Combustion Engineering Crosstraining Course (R-325C)
Course Outline

Day	Title		Location	Chapter
1	Travel			
2	Course Introduction		Classroom	
	Introduction to CE Systems		Classroom	325-1
	RCS, RCPs, SGs		Classroom	325-2.1,2.2,2.3
	Simulator Introduction		Simulator	
3	CEAs and CEDs		Classroom	325-3
	Reactor Regulating System		Classroom	325-4
	CVCS and Makeup System	(NEWS)	Classroom	325-5
	Simulator Exercises		Simulator	
4	Pressurizer Level and Pressure Control Systems		Classroom	325-6.1,6.2
	Steam Dump Bypass and Feedwater Control Systems		Classroom	325-7,8
	Excore Nuclear Instrumentation		Classroom	325-9.1
	Incore Nuclear Instrumentation		Classroom	325-9.2
	Simulator Exercises		Simulator	
5	Emergency Core Cooling Systems		Classroom	325-11.1, 11.2, 11.3
	Containment Spray System		Classroom	325-11.4
	Auxiliary Feedwater System		Classroom	325-11.5
	Simulator Exercises		Simulator	
6	Reactor Protection System		Classroom	325-10.1
	Thermal Margin Low Pressure and Axial Shape Index		Classroom	325-10.2
	Engineered Safety Features Actuation System	(NEWS)	Classroom	325-10.3
	Simulator Exercises		Simulator	
7	CPC, CEAC, COLSS		Classroom	325-12.1,12.2, 12.3
	Power Distribution Limits		Classroom	325-13
	Normal Operating Limits		Classroom	325-14
	Simulator Exercises		Simulator	
8	CE Plant Differences (Selected Topics) RPCBS		Classroom	325-15
	Classroom Examination			
9	**BEGIN SPLIT SHIFTS**		Simulator	

(Group A 8:00 AM -4:00 PM, Group B 2:00 PM - 10:00 PM) Simulator
Simulator

Simulator Operation
Off-Normal Operations Classroom
10 Simulator Technical Specifications Classroom
Simulator

EOP Introduction Simulator
Standard Post Trip Actions
Power Maneuvering and Faults
Uncomplicated Reactor Trips Classroom
Classroom
11 Simulator

LOCA Optimal Recovery Procedure Simulator
SGTR Optimal Recovery Procedure
LOCAs
SGTRs Classroom
Classroom
12 Simulator

ESDE Optimal Recovery Procedure Simulator
LOAF Optimal Recovery Procedure
Steam Line Breaks Classroom
Loss of Feedwater Events Classroom
13 Simulator

LOOP Optimal Recovery Procedure Simulator
SBO Optimal Recovery Procedure Simulator
Walkdown Electrical Distribution System
Loss of Offsite Power/Forced Circulation Classroom
Simulator
14 Simulator

Functional Recovery Procedure Simulator
LOCA + SGTR Simulator
ATWS Simulator
SGTR + ESDE
LOAF + Transfer to FRP
LOCA + ESDE
15

Lower Mode Operation/Mid Loop
Review
Simulator Examination

UNITED STATES
NUCLEAR REGULATORY COMMISSION
TECHNICAL TRAINING CENTER

COMBUSTION ENGINEERING
TECHNOLOGY CROSS TRAINING COURSE
SYSTEMS MANUAL

LESSON PLANS

COMBUSTION ENGINEERING LESSON PLAN

325C CHAP. 1

~~Lesson No. 305 - /905-1CE~~	Title: CE Systems Introduction	
Written by: Larry Bell	Approved by: Larry Bell	Date: ~~10/22/92~~ 9/96

1.0 TRAINING AIDS - NONE

T/Ps 1-1 THRU 1-8

2.0 REFERENCES

2.1 CE Systems Manual

2.2 CE Technical Managers Manual

COMBUSTION ENGINEERING LESSON PLAN

3250-1

~~Lesson No.305- /905-1C~~	Title: CE Systems Introduction	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/22/92

3.0 Objectives

3.1 Identify the major components included in the primary and secondary cycles.
3.2 Describe how reactor coolant system temperature and secondary system pressure change with load.
3.3 State the function of Engineered Safety Features.
3.4 Describe how heat from the primary cycle and primary cycle components is rejected to the environment.

4.0 PRESENTATION

4.1 General Information
  4.1.1 CE Plants can be arranged in to the following types:
    4.1.1.1 204 Fuel Assembly Plants - Palisades
    4.1.1.2 133 Fuel Assembly Plants - Fort Calhoun
    4.1.1.3 217 Fuel Assembly Plants
      - Maine Yankee (3 Loops)
      - Calvert Cliffs 1 & 2
      - Saint Lucie 1 & 2
      - Millstone 2
    4.1.1.4 177 Fuel Assembly Plants - Arkansas Nuclear One - Unit 2
    4.1.1.5 217 Fuel Assembly Plants - 150 Inch Fuel
      - San Onofre 2 & 3
      - Waterford 3
    4.1.1.6 241 Fuel Assembly Plants - 150 Inch Fuel - Palo Verde 1, 2, & 3
  4.1.2 Pressurized Water Design
    4.1.2.1 Primary Cycle
    4.1.2.2 Secondary Cycle

Figure 1-1
Page 1-[illegible]11

4.2 Plant Layout
  4.2.1 Containment Building
    4.2.1.1 Seismic Structure
    4.2.1.2 Houses the reactor and reactor coolant system
    4.2.1.3 Safety Injection Tanks - ECCS equipment
    4.2.1.4 Chemical and Volume Control System Regenerative Heat Exchanger

COMBUSTION ENGINEERING LESSON PLAN

325C-1

~~Lesson No.305- /905-1C~~	Title: CE Systems Introduction

Written by: Larry Bell	Approved by: Larry Bell	Date: 10/22/92

- 4.2.2 Auxiliary Building
  - 4.2.2.1 ECCS Systems
  - 4.2.2.2 CVCS
  - 4.2.2.3 Radioactive Waste Systems
- 4.2.3 Turbine Building
  - 4.2.3.1 Turbine-Generator
  - 4.2.3.2 Power Conversion System Components

Figure 1-2
Page 1-[illegible] 13

Objective 1

4.3 Reactor

- 4.3.1 Major Components
  - 4.3.1.1 Upper Hemispherical Head
    - Closure for Vessel
    - CEDMs
    - Fixed Incore Neutron Detectors
  - 4.3.1.2 Right Circular Cylinder
    - Two 42 in. Outlet (T-Hot) Legs
    - Four 30 in. Inlet (T-Cold) Legs
    - Snubber Assembly - prevents motion
    - Core Stop - state purpose

TM - Incore Instruments penetrate lower head on some designs.

  - 4.3.1.3 Lower Head - Closure Assembly
  - 4.3.1.4 Flow Skirt - mixes loop flows
  - 4.3.1.5 Core Support Assembly
  - 4.3.1.6 Core
    - 217 Fuel Assemblies - 24 Month Core
    - 2700 MW(t)
    - 77 CEAs - each CEA has five fingers
  - 4.3.1.7 Upper Guide Structure
    - Hold down force on fuel
    - Guides CEAs

Figure 1-3
Page 1-[illegible] 15

Objective 1

4.4 Reactor Coolant System

- 4.4.1 Two Heat Transport Loops
  - 4.4.1.1 One Hot Leg
  - 4.4.1.2 One Steam Generator
  - 4.4.1.3 Two SG Outlets
  - 4.4.1.4 Two RCPs
- 4.4.2 Steam Generators
  - 4.4.2.1 About 8000 tubes
  - 4.4.2.2 Dry Saturated Steam

COMBUSTION ENGINEERING LESSON PLAN

325C - 1
~~Lesson No.305 /905-1C~~
Title: CE Systems Introduction
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4.4.3 Pressurizer
- 4.4.3.1 Purpose - normal pressure 2250 psia
- 4.4.3.2 1500 cubic feet capacity
- 4.4.3.3 Electical Heaters
- 4.4.3.4 Spray from discharge of both loop ll RCPs
- 4.4.3.5 Auxiliary Spray from CVCS
- 4.4.3.6 Surge Line connected to 11 hot leg
- 4.4.3.7 2 code safety valves
- 4.4.3.8 2 PORVs

TM-ANO2 and later plants do not have PORVs

Objective 1

4.4.4 Major Penetrations
- 4.4.4.1CVCS Letdown - 12A RCP suction line
- 4.4.4.2 Charging - 11A and 12B RCP discharges
- 4.4.4.3 ECCS Injections - discharges of all 4 RCPs
- 4.4.4.4 Loop drains - all four pump suction lines

Figure 1-6
Page 1-[redacted] 21

Objective 2

4.4.5 RCS Parameters
- 4.4.5.1 2250 psia
- 4.4.5.2 Tavg 532 to 572.5
- 4.4.5.3 Steam Pressure - 900 to 850

Figure 1-4
Page 1-[redacted] 17

Objective 3

4.5 Emergency Core Cooling System
- 4.5.1 Two active and one passive system
- 4.5.2 HPSI
  - 4.5.2.1 Three centrifugal pumps
  - 4.5.2.2 Shutoff head of approximately 1400 psia
  - 4.5.2.3 Active during the injection and recirculation phase
- 4.5.3 SITs
  - 4.5.3.1 Four SITs
  - 4.5.3.2 200 psig nitrogen pressure
  - 4.5.3.3 passive system
- 4.5.4 LPSI
  - 4.5.4.1 Two centrifugal pumps
  - 4.5.4.2 Shutoff head of approximately 180 psia
  - 4.5.4.3 Tripped when recirculation phase is automatically initiated
  - 4.5.4.4 Also used for decay heat removal (Shutdown Cooling) during plant cooldowns and in cold shutdown.

Point out
No Hx shown

COMBUSTION ENGINEERING LESSON PLAN

325C -1

~~Lesson No.305- /905-1C~~

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4.6 Engineered Safety Features Actuation Signals

1740 psia or 2.8 psig

- 4.6.1 SIAS
  - 4.6.1.1 Low Pressurizer pressure or high containment pressure
  - 4.6.1.2 Actuates ECCS - diesel generators - cooling water etc.

703 psia

- 4.6.2 SGIS
  - 4.6.2.1 Low SG pressure
  - 4.6.2.2 Isolates faulted SG

2.8 psig

- 4.6.3 CIS
  - 4.6.3.1 High Containment pressure
  - 4.6.3.2 Isolates non-vital penetrations starts fan coolers

4.25 psig

- 4.6.4 CSAS
  - 4.6.4.1 High-high containment pressure
  - 4.6.4.2 Actuates containment spray

30 inches

- 4.6.5 RAS
  - 4.6.5.1 Low RWT level
  - 4.6.5.2 Actions
    - Opens sump valves
    - Trips LPSI pumps

Figure 1-5
Page 1-[illegible] 19

4.7 Reactor Protection System

- 4.7.1 General
  - 4.7.1.1 Purposes
    - Barrier protection during anticipated operational occurrences
    - Assists the ESF system by ensuring reactor is shutdown during accidents
  - 4.7.1.2 Purpose is accomplished by opening power supplies to CEAs
  - 4.7.1.3 RPS operates on 2 out of 4 coincidence logic

TM - CPC trips and no loss of load trip on ANO2 and newer.

