl Number	0.7270	4.1046
Bulk Visc (lbm/ft·hr)	0.0478	1.5043
Skin Visc (lbm/ft·hr)		1.4858
Density (lbm/ft³)	0.0642	61.8789
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0158	0.3661

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,590.49
j Factor	0.0079
Air-Side ho (BTU/hr·ft²·°F)	8.70
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.02
Effective Area (ft²)	905.33
LMTD	16.96
Total Heat Transferred (BTU/hr)	92,439
Surface Effectiveness (Eta)	0.9145
Sensible Heat Transferred (BTU/hr)	92,439
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	123.37	107.03
Outlet Temperature (°F)	119.52	108.04
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	121.44	107.53
Skin Temperature (°F)	110.92	108.53
Velocity ***	3,727.50	5.52
Reynold's Number	905**	35,491
Prandtl Number	0.7273	4.1567
Bulk Visc (lbm/ft·hr)	0.0476	1.5216
Skin Visc (lbm/ft·hr)		1.5062
Density (lbm/ft³)	0.0646	61.8945
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3656

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,580.35
j Factor	0.0078
Air-Side ho (BTU/hr·ft²·°F)	8.68
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.01
Effective Area (ft²)	905.33
LMTD	13.82
Total Heat Transferred (BTU/hr)	75,142
Surface Effectiveness (Eta)	0.9147
Sensible Heat Transferred (BTU/hr)	75,142
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	119.52	106.20
Outlet Temperature (°F)	116.38	107.03
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.95	106.62
Skin Temperature (°F)	109.38	107.43
Velocity ***	3,727.50	5.52
Reynold's Number	910**	35,160
Prandtl Number	0.7275	4.1998
Bulk Visc (lbm/ft·hr)	0.0474	1.5359
Skin Visc (lbm/ft·hr)		1.5231
Density (lbm/ft³)	0.0650	61.9071
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3653

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,572.09
j Factor	0.0078
Air-Side ho (BTU/hr·ft²·°F)	8.67
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	6.00
Effective Area (ft²)	905.33
LMTD	11.26
Total Heat Transferred (BTU/hr)	61,127
Surface Effectiveness (Eta)	0.9148
Sensible Heat Transferred (BTU/hr)	61,127
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	116.38	105.54
Outlet Temperature (°F)	113.83	106.20
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	115.11	105.87
Skin Temperature (°F)	108.12	106.54
Velocity ***	3,727.50	5.52
Reynold's Number	913**	34,892
Prandtl Number	0.7277	4.2354
Bulk Visc (lbm/ft·hr)	0.0472	1.5478
Skin Visc (lbm/ft·hr)		1.5372
Density (lbm/ft³)	0.0653	61.9172
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3650

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,565.36
j Factor	0.0078
Air-Side ho (BTU/hr·ft²·°F)	8.66
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.99
Effective Area (ft²)	905.33
LMTD	9.18
Total Heat Transferred (BTU/hr)	49,756
Surface Effectiveness (Eta)	0.9149
Sensible Heat Transferred (BTU/hr)	49,756
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	77,999.05	74,508.32
Inlet Temperature (°F)	113.83	104.99
Outlet Temperature (°F)	111.76	105.54
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	112.79	105.26
Skin Temperature (°F)	107.10	105.81
Velocity ***	3,727.50	5.52
Reynold's Number	916**	34,673
Prandtl Number	0.7279	4.2648
Bulk Visc (lbm/ft·hr)	0.0470	1.5575
Skin Visc (lbm/ft·hr)		1.5487
Density (lbm/ft³)	0.0655	61.9254
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0155	0.3648

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,559.87
j Factor	0.0078
Air-Side ho (BTU/hr·ft²·°F)	8.65
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.98
Effective Area (ft²)	905.33
LMTD	7.48
Total Heat Transferred (BTU/hr)	40,520
Surface Effectiveness (Eta)	0.9150
Sensible Heat Transferred (BTU/hr)	40,520
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment F to
Proto-Power Calculation
97-200
Revision A

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 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

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

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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·°F/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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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·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)	
Average Temp (°F)	132.01	106.56		
Skin Temperature (°F)	108.73	108.68	U Overall (BTU/hr·ft²·°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)	

** 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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,641.50	74,586.94
Inlet Temperature (°F)	120.85	102.63
Outlet Temperature (°F)	115.68	103.87
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	118.26	103.25
Skin Temperature (°F)	104.55	104.52
Velocity ***	3,423.68	5.52
Reynold's Number	835**	33,989
Prandtl Number	0.7275	4.3645
Bulk Visc (lbm/ft·hr)	0.0474	1.5905
Skin Visc (lbm/ft·hr)		1.5697
Density (lbm/ft³)	0.0650	61.9522
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3640

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,545.48
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.20
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	
U Overall (BTU/hr·ft²·°F)	6.88
Effective Area (ft²)	905.33
LMTD	14.86
Total Heat Transferred (BTU/hr)	92,611
Surface Effectiveness (Eta)	0.9190
Sensible Heat Transferred (BTU/hr)	92,611
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,641.50	74,586.94
Inlet Temperature (°F)	115.68	101.68
Outlet Temperature (°F)	111.72	102.63
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	113.70	102.15
Skin Temperature (°F)	103.15	103.13
Velocity ***	3,423.68	5.52
Reynold's Number	840**	33,597
Prandtl Number	0.7278	4.4206
Bulk Visc (lbm/ft·hr)	0.0471	1.6091
Skin Visc (lbm/ft·hr)		1.5926
Density (lbm/ft³)	0.0655	61.9666
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0155	0.3636

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,535.34
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.18
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	
U Overall (BTU/hr·ft²·°F)	6.87
Effective Area (ft²)	905.33
LMTD	11.43
Total Heat Transferred (BTU/hr)	71,038
Surface Effectiveness (Eta)	0.9191
Sensible Heat Transferred (BTU/hr)	71,038
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,641.50	74,586.94	Tube-Side hi (BTU/hr·ft²·°F)	1,527.56
Inlet Temperature (°F)	111.72	100.95	j Factor	0.0080
Outlet Temperature (°F)	108.67	101.68	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)	
Average Temp (°F)	110.19	101.31		
Skin Temperature (°F)	102.08	102.06	U Overall (BTU/hr·ft²·°F)	6.85
Velocity ***	3,423.68	5.52	Effective Area (ft²)	905.33
Reynold's Number	844**	33,298	LMTD	8.79
Prandtl Number	0.7280	4.4644	Total Heat Transferred (BTU/hr)	54,554
Bulk Visc (lbm/ft·hr)	0.0469	1.6236		
Skin Visc (lbm/ft·hr)		1.6106	Surface Effectiveness (Eta)	0.9193
Density (lbm/ft³)	0.0659	61.9776	Sensible Heat Transferred (BTU/hr)	54,554
Cp (BTU/lbm·°F)	0.2402	0.9990	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.0155	0.3633	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)	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·ft·°F)	0.0154	0.3630	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,641.50	74,586.94
Inlet Temperature (°F)	106.33	99.95
Outlet Temperature (°F)	104.53	100.38
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	105.43	100.17
Skin Temperature (°F)	100.63	100.61
Velocity ***	3,423.68	5.52
Reynold's Number	850**	32,893
Prandtl Number	0.7283	4.5250
Bulk Visc (lbm/ft·hr)	0.0465	1.6436
Skin Visc (lbm/ft·hr)		1.6357
Density (lbm/ft³)	0.0663	61.9922
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0154	0.3628

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,516.95
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	
U Overall (BTU/hr·ft²·°F)	6.84
Effective Area (ft²)	905.33
LMTD	5.21
Total Heat Transferred (BTU/hr)	32,255
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	32,255
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment G to
Proto-Power Calculation
97-200
Revision A

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 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

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)	19,321.00
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

ComEd -- LaSalle

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·ft²·°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	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²·°F/BTU)	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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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)	

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71,397.61	74,586.94	Tube-Side hi (BTU/hr·ft²·°F)	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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,397.61	74,586.94
Inlet Temperature (°F)	123.61	102.87
Outlet Temperature (°F)	118.51	104.09
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	121.06	103.48
Skin Temperature (°F)	107.62	104.72
Velocity ***	3,412.02	5.52
Reynold's Number	829**	34,070
Prandtl Number	0.7273	4.3531
Bulk Visc (lbm/ft·hr)	0.0476	1.5868
Skin Visc (lbm/ft·hr)		1.5664
Density (lbm/ft³)	0.0647	61.9493
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3641

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,547.37
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.76
Effective Area (ft²)	905.33
LMTD	17.46
Total Heat Transferred (BTU/hr)	91,006
Surface Effectiveness (Eta)	0.9190
Sensible Heat Transferred (BTU/hr)	91,006
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,397.61	74,586.94
Inlet Temperature (°F)	118.51	101.89
Outlet Temperature (°F)	114.44	102.87
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	116.48	102.38
Skin Temperature (°F)	105.70	103.38
Velocity ***	3,412.02	5.52
Reynold's Number	834**	33,678
Prandtl Number	0.7276	4.4089
Bulk Visc (lbm/ft·hr)	0.0473	1.6052
Skin Visc (lbm/ft·hr)		1.5885
Density (lbm/ft³)	0.0652	61.9637
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0156	0.3637

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,537.35
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.17
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.75
Effective Area (ft²)	905.33
LMTD	13.99
Total Heat Transferred (BTU/hr)	72,805
Surface Effectiveness (Eta)	0.9192
Sensible Heat Transferred (BTU/hr)	72,805
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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)	

** 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·°F/BTU	0.00031430
Outlet Specific Humidity	0.0203		Overall Fouling (hr·ft²·°F/BTU)	0.02832467
Average Temp (°F)	109.87	100.80		
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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,397.61	74,586.94
Inlet Temperature (°F)	108.56	99.98
Outlet Temperature (°F)	106.46	100.48
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	107.51	100.23
Skin Temperature (°F)	101.94	100.75
Velocity ***	3,412.02	5.52
Reynold's Number	845**	32,915
Prandtl Number	0.7282	4.5216
Bulk Visc (lbm/ft·hr)	0.0467	1.6424
Skin Visc (lbm/ft·hr)		1.6333
Density (lbm/ft³)	0.0661	61.9914
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0154	0.3629

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,517.67
j Factor	0.0080
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.02832467
U Overall (BTU/hr·ft²·°F)	5.72
Effective Area (ft²)	905.33
LMTD	7.23
Total Heat Transferred (BTU/hr)	37,443
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	37,443
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment H to
Proto-Power Calculation
97-200
Revision A

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/in^2
P_a = Dry Air Pressure, lbf/in^2
P_s = Saturated Air Pressure, lbf/in^2
P_v = 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
ρ = Moist air Density, lbm/ft^3
ρ_a = Dry Air Density, lbm/ft^3
ρ_v = 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

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-°R)

For water vapor:

$$\rho_v = \left(\frac{144}{R_v}\right)\frac{P_v}{(459.67+T)}$$ Equation [6]

where:
R_v = 85.778 (ft-lbf)/(lbm-°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 = 0.001007276
c = 0.00001888033
d = 0.0000003775047
e = 4.871208E-10
f = 2.109071E-11

5. WATER VAPOR PRESSURE

$$f(T_w) = a + bT_w + cT_w^2 + dT_w^3 + eT_w^4 + fT_w^5$$ Equation [9]

$$P_v(P,T,T_w) = \frac{[(2T_w - T - 2800)f(T_w)] - P(T_w - T)}{(T_w - 2800)}$$ Equation [10]

Where:
a = 0.02358607
b = 0.001007276
c = 0.00001888033
d = 0.0000003775047
e = 4.871208E-10
f = 2.109071E-11

$$P_v = \frac{WR_v P}{R_a + (WR_v)}$$ Equation [11]

6. MOIST AIR SPECIFIC HUMIDITY

$$W = \frac{m_v}{m_a} = \frac{\rho_v}{\rho_a}$$ Equation [12]

Where:

$$m_v = \frac{P_v V}{R_v(459.67 + T)}$$ Equation [13]

$$m_a = \frac{P_a V}{R_a(459.67 + T)}$$ Equation [14]

7. MOIST AIR RELATIVE HUMIDITY

$$\phi = \frac{x_v}{x_s} = \frac{P_v}{P_s}$$ Equation [15]

Moist Air Properties -- Given Dry Bulb and Relative Humidity *

Total Pressure:	P =	14.315	psia	
Dry Bulb Temperature:	T =	70	°F	
Moist Air Relative Humidity:	RH =	40	%	
Saturated Air Pressure:	$Ps = a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$	0.363236046	psia	Equation [8]
Vapor Pressure:	Pv = RH*Ps	0.145294418	psia	Equation [15]
Dry Air Pressure:	Pa =P - Pv =	14.16970558	psia	Equation [4]
Dry Air Density:	Rho a = (144/53.352)*(Pa/(459.67+T)) =	0.072204994	lbm/ft^3	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.000460501	lbm/ft^3	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.072665495	lbm/ft^3	Equation [7]
Specific Humidity:	W = Rho v / Rho a =	0.006377682		Equation [12]
Equation Coefficients:	a =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* Coil Specification Conditions

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 =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* Coil Benchmark Conditions

Moist Air Properties -- Given Dry Bulb and Wet Bulb Temperatures *

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 =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* LaSalle Station Reference Conditions

Moist Air Properties -- Given Dry Bulb and Relative Humidity *

Total Pressure:	P =	14.315	psia	
Dry Bulb Temperature:	T =	148	°F	
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	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/ft^3	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001248351	lbm/ft^3	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.062823454	lbm/ft^3	Equation [7]
Specific Humidity:	W = Rho v / Rho a =	0.020273629		Equation [12]
Equation Coefficients:	a =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* LaSalle Station Reference Conditions (RH = 12.76 %)

Moist Air Properties -- Given Dry Bulb and Specific Humidity *

Total Pressure:	P =	14.315	psia	
				Inlet Air Flow
Dry Bulb Temperature:	T =	104.53	°F	19386.84858
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)) =	0.066319289	lbm/ft^3	Equation [5]
Water Vapor Density:	Rho v = (144/85.778)*(Pv/(459.67+T)) =	0.001344533	lbm/ft^3	Equation [6]
Moist Air Density:	Rho = Rho a + Rho v =	0.067663821	lbm/ft^3	Equation [7]
Saturated Air Pressure:	$Ps = a+(b*T)+(c*T^2)+(d*T^3)+(e*T^4)+(f*T^5) =$	1.087702551	psia	Equation [8]
Moist Air Relative Humidity:	RH = Pv /Ps =	41.54394211	%	Equation [15]
Equation Coefficients:	a =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

*Coil Outlet Conditions (Clean)

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 =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* Coil Outlet Conditions (Service)

Moist Air Properties -- Given Dry Bulb and Specific Humidity *

Total Pressure:	P =	14.315	psia	
				Inlet Air Flow
Dry Bulb Temperature:	T =	109.96	°F	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]
Equation Coefficients:	a =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* Coil Outlet Conditions (Limiting Flow - 75 gpm)

Moist Air Properties -- Given Dry Bulb and Specific Humidity *

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:	a =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

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* Coil Outlet Conditions (Limiting Flow - 108 gpm)

Moist Air Properties -- Given Dry Bulb and Specific Humidity *

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 =	2.358607E-02		
	b =	1.007276E-03		
	c =	1.888033E-05		
	d =	3.775047E-07		
	e =	4.871208E-10		
	f =	2.109071E-11		

* Coil Outlet Conditions (Limiting Flow - 115 gpm)

Attachment I to
Proto-Power Calculation
97-200
Revision A

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
	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

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

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·ft·°F)	0.0162	0.3688	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	140.61	111.52
Outlet Temperature (°F)	134.20	114.57
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	137.40	113.04
Skin Temperature (°F)	120.67	115.59
Velocity ***	3,391.01	2.77
Reynold's Number	807**	18,774
Prandtl Number	0.7261	3.9116
Bulk Visc (lbm/ft·hr)	0.0486	1.4398
Skin Visc (lbm/ft·hr)		1.4043
Density (lbm/ft³)	0.0630	61.8163
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0161	0.3676

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	937.48
j Factor	0.0082
Air-Side ho (BTU/hr·ft²·°F)	8.23
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.20
Effective Area (ft²)	905.33
LMTD	24.19
Total Heat Transferred (BTU/hr)	113,794
Surface Effectiveness (Eta)	0.9187
Sensible Heat Transferred (BTU/hr)	113,794
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	134.20	108.86
Outlet Temperature (°F)	128.63	111.52
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	131.42	110.19
Skin Temperature (°F)	116.84	112.44
Velocity ***	3,391.01	2.76
Reynold's Number	813**	18,249
Prandtl Number	0.7266	4.0355
Bulk Visc (lbm/ft·hr)	0.0482	1.4812
Skin Visc (lbm/ft·hr)		1.4484
Density (lbm/ft³)	0.0636	61.8573
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0159	0.3666

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	923.12
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.20
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.18
Effective Area (ft²)	905.33
LMTD	21.08
Total Heat Transferred (BTU/hr)	98,800
Surface Effectiveness (Eta)	0.9189
Sensible Heat Transferred (BTU/hr)	98,800
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	128.63	106.56
Outlet Temperature (°F)	123.80	108.86
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	126.21	107.71
Skin Temperature (°F)	113.52	109.69
Velocity ***	3,391.01	2.76
Reynold's Number	819**	17,797
Prandtl Number	0.7270	4.1483
Bulk Visc (lbm/ft·hr)	0.0479	1.5188
Skin Visc (lbm/ft·hr)		1.4886
Density (lbm/ft³)	0.0641	61.8920
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0158	0.3657

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	910.59
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.18
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.16
Effective Area (ft²)	905.33
LMTD	18.38
Total Heat Transferred (BTU/hr)	85,857
Surface Effectiveness (Eta)	0.9191
Sensible Heat Transferred (BTU/hr)	85,857
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	123.80	104.55
Outlet Temperature (°F)	119.59	106.56
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	121.69	105.56
Skin Temperature (°F)	110.63	107.30
Velocity ***	3,391.01	2.76
Reynold's Number	823**	17,408
Prandtl Number	0.7273	4.2505
Bulk Visc (lbm/ft·hr)	0.0476	1.5528
Skin Visc (lbm/ft·hr)		1.5252
Density (lbm/ft³)	0.0646	61.9215
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3649

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	899.66
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.16
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.15
Effective Area (ft²)	905.33
LMTD	16.03
Total Heat Transferred (BTU/hr)	74,667
Surface Effectiveness (Eta)	0.9193
Sensible Heat Transferred (BTU/hr)	74,667
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	119.59	102.81
Outlet Temperature (°F)	115.93	104.55
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	117.76	103.68
Skin Temperature (°F)	108.11	105.21
Velocity ***	3,391.01	2.76
Reynold's Number	828**	17,071
Prandtl Number	0.7276	4.3429
Bulk Visc (lbm/ft·hr)	0.0473	1.5834
Skin Visc (lbm/ft·hr)		1.5583
Density (lbm/ft³)	0.0650	61.9466
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0156	0.3642

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	890.12
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.13
Effective Area (ft²)	905.33
LMTD	13.98
Total Heat Transferred (BTU/hr)	64,980
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	64,980
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	115.93	101.29
Outlet Temperature (°F)	112.74	102.81
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	114.33	102.05
Skin Temperature (°F)	105.92	103.40
Velocity ***	3,391.01	2.76
Reynold's Number	832**	16,780
Prandtl Number	0.7278	4.4260
Bulk Visc (lbm/ft·hr)	0.0471	1.6109
Skin Visc (lbm/ft·hr)		1.5881
Density (lbm/ft³)	0.0654	61.9680
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0156	0.3636

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	881.79
j Factor	0.0081
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
U Overall (BTU/hr·ft²·°F)	5.12
Effective Area (ft²)	905.33
LMTD	12.20
Total Heat Transferred (BTU/hr)	56,584
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	56,584
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec): Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	70,957.87	37,293.47
Inlet Temperature (°F)	112.74	99.97
Outlet Temperature (°F)	109.96	101.29
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	111.35	100.63
Skin Temperature (°F)	104.01	101.81
Velocity ***	3,391.01	2.76
Reynold's Number	835**	16,528
Prandtl Number	0.7280	4.5004
Bulk Visc (lbm/ft·hr)	0.0469	1.6354
Skin Visc (lbm/ft·hr)		1.6149
Density (lbm/ft³)	0.0657	61.9863
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0155	0.3630

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	874.52
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.12
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.11
Effective Area (ft²)	905.33
LMTD	10.65
Total Heat Transferred (BTU/hr)	49,300
Surface Effectiveness (Eta)	0.9197
Sensible Heat Transferred (BTU/hr)	49,300
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Limiting Flow Analysis -- 108 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 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

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

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 (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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,166.65	53,702.59
Inlet Temperature (°F)	139.36	107.92
Outlet Temperature (°F)	132.18	110.31
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	135.77	109.11
Skin Temperature (°F)	116.99	111.30
Velocity ***	3,400.99	3.98
Reynold's Number	811**	25,996
Prandtl Number	0.7262	4.0838
Bulk Visc (lbm/ft·hr)	0.0485	1.4973
Skin Visc (lbm/ft·hr)		1.4649
Density (lbm/ft³)	0.0632	61.8725
Cp (BTU/lbm·°F)	0.2402	0.9988
K (BTU/hr·ft·°F)	0.0160	0.3662

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,228.62
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.24
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.33
Effective Area (ft²)	905.33
LMTD	26.49
Total Heat Transferred (BTU/hr)	127,833
Surface Effectiveness (Eta)	0.9186
Sensible Heat Transferred (BTU/hr)	127,833
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,166.65	53,702.59
Inlet Temperature (°F)	132.18	105.94
Outlet Temperature (°F)	126.21	107.92
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	129.19	106.93
Skin Temperature (°F)	113.51	108.77
Velocity ***	3,400.99	3.98
Reynold's Number	818**	25,424
Prandtl Number	0.7267	4.1849
Bulk Visc (lbm/ft·hr)	0.0481	1.5310
Skin Visc (lbm/ft·hr)		1.5025
Density (lbm/ft³)	0.0639	61.9028
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0159	0.3654

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,213.64
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.21
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.31
Effective Area (ft²)	905.33
LMTD	22.12
Total Heat Transferred (BTU/hr)	106,417
Surface Effectiveness (Eta)	0.9189
Sensible Heat Transferred (BTU/hr)	106,417
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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·ft·°F)	0.0157	0.3642	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
Inlet Temperature (°F)	117.07	101.76
Outlet Temperature (°F)	113.60	102.91
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	115.34	102.33
Skin Temperature (°F)	106.18	103.43
Velocity ***	3,400.99	3.97
Reynold's Number	833**	24,235
Prandtl Number	0.7277	4.4115
Bulk Visc (lbm/ft·hr)	0.0472	1.6061
Skin Visc (lbm/ft·hr)		1.5876
Density (lbm/ft³)	0.0653	61.9643
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0156	0.3637

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,181.90
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.28
Effective Area (ft²)	905.33
LMTD	12.92
Total Heat Transferred (BTU/hr)	61,737
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	61,737
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,166.65	53,702.59
Inlet Temperature (°F)	113.60	100.79
Outlet Temperature (°F)	110.71	101.76
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	112.15	101.27
Skin Temperature (°F)	104.49	102.20
Velocity ***	3,400.99	3.97
Reynold's Number	837**	23,965
Prandtl Number	0.7279	4.4663
Bulk Visc (lbm/ft·hr)	0.0470	1.6242
Skin Visc (lbm/ft·hr)		1.6084
Density (lbm/ft³)	0.0656	61.9780
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0155	0.3633

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,174.58
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.27
Effective Area (ft²)	905.33
LMTD	10.81
Total Heat Transferred (BTU/hr)	51,562
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	51,562
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,166.65	53,702.59
Inlet Temperature (°F)	110.71	99.99
Outlet Temperature (°F)	108.29	100.79
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	109.50	100.39
Skin Temperature (°F)	103.09	101.17
Velocity ***	3,400.99	3.97
Reynold's Number	840**	23,740
Prandtl Number	0.7281	4.5129
Bulk Visc (lbm/ft·hr)	0.0468	1.6396
Skin Visc (lbm/ft·hr)		1.6261
Density (lbm/ft³)	0.0659	61.9893
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0154	0.3629

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,168.45
j Factor	0.0080
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
U Overall (BTU/hr·ft²·°F)	5.26
Effective Area (ft²)	905.33
LMTD	9.05
Total Heat Transferred (BTU/hr)	43,086
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	43,086
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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
	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

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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Limiting Flow Analysis -- 115 gpm Case

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·ft²·°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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	139.18	107.45
Outlet Temperature (°F)	131.90	109.72
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	135.54	108.58
Skin Temperature (°F)	116.48	110.70
Velocity ***	3,402.31	4.24
Reynold's Number	811**	27,532
Prandtl Number	0.7262	4.1080
Bulk Visc (lbm/ft·hr)	0.0485	1.5054
Skin Visc (lbm/ft·hr)		1.4737
Density (lbm/ft³)	0.0633	61.8799
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0160	0.3660

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,288.13
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.24
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.35
Effective Area (ft²)	905.33
LMTD	26.78
Total Heat Transferred (BTU/hr)	129,763
Surface Effectiveness (Eta)	0.9186
Sensible Heat Transferred (BTU/hr)	129,763
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	131.90	105.57
Outlet Temperature (°F)	125.87	107.45
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	128.88	106.51
Skin Temperature (°F)	113.06	108.28
Velocity ***	3,402.31	4.23
Reynold's Number	818**	26,955
Prandtl Number	0.7268	4.2049
Bulk Visc (lbm/ft·hr)	0.0480	1.5376
Skin Visc (lbm/ft·hr)		1.5101
Density (lbm/ft³)	0.0639	61.9086
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0159	0.3653

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,273.11
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.21
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.33
Effective Area (ft²)	905.33
LMTD	22.23
Total Heat Transferred (BTU/hr)	107,371
Surface Effectiveness (Eta)	0.9189
Sensible Heat Transferred (BTU/hr)	107,371
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 4(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	125.87	104.01
Outlet Temperature (°F)	120.87	105.57
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	123.37	104.79
Skin Temperature (°F)	110.23	106.27
Velocity ***	3,402.31	4.23
Reynold's Number	824**	26,480
Prandtl Number	0.7272	4.2880
Bulk Visc (lbm/ft·hr)	0.0477	1.5652
Skin Visc (lbm/ft·hr)		1.5414
Density (lbm/ft³)	0.0645	61.9318
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0158	0.3646

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,260.64
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.19
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.32
Effective Area (ft²)	905.33
LMTD	18.46
Total Heat Transferred (BTU/hr)	88,937
Surface Effectiveness (Eta)	0.9191
Sensible Heat Transferred (BTU/hr)	88,937
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 5(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	120.87	102.72
Outlet Temperature (°F)	116.73	104.01
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	118.80	103.36
Skin Temperature (°F)	107.89	104.60
Velocity ***	3,402.31	4.23
Reynold's Number	829**	26,089
Prandtl Number	0.7275	4.3589
Bulk Visc (lbm/ft·hr)	0.0474	1.5887
Skin Visc (lbm/ft·hr)		1.5682
Density (lbm/ft³)	0.0649	61.9508
Cp (BTU/lbm·°F)	0.2402	0.9989
K (BTU/hr·ft·°F)	0.0157	0.3641

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,250.27
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.17
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.31
Effective Area (ft²)	905.33
LMTD	15.34
Total Heat Transferred (BTU/hr)	73,733
Surface Effectiveness (Eta)	0.9192
Sensible Heat Transferred (BTU/hr)	73,733
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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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 6(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	116.73	101.65
Outlet Temperature (°F)	113.30	102.72
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	115.02	102.18
Skin Temperature (°F)	105.94	103.22
Velocity ***	3,402.31	4.23
Reynold's Number	834**	25,766
Prandtl Number	0.7277	4.4190
Bulk Visc (lbm/ft·hr)	0.0472	1.6086
Skin Visc (lbm/ft·hr)		1.5911
Density (lbm/ft³)	0.0653	61.9663
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0156	0.3636

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,241.66
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.15
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.30
Effective Area (ft²)	905.33
LMTD	12.75
Total Heat Transferred (BTU/hr)	61,173
Surface Effectiveness (Eta)	0.9194
Sensible Heat Transferred (BTU/hr)	61,173
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