- 4.7.2 Reactor Trips
  - 4.7.2.1 High Start-up Rate
  - 4.7.2.2 High linear power
  - 4.7.2.3 Axial Power Distribution
  - 4.7.2.4 Thermal Margin/Low Pressure
  - 4.7.2.5 High Pressurizer Pressure
  - 4.7.2.6 Low RCS Flow
  - 4.7.2.7 Loss of Load
  - 4.7.2.8 Low SG Level
  - 4.7.2.9 Low SG Press
  - 4.7.2.10 High Containment Press

COMBUSTION ENGINEERING LESSON PLAN

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~~Lesson No.305- /905-1C~~ | Title: CE Systems Introduction

Written by: Larry Bell | Approved by: Larry Bell | Date: 10/22/92

4.8 Reactor Control
  4.8.1 Two methods available
    4.8.1.1 CEAs
    4.8.1.2 Soluable Poison
  4.8.2 Control is normally accomplished by soluable poison control.

4.9 Instrumentation
  4.9.1 Control and protection instrumentation is completely separate.
  4.9.2 Failure of control instrument will not directly affect RPS.

4.10 Plant Electrical Systems
  4.10.1 Electrical Output - 880 MWe
  4.10.2 Onsite Voltages
    4.10.2.1 13.8 kV - RCPs
    4.10.2.2 Non - vital 4.16kV - large secondary plant loads
    4.10.2.3 Vital 4.16kV - ECCS - diesel generators

Figure 1-7
Page 1-[illegible]23
Objective 1

4.11 CVCS
  4.11.1 From 12A RCP suction
  4.11.2 Regenerative heat exchanger
  4.11.3 Variable letdown flow
  4.11.4 Letdown heat exchanger
  4.11.5 Purification devices
  4.11.6 VCT
    4.11.6.1 Collects letdown
    4.11.6.2 Collects CBO
    4.11.6.3 Interfaces with soluable control system
  4.11.7 Charging pumps
    4.11.7.1 Three constant speed PD pumps
    4.11.7.2 Number of running pumps is a function of pzr lvl
    4.11.7.3 Started by SIAS signal
  4.11.8 Charging returns
    4.11.8.1 RCPs 11A and 12B discharges
    4.11.8.2 Auxiliary Spray

Figure 1-4
Page 1-[illegible]17 - add SDC heat exchangers.
Objective 1

4.12 Shutdown Cooling System
  4.12.1 Uses LPSI and containment spray components
  4.12.2 Trace flow path

COMBUSTION ENGINEERING LESSON PLAN

325C -1

~~Lesson No.305- /905-1C~~	Title: CE Systems Introduction	
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	4.13 Cooling Water Systems
	4.13.1 CCW
	4.13.1.1 SDC heat exchangers
	4.13.1.2 Letdown heat exchanger
	4.13.1.3 RCPs
	4.13.1.4 Cooled by Salt Water
	4.13.2 Salt Water
	4.13.2.1 Cools CCW
	4.13.2.2 Cools Service Water
	4.13.2.3 Cools Diesels
Objective 4	**4.13.2.4 Salt Water and Chesapeake Bay - ultimate heat sink**
	4.13.3 Service Water
	4.13.3.1 Cools containment fan coolers
	4.13.3.2 Cools power conversion system components
Objective 4	4.13.4 Circulating Water
	4.13.4.1 Condenses low pressure turbine exhaust steam
	4.13.4.2 Heat sink for secondary cycle during normal operations.
Figure 1-8	4.14 Condensate and FW System
Page 1-[redacted]25	4.14.1 Trace flow path
Objective 1	4.14.2 Bypass valve control
	4.14.3 FW reg valve control

COMBUSTION ENGINEERING LESSON PLAN

325C-2.1,2.2,2.3

~~Lesson No.305-06/905-3C~~	Title: REACTOR COOLANT SYSTEM

Written by: Loren F. Donatell	Approved by: Larry Bell	Date: 11/2/92

1.0 TRAINING AIDS/SPECIAL INSTRUCTIONS

1.1 Transparency Package for ~~305-06/905-3C~~ 325C-2.1,2.2,2.3

1.2 Lesson Module for ~~305-06/905-3C~~

2.0 REFERENCES

2.1 CE Systems Manual, Chapter 3

2.2 CCNPP System Description No.5, Reactor Coolant System

2.3 CCNPP System Description No. 17, Steam Generator

2.4 CCNPP System Description No. 62, RCS Instrumentation

COMBUSTION ENGINEERING LESSON PLAN		
Lesson No.305-06/905-3C	Title: REACTOR COOLANT SYSTEM	
Written by: Loren F. Donatell	Approved by: Larry Bell	Date: 11/2/92

3.0 PRESENTATION

3.1 Learning Objectives

3.1.1 Cover Objectives in manual

3.2 Introduction

3.2.1 System Purposes

a. Transfer the heat produced in the reactor to the steam generators
b. Provide the second barrier to prevent the escape of fission products to the public

3.2.2 General Description

Figure 2.1-1
Page 2.1-17

Figure 2.1-2
Page 2.1-19

3.2.2.1 Reactor Coolant System
- a. 4 RCPs
- b. 2 Hot Legs, 42 " dia.
- c. 4 Cold Legs, 30 " dia.
- d. 2 Steam Generators
- e. Compact design
  - 1. Minimize Containment Building pressure in event of a LBLOCA
- f. Carbon steel, clad with SS internally
- g. 2500 psia design pressure
- h. 650 °F design temperature
- i. Pressurizer maintains subcooling
  - 1. 1500 cubic feet
- j. 122 x 10^6 lb/hr

Show Typical RCS Support System 2.1-3 2.1-21

Figure ~~3.1-3~~ 2.1-4
Page ~~3.1-21~~ 2.1-23

3.3 RCS Penetrations

3.3.1 Hot Leg Penetrations

a. Surge Line (11 hot leg) allows a flow path between the pressurizer and the RCS for pressure control and volumetric changes to the reactor coolant
   1. 12" ID

b. Shutdown Cooling System suction penetration (12 hot leg) is used to remove decay and residual heat during cool downs and during cold shutdown
    1. 14" ID
    2. May be placed in service at 260 psia and 300 °F

c. RCS Sample line (11 hot leg) provides information about RCS chemistry
    1. 1/2 " ID

d. RCS Drain line (11 hot leg) to the Reactor Drain Tank for maintenance drain down and connection for a temporary level indicator (tygon tube)

3.3.2 Cold Leg Penetrations

a. CVCS LETDOWN line (12A RCP suction) supplies water to the CVCS for purification
    1. 2 " ID

b. CVCS CHARGING lines (11A and 12B RCP discharges) return purified coolant to the RCS
    1. 2 " ID

c. ECCS penetrations (discharge of all RCPs) serve as a common injection point for HPSI, LPSI, SITs, and SDC return
    1. 12 " ID

d. Spray line penetrations (discharge of 11A and 11B RCPs)
    1. Controlled by pressurizer pressure
    2. 3 " ID

e. Cold leg loop drains for maintenance drain down
    1. Drain to RDT - pumped to BMS
    2. 2 " ID

COMBUSTION ENGINEERING LESSON PLAN		
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Figure 2.1-5
Page 2.1-25

3.4 RCS Instrumentation

3.4.1 Hot Leg Temperature

a. 5 RTDs in each hot leg
  1. 4 RTDs supply wide range (0-700 °F safety grade signals to the RPS for: Delta T power reference calculation used in the TMLP trip circuitry
  2. 1 RTD supplies a narrow range (515-615 oF) control grade signal to RRS and a high hot leg temp. alarm in the main control room
  3. Other inputs to the Plant Computer, Indication, Alarm and the Subcooled Margin Monitor

3.4.2 Cold Leg Temperature

a. 3 RTDs in each cold leg
  1. 2 RTDs supply wide range (0-700 °F) safety grade signals to the RPS for Delta T power reference calculation used in the TMLP trip circuitry
  2. 1 RTD supplies a control grade signal to the RRS, CEDS (AWP), and the PORV control circuitry for MPT protection through a selector switch(loop 11A or 11B)

3.4.3 Loop Flow

a. Steam Generator D/P
b. 4 detectors per S.G.
c. Summed with corresponding detector in other loop resulting in four independent channels of coolant flow
d. RPS for loss of flow trip
e. Indication in the Main Control Room

Figure 2.1-6
Page 2.1-27

3.5 Pressurizer

3.5.1 Purpose

a. Maintain RCS pressure at 2250 psia

b. Compensate for changes in the reactor coolant volume due to load changes

3.5.2 Pressurizer Design

a. Carbon steel clad internally with SS

b. ~ 37 feet high

c. ~ 9 feet in dia.

d. supported by a cylindrical skirt welded to its bottom head

e. 1500 cubic feet

f. Water volume varies with program

g. 600 -800 cubic feet of water volume is based on:

1. Maintaining RCS operating pressure
2. Compensate for changes in coolant volume during load changes. The total coolant volume changes are kept as small as possible and within the capacity of the CVCS
3. Contain sufficient volume to prevent draining the pressurizer and preclude a safety injection actuation as a result of a reactor trip or loss of load event
4. Limit the water volume to minimize the energy release and resultant containment pressure during a LBLOCA
5. Prevent uncovering of the heaters by the outsurge of water following a design load decrease of a 10% step or a 5%/ min. ramp

6. Provide sufficient volume to accept the insurge following a load rejection without the water level reaching the safety valve and PORV nozzles

3.5.3 Pressurizer Heaters

a. Purpose
   1. Initially form the steam bubble
   2. Increase pressure to normal operating pressure
   3. Maintain normal operating pressure

b. 120 Heaters

c. Rated at 480 VAC and 12.5 kW each

d. Approximately 7' long

e. Vertically mounted through the bottom head

f. Two groups
   1. Proportional
   2. Backup

g. Proportional Group
   1. Compensate for losses to ambient
   2. 24 Heaters
   3. Two 150 kW Banks
   4. Maximum power at 2225 psia
   5. Minimum power at 2275 psia

h. Backup Group
   1. Four Banks of 24 Heaters
   2. 96 Heaters total
   3. 300 kW per bank
   4. On at 2200 psia
   5. Off at 2225 psia
   6. Two banks powered from emergency buses to assure pressurizer control for natural circulation flow following a loss of off-site power - T. S. requirement for 150 kW

i. All heaters interlocked with low pressurizer level

COMBUSTION ENGINEERING LESSON PLAN		
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Written by: Loren F. Donatell	Approved by: Larry Bell	Date: 11/2/92

Figure 2.1-7
Page2.1-29

3.5.4 Pressurizer Surge Line
- a. Connects 11 hot leg to bottom of pressurizer
- b. Thermal sleeve minimizes thermal stress
- c. Temperature element in surge line alerts operators to possible loss of spray bypass flow
- d. 12 " ID

3.5.5 Pressurizer Spray
- a. From discharge of 11A and/or 11B RCPs
- b. 375 gpm maximum flow rate
- c. Controlled by the Pressurizer Pressure Control System (PPCS)
- d. Open at 2300 psia
- e. Close at 2275 psia
- f. NSR