Extrapolation Calculation for Row 7(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	113.30	100.76
Outlet Temperature (°F)	110.45	101.65
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	111.87	101.20
Skin Temperature (°F)	104.33	102.07
Velocity ***	3,402.31	4.23
Reynold's Number	837**	25,499
Prandtl Number	0.7279	4.4700
Bulk Visc (lbm/ft·hr)	0.0470	1.6254
Skin Visc (lbm/ft·hr)		1.6106
Density (lbm/ft³)	0.0656	61.9789
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0155	0.3633

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,234.50
j Factor	0.0081
Air-Side ho (BTU/hr·ft²·°F)	8.14
Tube Wall Resistance (hr·ft²·°F/BTU	0.00031430
Overall Fouling (hr·ft²·°F/BTU)	0.03976622
U Overall (BTU/hr·ft²·°F)	5.29
Effective Area (ft²)	905.33
LMTD	10.60
Total Heat Transferred (BTU/hr)	50,784
Surface Effectiveness (Eta)	0.9195
Sensible Heat Transferred (BTU/hr)	50,784
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Extrapolation Calculation for Row 8(Dry)

	Air-Side	Tube-Side
Mass Flow (lbm/hr)	71,194.37	57,183.32
Inlet Temperature (°F)	110.45	100.02
Outlet Temperature (°F)	108.08	100.76
Inlet Specific Humidity	0.0203	
Outlet Specific Humidity	0.0203	
Average Temp (°F)	109.26	100.39
Skin Temperature (°F)	102.99	101.11
Velocity ***	3,402.31	4.23
Reynold's Number	840**	25,278
Prandtl Number	0.7281	4.5130
Bulk Visc (lbm/ft·hr)	0.0468	1.6396
Skin Visc (lbm/ft·hr)		1.6270
Density (lbm/ft³)	0.0659	61.9894
Cp (BTU/lbm·°F)	0.2402	0.9990
K (BTU/hr·ft·°F)	0.0154	0.3629

** Reynolds Number Outside Range of Equation Applicability

Tube-Side hi (BTU/hr·ft²·°F)	1,228.54
j Factor	0.0080
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
U Overall (BTU/hr·ft²·°F)	5.28
Effective Area (ft²)	905.33
LMTD	8.82
Total Heat Transferred (BTU/hr)	42,181
Surface Effectiveness (Eta)	0.9196
Sensible Heat Transferred (BTU/hr)	42,181
Latent Heat Transferred (BTU/hr)	
Heat to Condensate (BTU/hr)	

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment J to
Proto-Power Calculation
97-200
Revision A

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) $q = U\, A_o\, LMTD$

Where:

q = Heat transfer rate at test conditions (BTU/hr)
U = Overall heat transfer coefficient at test conditions (BTU/hr-°F-ft^2)
A_o = 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)
$\dot{m}$ = Mass flow rate at test conditions (lbm/hr)
c_p = 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 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:

3) $$R = \frac{1}{U} = \frac{A_o \, LMTD_{Test}}{q_{Test}}$$

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_o = Outside heat transfer surface area (ft²)
- LMTD = Log Mean Temperature Difference at test conditions (°F)
- q = Heat transfer rate at test conditions (BTU/hr)

and

4) $$R_f = R - \frac{1}{h_o \eta_s} - R_w - \left(\frac{A_o}{A_i}\right)\frac{1}{h_i}$$

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_s = Fin surface effectiveness
- R_w = Wall thermal resistance at test conditions (hr-°F-ft²/ BTU)
- A_o = Outside heat transfer surface area (ft²)
- A_i = Inside heat transfer surface area (ft²)
- 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-°F-ft²/ BTU)
- h_{o*} = 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-°F-ft²/ BTU)
- A_o = Outside heat transfer surface area (ft²)
- A_i = Inside heat transfer surface area (ft²)

h_i* = Inside convection film coefficient at extrapolation conditions ($BTU/hr\text{-}°F\text{-}ft^2$)

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 ($hr\text{-}°F\text{-}ft^2/\ BTU$)
- U* = Overall heat coefficient at extrapolation conditions ($BTU/hr\text{-}°F\text{-}ft^2$)
- 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., ΔD) due to changes in each of the independent variables (ΔA, ΔB, ΔC) 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:

$$\frac{U_D}{D} = \left[\left(\frac{\partial D}{\partial A}\right)^2\left(\frac{\Delta A}{D}\right)^2 + \left(\frac{\partial D}{\partial B}\right)^2\left(\frac{\Delta B}{D}\right)^2 + \left(\frac{\partial D}{\partial C}\right)^2\left(\frac{\Delta C}{D}\right)^2\right]^{1/2}$$

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_o and area uncertainty, U_{A_o}

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.

1) **Uncertainty in Calculation of Heat Transfer Area (A_o)**

Governing Equation

$q = U\, A_o\, LMTD$

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:

$$A_{o_{Tube}} = \pi\, N_T N_L L_C d_o (1 - \lambda\, t_{FR})$$

$$A_{o_{Fin}} = \pi \lambda N_T N_L L_C \left[H_F t_{FT} + (H_F + d_o)\sqrt{\left(\frac{H_F - d_o}{2}\right)^2 + \left(\frac{t_{FR} - t_{FT}}{2}\right)^2} \right]$$

$$A_{o_{Total}} = \pi N_T N_L L_C \left\{ d_o (1 - \lambda\, t_{FR}) + \lambda \left[H_F t_{FT} + (H_F + d_o)\sqrt{\left(\frac{H_F - d_o}{2}\right)^2 + \left(\frac{t_{FR} - t_{FT}}{2}\right)^2} \right] \right\}$$

where:

N_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:

$$A_{o_{Total}} = \pi N_T N_L L_C \left\{ d_o (1 - \lambda\, t_F) + \lambda \left[H_F t_F + (H_F + d_o)\frac{(H_F - d_o)}{2} \right] \right\}$$

$$A_{o_{Total}} = \pi N_T N_L L_C \left\{ d_o - \lambda\, d_o t_F + \frac{\lambda}{2}\left[2 H_F t_F + H_F^2 - d_o^2 \right] \right\}$$

Assumptions

$U_{N_T} = 0$

$U_{N_L} = 0$

$U_{\lambda} = 0$

Analysis

$$\frac{U_{A_o}}{A_o} = \left\{ \left(\frac{\partial A_o}{\partial d_o}\right)^2 \left(\frac{U_{d_o}}{A_o}\right)^2 + \left(\frac{\partial A_o}{\partial L_c}\right)^2 \left(\frac{U_{L_c}}{A_o}\right)^2 + \left(\frac{\partial A_o}{\partial t_F}\right)^2 \left(\frac{U_{t_F}}{A_o}\right)^2 + \left(\frac{\partial A_o}{\partial H_F}\right)^2 \left(\frac{U_{H_F}}{A_o}\right)^2 \right\}^{1/2}$$

where,

$$\left(\frac{\partial A_o}{\partial d_o}\right) = \pi N_T N_L L_c \{(1 - \lambda t_F) - \lambda d_o\}$$

$$\left(\frac{\partial A_o}{\partial L_c}\right) = \pi N_T N_L \left\{ d_o - \lambda d_o t_F + \frac{\lambda}{2}\left[2H_F t_F + H_F^2 - d_o^2\right]\right\}$$

$$\left(\frac{\partial A_o}{\partial t_F}\right) = \pi N_T N_L L_c \lambda \{H_F - d_o\}$$

$$\left(\frac{\partial A_o}{\partial H_F}\right) = \pi N_T N_L L_c \lambda \{t_F + H_F\}$$

2) Uncertainty in Calculation of Heat Transfer Rate at Test Conditions

Governing Equation

$$q_{Test} = \dot{m} c_p (T_{c_o} - T_{c_i}) = \rho Q c_p \Delta T$$

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

$$\frac{U_{q_{test}}}{q_{test}} = \left[\left(\frac{\partial q_{test}}{\partial \rho} \right)^2 \left(\frac{U_\rho}{q_{test}} \right)^2 + \left(\frac{\partial q_{test}}{\partial Q_{SW}} \right)^2 \left(\frac{U_Q}{q_{test}} \right)^2 + \left(\frac{\partial q_{test}}{\partial c_p} \right)^2 \left(\frac{U_{c_p}}{q_{test}} \right)^2 + \left(\frac{\partial q_{test}}{\partial \Delta T} \right)^2 \left(\frac{U_{\Delta T}}{q_{test}} \right)^2 \right]^{1/2}$$

$$\frac{U_{q_{test}}}{q_{test}} = \left[(Q_{SW}\, c_p\, \Delta T)^2 \left(\frac{U_\rho}{q_{test}} \right)^2 + (\rho Q_{SW}\, \Delta T)^2 \left(\frac{U_{c_p}}{q_{test}} \right)^2 \right]^{1/2}$$

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_{LMTD} is negligible

Analysis

$$\frac{U_R}{R} = \left[\left(\frac{\partial R}{\partial A_o}\right)^2\left(\frac{U_{A_o}}{R}\right)^2 + \left(\frac{\partial R}{\partial LMTD}\right)^2\left(\frac{U_{LMTD}}{R}\right)^2 + \left(\frac{\partial R}{\partial q_{test}}\right)^2\left(\frac{U_{q_{test}}}{R}\right)^2\right]^{1/2}$$

$$\frac{U_R}{R} = \left[\left(\frac{LMTD}{q_{test}}\right)^2\left(\frac{U_{A_o}}{R}\right)^2 + \left(\frac{-A_o LMTD}{q_{test}^2}\right)^2\left(\frac{U_{q_{test}}}{R}\right)^2\right]^{1/2}$$

U_{A_o} (Evaluated in Section 1)

$U_{q_{test}}$ (Evaluated in Section 2)

4) **Uncertainty in Calculation of Fouling Factor at Test Conditions**

Governing Equation

$$R_f = R - \frac{1}{h_o \eta_s} - R_w - \left(\frac{A_o}{A_i}\right)\frac{1}{h_i} = R - \frac{1}{h_{o,eff}} - R_w - \left(\frac{A_o}{A_i}\right)\frac{1}{h_i}$$

Where,

$h_{o,eff}$ = effective outside film coefficient = (h_o) x (η_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

$$\frac{U_{R_f}}{R_f} = \left[\left(\frac{\partial R_f}{\partial R}\right)^2\left(\frac{U_R}{R_f}\right)^2 + \left(\frac{\partial R_f}{\partial h_{o,eff}}\right)^2\left(\frac{U_{h_{o,eff}}}{R_f}\right)^2 + \left(\frac{\partial R_f}{\partial R_w}\right)^2\left(\frac{U_{R_w}}{R_f}\right)^2 + \left(\frac{\partial R_f}{\partial h_i}\right)^2\left(\frac{U_{h_i}}{R_f}\right)^2\right]^{1/2}$$

$$\frac{U_{R_f}}{R_f} = \left[\left(\frac{U_R}{R_f}\right)^2 + \left(\frac{1}{h_{o,eff}^2}\right)^2\left(\frac{U_{h_{o,eff}}}{R_f}\right)^2 + \left(\frac{U_{R_w}}{R_f}\right)^2 + \left(\frac{A_o}{A_i}\frac{1}{h_i^2}\right)^2\left(\frac{U_{h_i}}{R_f}\right)^2\right]^{1/2}$$

U_R (Evaluated in Section 3)

5) **Uncertainty in Calculation of Heat Transfer Resistance at Extrapolation Conditions**

Governing Equation

$$R^* = R_f + \frac{1}{h_{o,eff}^*} + R_w + \left(\frac{A_o}{A_i}\right)\frac{1}{h_i^*}$$

Assumptions

$$\left(\frac{\partial R^*}{\partial A_o}\right)^2\left(\frac{U_{A_o}}{R^*}\right)^2 \approx 0$$

$$\left(\frac{\partial R^*}{\partial A_i}\right)^2\left(\frac{U_{A_i}}{R^*}\right)^2 \approx 0$$

(i.e., the uncertainty in dimensions is negligible compared to the thermal resistance and convection coefficient uncertainties)

Analysis

$$\frac{U_{R^*}}{R^*} = \left[\left(\frac{\partial R^*}{\partial R_f}\right)^2\left(\frac{U_{R_f}}{R^*}\right)^2 + \left(\frac{\partial R^*}{\partial h_{o,eff}^*}\right)^2\left(\frac{U_{h_{o,eff}^*}}{R^*}\right)^2 + \left(\frac{\partial R^*}{\partial R_w}\right)^2\left(\frac{U_{R_w}}{R^*}\right)^2 + \left(\frac{\partial R^*}{\partial h_i^*}\right)^2\left(\frac{U_{h_i^*}}{R^*}\right)^2\right]^{1/2}$$

$$\frac{U_{R^*}}{R^*} = \left[\left(\frac{U_{R_f}}{R^*}\right)^2 + \left(-\frac{1}{h_{o,eff}^{*2}}\right)^2\left(\frac{U_{h_{o,eff}^*}}{R^*}\right)^2 + \left(\frac{U_{R_w}}{R^*}\right)^2 + \left(-\frac{A_o}{A_i}\frac{1}{h_i^{*2}}\right)^2\left(\frac{U_{h_i^*}}{R^*}\right)^2\right]^{1/2}$$

U_{R_f} (Evaluated in Section 4)

$U_{R_f} = 0$ (for extrapolation calculations only, i.e., no fouling calculation)

6) **Uncertainty in Calculation of Heat Transfer Rate at Extrapolation Conditions**

Governing Equation

$q^* = (1/R^*)\,(A_o)\,(LMTD^*)$

Assumptions

$U_{LMTD} \approx 0.0$

Analysis

$$\frac{U_{q^*}}{q^*} = \left[\left(\frac{\partial q^*}{\partial R^*}\right)^2 \left(\frac{U_{R^*}}{q^*}\right)^2 + \left(\frac{\partial q^*}{\partial A_o}\right)^2 \left(\frac{U_{Q^*}}{q^*}\right)^2 + \left(\frac{\partial q^*}{\partial (LMTD^*)}\right)^2 \left(\frac{U_{LMTD^*}}{q^*}\right)^2\right]^{1/2}$$

$$\frac{U_q^*}{q^*} = \left[\left(-R^{*-2} A_o\ LMTD^*\right)^2 \left(\frac{U_{R^*}}{q^*}\right)^2 + \left(\frac{1}{R^*} LMTD^*\right)^2 \left(\frac{U_{A_o}}{q^*}\right)^2\right]^{1/2}$$

U_R (Evaluated in Section 5)

U_{A_o} (Evaluated in Section 1)

7) **Uncertainty in Calculation of Extrapolated Heat Transfer for Entire Unit**

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.

$q_{tot} = q_1 + q_2 + q_3 \ldots\ldots + q_n$

where, " n " is the number of tube rows in the unit.

$$\frac{Uq_{tot}}{q_{tot}} = \left[\left(\frac{\partial q_{tot}}{\partial q_1}\right)^2 \left(\frac{Uq_1}{q_{tot}}\right)^2 + \left(\frac{\partial q_{tot}}{\partial q_2}\right)^2 \left(\frac{Uq_2}{q_{tot}}\right)^2 + \left(\frac{\partial q_{tot}}{\partial q_2}\right)^2 \left(\frac{Uq_3}{q_{tot}}\right)^2 + \ldots\ldots\ldots\ldots \left(\frac{\partial q_{tot}}{\partial q_n}\right)^2 \left(\frac{Uq_n}{q_{tot}}\right)^2 \right]^{1/2}$$

Assuming that the extrapolated heat transfer rates of the various rows do not depend on each other, the above expression becomes:

$$\frac{Uq_{tot}}{q_{tot}} = \left[\left(\frac{Uq_1}{q_{tot}}\right)^2 + \left(\frac{Uq_2}{q_{tot}}\right)^2 + \left(\frac{Uq_3}{q_{tot}}\right)^2 + \ldots\ldots\ldots\ldots \left(\frac{Uq_n}{q_{tot}}\right)^2 \right]^{1/2}$$

Definition of Analytical Uncertainty Analysis Terms

Ao/Ai =	Heat transfer area ratio
di (in) =	Tube inside diameter
Ao (ft^2) =	Outside heat transfer area
do (in) =	Tube outside diameter
Udo/do (%) =	Uncertainty in tube outside diameter (as a percentage)
Udo =	Uncertainty in tube outside diameter (absolute)
Nt =	Number of tubes in given row
Nl =	Number of rows in heat exchanger
Lambda (fins/in) =	Fin pitch
L (Ft) =	Tube length
UL/L (%) =	Uncertainty in tube length (as a percentage)
UL(ft) =	Uncertainty in tube length (absolute)
tfin (in) =	Fin thickness
Utfin/tfin (%) =	Uncertainty in fin thickness (as a percentage)
Utfin (in) =	Uncertainty in fin thickness (absolute)
hfin (in) =	Fin height
Uhfin/hfin (%) =	Uncertainty in fin height (as a percentage)
Uhfin (in) =	Uncertainty in fin height (absolute)
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
Urho/rho (%) =	Uncertainty in cooling water density (as a percentage)
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)
qtest (Btu/hr) =	Calculated test heat transfer for coil section
LMTD (DegF) =	Calculated log mean temperature difference
Uo =	Heat transfer coefficient
R = (1/Uo) =	Heat transfer resistance
Rf [(hr-DegF-ft^2)/Btu] =	Fouling resistance
Etas =	
ho [Btu/(hr-DegF-ft^2)] =	Outside film coefficient
ho(eff) [Btu/(hr-DegF-ft^2)] =	Effective outside film coefficient
Uho/ho (%) =	Uncertainty in outside film coefficient (as a percentage)
Uho =	Uncertainty in outside film coefficient (absolute)
hi [Btu/(hr-DegF-ft^2)] =	Inside film coefficient
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)

Analytical Uncertainty Analysis -- Uncertainty Inputs

Parameter	Definition	Value (%)	
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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PROTO-HX 3.01 by Proto-Power Corporation (SN#PHX-0000) 06/22/98
ComEd -- LaSalle
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	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	%	
Tube Fluid Name		Fresh Water
Tube Fouling Factor		0.002
Air-Side Fouling		0.002
Design Heat Transfer (BTU/hr)		750000
Atmospheric Pressure		14.315
Sensible Heat Ratio		1
Performance Factor (% Reduction)		0
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)		104.25
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
Number of Coils Per Unit		2.000
Number of Tube Rows		8.000
Number of Tubes Per Row		20
Active Tubes Per Row		20
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
Tube Wall Conductivity (BTU/hr·ft·°F)		225

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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

Extrapolation Calculation Summary

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71166.65	53702.59	Tube-Side hi (BTU/hr·ft^2·°F)	
Inlet Temperature (°F)	148	100	j Factor	
Outlet Temperature (°F)	108.2854	113.1719	Air-Side ho (BTU/hr·ft^2·°F)	
Inlet Specific Humidity			Tube Wall Resistance (hr·ft^2·°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·ft^2·°F)	
Velocity ***			Effective Area (ft^2)	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/ft^3)			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·ft^2·°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·ft^2·°F)	8.272452
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft^2·°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·ft^2·°F)	5.351471
Velocity ***	3400.987	3.981516	Effective Area (ft^2)	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 (lbm/ft^3)	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)	

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 2(Dry)

	Air-Side	Tube-Side		
Mass Flow (lbm/hr)	71166.65	53702.59	Tube-Side hi (BTU/hr·ft^2·°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·ft^2·°F)	8.238629
Inlet Specific Humidity	0.020268		Tube Wall Resistance (hr·ft^2·°F/BTU)	0.000314
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft^2·°F/BTU)	0.039766
Average Temp (°F)	135.7735	109.114		
Skin Temperature (°F)	116.9946	111.2983	U Overall (BTU/hr·ft^2·°F)	5.330976
Velocity ***	3400.987	3.979115	Effective Area (ft^2)	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/ft^3)	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)	

** Reynolds Number Outside Range of Equation Applicability

Extrapolation Calculation for Row 3(Dry)

	Air-Side	Tube-Side

Mass Flow (lbm/hr)	71166.65	53702.59	Tube-Side hi (BTU/hr·ft²·°F)	1213.64
Inlet Temperature (°F)	132.1832	105.9385	j Factor	0.008123
Outlet Temperature (°F)	126.2057	107.9223	Air-Side ho (BTU/hr·ft²·°F)	8.210501
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)	129.1941	106.9309		
Skin Temperature (°F)	113.5129	108.7712	U Overall (BTU/hr·ft²·°F)	5.313799
Velocity ***	3400.987	3.977169	Effective Area (ft²)	905.3315
Reynold's Number	817.7239 **	25424.42	LMTD	22.12061
Prandtl Number	0.726741	4.184867	Total Heat Transferred (BTU/hr)	106416.7
Bulk Visc (lbm/ft·hr)	0.048065	1.530964		
Skin Visc (lbm/ft·hr)		1.502521	Surface Effectiveness (Eta)	0.918865
Density (lbm/ft³)	0.063881	61.90278	Sensible Heat Transferred (BTU/hr)	106416.7
Cp (BTU/lbm·°F)	0.240245	0.998873	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.015889	0.365416	Heat to Condensate (BTU/hr)	

** 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)	

** 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)	

** Reynolds Number Outside Range of Equation Applicability

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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/hr·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

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)	115.3358	102.3309		
Skin Temperature (°F)	106.1782	103.4274	U Overall (BTU/hr·ft²·°F)	5.277229
Velocity ***	3400.987	3.973217	Effective Area (ft²)	905.3315
Reynold's Number	832.9599 **	24235.25	LMTD	12.92208
Prandtl Number	0.727713	4.411482	Total Heat Transferred (BTU/hr)	61737.04
Bulk Visc (lbm/ft·hr)	0.047186	1.606085		
Skin Visc (lbm/ft·hr)		1.587634	Surface Effectiveness (Eta)	0.91939
Density (lbm/ft³)	0.065285	61.96434	Sensible Heat Transferred (BTU/hr)	61737.04
Cp (BTU/lbm·°F)	0.240244	0.998954	Latent Heat Transferred (BTU/hr)	
K (BTU/hr·ft·°F)	0.015578	0.363684	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·ft²·°F/BTU)	0.000314
Outlet Specific Humidity	0.020268		Overall Fouling (hr·ft²·°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)	

** 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·ft²·°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)	0.046811	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

*** 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)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =	[redacted]
Ai (ft^2) =	[redacted]
Ao (ft^2) =	[redacted]
Ao/Ai =	[redacted]
do (ft) =	[redacted]
Udo/do (%) =	[redacted]
Udo (ft) =	[redacted]
Nt =	[redacted]
Nl =	[redacted]
Lambda (fins/ft) =	[redacted]
L (ft) =	[redacted]
UL/L (%) =	[redacted]
UL(ft) =	[redacted]
tfin (ft) =	[redacted]
Utfin/tfin (%) =	[redacted]
Utfin (ft) =	[redacted]
hfin (ft) =	[redacted]
Uhfin/hfin (%) =	[redacted]
Uhfin (ft) =	[redacted]
Mdotc (lbm/hr) =	[redacted]
Q (Ft^3/hr) =	[redacted]
DT (DegF) =	[redacted]
rho (lbm/ft^3) =	[redacted]
Urho/rho (%) =	[redacted]
Urho =	[redacted]
Cp (Btu/lbm/DegF) =	[redacted]
UCp/Cp (%) =	[redacted]
UCp =	[redacted]
q (Btu/hr) =	[redacted]
LMTD (DegF) =	[redacted]
Uo =	[redacted]
R = (1/Uo) =	[redacted]
Rf [(hr-DegF-ft^2)/Btu] =	[redacted]
Etas =	[redacted]
ho [Btu/(hr-DegF-ft^2)] =	[redacted]
ho(eff) [Btu/(hr-DegF-ft^2)] =	[redacted]
Uho/ho (%) =	[redacted]
Uho =	[redacted]
hi [Btu/(hr-DegF-ft^2)] =	[redacted]
Uhi/hi (%) =	[redacted]
Uhi =	[redacted]
Rw [(hr-DegF-ft^2)/Btu] =	[redacted]
URw/Rw (%) =	[redacted]
URw =	[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	868.4794234
DT* (DegF) =	2.86638485
rho* (lbm/ft^3) =	61.83519479
Urho*/rho* (%) =	2
Urho* =	1.236703896
Cp* (Btu/lbm/DegF) =	0.998820251
UCp*/Cp* (%) =	2
UCp* =	0.019976405
q* (Btu/hr) =	153749.4783
LMTD* (DegF) =	31.73458665
Uo* =	5.351471122
R* = (1/Uo*) =	0.186864505
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.918316031
ho* [Btu/(hr-DegF-ft^2)] =	8.27245205
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.596725335
Uho*/ho* (%) =	15
Uho* =	1.1395088
hi* [Btu/(hr-DegF-ft^2)] =	1246.548746
Uhi*/hi* (%) =	15
Uhi* =	186.9823119
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

Proto-Power Calc: 97-200
Attachment: J
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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

[redacted]

3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):

[redacted]

4 Analytical Uncertainty in Observed Rf

[redacted]

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*	Ao	UAo	LMTD*	Uq*/q*	Uq*
153749.4783	0.18686	0.02026	905.33147	36.82236	31.73459	0.11581	17805.20662

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate
(Row 2)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =	[illegible]
Ai (ft^2) =	[illegible]
Ao (ft^2) =	[illegible]
Ao/Ai =	[illegible]
do (ft) =	[illegible]
Udo/do (%) =	[illegible]
Udo (ft) =	[illegible]
Nt =	[illegible]
Nl =	[illegible]
Lambda (fins/ft) =	[illegible]
L (ft) =	[illegible]
UL/L (%) =	[illegible]
UL(ft) =	[illegible]
tfin (ft) =	[illegible]
Utfin/tfin (%) =	[illegible]
Utfin (ft) =	[illegible]
hfin (ft) =	[illegible]
Uhfin/hfin (%) =	[illegible]
Uhfin (ft) =	[illegible]
Mdotc (lbm/hr) =	[illegible]
Q (Ft^3/hr) =	[illegible]
DT (DegF) =	[illegible]
rho (lbm/ft^3) =	[illegible]
Urho/rho (%) =	[illegible]
Urho =	[illegible]
Cp (Btu/lbm/DegF) =	[illegible]
UCp/Cp (%) =	[illegible]
UCp =	[illegible]
q (Btu/hr) =	[illegible]
LMTD (DegF) =	[illegible]
Uo =	[illegible]
R = (1/Uo) =	[illegible]
Rf [(hr-DegF-ft^2)/Btu] =	[illegible]
Etas =	[illegible]
ho [Btu/(hr-DegF-ft^2)] =	[illegible]
ho(eff) [Btu/(hr-DegF-ft^2)] =	[illegible]
Uho/ho (%) =	[illegible]
Uho =	[illegible]
hi [Btu/(hr-DegF-ft^2)] =	[illegible]
Uhi/hi (%) =	[illegible]
Uhi =	[illegible]
Rw [(hr-DegF-ft^2)/Btu] =	[illegible]
URw/Rw (%) =	[illegible]
URw =	[illegible]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	867.9558527
DT* (DegF) =	2.383163429
rho* (lbm/ft^3) =	61.87249518
Urho*/rho* (%) =	2
Urho* =	1.237449904
Cp* (Btu/lbm/DegF) =	0.998845052
UCp*/Cp* (%) =	2
UCp* =	0.019976901
q* (Btu/hr) =	127832.8305
LMTD* (DegF) =	26.4867136
Uo* =	5.3309758
R* = (1/Uo*) =	0.187582919
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.918615579
ho* [Btu/(hr-DegF-ft^2)] =	8.238028585
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.568132571
Uho*/ho* (%) =	15
Uho* =	1.135219886
hi* [Btu/(hr-DegF-ft^2)] =	1228.617186
Uhi*/hi* (%) =	15
Uhi* =	184.2925779
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 2)

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

[redacted]

3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):

[redacted]

4 Analytical Uncertainty in Observed Rf

[redacted]

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*
127832.8305	0.18758	0.02035	905.33147	36.82236	26.48671	0.11586	14810.09844

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate
(Row 3)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =
Ai (ft^2) =
Ao (ft^2) =
Ao/Ai =
do (ft) =
Udo/do (%) =
Udo (ft) =