3.5.6 Pressurizer Spray Bypass
- a. In parallel with each spray valve
- b. 1.5 gpm / valve
- c. Prevent thermal shock on spray nozzle
- d. Help maintain boron concentration in the pressurizer equal to RCS boron concentration
- e. Temperature elements installed in each spray line to warn operators of a possible loss of spray bypass flow

3.5.7 Auxiliary Spray
- a. Supplied from the CVCS charging pumps
- b. Used during start-up/shutdown periods when the RCPs are not running
- c. Used to control pressurizer pressure during natural circulation

3.5.8 Pressurizer Overpressure Protection

a. High Pressure Reactor Trip at 2400 psia
    1. Signal opens the PORVs

b. If no High Pressure Reactor Trip occurs the PORVs do not open and the Code Safety Valves provide overpressure protection

c. Power Operated Relief Valves
    1. Set below the Code Safety Valves
    2. Operate with a High Pressure Trip
    3. Both have isolation valves
    4. 153,000 lbm/hr capacity each
    5. Relieve to Quench Tank
    5. Setpoint can be changed for MPT to 400 psia when <330 °F

PORV
DESIGN
BASES

    6. The PORVs have sufficient capacity to handle the maximum steam surge from a continuous CEA withdrawal incident starting from low power, without letdown or pressurizer spray operable, OR

    handle the maximum steam surge from a loss of load incident at full power, with the pressurizer spray operable and a reactor trip on high pressure

d. Code Safety Valves
    1. Two spring-loaded, self actuated
    2. Common discharge pipe with PORVs
    3. Set at 2500 psia and 2565 psia
    4. Capacity of 296,065 lbm/hr and 302,000 lbm/hr
    5. Prevent exceeding 110% of design pressure(ASME requirement)
    6. Relieve to the Quench Tank

CODE
SAFETY
DESIGN
BASES

7. Relief capacity based on 100% loss of load with the following conservatism assumed for the analysis:

   Loss of load without a reactor trip until the first RPS trip setpoint is reached (Pressurizer Pressure High).

   Initial reactor power is at rated thermal power.

   No credit was taken for Steam Dump and Bypass Control System (SDBCS) actions.

   No credit was taken for the operation of the PORVs.

   The valves reach maximum flow capacity at 103% of design setpoint or less (3% accumulation).

   The valves reseat at not less than 96% of the setpoint pressure (4% blowdown).

   The valves start to relieve within 1% of setpoint pressure (setpoint tolerance).

COMBUSTION ENGINEERING LESSON PLAN		
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2.1-10
Figure 3.~~1~~-~~3~~5
Page 3.~~1~~-35
2.1-35

3.5.9 Quench Tank
- a. 217 cubic feet
- b. ~ 100 cubic feet of water blanketed by a 3 psig nitrogen overpressure
- c. Relief setpoint of 35 psig
- d. Rupture disk at 100 psig
- e. Drains to the RDT by gravity
- f. Demineralized water supply to maintain inventory
- g. The Quench Tank water level is sufficient to reduce the necessary tank volume and pressure requirements to accommodate the Code Safety Valve discharge from two consecutive events:

QUENCH TANK DESIGN BASES

Loss of load from 10% power without a concurrent loss of load reactor trip followed by a discharge caused by a continuous CEA withdrawal accident that occurs as the plant is returned to power

~~2.7~~
Figure ~~3.1-9~~ 2.1-7
Page ~~3.1-33~~ 2.1-29
~~2.29~~

2.1-9
pg 2.1-33

3.5.10 Pressurizer Instrumentation
- a. Code Safeties and PORVs
  1. Temperature elements in combined discharge
  2. Acoustic monitors for position indication
- b. Pressurizer Level Instruments
  1. Three transmitters
  2. NSR
  3. Two transmitters used by the PLCS are calibrated for operating temperature (653°F)
  4. One transmitter is density compensated for start-ups and shutdowns

c. Pressurizer Pressure Instruments
    1. Ten transmitters total
    2. Four transmitters for RPS (high pressure trip and pre-trip, TMLP trip and pre-trip, AWP), ESFAS (low-low pres sure for SIAS) and main control room indication. Narrow Range, 1500 - 2500 psia
    3. Two wide range (0 - 4000 psia) to two independent SCMM channels
    4. Two narrow range control channels PPCS, RRS and alarm
    5. Two low range (0 - 1600 psia) for shutdown pressure indication, SIT isolation valve auto open (300 psia), SDC return valve auto closure, and input to the MPT logic circuitry

Figure 2.1-8
Page 2.1-31

d. Pressurizer Temperature Instrumentation
    1. Single RTD installed in the steam space for indication only

3.6 Low Temperature Overpressure Protection

3.6.1 Historically maintained solid water conditions on CVCS float
    a. Pressure control with letdown backpressure
    b. Letdown valves fully open
    c. Single charging pump in service
    d. Problems
        1. Events that increase RCS volume due to temperature increase such as pressurizer heaters on or loss of SDC
        2. Events involving an increase in RCS inventory such as start of RCPs in a cold system with residual heat in the steam generators

3. Failure of the pressure vessel due to low-temperature overpressure events

e. Unresolved Safety Issue A-26 (NUREG-0371, 1978)

1. Procedual changes

Disabling HPSI pumps in cold shutdown

Removing power from all but a minimum number of heaters

Allowing only one charging pump during cold shutdown

2. Equipment modifications

Addition of low pressure setpoint reliefs to the charging system

Addition of a low setpoint to PORV control circuitry

Addition of low setpoint reliefs to the pressurizer

3.6.2 Calvert Cliffs
- a. PORV low setpoint and control circuitry
  1. Reset from 2400 psia to 400 psia
  2. When T_c decreases to 330 °F
  3. ENABLE light at 330 °F and <400 psia for operators to position handswitches in logic circuitry

3.7 TMI - 2 Modifications

Figure 2.1-11
Page 2.1-37

3.7.1 Saturation Monitors

a. Microprocessor with steam tables in ROM
b. High select temperature (210 °F - 710 °F)
c. Low select pressure (0 - 4000 psia)
d. Alarm at 30 °F subcooling
e. Redundant and vital powered

Figure 2.1-12
Page 2.1-39

3.7.2 RCS High Point Vents

a. Installed to remove non-condensable gases from the reactor vessel and pressurizer to promote natural circulation
b. Reduced valves
c. Orifice to reduce flow in event of down stream breaks
d. Relieve to Quench Tank or Containment

Figure 2.1-13
Page 2.1-41

3.7.3 Reactor Vessel Level

a. Inadequate core cooling modification
b. 11 sensors
    1. 2 in upper head
    2. 3 in upper guide structure
    3. 6 in fuel assemblies
c. Heated and unheated junction thermocouples
    1. chromel-alumel
    2. As steam replaces liquid, the temperature of the heated junction goes up in relation to the unheated junction due to steam blanketing
    3. Sensors shielded to avoid overcooling due to direct water contact during two phase conditions
d. Vessel level supplied to the SPDS

COMBUSTION ENGINEERING LESSON PLAN

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Written by: Loren F. Donatell | Approved by: Larry Bell | Date: 11/2/92

3.8 Reactor Coolant Pumps

3.8.1 Cover Objectives in manual

3.8.2 Purposes
- a. Provide forced circulation of reactor coolant for the removal of core heat
- b. Improve DNBR during the loss of all reactor coolant pump motor power
- c. Provide energy to heat up the RCS from ambient temperature to greater than the minimum temperature for criticality prior to start up

Figure 2,2-1
Page 2.2-10
Pump Operating Curve

3.8.3 General Design
- a. vertical shaft, single suction, single stage, centrifugal pump
- b. 81,200 gpm (120,000 gpm single pump)
- c. Four pumps provide core with 122 x 10^6 lbm/hr
- d. Four pumps required for critical operation

Figure 2.2-2
Page 2.2-13

3.8.4 Pump Construction

3.8.4.1 Pump Case Assembly
- a. Forms the volute
- b. Wear ring interfaces the impeller and case

3.8.4.2 Pump Cover
- a. Supports the heat exchanger and the hydrostatic bearing
- b. Two metallic "O" rings seal the cover to the case
- c. Telltale drain between "O" rings with an RTD which alarms in the control room

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3.8.4.3 Heat Exchanger
- a. Comprised of concentric tubes
- b. Tubes arranged concentric to pump shaft
- c. Reactor coolant in the inner tube
- d. CCW in the outer tube

3.8.4.4 Driver Mount
- a. Supports and aligns the motor

3.8.4.5 Rotating Element Assembly
- a. Pump shaft
- b. Shaft bearing journal
- c. Impeller
- d. Auxiliary impeller
- e. Recirculating impeller
- f. Pump half-coupling
- g. Thrust disc
- h. Motor half-coupling

Figure ~~3.2-3~~ 2.2-3
Page ~~3.2-15~~ 2.2-15

Figure ~~3.2-4~~ 2.2-4
Page ~~3.2-17~~ 2.2-17

3.8.5 Reactor Coolant Pump Seal Assembly

3.8.5.1 Concentric Tube Heat Exchanger
- a. Recirculation impeller supplies ~ 40 gpm of reactor coolant up through the inner tubes
- b. CCW supplied at ~ 45gpm to outer tubes
    1. ~ 17 gpm to thermal barrier
    2. ~ 28 to heat exchanger
- c. CCW flows down thought outer tubes

3.8.5.2 Mechanical Seals
- a. 4 mechanical seals
    1. 3 contain RCS pressure
    2. 4th is a vapor seal capable of full RCS pressure
- b. Construction
    1. Shaft mounted Titanium Carbide
    2. Stationary Graphite
    3. Aligned by springs on rotating face

e. Operation of seals
  1. Cooled by 1 gpm of CBO
  2. Pressure breakdown devices installed in parallel with seals
  3. Breakdown devices set operating pressure (dp) to ~ 700 psid
  4. Flow rate of 1 gpm enters the seal area at 2250 psia
  5. 99% of flow goes through the break down devices and 1% through seals
  6. Flow collected in \cbo line and sent to the VCT

f. Seal failure
  1. Table 3.~~2~~3-1 on Page3.~~2~~3-5
  2. A seal failure causes an increase in CBO flow and an increase in the differential pressure across the remaining seals

3.8.6 RCP Flow Paths

3.8.6.1 Reactor Coolant

a. RCS flow from the Steam Generator to the eye of the impeller, through the volute and to the RCS piping
b. RCS flow through the auxiliary impeller, to the journal bearing, along the shaft, past the thermal barrier to the seal cavity
c. Seal cavity recirculation by the seal water impeller to the inner pipe of the heat exchanger and to the seals and breakdown devices
d. Small flow past the seals and breakdown devices to the VCT (1 gpm) or the RCDT (< 0.3 gph) to containment sump from #4 seal.