Nt =
Nl =
Lambda (fins/ft) =
L (ft) =
UL/L (%) =
UL(ft) =

tfin (ft) =
Utfin/tfin (%) =
Utfin (ft) =

hfin (ft) =
Uhfin/hfin (%) =
Uhfin (ft) =

Mdotc (lbm/hr) =
Q (Ft^3/hr) =
DT (DegF) =
rho (lbm/ft^3) =
Urho/rho (%) =
Urho =

Cp (Btu/lbm/DegF) =
UCp/Cp (%) =
UCp =

q (Btu/hr) =
LMTD (DegF) =
Uo =
R = (1/Uo) =
Rf [(hr-DegF-ft^2)/Btu] =
Etas =
ho [Btu/(hr-DegF-ft^2)] =
ho(eff) [Btu/(hr-DegF-ft^2)] =
Uho/ho (%) =
Uho =

hi [Btu/(hr-DegF-ft^2)] =
Uhi/hi (%) =
Uhi =

Rw [(hr-DegF-ft^2)/Btu] =
URw/Rw (%) =
URw =

[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314730
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	867.5312111
DT* (DegF) =	1.98378479
rho* (lbm/ft^3) =	61.9027807
Urho*/rho* (%) =	2
Urho* =	1.238055614
Cp* (Btu/lbm/DegF) =	0.998873053
UCp*/Cp* (%) =	2
UCp* =	0.019977461
q* (Btu/hr) =	106416.6914
LMTD* (DegF) =	22.12060653
Uo* =	5.313798755
R* = (1/Uo*) =	0.188189287
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.91886488
ho* [Btu/(hr-DegF-ft^2)] =	8.210500587
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.544340639
Uho*/ho* (%) =	15
Uho* =	1.131651096
hi* [Btu/(hr-DegF-ft^2)] =	1213.639786
Uhi*/hi* (%) =	15
Uhi* =	182.0459679
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

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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**

[redacted]

3 **Analytical Uncertainty in Observed Heat Transfer Resistance (R):**

[redacted]

4 **Analytical Uncertainty in Observed Rf**

[redacted]

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*
106416.6914	0.18819	0.02042	905.33147	36.82236	22.12061	0.11590	12333.18129

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 4)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =
Ai (ft^2) =
Ao (ft^2) =
Ao/Ai =
do (ft) =
Udo/do (%) =
Udo (ft) =

Nt =
Nl =
Lambda (fins/ft) =
L (ft) =
UL/L (%) =
UL(ft) =

tfin (ft) =
Utfin/tfin (%) =
Utfin (ft) =

hfin (ft) =
Uhfin/hfin (%) =
Uhfin (ft) =

Mdotc (lbm/hr) =
Q (Ft^3/hr) =
DT (DegF) =
rho (lbm/ft^3) =
Urho/rho (%) =
Urho =

Cp (Btu/lbm/DegF) =
UCp/Cp (%) =
UCp =

q (Btu/hr) =
LMTD (DegF) =
Uo =
R = (1/Uo) =
Rf [(hr-DegF-ft^2)/Btu] =
Etas =
ho [Btu/(hr-DegF-ft^2)] =
ho(eff) [Btu/(hr-DegF-ft^2)] =
Uho/ho (%) =
Uho =

hi [Btu/(hr-DegF-ft^2)] =
Uhi/hi (%) =
Uhi =

Rw [(hr-DegF-ft^2)/Btu] =
URw/Rw (%) =
URw =

[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.70622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	867.1848829
DT* (DegF) =	1.653237217
rho* (lbm/ft^3) =	61.92750285
Urho*/rho* (%) =	2
Urho* =	1.238550057
Cp* (Btu/lbm/DegF) =	0.998901516
UCp*/Cp* (%) =	2
UCp* =	0.01997803
q* (Btu/hr) =	88680.6339
LMTD* (DegF) =	18.48393207
Uo* =	5.29940128
R* = (1/Uo*) =	0.188700562
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.919072522
ho* [Btu/(hr-DegF-ft^2)] =	8.187087926
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.524527551
Uho*/ho* (%) =	15
Uho* =	1.128679133
hi* [Btu/(hr-DegF-ft^2)] =	1201.114277
Uhi*/hi* (%) =	15
Uhi* =	180.1671416
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

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

[redacted]

3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):

[redacted]

4 Analytical Uncertainty in Observed Rf

[redacted]

5 Analytical Uncertainty in Overall Extrapolation Heat Transfer Resistance:

R*	ho*	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

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate
(Row 5)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =	[redacted]
Ai (ft^2) =	
Ao (ft^2) =	
Ao/Ai =	
do (ft) =	
Udo/do (%) =	
Udo (ft) =	
Nt =	
Nl =	
Lambda (fins/ft) =	
L (ft) =	
UL/L (%) =	
UL(ft) =	
tfin (ft) =	
Utfin/tfin (%) =	
Utfin (ft) =	
hfin (ft) =	
Uhfin/hfin (%) =	
Uhfin (ft) =	
Mdotc (lbm/hr) =	
Q (Ft^3/hr) =	
DT (DegF) =	
rho (lbm/ft^3) =	
Urho/rho (%) =	
Urho =	
Cp (Btu/lbm/DegF) =	
UCp/Cp (%) =	
UCp =	
q (Btu/hr) =	
LMTD (DegF) =	
Uo =	
R = (1/Uo) =	
Rf [(hr-DegF-ft^2)/Btu] =	
Etas =	
ho [Btu/(hr-DegF-ft^2)] =	
ho(eff) [Btu/(hr-DegF-ft^2)] =	
Uho/ho (%) =	
Uho =	
hi [Btu/(hr-DegF-ft^2)] =	
Uhi/hi (%) =	
Uhi =	
Rw [(hr-DegF-ft^2)/Btu] =	
URw/Rw (%) =	
URw =	

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	866.9018227
DT* (DegF) =	1.378817728
rho* (lbm/ft^3) =	61.94772338
Urho*/rho* (%) =	2
Urho* =	1.238954468
Cp* (Btu/lbm/DegF) =	0.99892883
UCp*/Cp* (%) =	2
UCp* =	0.019978577
q* (Btu/hr) =	73965.20571
LMTD* (DegF) =	15.45192966
Uo* =	5.287338658
R* = (1/Uo*) =	0.189131067
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.919245643
ho* [Btu/(hr-DegF-ft^2)] =	8.167578221
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.508010691
Uho*/ho* (%) =	15
Uho* =	1.126201604
hi* [Btu/(hr-DegF-ft^2)] =	1190.652195
Uhi*/hi* (%) =	15
Uhi* =	178.5978293
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 5)

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**

[redacted]

3 **Analytical Uncertainty in Observed Heat Transfer Resistance (R):**

[redacted]

4 **Analytical Uncertainty in Observed Rf**

[redacted]

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**

q*	R*	UR*	Ao	UAo	LMTD*	Uq*/q*	Uq*
73965.2057	0.18913	0.02054	905.33147	36.82236	15.45193	0.11596	8576.66300

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 6)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =
Ai (ft^2) =
Ao (ft^2) =
Ao/Ai =
do (ft) =
Udo/do (%) =
Udo (ft) =

Nt =
Nl =
Lambda (fins/ft) =
L (ft) =
UL/L (%) =
UL(ft) =

tfin (ft) =
Utfin/tfin (%) =
Utfin (ft) =

hfin (ft) =
Uhfin/hfin (%) =
Uhfin (ft) =

Mdotc (lbm/hr) =
Q (Ft^3/hr) =
DT (DegF) =
rho (lbm/ft^3) =
Urho/rho (%) =
Urho =

Cp (Btu/lbm/DegF) =
UCp/Cp (%) =
UCp =

q (Btu/hr) =
LMTD (DegF) =
Uo =
R = (1/Uo) =
Rf [(hr-DegF-ft^2)/Btu] =
Etas =
ho [Btu/(hr-DegF-ft^2)] =
ho(eff) [Btu/(hr-DegF-ft^2)] =
Uho/ho (%) =
Uho =

hi [Btu/(hr-DegF-ft^2)] =
Uhi/hi (%) =
Uhi =

Rw [(hr-DegF-ft^2)/Btu] =
URw/Rw (%) =
URw =

[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	866.6693232
DT* (DegF) =	1.150842416
rho* (lbm/ft^3) =	61.96434196
Urho*/rho* (%) =	2
Urho* =	1.239286839
Cp* (Btu/lbm/DegF) =	0.998954126
UCp*/Cp* (%) =	2
UCp* =	0.019979083
q* (Btu/hr) =	61737.04355
LMTD* (DegF) =	12.92207564
Uo* =	5.277228882
R* = (1/Uo*) =	0.189493392
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.919390072
ho* [Btu/(hr-DegF-ft^2)] =	8.151309092
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.494232656
Uho*/ho* (%) =	15
Uho* =	1.124134898
hi* [Btu/(hr-DegF-ft^2)] =	1181.899042
Uhi*/hi* (%) =	15
Uhi* =	177.2848562
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-08

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 6)

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

[redacted]

3 Analytical Uncertainty in Observed Heat Transfer Resistance (R):

[redacted]

4 Analytical Uncertainty in Observed Rf

[redacted]

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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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 7)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =
Ai (ft^2) =
Ao (ft^2) =
Ao/Ai =
do (ft) =
Udo/do (%) =
Udo (ft) =

Nt =
Nl =
Lambda (fins/ft) =
L (ft) =
UL/L (%) =
UL(ft) =

tfin (ft) =
Utfin/tfin (%) =
Utfin (ft) =

hfin (ft) =
Uhfin/hfin (%) =
Uhfin (ft) =

Mdotc (lbm/hr) =
Q (Ft^3/hr) =
DT (DegF) =
rho (lbm/ft^3) =
Urho/rho (%) =
Urho =

Cp (Btu/lbm/DegF) =
UCp/Cp (%) =
UCp =

q (Btu/hr) =
LMTD (DegF) =
Uo =
R = (1/Uo) =
Rf [(hr-DegF-ft^2)/Btu] =
Etas =
ho [Btu/(hr-DegF-ft^2)] =
ho(eff) [Btu/(hr-DegF-ft^2)] =
Uho/ho (%) =
Uho =

hi [Btu/(hr-DegF-ft^2)] =
Uhi/hi (%) =
Uhi =

Rw [(hr-DegF-ft^2)/Btu] =
URw/Rw (%) =
URw =

[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622391
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Nl =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	866.4778558
DT* (DegF) =	0.961153774
rho* (lbm/ft^3) =	61.97803436
Urho*/rho* (%) =	2
Urho* =	1.239560687
Cp* (Btu/lbm/DegF) =	0.998976998
UCp*/Cp* (%) =	2
UCp* =	0.01997954
q* (Btu/hr) =	51562.15469
LMTD* (DegF) =	10.80974049
Uo* =	5.268757019
R* = (1/Uo*) =	0.189798086
Rf [(hr-DegF-ft^2)/Btu] =	0.039765224
Etas =	0.919510644
ho* [Btu/(hr-DegF-ft^2)] =	8.137732539
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.482731685
Uho*/ho* (%) =	15
Uho* =	1.122409753
hi* [Btu/(hr-DegF-ft^2)] =	1174.576497
Uhi*/hi* (%) =	15
Uhi* =	176.1864745
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

Proto-Power Calc: 97-200
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 7)

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**

[redacted]

3 **Analytical Uncertainty in Observed Heat Transfer Resistance (R):**

[redacted]

4 **Analytical Uncertainty in Observed Rf**

[redacted]

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

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 8)

I. PROTO-HX Output -- Fouling Calculation

di (ft) =
Ai (ft^2) =
Ao (ft^2) =
Ao/Ai =
do (ft) =
Udo/do (%) =
Udo (ft) =

Nt =
Ni =
Lambda (fins/ft) =
L (ft) =
UL/L (%) =
UL(ft) =

tfin (ft) =
Utfin/tfin (%) =
Utfin (ft) =

hfin (ft) =
Uhfin/hfin (%) =
Uhfin (ft) =

Mdotc (lbm/hr) =
Q (Ft^3/hr) =
DT (DegF) =
rho (lbm/ft^3) =
Urho/rho (%) =
Urho =

Cp (Btu/lbm/DegF) =
UCp/Cp (%) =
UCp =

q (Btu/hr) =
LMTD (DegF) =
Uo =
R = (1/Uo) =
Rf [(hr-DegF-ft^2)/Btu] =
Etas =
ho [Btu/(hr-DegF-ft^2)] =
ho(eff) [Btu/(hr-DegF-ft^2)] =
Uho/ho (%) =
Uho =

hi [Btu/(hr-DegF-ft^2)] =
Uhi/hi (%) =
Uhi =

Rw [(hr-DegF-ft^2)/Btu] =
URw/Rw (%) =
URw =

[redacted]

II. PROTO-HX Output -- Extrapolation Calculation

di (ft) =	0.043916667
Ai (ft^2) =	23.97198819
Ao (ft^2) =	905.3314736
Ao/Ai =	37.76622301
do (ft) =	0.052083333
Udo/do (%) =	8
Udo (ft) =	0.004166667
Nt =	20
Ni =	2
Lambda (fins/ft) =	120
L (ft) =	8.6875
UL/L (%) =	0.24
UL(ft) =	0.02085
tfin (ft) =	0.001
Utfin/tfin (%) =	4.17
Utfin (ft) =	0.0000417
hfin (ft) =	0.124583333
Uhfin/hfin (%) =	1.34
Uhfin (ft) =	0.001669417
Mdotc* (lbm/hr) =	53702.59431
Q* (Ft^3/hr) =	866.3197684
DT* (DegF) =	0.803149924
rho* (lbm/ft^3) =	61.9893442
Urho*/rho* (%) =	2
Urho* =	1.239786884
Cp* (Btu/lbm/DegF) =	0.998987031
UCp*/Cp* (%) =	2
UCp* =	0.019979741
q* (Btu/hr) =	43086.42909
LMTD* (DegF) =	9.045035483
Uo* =	5.261657907
R* = (1/Uo*) =	0.190054165
Rf [(hr-DegF-ft^2)/Btu] =	0.039766224
Etas =	0.919611352
ho* [Btu/(hr-DegF-ft^2)] =	8.126396117
ho*(eff) [Btu/(hr-DegF-ft^2)] =	7.47312612
Uho*/ho* (%) =	15
Uho* =	1.120968918
hi* [Btu/(hr-DegF-ft^2)] =	1168.449288
Uhi*/hi* (%) =	15
Uhi* =	175.2673932
Rw* [(hr-DegF-ft^2)/Btu] =	0.0003143
URw*/Rw* (%) =	2
URw* =	6.28601E-06

Proto-Power Calc: 97-200
Attachment: J
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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate (Row 8)

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**

[redacted]

3 **Analytical Uncertainty in Observed Heat Transfer Resistance (R):**

[redacted]

4 **Analytical Uncertainty in Observed Rf**

[redacted]

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

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate

	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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Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate

	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)

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate

	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)

Analytical Uncertainty Calculation for Extrapolation Heat Transfer Rate

	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**

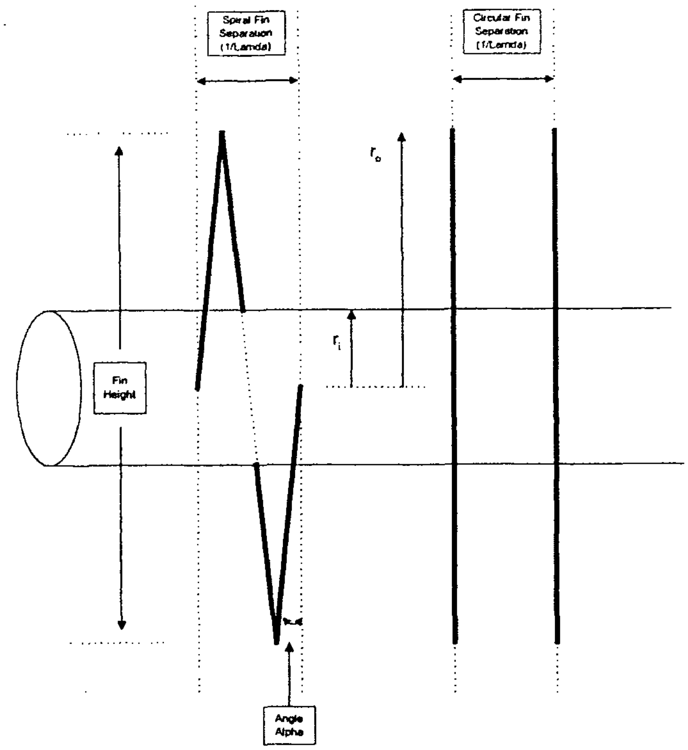
Uqtot/qtot = **4.88%** (150 gpm case)

Attachment K to
Proto-Power Calculation
97-200
Revision A

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:

$$A_{cf} = 2\int_{ri}^{ro}\int_{0}^{2\pi} rdrd\theta = 2\pi(r_o^2 - r_i^2)$$

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

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:

$$\tan\alpha = \frac{\frac{1}{4}(\text{fin separation})}{r_o} = \frac{1}{4 r_o \lambda}$$

$$\alpha = \tan^{-1}\left(\frac{1}{4 r_o \lambda}\right)$$

where:
λ = fin pitch

Substituting fin height into the expression yields the following:

$$\alpha = \tan^{-1}\left(\frac{2}{4 H_f \lambda}\right) = \tan^{-1}\left(\frac{1}{2 H_f \lambda}\right)$$

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:

$$\alpha = \tan^{-1}\left(\frac{1}{2 H_f \lambda}\right) = \tan^{-1}\left(\frac{1}{2(1.487)(10)}\right) = \tan^{-1}(0.033625) = 1.93^\circ$$

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°). 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.

Attachment L to Proto-Power Calculation 97-200 Revision A

ComEd

A Unicom Company

LASALLE STATION FAX TRANSMITTAL

FAX: (815) 357-1262 or (815) 357-6761 EXT. 2268

TO: LLOYD PHILPOT

DEPARTMENT: PROTO POWER

PHONE NUMBER: (860) 446-9725

FAX NUMBER: (860) 448-4860

****

FROM: BOB AYER

DEPARTMENT: SYS. ENGR

PHONE NUMBER: (815) 357-6761 EXT 3277

FAX NUMBER:

NUMBER OF PAGES FAXED 5 (including cover sheet)

NOTES:

DIRECT TELEPHONE LINE: 815-357-6761 / TIE LINE 8-527-DESIRED EXT.

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COMED NUCLEAR DESIGN INFORMATION TRANSMITTAL

☒ SAFETY-RELATED ☐ NON-SAFETY-RELATED ☐ REGULATORY RELATED	Originating Organization Section: SEB Company: ComEd	**NDIT No.: LS-0835** Upgrade 0 Page 1 of 2

Station: LaSalle County Units: 1

Design Change Authority No N/A

System: VY

To: Lloyd Philpot, Proto-Power

Subject:
Dimensional Verification for Tubing and Fins for Cooler 1VY02A

Name	Position	Signature	Date
Ayer, Robert A. (Preparer)	Engineer	[signature]	6/19/98
Friedrich, Rich (Reviewer)	Engineer	[signature]	6/19/98
Hall, Rich (Approver)	DE- Mech. Supv.	[signature]	6/19/98

Status of Information: ☒ Approved for Use ☐ Unverified ☐ Engineering Judgement

Verification Method N/A

Schedule:

Purpose of Issuance

Transmittal of Dimensions to Proto-Power for Heat Exchanger Analysis

Source of Information

Walkdown performed on the 1VY02A cooler by R. Ayer (System Engineering) and R. Friedrich(Design Engineering) on 6/19/98.

Description of Information

The following measurements were obtained for the 1VY02A room cooler at the request of Proto-Power Corporation via fax on 6/13/98. These measurements were obtained at ambient conditions with the system shutdown. Attached is a hard copy of the request and measurements obtained in the field.

Tube Outside Diameter:	0.630 +/- 0.05 in.
Fin Height:	1.495 +/- 0.02 in.
Transverse Tube Pitch:	1.452 +/- 0.02 in.
Effective Finned Tube Length:	104.25 +/- 0.25 in.

The first three of these measurements were taken with a calibrated set of calipers (MMD Id. No. 8049, cal due date 9/98). The tube length measurements was taken with a metal tape measure. The uncertainties listed above are engineering best estimates based on the the measurement techniques used.

Distribution: SEAG

Wilhelmsen, George R. - ComEd, SES-BOP

Miller, William J. - ComEd, SE

Szumski, Daniel R. - ComEd, SES-BOP

WIN No.

COMED NUCLEAR DESIGN INFORMATION 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 pitch 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

I need walkdown confirmation in what ever format is suitable for design input for the following coil layout dimensions (refer to attached sketch):

d_o - tube outside diameter

h_{fin} - fin height (outside diameter of circle cut by outside fin edge)

S_T - 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).

S_L - longitudinal tube pitch (tube center to tube center but front fin edge to front fin edge or front tube edge to front tube edge will work as well)

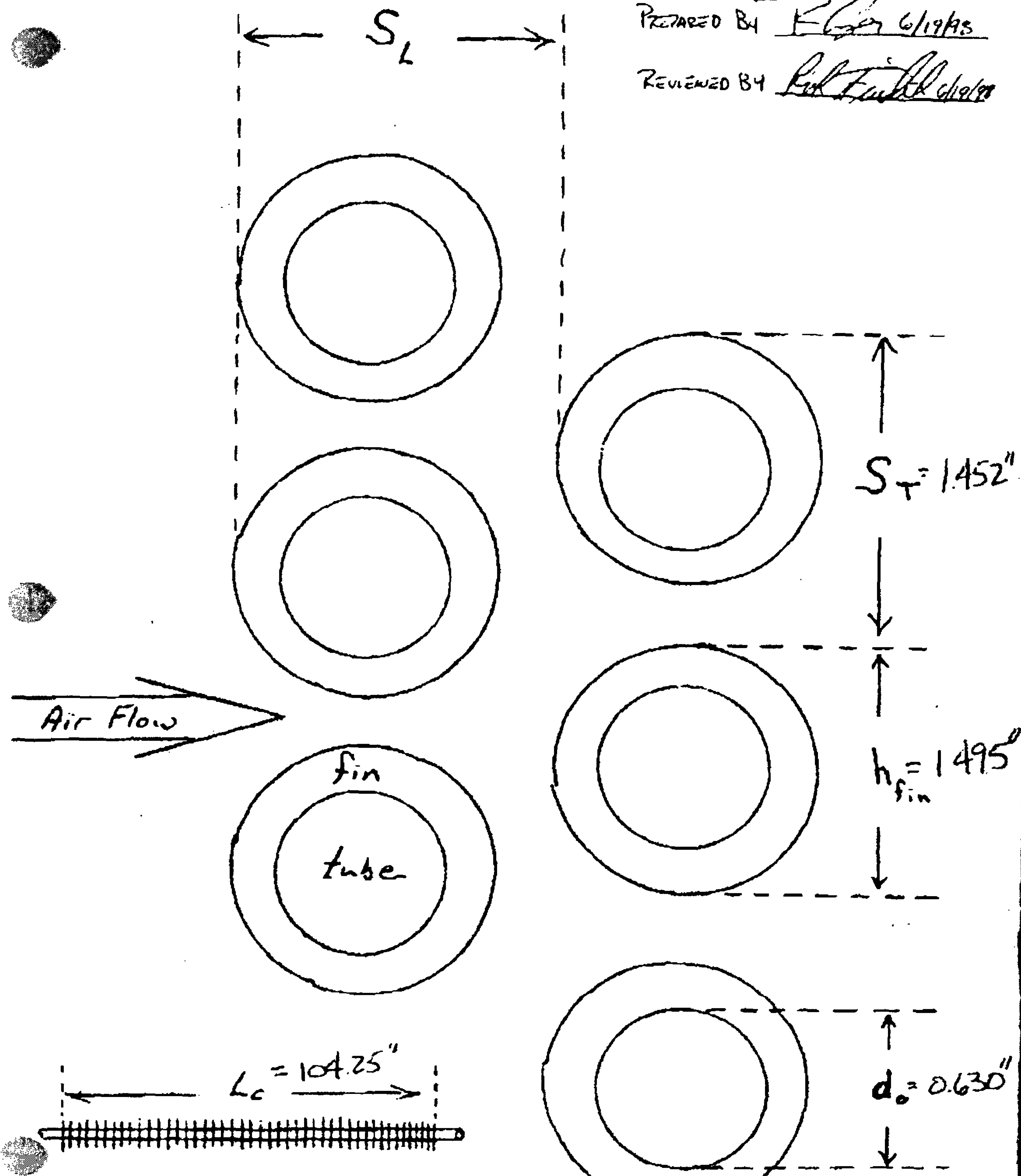
L_c - <u>finned</u> length of coil (outer fin to outer fin)

Obviously VY02A is the most important but the info would be good to have for all 4 coolers

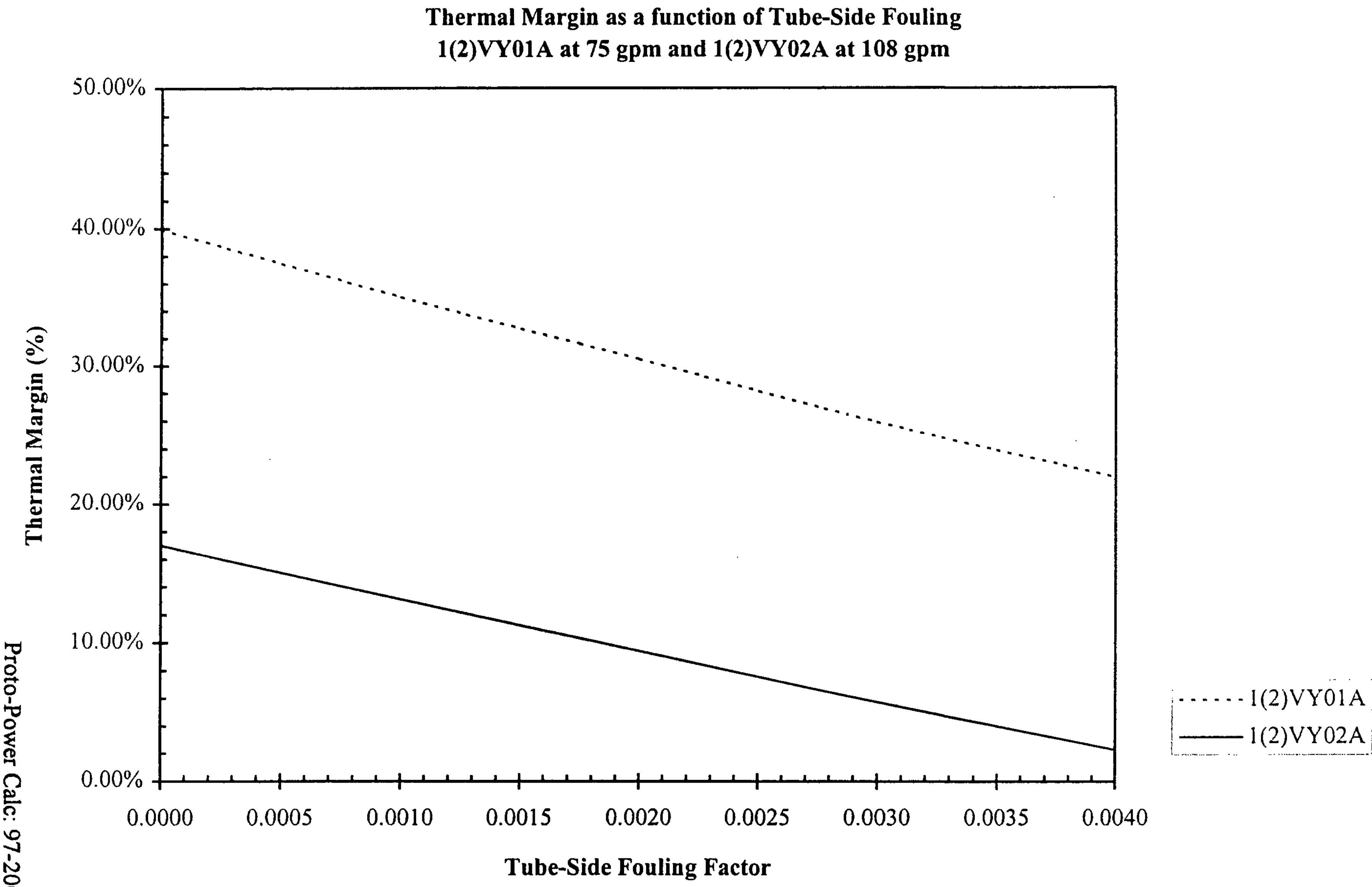
NDIT No. LS-0835 P.03
PAGE ~~3 of 3~~ 2 of 2