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3.8.6.2 Component Cooling Water
- a. Divides into two streams
- b. 17 gpm to the thermal barrier
- c. 28 gpm to the integral heat exchanger

Figure ~~3.3-5~~ 2.2-5
Page ~~3.3-19~~ 2.2-19

3.8.7 RCP Motor

3.8.7.1 Design
- a. Vertical, solid shaft,3-phase,squirrel cage induction motor
- b. ~~880~~ rpm [illegible] RPM
- c. 6000 h.p.(cold), 4500 h.p. (hot)
- d. 13.8 kVAC
- e. Air cooled
- f. CCW cools air (155 gpm)

3.8.7.2 Bearings
- a. Radial bearing
  1. Maintain rotor alignment
  2. Oil lubricated from self-contained reservoir and rotation of bearing race
- b. Thrust bearing
  1. Kingsbury double acting
  2. Compensates for hydraulic forces
  3. With the pump radial bearing , supports the weight of the motor and pump
  4. Oil lift pump for starting (Stops after RCP is running)

3.8.7.3 Flywheel
- a. Installed on motor rotor
- b. Increases coastdown time which improves DNBR after a loss of pumping power event
- c. Safety Related

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3.8.7.4 Anti-Reverse Rotation Device

- a. Minimizes motor starting torque
  - 1. Deceleration-Acceleration causes excess currents
- b. Minimizes reverse flow through an idle pump
  - 1. More core flow - DNBR improves

Figure ~~2-6~~ 2.2-6
Page ~~3-21~~ 2.2-21

3.8.8 Instrumentation

3.8.8.1 Pump

- a. Seal pressure
  - 1. 3 detectors
  - 2. Lower, middle and upper seal (lower not indicated in MCR)
  - 3. Middle and upper alarm in MCR
  - 4. Table 3.2-1 for typical failure indication
- b. Seal area temperature
  - 1. Outlet of primary coolant from the lower seal
  - 2. Alarm in MCR
- c. CBO flow
  - 1. High and low flow alarm in MCR
  - 2. 1.25 gpm high (1.0 normal)
  - 3.Indicates seal failure
- d. CBO temperature
  - 1. High temperature alarm in MCR
  - 2. Indicates seal failure
  - 3. Indicates loss of CCW
- e. Eccentricity and vibration
  - 1. 2 probes on each pump
  - 2. Alarm in MCR

3.8.8.2 Motor
- a. Stator winding temperature
  - 1. Alarm in MCR
- b. Upper motor guide bearing temperature
  - 1. Alarm in MCR
- c. Lower motor guide bearing temperature
  - 1. Alarm in MCR
- d. Upper oil reservoir level
  - 1. Alarm in MCR
- e. Lower oil reservoir level
  - 1. Alarm in MCR
- f. Upper motor thrust bearing temperature
  - 1. Alarm in MCR
- g. Lower motor thrust bearing temperature
  - 1. Alarm in MCR
- h. 2 motor vibration switches
  - 1. Common Alarm in MCR
- i. Lubricating oil cooler outlet temperature
  - 1. No alarm
- j. Lubricating oil cooler inlet temperature
  - 1. No alarm
- k. Oil lift system pressure
  - 1. Local indication
  - 2. Pressure switch operates contact in the RCP breaker permissive circuit
  - 3. Low pressure alarm in MCR

3.8.9 RCP Starting Circuitry

3.8.9.1 Oil Lift Pump
- a. Pressure switch operates contact in RCP breaker closing circuit
- b. Oil lift pump times out 30 seconds after start

3.8.9.2 Synchronizing Stick
- a. Must be inserted to start a RCP

3.8.9.3 CCW Pressure
- a. Pressure switch operates contact in RCP breaker closing circuit

3.9 Steam Generators

3.9.1 Cover Objectives in manual

3.9.2 Purposes

a. Produce dry saturated steam for the turbine-generator and its auxiliary systems
b. Act as a heat sink for the RCS during normal, abnormal, and emergency conditions
c. Provide a barrier between the radioactive RCS and the non-radioactive secondary system

Figure 2.3-1
Page 2.3-17

3.9.3 General Description

3.9.3.1 Vertical shell and U-tube heat exchanger

3.9.3.1 Connections

a. Main Feedwater
b.Auxiliary Feedwater
c. Main Steam
d. Steam Generator Blowdown
e. Instrumentation
    1. Level
    2. Pressure
    3. RCS Flow
f. 2 Primary Manways
g. 2 Secondary Manways
h. 2 Secondary Handholes
i. Support Skirt attached to bottom

3.9.3.2 Internal Structure

a. Downcomer Region
    1. Circular area between the tube wrapper and the outer shell
b. Evaporator Region
    1. Area inside of the tube wrapper extending from the tube sheet to the top of the tube bundle

c. Riser Section
    1. Transition area from the evaporator to the steam drum
d. Steam Drum
    1. Area inside the upper shell extending from the bottom of the steam separator support plate to the Main Steam outlet nozzle

3.9.4 Flow Paths

3.9.4.1 RCS
- a.Inlet nozzle to Inlet plenum
- b. Divider plate separates inlet and outlet
- c. Through tubes
- d. Outlet plenum
- e. Out through two outlet nozzles

3.9.4.2 Secondary
- a.Main feedwater nozzle
- b. Feed ring
- c. Downcomer
- d. Over tube sheet
- e. Upward into evaporator region
- f. Riser section
- g. Steam Drum
- h. Steam separators
- i. Steam dryers
- j. Deflector plate
- k. Exit through the main steam nozzle

3.9.5 Construction

3.9.5.1 General Information
- a. Vertical Class A vessel
- b. Carbon Steel
- c. ASME Section III

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d. Dry weight of 1,004,000 pounds
e. Upper shell 239 3/4 inch O.D. (~ 20 ft.)
f. Lower shell 165 inch O.D. (13 3/4 ft.)

3.9.5.2 Primary Side
- a. Lower Hemispherical Head
  1. One 42" inlet nozzle, carbon steel clad with S.S.
  2. Two 30" outlet nozzles, carbon steel clad with S.S.
  3. S.S. divider plate to separate flows
  4. Four instrument penetrations for flow measurement low side dp
  5. Two 16" manways
- b. Tube Sheet
  1. 21 1/2" thick flat disc forging
  2. Clad with Inconel on primary side
  3. Welded to primary head and lower shell along circumference
  4. Reinforced by a forged tube sheet support cylinder between the center of the tube sheet and the primary head
  5. Separates primary and secondary
  6. Contains U-tube penetrations
- c. U-Tubes
  1. Inconel
  2. 8,519 vertical tubes
  3. 3/4" O.D.
  4. .048" wall thickness
  5. Explosively expanded into tube sheet
  6. Egg crate supports every three feet
  7. Top of bundle supported by Batwing support assembly

Figure 2.3-2
Page 2.3-19

Figure 2.3-3
Page 2.3-21

Figure 2.3-4
Page 2.3-23

Figure ~~3.3-5~~ 2.3-5
Page ~~3.3-23~~ 2.3-25

3.9.5.3 Secondary Side

- a. Two 16" manways into steam drum area
- b. Two 6" handholes for tube bundle inspection
- c. One 18" Main Feedwater Nozzle
  - 1. Top of Downcomer region
- d. Main feed ring
  - 1. 12" torus
  - 2. Encircles all but three feet of the downcomer annulus
  - 3. Capped on both ends
  - 4. "J" tubes mounted on top
  - 5. Distributes feedwater to the downcomer

Aux feed inside
main feed ring

- e. One 4" Auxiliary Feedwater Nozzle
  - 1. Located just below the main feedwater nozzle
- f. Auxiliary feed ring
  - 1. 4" pipe
  - 2. Encircles ~ 1/3 of the downcomer region
- g. Downcomer
  - 1. Feedwater mixes with recirculating water
  - 2. Inside wall of the steam generator vessel shell and outside wall of tube wrapper
- h. Tube wrapper
  - 1. Steel cylinder
  - 2. Fully encloses the tube bundle
  - 3. separates the downcomer and the evaporator regions
- i. Evaporator region
  - 1. Tube bundle
  - 2. Produces saturated steam

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j. Steam Drum
  1. 166 centrifugal steam separators
  2. 126 chevron steam dryers

Figure ~~3-6~~ 2.3-6
Page ~~3-25~~ 2.3-27

k. Steam separators
  1. Perforated cylinders
  2. Vanes in lower section
  3. Imparts swirling motion
  4. Moisture drains through holes to the separator support plate sump
  5. Removes the bulk of the moisture
  6. Steam exits through top center hole

l. Support plate sump
  1. Collects drainage
  2. Drains to downcomer region

Figure ~~3-7~~ 2.3-7
Page ~~3-27~~ 2.3-29

m. Steam dryers
  1. Corrugated metal baffle plates
  2. Drain to the support plate sump
  3. Steam exits at 99.8% quality

n. Steam deflector plate
  1. Dp of flow
  2. Limit blowdown

o. Main steam outlet nozzle
  1. 34" I.D.

Page ~~[illegible]~~
2.3-5,6

3.9.6 Design Transients

3.9.6.1 Reactor Plant Cyclic Transients

3.9.6.2 Abnormal Transients

3.9.6.3 Allowable Stress Limits

3.9.7 Operating Characteristics

3.9.7.1 Heat Transfer
  a. $Q=UA(T_{avg} - T_{sat})$
  b. RCS temperature program

Figure ~~3-8~~ 2.3-8
Page ~~3-29~~ 2.3-31

3.9.6.2 Shrink and Swell
- a. Explain
- b. Explain effects at low power
    - 1. Recirculation
    - 2. Recirculation breakdown

3.9.6.3 Internal Circulation
- a. The quantity of water to downcomer from the moisture separating equipment is much larger than the volume of incoming feedwater
- b. Circulation keeps heat transfer surfaces wet
- c. Circulation preheats feedwater minimizing thermal stress
- d. Recirculation Ratio
    - 1. C_r = riser flow / exit steam flow
    - 2. Ratio affected by a change in rate of heat transfer
    - 3. Ratio affected by change in S.G. pressure

3.9.7 Steam Generator Chemistry Control

3.9.7.1 Purpose
- a. Ensure equipment integrity
    - 1. Cracking and Pitting
- b. Minimize general surface corrosion
- c. Prevent moisture carryover
- d. Minimize fouling of heat transfer surfaces

3.9.7.2 Specifications
- a. Table ~~3[illegible]~~ 23-1, Page ~~[illegible]8~~ 2.3-11
- b. pH Control
    - 1. High pH minimizes corrosion of steel and iron
    - 2. High pH helps maintain Magnetite film
    - 3. Controlled by adding ammonium hydroxide to the condensate system

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c. Oxygen Control
   1. Minimize pitting
   2. Necessary for chloride stress corrosion
   3. Develops non-protective corrosion product
   4. Deaerate condensate
   5. Add hydrazine to condensate
   6. Oxygen specification on condensate

d. Conductivity
   1. Prevent formation of hard scale on S.G. tubes
   2. Impurities: calcium, magnesium, and sodium

e. Chlorides
   1. Chloride stress corrosion

f. Solids Control
   1. Increase corrosion
   2. Decrease heat transfer surface
   3. Hard scale
   4. Soft sludge
   5. Measure silica

Figure ~~3-9~~ 2.3-9
Page ~~3-31~~ 2.3-33

3.9.8 Steam Generator Blowdown and Recovery System

3.9.8.1 Purpose

a. Maintain S.G. water chemistry limits by continuous removal of impurities through blowdown

b. Provide indication of a primary to secondary leak by sampling blowdown for radioactivity

c. Minimize loss of secondary inventory by purification of blowdown and return to the condenser hotwell

3.9.8.2 System Description
  a. Bottom Blowdown
    1. 2" line
    2. Blowdown ring internally mounted on the tube sheet
    3. Ring near the domed head of the tube sheet support cylinder
  b. Surface Blowdown
    1. 1" line
    2. Header above the feedwater ring
  c. Blowdown lines
    1. Separate
    2. Isolate on CIS
  d. Blowdown Tank
    1. 2,350 gal.
  e. Blowdown rate is manually set, normally
    1. 150 gpm
  f. Radiation detection
    1. Recirculation of 0.3 gpm
    2. Pump, cooler, radiation detector
  g. Normal operation
    1. Head provided by the tank
    2. Coolers reduce temperature for ion exchange
    3. One cooler cooled by condensate, other cooled by service water
    4. Filtered for insoluble impurities
    5. Ion exchange for soluble impurities
  h. Ion exchanger outlet
    1. Normally to the condenser
    2. Circulating water system during draining activities
    3. Miscellaneous Waste System (MWS) automatically if high radiation is sensed on the ion exchanger outlet

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Figure ~~3.4-10~~ 2.3-10
Page ~~3.4-53~~ 2.3-35

3.9.9 Steam Generator Instrumentation

3.9.9.1 Steam Generator Level
- a. 10 transmitters
- b. 6 Narrow range
  1. 0-100% of 183.16" 15.26'
  2. Upper tap in steam drum at 614 5/16"
  3. Lower tap in downcomer at 431 5/32" 35.93'
  4. Four supply RPS for low level reactor trip and high level turbine trip — 7% — 92.5
  5. Two supply FWCS
- c. 4 Wide range
  1. Tube sheet to upper tap 486" 40.5'
  2. Actuate the Emergency Feedwater System at-170"(65% narrow range)
     14.17' 170" below 0 control level

3.9.9.2 Steam Generator Pressure
- a. 4 safety related transmitters
  1. connected to upper level taps
- b. ESF
  1. SGIS at ~~500~~ 703 psia closes the MSIVs and the MFIVs
- c. RPS
  1. Reactor trip at ~~500~~ 703 psia for steam line break protection
  2. Asymmetric S.G. circuit for TM/LP for MSIV closure at power

3.9.9.3 RCS Flow
- a. 4 dp taps in S.G. outlet plenum
- b. Low side taps
- c. RPS low flow trip

3.10 System Operations

3.10.1 Plant Start-up

3.10.1.1 Initial Conditions

- a. Reactor is shutdown
  - 1. Shutdown Margin of 3%
- b. SDC in operation
- c. Rcs drained for maintenance
- d. RCS temperature <200 °F
- e. RCS is vented to atmosphere
- f. SGs are in wet layup
  - 1. Hydrazine and Ammonium Hydroxide for chemistry control

3.10.1.2 Major Steps

- a. Fill and Vent RCS
  - 1. CVCS or SDC
- b. Drain down the SGs to operating level
- c. Begin heatup of the pressurizer to ~ 300 °F
- d. Form bubble in pressurizer
  - 1. Decreasing level with no decrease in pressure
- e. Establish automatic pressurizer level control
- f. Increase RCS pressure with heater operation
- g. Minimum pressure of 270 psia
  - 1. Proper seal operation at 200 psia
  - 2. NPSH for RCPs at 266psia
- h. One RCP in each loop for 3-5 minutes
  - 1. Sweeps the S.G.
- i. Final RCS vent
- j. Start three RCPs to begin heatup
  - 1. 6000 HP vs. 4500 HP
  - 2. < 500 °F water density may lift fuel assemblies causing fretting
  - 3. 3.2 MWth / pump
- k Secure SDC and realign
- l.. Open SIT outlet valves prior to 300 psia
- m. At 500 °F start the forth RCP

- n. Place pressurizer pressure control in automatic
- o. Establish no load Tave with SDBCS in automatic
- p. Establish desired boron concentration
- q. Withdraw CEAs to establish criticality
- r. Escalate power

3.10.2 Plant Shutdown

- a. Shift generator load to grid while reducing reactor power by boration
- b. Trip the turbine at ~10% power
- c. Secure Main Feedwater and establish Auxiliary Feedwater for S.G. level control at ~ 3% power
- d. Shutdown the reactor by inserting CEAs
- e. Trip one RCP in each loop
- f. Cooldown by dumping steam to condenser
- g. Volume control by CVCS
- h. Pressure control by spray valve manual operation
- i. Place SDC in operation <300 °F and < 260 psia
- j. Secure RCPs
- k. Further pressure reduction by auxiliary spray

325C-3

Lesson Title: CEA Mechnical, Electrical, RPI Date: 5/20/87 Rev: 0

Program: ~~R-205P-9, 10~~ e Author: T. L. Bell

Reviewed by: TL Bell

1.0 Special Instructions and Training Aids

- 1.1 R205-9,10 Viewgraph Package

2.0 References

- 2.1 CE Systems Manual Section Chapter 8
- 2.2 ANO2 NSSS Lectures

dCNPP Plant DESC. #60

Notes	Lesson Plan (Continuation Sheet)
OBJECTIVES TP	3.0 Objectives
	3.1 Cover learning objectives on page 8.1-1
	4.0 Presentation
Reactor TP Fig 3.1-1 PG 3.1-29	4.1 Mechanical Construction
	4.1.1 Mechanism may be divided into 3 parts
	4.1.1.1 Drive shaft assembly
	4.1.1.2 Pressure housing and drive unit
	4.1.1.2 Coil assemblies
FIGURE 8-1 PG 8-19	4.1.2 Drive Shaft Assembly
	COLLET TP 4.1.2.1 Collet at bottom of extension shaft coupled to CEA
FIG 8-2 PG 8-21	4.1.2.2 Extension shaft contains grooves that allow grippers to move rod
	4.1.2.3 Top extension shaft - allows coupling and uncoupling
	4.1.2.4 Magnet assembly actuates reed switches used in rod position indication.
FIG 8-3 PG 8-23	4.1.3 Pressure Housing and Drive Unit
	4.1.3.1 Bottom of unit threaded to CEA nozzle on vessel head-seal welded
	4.1.3.2 Upper part of unit sealed with a threaded cap and seal welded
	4.1.2.3 RCS pressure boundary
	4.1.3.4 2 latches (grippers) move CEA via grooves in extension shaft
	FIG 8-7 UPPER GRIPPER FIG 8-8 LOWER GRIPPER
FIG 8-4 (BOTTOM OF UPPER PRESSURE HOUSING)	
FIG 8-5 (TOP OF UPPER PRESSURE HOUSING AND VENT)	

Notes	Lesson Plan (Continuation Sheet)
FIG 8-6	4.1.3.5 "Necked down" shape concentrates magnetic lines of flux from electro-magnetic coils
FIG 8-9	4.1.4 Electromagnetic Coils
	4.1.4.1 5 Coils
	o Lift Coil - used to move extension shaft
~~FIG 8-7~~	o Upper Gripper - normal holding coil
40step/min ≈ 30"/min 4 step/min = 3"/min	o Pull Down - repositions upper gripper for next step
	o Load Transfer - transfers load between upper and lower grippers during movement
~~FIG 8-8~~	o Lower Gripper - holds CEA during intermediate movement steps
FIG 8-10	4.1.4.2 CEA Withdrawal Sequence
	(a) CEA is moved in 3/4 inch steps
	(b) Initial condition - upper gripper energized holding CEA
	(c) Lift coil energized pulling CEA up 3/4"
	(d) Lower gripper energized to hold CEA in new position
	(e) Load transfer coil energized pulling lower gripper up 1/16" - positive engagement

Notes	Lesson Plan (Continuation Sheet)
	(f) Upper gripper deenergized
	(g) Pull down coil pulls upper gripper down
	(h) Upper gripper engaged
	(i) Load transfer disengaged - xfers load to upper grippers
FIG 8-11	4.1.4.3 CEA Insertion
	(a) Initial conditions - upper gripper energized
	(b) Energize lower grippers
	(c) Load transfer coil energized - positive lower gripper engagement
	(d) Deenergize upper grippers
	(e) Lift coil energized - pulls gripper up 3/4".
	(f) Energize upper grippers
	(g) Load transfer deenergizes
	(h) Lower gripper deenergizes
	(i) Lift coil deenergizes - CEA drops 3/4"
	4.1.4.4 Withdrawal/insertion sequence controlled by CEDMCS
FIG 8-12	4.2 CEA Power Supplies
	4.2.1 General
	4.2.1.1 Redundant MG sets
	4.2.1.2 Output breakers/control cabinet
	4.2.1.3 Reactor trip circuit breakers

Notes	Lesson Plan (Continuation Sheet)

- 4.2.2 MG sets
  - 4.2.2.1 Motor
    - (a) 480 VAC-3ϕ-60 Hz induction motor
    - (b) Non vital power
    - (c) Drives generator and flywheel
    - (d) Flywheel - maintains generator output during momentary losses of power (< 1 min)
  - 4.2.2.2 Generator
    - (a) 240 VAC-3ϕ-60 hz output
    - (b) Either generator is capable of supplying full load
- 4.2.3 Control Cabinet
  - 4.2.3.1 Motor start/stop
  - 4.2.3.2 Synchroscope
  - 4.2.3.3 Output breakers
- 4.2.4 Reactor Trip Circuit Breakers
  - 4.2.4.1 Circuit breakers #9 is <u>not</u> a RTCB
    - (a) Maintains MG set synchronization
  - 4.2.4.2 PPS controls opening of Bkrs 1-8
  - 4.2.4.3 Breakers operate in pairs
    - (a) Allow on-line testing
    - (b) Single failure will not cause trip
    - (c) 1x2x2 logic
    - (d) Plant computer input - CEA drop time
  - 4.2.4.4 UV Coils
    - (a) Generate turbine trip on reactor trip
    - (b) FWCS RTO
    - (c) SDBCS

Notes	Lesson Plan (Continuation Sheet)
	4.2.4.5 Power supplied to 2 power busses ~ 1/2 CEAs powered from each bus 4.3 Control Element Drive Mechanism Control System 4.3.1 General 4.3.1.1 Provides CEA control 4.3.1.2 Downstream RTCBs => cannot interfere with PPS. 4.3.1.3 Coil power switches - supplies 5 coils 4.3.1.4 Logic controls power switch
FIG 8-13	4.3.2 Power Distribution 4.3.2.1 Block Diagram (Typical of 2 busses) 4.3.2.2 Distribution bus supply subgroups (a) ~ 10 subgroups per bus (b) Individual CEA breakers (c) Coil switch 4.3.2.3 Hold Bus (a) Rectified input (50 VDC) (b) Subgroup xfer for maintenance (c) Supplies power to upper grippers only
FIG 8-14	4.3.3 Coil Power Switch 4.3.3.1 Block Diagram 4.3.3.2 3 SCRS/Coil 4.3.3.3 Logic circuit controls coil energization by controlling SCR gate 4.3.3.4 High/low Logic (a) High => initial coil energization => more energy (b) Low => holding mode (c) Controlled by logic