PREPARED BY [signature] 6/19/98

REVIEWED BY [signature] 6/19/98



Attachment M to
Proto-Power Calculation
97-200
Revision A



Proto-Power Calc: 97-200
Attachment: M
Rev: A Page 2 of 32

Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils
Fouling Sensitivity: 75 gpm at f=0.000

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	
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

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)	19,289.00
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

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·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)	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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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	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

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)	19,244.00
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

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·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)	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·°F/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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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
	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

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

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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·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·ft·°F)	0.0162	0.3688	Heat to Condensate (BTU/hr)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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	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

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)	19,160.00
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

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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·°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)	651,570
Bulk Visc (lbm/ft·hr)				
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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.004

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 + -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

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)	19,123.00
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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 75 gpm at f=0.004

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·°F/BTU	0.00031430
Outlet Specific Humidity			Overall Fouling (hr·ft²·°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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.000

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	
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

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)	19,347.00
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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.000

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·°F)	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 Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 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	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

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)	19,301.00
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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.001

Extrapolation Calculation Summary

	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·°F/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)	

Extrapolation Calculation for Row 1(Dry)

	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·°F/BTU)	0.02088311
Average Temp (°F)	143.32	112.08		
Skin Temperature (°F)	118.84	114.90	U Overall (BTU/hr·ft²·°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)	

** Reynolds Number Outside Range of Equation Applicability

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.002

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
	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

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

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 (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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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	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

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

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Calculation Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.003

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·°F/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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

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Data Report for: 1(2)VY01A & 02A - CSCS Equipment Area Cooling Coils

Fouling Sensitivity: 108 gpm at f=0.004

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 + -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

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

ComEd -- LaSalle

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·ft²·°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)	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

*** Air Mass Velocity (Lbm/hr·ft²), Tube Fluid Velocity (ft/sec); Air Density at Inlet T, Other Properties at Average T

Attachment N to
Proto-Power Calculation
97-200
Revision A

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 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 6/29/98	S. Ingalls 6/29/98	L. Philpot 6/30/98

Revision History

Revision	Revision Description
A	Original Issue

PROTO-POWER CORPORATION GROTON, CONNECTICUT	CALC NO. 97-195	REV A	PAGE iii OF v
	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			

CALCULATION VERIFICATION FORM

REVIEW METHOD:

Approach Checked:	☑	N/A ☐
Logic Checked:	☑	N/A ☐
Arithmetic Checked:	☑	N/A ☐
Alternate Method (Attach Brief Summary)	☐	N/A ☑
Computer Program Used (Attach Listing)	☐	N/A ☑
Other	☐	N/A ☑

EXTENT OF VERIFICATION:

Complete Calculation:	☑
Revised areas only:	☐
Other (describe below):	☐

*Errors Detected

Minor Editorial

*Error Resolution

Corrected

*Other Comments

*Extra References Used

*(Attach extra sheets if needed)

CALCULATION FOUND TO BE VALID AND CONCLUSIONS TO BE CORRECT AND REASONABLE:

IDV Signature: Scott M. Ingalls   Initials: SMI

Printed Name: Scott M. Ingalls   Date: 6/29/98

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A	Proto-Power Calc. 97-195, Rev. A; Vendor Supplied Hx. Information	3
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F	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Calculation Reports for Fouling Sensitivity	6
G	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Calculation Reports for Minimum Service Water Flow	17
H	Proto-Power Calc. 97-195, Rev. A; PROTO-HX™ Version 3.02 Model	2 (and disk)

Complete Calc (total number of pages) 73

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-HX™, Version 3.02, will allow timely analysis of data resulting from the test program.

3. DESIGN INPUTS

The PROTO-HX™ 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-HX™ 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 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 (ft^2)	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

Table 3-2 Construction Details

Parameter	Value	Reference
Pitch Type	Triangle	8.11

The vendor data sheet shows the effective area as 479 ft^2, however, based on the outside tube diameter and tube length, this value is a gross area (A_{gr}) approximation:

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

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

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

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

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

where:

A_{gr} – Heat Exchanger Gross Area, ft^2

A_{eff} – Heat Exchanger Effective Area, ft^2

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-HX™ 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

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-HX™ Version 3.02 with the manufacturer's specifications for thermal performance.

4.1. PROTO-HX™ 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-HX™ to be 0.490 ft^2.

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-HX™ to be 0.780.

4.2. PROTO-HX™ FLOW RATE INPUTS

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.

$$Q_{phx} = Q_{temp} \cdot \frac{\rho_{temp}}{\rho_{60°F}} \qquad \text{Equation 3}$$

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-HX™ 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-HX™ 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-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. The PROTO-HX™ 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-HX™ MODEL

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

Table 6-1 Model Benchmark Correlation

Parameter	PROTO-HX™	Data Sheet	Percent Difference
Effective Area, ft²	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 %

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-HX™ calculations performed with the Standby Jacket Water Cooler model will use the effective area of 471.23 ft^2. This change is made to the PROTO-HX™ 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-HX™ input, until the required heat load was matched. Table 6-3 shows the results of the PROTO-HX™ 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 ft^2 °F/Btu for this analysis. The tube-side fouling factor is calculated from the overall fouling found from the PROTO-HX™ iteration process.

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

$$f_{total} = f_{shell} + (\text{Area Ratio}) \cdot f_{tube} \qquad \text{Equation 4}$$

$$\text{Area Ratio} = \frac{\text{Tube OD}}{\text{Tube ID}} \qquad \text{Equation 5}$$

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

From the vendor datasheet the design overall fouling factor is

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

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 :

$$f_{tube} = \frac{(f_{adjusted} - f_{shell})}{\text{Area Ratio}} = \frac{(0.002782 - 0.0005)\ ^{\text{hr ft}^2\ °\text{F}}\!/_{\text{Btu}}}{1.150} = 0.001984\ ^{\text{hr ft}^2\ °\text{F}}\!/_{\text{Btu}}$$

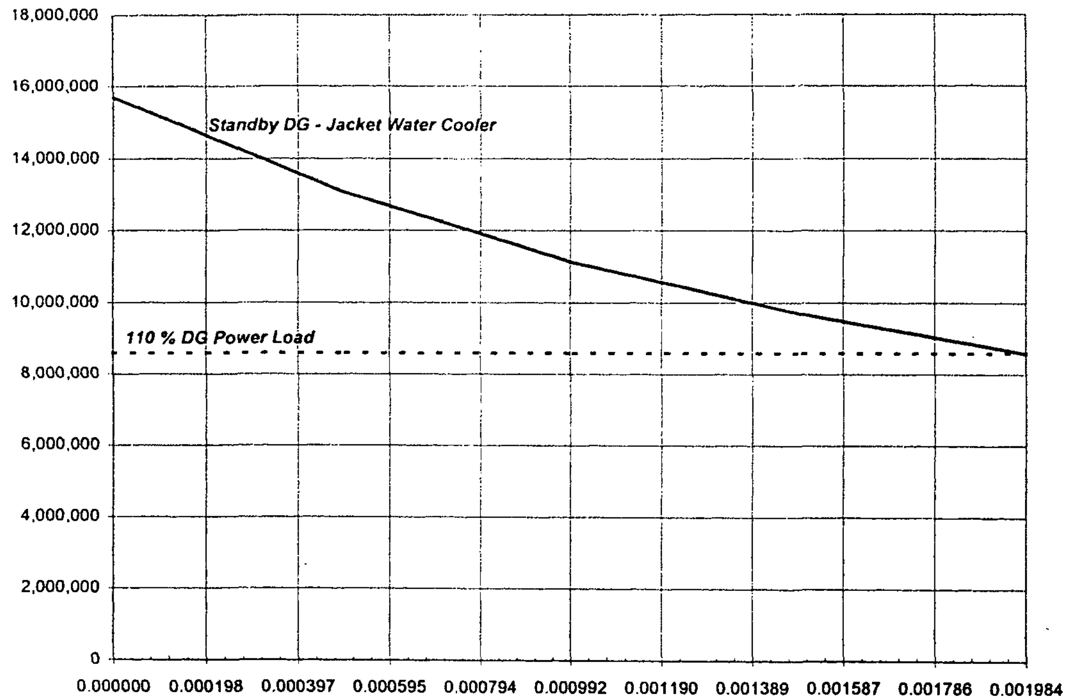
The PROTO-HX™ heat exchanger data sheet is changed to reflect the adjusted design fouling as calculated above. Like the effective area change in the heat exchanger data sheet, this change is made without recalculating the Hoff factor.

Attachment E includes a final model calculation report for the Reference Conditions and the adjusted tube-side fouling entered into the PROTO-HX™ 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 ft^2 °F/Btu) by increments of 0.0005 (hr ft^2 °F/Btu). As in Section 6.2, the shell-side fouling factor is held constant at 0.0005 (hr ft^2 °F/Btu). The PROTO-HX™ Calculation Reports for the fouling sensitivity can be found in Attachment F.

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-HX™ reports can be found in Attachment E.

$$\text{margin} = \text{Heat Rate} - \text{Heat Rate}_{\text{required}} \quad \text{Equation 6}$$

$$\%\,\text{margin} = 100 \cdot \left(\frac{\text{margin}}{\text{Heat Rate}_{\text{required}}} \right) \quad \text{Equation 7}$$

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-HX™ flow rates are made in accordance with Equation 3. Values for fluid density are obtained from Reference 8.12.

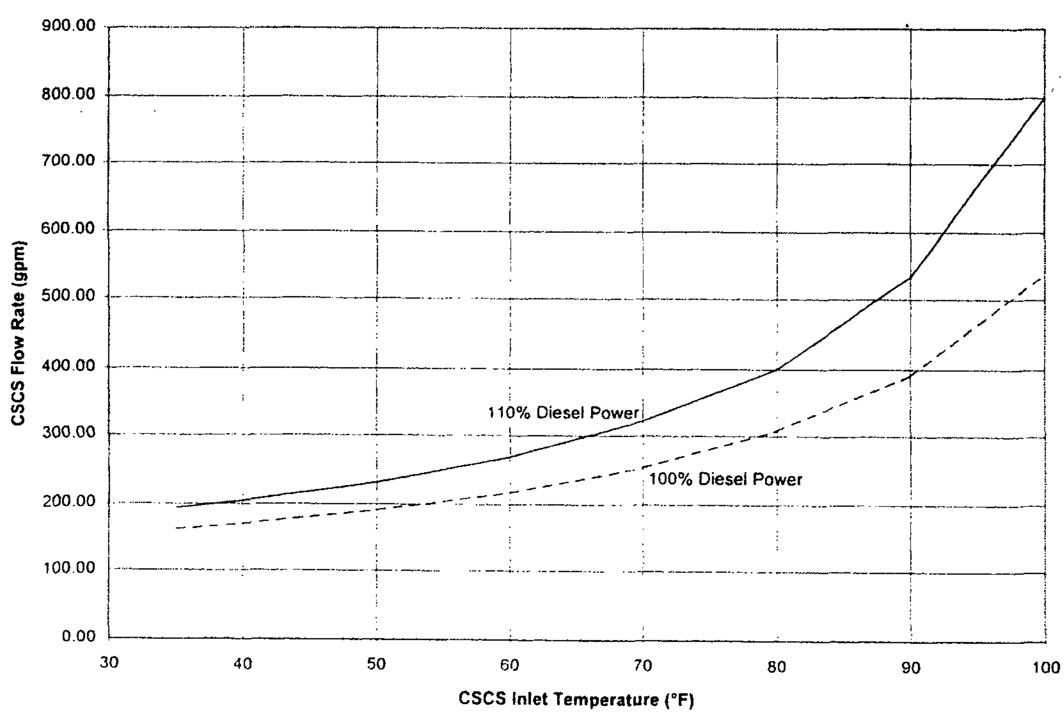
Table 6-5 Minimum CSCS Flow Rate at 100% Power

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft^3)	PROTO-HX™ 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

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

CSCS Inlet Temperature (°F)	Density at Inlet Temperature (lbm/ft^3)	PROTO-HX™ 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



7. CONCLUSION

7.1. PROTO-HX™ MODEL

The Standby Jacket Water Cooler model was developed using PROTO-HX™, 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 ft^2 °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.

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

Attachment A to
Proto-Power Calculation
97-197
Revision A

STEWART & STEVENSON SERVICES, INC.