Notes	Lesson Plan (Continuation Sheet)
FIG 8-15	4.4 CEDMCS Control Panel
	4.4.1 Purpose-allows manual or automatic control of CEAs
	4.4.2 CEA Group Assignments Fig 3.1-21 CEA MAP
	A & B - Shutdown Banks - no control functions 1-6 - regulatory groups - Control pwr/t_{ave}
	P - Part lengths - axial power shape
	4.4.3 Control Panel Lights XTRA DRAWING
	4.4.3.1 Group lights - energized when gp selected
	4.4.3.2 In/Out arrows - Indicate commanded motion direction
	4.4.3.3 Individual Lights
	(a) Red - fully withdrawn (150")
	(b) White - control available
	(c) Green - fully inserted (0")
	4.4.4 Control Modes
	4.4.4.1 Manual Individual
	(a) Any of 81 CEAs may be positioned
	(b) CEA selected by TENS and UNITS switches
	(c) Dropped rod recovery - testing
	4.4.4.2 Automatic Sequential
	(a) Groups 1-6 only
	(b) CEAs positioned by RRS signal
	(c) Sequence
	• 90" withdrawal - next group starts to move
	• 60" insertion - previous group starts to move

Notes	Lesson Plan (Continuation Sheet)
	4.4.4.3 Automatic Sequential Interlocks
	(a) CWP
	(b) AWP
	(c) AMI
	4.4.4.4 Manual Sequential
	(a) Groups 1-6 only
	(b) Sequenced as above
	4.4.4.5 Manual Group
	(a) All CEA groups
	(b) Group determined by GROUP SELECT switch
	(c) Normal control mode for shutdown banks
	4.4.4.6 P - Part Length
	(a) Used to position Part Length CEAs
	4.5 Operation and Logic Diagrams
	4.5.1 Initial Conditions (Use Reactor Startup and Power Escalation)
	4.5.1.1 ECP calculated
	4.5.1.2 Plant in condition to support reactor startup
FIG 8-16	4.5.2 Shutdown Bank Withdrawal
	4.5.2.1 Select MG
	4.5.2.2 Select Shutdown Bank A
	4.5.2.3 Withdraw CEAs to upper group stop (145")
FIG 8-17	4.5.2.4 Select MI and TENS-UNITS to pull each CEA to upper electrical limit
	4.5.2.5 UEL - stops CEA motion
	4.5.2.6 Repeat 2-4 for Bank B

Notes	Lesson Plan (Continuation Sheet)
FIG 8-18	4.5.3 Regulating Group Withdrawal
	4.5.3.1 Select MS
	4.5.3.2 Groups 1-6 withdrawn in sequence 90↑ 60↓
	4.5.3.3 UGS stops motion
	(a) MI withdrawal may be used
	4.5.3.4 Criticality/power escalation
	4.5.4 Auto Sequential
	4.5.4.1 ≥ 15% - place in automatic
	4.5.4.2 RRS positions CEAs
	4.6 CED Inhibits/Prohibits
	4.6.1 Control Withdrawal Prohibits (CWP)
	4.6.1.1 PPS generated
	4.6.1.2 2/4 Hi pzr press, DNBR, LPD
	4.6.2 AWP
	4.6.2.1 RRS/SDBCS generated
	4.6.2.2 Hi T_c, H, (T_{ave}-T_{ref}), any SDECS valve open
	4.6.3 AMI
	4.6.3.1 SDBCS generated
	4.6.3.2 Pwr < 15%, or AMI
	4.7 Rod Position Indication
	4.7.1 3 ~~Two~~ methods of position indication
	4.7.1.1 Actual rod position
	4.7.1.2 Demanded rod position
FIG 8-20	4.7.2 Actual Rod Position
	4.7.2.1 Safety system
	4.7.2.2 Reed switches activated by magnet on CEA shaft (switches 1.5" apart)
	4.7.2.3 Cuts resistors in and out of voltage divider network
	4.7.2.4 2 RSPTS per CEA

Notes	Lesson Plan (Continuation Sheet)

4.7.2.5 RSPT outputs
  (a) CEAC inputs - every rod - rod misalignment
  (b) CPC - 20 CEAs/CPC - target rods - radial flux calc.
  (c) UEL & LEL - stops rod motion
  (d) computer input (LEL) - rod drop times (i.e., CKT BKR opening time LEL actuation time

4.7.3 Demanded Rod Position
  4.7.3.1 Not safety related
  4.7.3.2 Computer counts pulses sent to coils
  4.7.3.3 Assumes CEA moves each time it is commanded to move
  4.7.3.4 Demanded position outputs
    (a) Indication - MI selection determines output on digital meters
    (b) Sequence interlocks - UGS-LGS
    (c) Computer generated PPDIL & PDIL alarms
    (d) COLSS inputs

5.0 Technical Specifications
  5.1 Position Indication
    5.1.1 Operable position indication required for:
      5.1.1.1 Compliance with rod position requirements
      5.1.1.2 CPC/CEAC operability
      5.1.1.3 2/3 systems required

Notes	Lesson Plan (Continuation Sheet)
	5.1.2 CEA drop time ($\leq$ 3 seconds) 5.1.2.1 Assumed drop time in Safety Analysis 5.1.3 PDIL 5.1.3.1 SDM 5.1.3.2 Ejected Rod 5.1.3.3 Peaking Factors 5.1.4 Alignment Requirements 5.1.4.1 Spec 3.1.3.1

Lesson Title: Reactor Regulating System	Date: 10/8/85 Rev.: 0
Program: ~~R-205P-11~~ 325C -4	Author: T. L. Bell
	Reviewed by: T. L. Bell

1.0 Special Instructions and Training Aids

1.1 Training Aids

1.1.1 Viewgraphs package for R-205P-11

2.0 References

2.1 CE Systems Manual - Section 11.3

2.2 CCSD

Notes	Lesson Plan (Continued)
	3.0 Objectives
	3.1 Cover objectives on page 11.3-1
	4.0 Presentation
PG 11.3-1	4.1 Purposes of RRS
	4.1.1 Control Tave from 15% to 100%
	4.1.1.1 Steady State
	4.1.1.2 5% ramp
	4.1.1.3 10% step
	4.1.2 Along with SDBCS, controls Tave during
	4.1.2.1 Load rejection
	4.1.2.2 Turbine trip
	4.1.2.3 Turbine setbacks
	4.1.3 Pzr Water Level Setpoint
	4.1.4 2 RRS - Either may be selected
	4.2 Basic Control Loop
	4.2.1 Needs setpoint (first stage pressure)
	4.2.2 Needs actual value - Tavg
FIGURE 11.3-1	4.3 RRS Inputs
PG 11.3-14 5	4.3.1 Temperatures
	4.3.1.1 Well mounted RTDs
	4.3.1.2 Non safety related (i.e. control grade)
	4.3.1.3 Hot Leg Temp
	(a) Narrow range - 525°F to 625°F
	(b) Selector switch
	4.3.1.4 Cold Leg Temp
	(a) Narrow range - 525°F to 625°F
	(b) 2 RTDs to selector switch
	(c) Non-selected → wide range
	(d) Selecting loop 1 & 2 minimizes effect of RTD failure

Notes	Lesson Plan (Continued)

549°
(f) High Tc AWP - minimize - ~~558~~°F approach to T_c T.S. limit

4.3.2 Tave Calculation

4.3.2.1 $(T_H + T_c)/2$

4.3.2.2 Outputs

(a) Temperature error (Tave-Tref)

(b) Pzr level setpoint

4.3.3 Turbine First Stage Pressure

4.3.3.1 Turbine First Stage Pressure Proportional to Plant (secondary power)

4.3.3.2 Controlling Tave for turbine efficiency

4.3.3.3 Converted to Tref signal

(a) 0% = 532 ~~545~~°F

(b) 100% = ~~583~~°F 573

(c) Temp setpoint

4.3.3.4 Power Mismatch

4.3.4 Control Channel Input

4.3.4.1 Compared with turbine power

4.3.5 Pressurizer Pressure

4.3.5.1 Temp change = pzr level change = pressure change

4.3.5.2 Not normally used

4.3.5.3 Control grade input

4.4 Circuitry

4.4.1 Temperature Summer

4.4.1.1 Tave - Tref

Notes | Lesson Plan (Continued)

4.4.1.2 Lead/Lag Circuit
- (a) signal delay
- (b) allows over and undershoots of reactor power to restore Tave = Tref

4.4.1.3 AWP on Hi Tave - Tref (5°F)

4.4.1.4 Temp Error Feeds Total Error Summer

4.4.2 Power Error

4.4.2.1 Anticipates change in Tave caused by a difference in turbine and reactor power

4.4.2.2 Looks at rate of change only

4.4.2.3 Feeds total error circuit

4.4.3 Total Error Summer

4.4.3.1 Combines temperature and power errors

4.4.3.2 Output used to determine CEA direction and speed

Figure 11.3-2
Page 11.3-~~13~~ 7

4.5 CEA Motion/Speed

4.5.1 Tave must deviate from Tref by 2°F to cause rod motion

4.5.2 Bistable action causes slow CEA speed (3 inches/min)

4.5.3 Errors >3°F cause high speed withdrawal (30 inches/min)

5.0 Operations

5.1 Power Escalation

5.1.1 Automatic Sequential must be selected

Notes	Lesson Plan (Continued)
	5.1.2 Power >15%
	5.1.3 PDIL prevents full escalation on CEAs
	5.1.3.1 With Gp 6 @ 112" - not enough reactivity to overcome power defect.
	5.1.3.2 CEAs and boron used to escalate power
	5.1.4 Philosophy
	5.1.4.1 CEA motion causes rapid local flux and temp changes
	5.1.4.2 CE believes rapid local temp changes lead to fuel failures
	5.1.4.3 Auto withdrawal removed at some units
Figure 11.3-3 Page 11.3-~~18~~ 9	5.1.5 Ramp Decrease
	5.1.5.1 Load change initiated at turbine EHC panel
	5.1.5.2 Reduction in turbine power causes output from temp and power error
	5.1.5.3 Immediate slow speed insertion
	5.1.5.4 Reactor power < Turbine Power (a) "Overcooling" allows Tave to be cooled to Tref (b) Undershoot → outward motion
Figure 11.3-~~5~~ 4 Page 11.3-~~17~~ 11	5.1.6 Step Decrease
	5.1.6.1 10% step shown
	5.1.6.2 Tave > Tref - lack of heat removal
	5.1.6.3 Tave > Tref - does not exceed deadband

Notes	Lesson Plan (Continued)
	6.0 Indications and Interfaces 6.1.1 Indications - page 11.3-7 6.1.2 Interfaces - page 11.3-8

COMBUSTION ENGINEERING LESSON PLAN

Lesson No: ~~305-07/905-8C~~ 325C-5	Title: CHEMICAL AND VOLUME CONTROL SYSTEM	
Written by: Loren F .Donatell	Approved by: Larry Bell	Date: 10/27/92

1.0 TRAINING AIDS/SPECIAL INSTRUCTIONS

1.1 Transparency Package for 305-07/905-8C
1.2 Lesson Module for 305-07/905-8C

2.0 REFERENCES

2.1 CE Systems Manual, Chapter 4
2.2 CCNPP System Description No. 6

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.305-07/905-8C	Title: CHEMICAL AND VOLUME CONTROL SYSTEM	
Written by: Loren F .Donatell	Approved by: Larry Bell	Date: 10/27/92

3.0 PRESENTATION

3.1 Learning Objectives

3.1.1 Cover objectives in manual

3.2 Introduction

3.2.1 System Purposes

a. Purification of the RCS
b .Control of RCS boron concentration
c. Control of RCS volume (Pressurizer Level)
d. Addition of corrosion inhibiting chemicals
e. Collect RCP controlled bleed off
f. Add boron to the RCS in the event of an accident
g. Supply Pressurizer Auxiliary spray
h. Continuous on-line measurement of RCS boron concentration and RCS activity
i. Provides a means of testing HPSI check valves

Figure 4-1
Page 4-13

3.2.2 Simplified System Diagram

3.3 CVCS System Description

Figure 4-2
Page 4-15

3.3.1 Letdown

3.3.1.1 RCS Interface
a. From RCP 12A suction

3.3.1.2 Letdown Stop Valve
a. CV-515
b. Close on High Temperature on Regenerative Heat Exchanger outlet. (470 °F)
1. Protect against loss of charging
2. Ensure cooling to Hx. prior to starting letdown

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.305-07/905-8C	Title: CHEMICAL AND VOLUME CONTROL SYSTEM	
Written by: Loren F .Donatell	Approved by: Larry Bell	Date: 10/27/92

- c. Close on SIAS.
    - 1. NSR penetration
    - 2. Prevent loss of additional inventory.

3.3.1.3 Letdown Containment Isolation Valve

- a. CV-516
- b. Close on SIAS
- c. Redundant to CV-515
- d. Close on CVCIS
    - 1. Actuates on penetration room pressure
    - 2. 2 detectors /room, 2 rooms, 2/4 logic at .5 psig

3.3.1.4 Regenerative Heat Exchanger

- a. U-tube heat exchanger
    - 1. letdown in tubes, charging in shell
- b. Initial cooling of letdown
    - 1. Ion Exchanger Operation
- c. Preheats charging
    - 1. Minimize thermal stress

3.3.1.5 Excess Flow Check Valve

- a. downstream of the regenerative heat exchanger
- b. Minimize consequences of a CVCS letdown line rupture
- c. Isolates when letdown flow >210 gpm

3.3.1.6 Letdown Flow Control
- a. CV-110P and CV-110Q
- b. Controlled by Pressurizer Level
- c. Level above program - selected valve(s) open
- d. Level below program - selected valve(s) close to minimum
- e. Maximum letdown is 128 gpm to prevent letdown from exceeding charging (132 gpm)
- f. Minimum letdown is 20 gpm to maintain preheat of charging
- g. Only one valve in service >1500 psia to prevent thermal shock from high flow
- h. Two valves may be in service at low pressure (<1500 psia)
- i. DP at normal flow is 1630 psid

3.3.1.7 High Pressure Relief
- a. 600 psig
- b. Piping design pressure is 650 psig
- c. Discharges to WMS

3.3.1.8 Letdown Heat Exchanger
- a. Final reduction in temperature
- b. Cooled by CCW on shell side
- c. Auto temperature control via CCW control valve
- d. Approximately 263°F in and 120°F out

Max. expected Regen. Hx outlet temp. is 450°F with Max letdown and Min. charging .Corresponding Sat. Press. is 422 psig

3.3.1.9 Letdown Back Pressure Regulators
- a. CV-201P and CV-201Q
- b. Maintain 460 psig on the letdown stream to prevent flashing
- c. Auto controlled to letdown line pressure
- d. Normally one valve selected for service with the other in standby
- e. Can select either valve or both

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.305-07/905-8C	Title: CHEMICAL AND VOLUME CONTROL SYSTEM	
Written by: Loren F .Donatell	Approved by: Larry Bell	Date: 10/27/92

3.3.1.10 Low Pressure Relief
- a. Set at 205 psig
- b. Discharges to the Reactor Coolant Waste Receiver Tank

3.3.1.11 Orifice
- a. Provides letdown flow indication
- b. DP causes flow through the boronometer and the radiation monitor

Figure 4-3
Page 4-17

3.3.1.12 Boronometer
- a. Contains a 1 curie PuBe neutron source
- b. Contains 4 BF3 detectors
- c. Output is inversely proportional to boron concentration due to neutron absorption by the boron between the source and the detector
- d. Device is temperature sensitive. Will be isolated by CV-521 at 145°F
- e. Flow rate is 1/2 gpm
- f. Instrument Range is 0 - 2050 +/- 35 ppm

3.3.1.13 Radiation Monitor
- a. NaI scintillation detector
- b. Monitors Gross Activity and I-135 Activity
- c. Failed fuel (I-135) and CRUD (Gross)

3.3.1.14 Letdown Filters
- a. Wound cartridge
- b. 98% retention for particles >3 microns
- c. Removes insoluble particles
- d. Prevents CRUD loading of resin

ANION (-)
exchange hydroxide ions for negatively charged impurities

CATION (+)
exchange hydrogen ions for metallic ions

3.3.1.15 Ion Exchangers
- a. 2 mixed bed, 1 deborating
- b. Automatic bypass on high temperature of 145°F
- c. Mixed Bed
  1. Soluble ion removal
  2. One in service; one in standby
  3. Anion / Cation in 3:1 ratio
  4. Remove fission products for activity limits
  5. Remove chlorides, fluorides, etc. for corrosion control
- d. Deborating
  1. Anion
  2. Reduce boron concentration from 30 ppm

3.3.1.16 Letdown Strainer
- a. Traps resin fines
- ~~b. Flushed to an Auxiliary Bldg. floor drain~~

3.3.1.17 Three-Way Valve
- a. CV-500
- b. Normal flow to VCT
- c. Alternate flow to WPS vacuum degasifier
  1. On VCT high level of 88%

3.3.2 Volume Control Tank

3.3.2.1 Purpose
- a. Collect Letdown and Controlled Bleed off
- b. Provide for Hydrogen Addition
- c. Interface to WPS
- d. Interface to Makeup System
- e. Normal suction source for the Charging pumps

3.3.2.2 Level Program
- a. Heatup from cold shutdown results in 20,000 to 30,000 gallons to WPS.

b. Large Dilutions
  1. Lower RCS boron concentration for criticality
  2. Compensate for power coefficient as power is increased to 100%
  3. Compensate for changes in Xenon concentration

3.3.2.3 Gas Interface
  a. Hydrogen
    1. 20 -40 psig overpressure for Oxygen
  b. Nitrogen
    1. Cover gas for maintenance purge
    2. Removed for operation. If introduced to the RCS it will form Nitric Acid
  c. Waste Gas System
    1. Remove Fission gases

3.3.2.4 Controlled Bleed Off
  a. 1 gpm per RCP
  b. Excess flow check valve
  c. Isolates on ~~CIS~~ SIAS
    1. Air operated valves CV-505,506
    2. Relief to Quench Tank when isolated

3.3.2.5 VCT Outlet Valve
  a. CV-501
  b. Motor Operated
  c. Closes on VCT low-low level (5.6%
  d. Closes on SIAS

3.3.3 Charging System

3.3.3.1 Purpose
  a. Return purified coolant to the RCS
  b. Add coolant to the RCS during an accident

3.3.3.2 Charging Pump Suction

- a. Normal from the VCT outlet
- b. RWT Supply
    - 1. CV-504
    - 2. Motor Operated
    - 3. Opens on VCT low-low level
- c. Gravity feed and boration supply
- d. Chemical feed
    - 1. LiOH for pH control
    - 2. N_2H^4 for Oxygen control in cold shutdown

3.3.3.3 Charging Pumps

- a. Positive Displacement
    - 1. 3 piston; 2 1/8" dia., 5" stroke
- b. 44 gpm
- c. Powered from 480 VAC vital buses
- d. Pump 13 may be powered from either bus (swing pump)
- e. Automatic start on SIAS
- f. Automatic start on Pressurizer level
- g. Protected by 2800 psig discharge relief
- h. Water lubricated packing
    - 1. Gravity fed from a small storage tank

3.3.3.4 Charging Return

- a Via Regenerative Heat Exchanger
- b. Normally lined up to two loops
    - 1. CV-519,518
- c. Auxiliary Spray when RCPs are not running
    - 1. CV-517

3.3.3.5 HPSI Check Valve Testing

- a. HPSI discharge too low to open check valves during normal operation (1400 psia)
- b. Line from common charging header to HPSI System
- c. Charging pumps show valve operability

3.4 Makeup System Description

3.4.1 Boric Acid Makeup System

3.4.1.1 Two Boric Acid Makeup Tanks
- a. 9,500 gallons each tank
- b. 12,700 ppm boron
- c. Ensure 1% SDM at EOL, Cold (<200°F) and Xenon Free

3.4.1.2 Gravity Feed Valves
- a. CV-508,509
- b. Direct to charging pump suction
- c. Open on SIAS

3.4.1.3 Boric Acid Pumps
- a. 143 gpm which is greater than the capacity of three charging pumps at 132 gpm
- b. 10 gpm recirculation
- c. 480VAC vital buses
- d. SIAS
  1. Both pumps start
  2. CV-514 opens
  3. Recirculation valves, CV-510 and CV-511 close
  4. Path is redundant to gravity feed

3.4.2 Reactor Makeup Water

3.4.2.1 Demineralized Water
- a. Demineralized Water Tank
  1. 350,000 gallons
  2. Filled from the demineralized water system
  3. Reservoir for Reactor Makeup Water

Lesson No.305-07/905-8C	Title: CHEMICAL AND VOLUME CONTROL SYSTEM

Written by: Loren F .Donatell	Approved by: Larry Bell	Date: 10/27/92

3.4.2.2 Reactor Coolant Makeup (RCMU)
- a. RCMU Pumps
- b. Two single stage centrifugal
- c. NSR - 480 VAC non-vital

3.4.3 Makeup Control System

3.4.3.1 Borate Mode
- a. Select addition rate
- b. Select batch size
- c. Open the Makeup Stop Valve
  - 1. CV-512
- d. Mode Selector Switch to "Borate"
- e. Boric Acid Pump starts
- f. CV-210Y controls the addition rate
- g. When addition equals the batch size CV-210Y closes and the boric acid pump will stop

3.4.3.2 Dilute Mode
- a. Select addition rate
- b. Select batch size
- c. Open the Makeup Stop Valve
  - 1. CV-512
- d. Mode Selector Switch to "Dilute"
- e. RCMU Pump starts
- f. CV-210X controls the addition rate
- g. When addition equals the batch size CV-210X closes and the RCMU pump will stop

3.4.3.2 Automatic Mode
- a. System controlled by VCT level
- b. Automatic makeup between 72% and 86%
  - 1. Blended makeup through CV-210Y, CV-210X, and CV-512
  - 2. Concentration determined by flow controller settings

3.4.3.3 Manual Mode

- a. Allows control of any control or control valve in system

3.5 Engineered Safety Features

3.5.1 Engineered Safety Features Actuation

- a. Letdown is isolated (NSR)
- b. VCT outlet valve closes
- c. All Charging Pumps start
- d. Both Boric Acid Pumps start
- e. Gravity feed addition valve opens
- f. Boric acid discharge opens directly to the charging pump suction
    - 1. CV-514
- * g. No credit in Safety Analysis
- h. Operator action required to secure system

* >80% FSAR assumes 80gpm chg flow.