RECIPROCATING ENGINE SALES
8631 EAST FREEWAY
HOUSTON, TEXAS 77029

WE ARE TRANSMITTING 2 PAGE(S) INCLUDING COVER. IF INCOMPLETE, PLEASE CALL, 713/671-6218 OR 713/671-6152

PLEASE DELIVER TO: DATE: 6/4/98

NAME: Duncan Phyfe FROM: Robert E. Mitcham

FIRM: COMED PHONE: 713/671-6137

FAX: 860-446-8292 FAX: 713/671-6127

REF: LaSalle Heat Exchanger Data Sheets

Please find enclosed data sheets you requested

– Robert Mitcham

Proto-Power Calc: 97-195
Attachment: A

AMERICAN STANDARD

HEAT TRANSFER DIVISION

BUFFALO, N.Y. 14240

HEAT EXCHANGER SPECIFICATION SHEET

#				
1			P.O. ~~xxx~~ NO.	F-68683-77339
2	CUSTOMER	Stewart & Stevenson for Commonwealth Edison	REFERENCE NO.	HU-974-126 Rev. 1
3	ADDRESS	LaSalle County Station Units 1 and 2	INQUIRY NO.	June 27, 1975
4	PLANT LOCATION		DATE	
5	SERVICE OF UNIT	Jacket Water Cooler	ITEM NO.	01 Alt.
6	SIZE 15156 CPK	TYPE TEMA AEW*	(HORIZ.) (VERT.) CONNECTED IN	
7	SQ. FT. SURF./UNIT (GROSS) (EFF.) 479	SHELLS/UNIT One	SQ. FT. SURF./SHELL (GROSS) (EFF.)	479

PERFORMANCE OF ONE UNIT

#		SHELL SIDE		TUBE SIDE	
10	FLUID CIRCULATED	Jacket Water		Raw Water	
11	TOTAL FLUID ENTERING	550,000 #/Hr		388,000 #/Hr	
12	VAPOR				
13	LIQUID	550,000 #/Hr		388,000 #/Hr	
14	STEAM				
15	NON-CONDENSABLES				
16	FLUID VAPORIZED OR CONDENSED				
17	STEAM CONDENSED				
18	GRAVITY				
19	VISCOSITY				
20	MOLECULAR WEIGHT				
21	SPECIFIC HEAT		BTU/LB-°F		BTU/LB-°F
22	THERMAL CONDUCTIVITY		BTU/HR-FT-°F		BTU/HR-FT-°F
23	LATENT HEAT		BTU/LB		BTU/LB
24	TEMPERATURE IN	190	°F	100	°F
25	TEMPERATURE OUT	174.4	°F	122.2	°F
26	OPERATING PRESSURE		PSIG		PSIG
27	NO. PASSES PER SHELL	One		Two	
28	VELOCITY	5	FT/SEC	8	FT/SEC
29	PRESSURE DROP	6.1	PSI	6	PSI
30	FOULING RESISTANCE (MIN.)	.00285 Total			
31	HEAT EXCHANGED-BTU/HR	8.6×10^6	MTD CORRECTED-°F	70.2	
32	TRANSFER RATE-SERVICE	255.2	CLEAN		

CONSTRUCTION OF ONE SHELL

#					
34	DESIGN PRESSURE	150	PSI	150	PSI
35	TEST PRESSURE	225	PSI	225	PSI
36	DESIGN TEMPERATURE	300	°F	300	°F
37	TUBES ARS Copper Alloy 142 No. 188 O.D. 3/4" BWG. 18	LENGTH 156"	PITCH 3/4" Tri.		
38	SHELL Steel I.D. O.D. 16"	SHELL COVER None	(INTEG) (REMOV)		
39	CHANNEL ~~xxxxxxxx~~ Muntz	CHANNEL COVER Steel			
40	TUBESHEET-STATIONARY Muntz	TUBESHEET-FLOATING Muntz			
41	BAFFLES-CROSS Steel TYPE	FLOATING HEAD COVER			
42	BAFFLES-LONG TYPE	IMPINGEMENT PROTECTION No			
43	TUBE SUPPORTS Steel				
44	TUBE TO TUBESHEET JOINT Rolled				
45	GASKETS Comp. Asbestos	Packing - Neoprene			
46	CONNECTIONS-SHELL SIDE IN 10"	OUT 10"	RATING 150# ANSI		
47	CHANNEL SIDE IN 8"	OUT 8"	RATING 150# ANSI		
48	CORROSION ALLOWANCE-SHELL SIDE 1/16" on C. Steel	TUBE SIDE 1/16" on C. Steel			
49	CODE REQUIREMENTS ASME Code III - 3 Stamped		TEMA CLASS "C"		
50	WEIGHTS-EACH SHELL 3260	BUNDLE 1860	FULL OF WATER 4410		
51	NOTE: INDICATE AFTER EACH PART WHETHER STRESS RELIEVED (S.R.) AND WHETHER RADIOGRAPHED (X-R)				
52	REMARKS: *Removable Tube Bundle				
	American Standard P/N 5-046-15-156-001	Proto-Power Calc: 97-195			
	American Standard Serial No. 8-20005	Attachment: A			
		Rev: A Page 3 of 3			

FORM 100-7 H.T. REVISED 1-70

JUN 04 '98 19:01

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

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.

REFERENCE 8.7

Name of Bidder: Stewart & Stevenson Services, Inc.

ENGINE-GENERATOR DATA, Cont.	(Insert all data in these columns)		
	BASE BID		ALTERNATE 1
	DIESEL GEN. 0	DIESEL GEN. 1A AND 2A	DIESEL GEN. 0, 1A AND 2A
(Contractor to furnish complete information 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 (SB111)		
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		

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Proto-Power Calc: 97-195
Attachment: B
Rev: A Page 3 of 3

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

5-046-15-156-001

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ. (Horiz. or Vert.) Kind Heat Exch. (Heat Ex.) Vessel No. 8-20005-01-1 (Mfrs. Serial No.) (State & State No.) Nat'l Bd. No. 29386 Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ____ Class 3

Items 4–8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. __ in. Length ____ ft. 152.438 in.

5. Seams: Long SML'S H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ____ T.S. ____ (b) Material ____ T.S. ____

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ____ (Material, Spec. No., T.S., Size, Number) Other fastening ____ (Describe or attach sketch)

7. Jacket Closure ____ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ____ Charpy Impact ____ ft-lb Pneumatic Hydrostatic or ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 (Subject to press.) in. Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB 111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 inches or gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell~~ CHANNEL: Material SML'S STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. __ in. Length ____ ft. 14.000 in.

12. Seams: Long SML'S (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL. SA285-C T.S. 55,000 (b) Material ____ T.S. ____ (c) Material ____ T.S. ____

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (Material, Spec. No., T.S., Size, Number) (b) ____ (c) ____ Other fastening ____ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ____ Charpy Impact ____ ft-lb Pneumatic Hydrostatic or ~~Combination~~ Test Pressure 225 psi

[1] If Postweld Heat-Treated
[2] List other internal or external pressures with coincident temperature ...

Proto-Power Calc: 97-195
Attachment: C
Rev: A Page 2 of 7

100-831 ... NB15-9386

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______

16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Diam. or Size	Type	Material	Thickness	Reinforcement Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106 B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106 B	.277	—	WELDED

17. Inspection Openings: Manholes, No. ______ Size ______ Location ______
Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.

Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL

Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850

Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/ 1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

J. A. Thomas
Inspector's Signature

Commissions NB 7710
National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19__

______ Commissions ______
Inspector's Signature National Board, State, Province and No.

Printed in U.S.A. (7/71) This form (E38) is obtainable from the ASME, 345 E. 47th St., New York, N.Y. 10017

5-046-15-156-001

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES ; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ (Horiz. or Vert.), Kind Heat Exch. (Heat Ex.) Vessel No. 8-20005-01-2 (Mfrs. Serial No.) (State & State No.) Nat'l Bd. No. 29387 Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ______ Class 3

Items 4–8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length 152.438 ft. ___ in.

5. Seams: Long SML'S H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ______ T.S. ______ (b) Material ______ T.S. ______

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

7. Jacket Closure ______ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ______ Charpy Impact ______ ft-lb ~~Pneumatic~~ Hydrostatic or ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary, Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 (Subject to press.) in. Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating, Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 inches or gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell~~ CHANNEL: Material SML'S STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. ___ in. Length 14.000 ft. ___ in.

12. Seams: Long SML'S (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL SA285-C T.S. 55,000 (b) Material ______ T.S. ______ (c) Material ______ T.S. ______

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (b) ______ (c) ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ______ Charpy Impact ______ ft-lb ~~Pneumatic~~ Hydrostatic or ~~Combination~~ Test Pressure 225 psi

[1] If Postweld Heat-Treated

[2] List other internal or external pressures with coincident temperature when applicable.

Proto-Power Calc 97194
Attachment: C
Rev: A Page 4 of 7

NB#29387

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______
16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Dia. or Size	Type	Material	Thickness	Reinforcement, Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106B	.277	—	WELDED

17. Inspection Openings: Manholes, No. ______ Size ______ Location ______
Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.
Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL
Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850
Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

J. A. Thomas
Inspector's Signature

Commissions NB 7710
National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19 ______

______
Inspector's Signature

Commissions ______
National Board, State, Province and No.

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

This form (E38) is obtainable from the ASME, 345 E. 47th St., New York, N.Y. 10017

5-046-15-156-001

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 TRANSFER DIVISION - BUFFALO, NEW YORK 14240 (Name and address of Manufacturer)

2. Manufactured for STEWART - STEVENSON SERVICES; HOUSTON, TEXAS (Name and address of Purchaser)

3. Type HORIZ. (Horiz. or Vert.) Kind Heat Exch. (Heat Ex.) Vessel No. 8-20005-01-3 (Mfrs. serial No.) Nat'l Bd. No. 29388 (State & State No.) Yr. Built 1976

3a. Applicable ASME Code: Section III, Edition 1974, Addenda date WINTER 1974, Case No. ______ Class 3

Items 4-8 incl. to be completed for single wall vessels, jackets of jacketed vessels, or shells of heat exchangers.

4. Shell: Material SMLS. STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. in. Length 152.438 ft. in.

5. Seams: Long SMLS H.T.[1] NO R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

6. Heads (a) Material ______ T.S. ______ (b) Material ______ T.S. ______

Location (Top, bottom, ends)	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a)								
(b)								

If removable, bolts used ______ (Material, Spec. No., T.S., Size, Number) Other fastening ______ (Describe or attach sketch)

7. Jacket Closure ______ (Describe as ogee & weld, bar, etc. If bar give dimensions, describe or sketch)

8. Design Pressure[2] 150 psi at 300 °F at temp. of — °F. Drop Weight ______ Charpy Impact ______ ft-lb Pneumatic Hydrostatic or ~~Combination~~ Test Pressure 225 psi

Items 9 and 10 to be completed for tube sections.

9. Tube Sheets: Stationary. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 17.250 (Subject to press.) in. Thickness .938 in. Attachment BOLTED (Welded, Bolted)

Floating. Material MUNTZ SB171 (Kind & Spec. No.) Dia. 15.000 in. Thickness 1.875 in. Attachment BOLTED

10. Tubes: Material ARS. COPPER SB111 (Kind & Spec. No.) O.D. 3/4 in. Thickness 18 inches or gage — Number 188 Type STRAIGHT (Straight or U)

Items 11 to 14 incl. to be completed for inner chambers of jacketed vessels, or channels of heat exchangers.

11. ~~Shell~~ CHANNEL: Material SMLS STL SA106-B (Kind & Spec. No.) T.S. 60,000 (Min. of range specified) Nominal Thickness .375 in. Corrosion Allowance .063 in. Dia. 16.000 ft. in. Length 14.000 ft. in.

12. Seams: Long SMLS (Welded, Dbl., Single) H.T.[1] NO (Yes or No) R.T. NONE Efficiency 100 %

Girth — H.T.[1] — R.T. — No. of Courses 1

13. Heads: (a) Material F.Q. STL. SA285-C T.S. 55,000 (b) Material ______ T.S. ______ (c) Material ______ T.S. ______

Location	Thickness	Crown Radius	Knuckle Radius	Elliptical Ratio	Conical Apex Angle	Hemispherical Radius	Flat Diameter	Side to Press. (Convex or Concave)
(a) ~~Top, bottom,~~ ends	1.250						19.500	FLAT
(b) Channel								
(c) Floating								

If removable, bolts used (a) ALLOY STL. SA193 B7 125,000 5/8-16 (Material, Spec. No., T.S., Size, Number) (b) ______ (c) ______ Other fastening ______ (Describe or attach sketch)

14. Design pressure[2] 150 psi at 300 °F at temp. of — °F. Drop weight ______ Charpy Impact ______ ft-lb Pneumatic Hydrostatic or Combination Test Pressure 225

[1] If Postweld Heat-Treated

[2] List other internal or external pressures with coincident temperature when applicable.

NB429388

FORM N-1 (back)

Items below to be completed for all vessels where applicable.

15. Safety Valve Outlets: Number ______ Size ______ Location ______

16. Nozzles:

Purpose (Inlet, Outlet, Drain)	Number	Dia. or Size	Type	Material	Thickness	Reinforcement, Material	How Attached
SHELL IN & OUT	2	10"-150# ASA	PIPE & FLG.	SA106B	.307	—	WELDED
TUBE IN & OUT	2	8"-150# ASA	PIPE & FLG.	SA106B	.277	—	WELDED

17. Inspection Manholes, No. ______ Size ______ Location ______
Openings: Handholes, No. ______ Size ______ Location ______
Threaded, No. ______ Size ______ Location ______

18. Supports: Skirt NO (Yes or No) Lugs — (Number) Legs — (Number) Other CRADLES (Describe) Attached WELDED TO SHELL (Where & How)

19. Remarks: JACKET WATER COOLER

(Brief description of service for which vessel was designed)

CERTIFICATION OF DESIGN

Design information on file at AMERICAN STD. HEAT TRANS. DIV. BUFFALO N.Y.
Stress analysis report on file at NOT APPLICABLE TO SECTION III CLASS 3 VESSEL
Design specifications certified by R. J. MAZZA Prof. Eng. State ILL Reg. No. 62-21850
Stress analysis report certified by NOT APPLICABLE Prof. Eng. State ______ Reg. No. ______

We certify that the statements made in this report are correct and that this nuclear vessel conforms to the rules of construction of the ASME Code, Section III.

Date 2/26/1976 Signed AMERICAN STANDARD HEAT TRANSFER DIVISION (Manufacturer) By R. R. Warner — R. R. Warner - Manager, Q.C.

Certificate of authorization Expires August 4, 1978 Certificate of Authorization No. 1164

CERTIFICATE OF SHOP INSPECTION

VESSEL MADE BY AMERICAN STANDARD HEAT TRANSFER DIVISION at Buffalo, New York

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of New York and employed by Lumbermens Mutual Casualty Co. Chicago, Illinois have inspected the pressure vessel described in this Manufacturer's Data Report on February 26 1976, and state that to the best of my knowledge and belief, the Manufacturer has constructed this pressure vessel in accordance with the ASME Code, Section III.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date February 26 1976

J. A. Thomas — Inspector's Signature Commissions NB 7710 — National Board, State, Province and No.

CERTIFICATE OF FIELD ASSEMBLY INSPECTION

I, the undersigned, holding a valid commission issued by the National Board of Boiler and Pressure Vessel Inspectors and/or the State or Province of ______ and employed by ______ of ______ have compared the statements in this Manufacturer's Data Report with the described pressure vessel and state that parts referred to as data items ______, not included in the certificate of shop inspection have been inspected by me and that to the best of my knowledge and belief the manufacturer has constructed and assembled this pressure vessel in accordance with the ASME Code, Section III. The described vessel was inspected and subjected to a hydrostatic test and/or Pneumatic Test of ______ psi.

By signing this certificate neither the Inspector nor his employer makes any warranty, expressed or implied, concerning the pressure vessel described in this Manufacturer's Data Report. Furthermore, neither the Inspector nor his employer shall be liable in any manner for any personal injury or property damage or a loss of any kind arising from or connected with this inspection.

Date ______ 19 ______

Inspector's Signature Commissions ______ National Board, State, Province and No.