Lesson Title: Pzr Level and Pressure	Date: 10/1/86 Rev.: 0
Program: ~~R205P-8~~ 325C - 6.1, 6.2	Author: Gage
	Reviewed By: Bell

1.0 Special Instructions and Training Aids

  1.1 R2-5P-8 Viewgraph Package

2.0 References

  2.1 CE Manual - Chapters 11.1 and 11.2

  2.2 Waterford 3 Training Manual

  2.3 ANO2 Training Manual

Notes

Lesson Plan (Continuation Sheet)

3.0 Objectives - pp 11.2-1 and 11.2-1

4.0 Pzr Pressure

- 4.1 Purposes - pg 11.1-1
- 4.2 System Description
  - 4.2.1 2 Groups of Heaters
    - 4.2.1.1 2 Banks of proportional 150KW eac
    - 4.2.1.2 4 ~~6~~ Banks of backup 300 KW each
  - 4.2.2 Pressure Control Station
    - 4.2.2.1 Manual/auto transfer capability
    - 4.2.2.2 Setpoint Adjustment
    - 4.2.2.3 Display (setpoint & pressrue)
  - 4.2.3 Pressure Indicator Controller Output
    - 4.2.3.1 Auto (Pressure - setpoint) (~~setpoint - indicated pressure~~)
    - 4.2.3.2 Manual (value set by operator)
  - 4.2.4 Spray Valves
    - 4.2.4.1 Both valves - 375 gpm
    - 4.2.4.2 Bypass flow - 1.5 gpm (27KW loss) maintain temperature of spray piping
- 4.3 Normal Operations
  - 4.3.1 controller setpoint = 2250 psia

    Δ setpoint → corresponding Δ heaters
    Δ spray
  - 4.3.2 Proportional controller

    cannot hold pressure at setpoint
  - 4.3.3 Equalize Boron Concentration

    85 gpm spray → will have difference between Pzr & RCS boron in 1 hour.

Notes

Lesson Plan (Continuation Sheet)

4.4 Protection Signals

- 4.4.1 High Pzr Pressure Rx Trip ~~(2400 psia)~~ 2360 psia
- 4.4.2 SI~~S~~ actuation ~~(700 psia)~~ 1770 psia
- 4.4.3 Low Pzr Pressure Rx Trip ~~(1600 psia)~~ 1770 psia
- 4.4.4 CPC input (DNBR)

5.0 Pzr Level

5.1 Purpose - pg 11.2-1

variable letdown (as a function of level error) balanced with number of constant speed pumps.

Accommodate the change in RCS volume

5.2 Level Program

- 5.2.1 Setpoint (from RRS - Tavg)
- 5.2.2 Setpoint increased with power to match expansion of coolant
- 5.2.3 If No Program
  - 5.2.3.1 Close to safety valve (solid plant)
  - 5.2.3.2 ~~Turbine~~ RT ~~unload~~ (Pzr empty)

5.3 Signal Processing

- 5.3.1 Limiter
  - 5.3.1.1 Min. 29 gpm maintains preheat capability for charging flow
  - 5.3.1.2 Max. 128 gpm consistent for total charging pump capability

5.4 Level Bistables

- 5.4.1 <~~25~~ 29% - heater protection (either channel)
- 5.4.2 Hi/Low level each channel
- 5.4.3 Hi level deviation (+~~13~~ 4.5% above setpoint)
  - 5.4.3.1 Backup to stop standby pump
  - 5.4.3.2 Turn on B/U heaters (in auto)
- 5.4.4 No reactor trips!

Notes	Lesson Plan (Continuation Sheet)

5.5 Charging Pumps

- 5.4.1 44 gpm each
- 5.4.2 CCP #3 powered from either emergency bus
- 5.4.3 Auto operation
    - 5.4.3.1 1 CCP running - 44 gpm
    - 5.4.3.2 Letdown - 40 gpm

FWCS 325C-7.0

I Learning Objectives:
1. State the functions of the Feedwater Control System
2. List the inputs used to control SG water level and how each input is used.
3. List the override signal associated with the FWCS.
4. Explain the two modes of automatic control for the feedwater control system (FWCS).
5. Explain the difference between actual and indicated SG level following a plant cooldown.
6. Describe the effect initial power level has on the magnitude of shrink and swell.

II Introduction
1. Each SG has independent 3-element and single element controllers.
2. Auto control above 15% power / 3- element controller.
3. Auto control below 15% power / 1- element controller.
4. Functions
   - Auto control >15% / 3- element
   - Reduce flow after turbine trip; shut main valve and position by-pass valve to supply 5% flow.
   - Allows operator to manually control main and by-pass valves.
   - Adjust speed of turbine driven main feed pumps.

III Inputs
1. SG Level
2. Steam Flow

1. 2-level detectors/SG.

2. elbow tap- biased for 10% min.. because of inaccuracies at low flow.
- calibrated for operation at 850 psia.

3. Feed Flow

3. venturi flow nozzle- biased for 10% min. because of inaccuracies at low flow.

IV Normal Operations
1. Below 15% Power

1.
- aux. feed used < 5% power, until MFP is placed in service.
- single element controller < 15% power
- set point = 65% level
- proportional band is 22%. Valve is full open when level is 22% below 65%.
- Valve capacity is 15% of 100% feed flow or 2150 gpm
- Manual isolation valves upstream of MFRV normally closed during startup because of leakage.

2.

- 3-element controller combines two error signals to position MFRV
- lag circuits anticipate changes. Faster change rate produces larger error signal.
- PI controller can have an output when no input deviation exists. This is necessary because MFRV must be continuously opened as power increases.
- Flow error gain is twice level gain to compensate for shrink and swell.
- Because of inaccuracies in flow signal at low power, MFRVs are normally operated in manual and closed at low power.
- FRV ΔP controls MFP speed.

1.

- Decrease power 10%.
  - level shrinks
  - control system receives two opposing signals.
  - low level demands valve to open
  - higher feed flow demands valve to close.
- initially, flow error is dominate due to larger gain of flow error signal.
  - if valves were allowed to open, a large overshoot in level would result.
- as flow error is reduced, level error becomes dominate to restore level to setpoint.

- gains, reset time, and lag times are adjusted to minimize overshoots and oscillations

2. Turbine trip causes reactor trip > 15% power.

- MFRV closes
- FRV B/P valve positions to 33% open
  - 5% feed flow
- ramps to 5% feed flow within 60 seconds.
- turbine trip override can restore manual control of the FRV B/P valves.

2. Above 15% Power

IV Transient Operation

1. Step change in power

2. Turbine Trip

3.

- leak in reference leg reduces high side pressure.
  - high level output
- leak in ΔP diaphragm
  - high level output
- Normal operation
  - one transmitter is used for 3-element controller and a level recorder.
  - one transmitter is used for 1-element controller, level alarms and level indicators.
- During transmitter failure, a selector switch can be positioned to allow all functions to be controlled from one transmitter.

3. Level transmitter failures

VI Summary

SDBCS

I Learning Objectives:
1. List the purposes of the SDBCS
2. Briefly describe how each purpose is accomplished.
3. List the input signals to the SDBCS.
4. Describe how overpressurization of the condenser is prevented.

II Introduction

1. SDBCS removes excess energy from the RCS by dumping steam to atmosphere and/or bypassing the turbine to the condenser.
- Load rejection or turbine trip
- Reactor trip
- Reactor startup
- Plant cooldown

III SDBCS Components
1. Six valves - two groups
2. bypass group
   - 4 valves bypass steam flow around turbine to condenser
   - rated at 40% of total steam flow
   - connected to main steam header downstream of isolation valves
3. Dump valves
   - 2 valves release directly to atmosphere
   - rated at 5% of rated steam flow
   - connected to main steam header upstream of isolation valves
4. Controls steam pressure without requiring operation of safety valves.
5. Valves designed to withstand maximum steam pressure of 1000 psig at 580 °F.

IV Operations
1. Load Rejection

1. 40% change in electrical load.
   - turbine control valves close
   - steam flow decreases causing steam pressure to increase
   - bypass valves begin to open when pressure reaches 895 psia
   - CEAs are being driven to add negative reactivity
   - reduction in power reduces steam pressure
   - as pressure decreases, pressure error decreases and bypass valves start to close

2. Turbine trip causes signal to be sent to atmospheric dump valves.

- 8% power ~ 535 °F
- 63% power ~ 557 °F
- turbine control valves close
- signals sent to the SDBCS is proportional
  - steam flow decreases causing steam pressure to increase
  - bypass valves begin to open when pressure reaches 895 psia
  - CEAs are being driven to add negative reactivity
  - reduction in power reduces steam pressure
  - as pressure decreases, pressure error decreases and bypass valves start to close
- if power is >63% ~ 557 °F the RRS supplies a Quick Open signal to all 6 valves.

3. Reactor trip

- reactor trip causes turbine trip
- above action results, except CEAs fall
- when Tavg decreases to 548 °F the QO signal is removed
- when Tavg decreases to 535 °F the dump valves close
- 5 °F deadband allows bypass valves to control pressure at 900 psia

4. Startup

- RCS heat is removed as SG pressure increases above 900 psia
- As power increases, Tavg increases, and steam pressure increases until bypass valves open to maintain pressure at 900 psia
- As turbine is loaded, steam flow increases, and steam pressure decreases until bypass valves close.
- If condenser vacuum is lost, bypass valves close, turbine trip permissive causes atmospheric valves to open.

5. Plant cooldown

- manual control of the steam pressure controller

2. Turbine trip

3. Reactor trip

4. Startup

5. Plant cooldown

V Summary

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. ~~905-2C~~ ~~305~~ 325C - 9.1	Title: Excore Nuclear Instrumentation	
Written by: Gage	Approved by:	Date: 10/27/92

1.0 Special Instructions and Training Aids

1.1 Viewgraphs for lesson ~~R905P-2C~~ 305 - 9.1

2.0 References

2.1 CE systems manual - section 9.1
2.2 Waterford training manual
2.3 CE systems 80 (Palo Verde)
2.4 ANO2 training manual
2.5 Training article NS-4
2.6 PPE manual - section 16
2.7 Calvert Cliffs systems description - section 57

Page ~~2-1~~
9.1-1

3.0 Learning Objectives

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 905-2C	Title: Excore Nuclear Instrumentation	
Written by: Gage	Approved by:	Date: 10/27/92

4.0 Presentation

9.1-
Page ~~2~~-1

4.1 Purposes

4.1.1 Monitor neutron flux (source level to 200% power)
4.1.2 Provide indication (power level & rate of change)
4.1.3 Provide signal to RRS (power level)
4.1.4 Provide signals to RPS (power level & rate of change)
4.1.5 Provide information on axial power distribution

9.1
Figure ~~2~~-1

4.2 Instrumentation Range

4.2.1 Design over a large neutron flux range (10^{-9} % to 200% full power)
4.2.2 Control range (RRS and supplying heat to RCS)
4.2.3 Safety range (cover all power levels)
  a. Log (WR shutdown, subpower level, criticality)
  b. Linear (power operations , RPS)

Note: minimum overlap ensures indication during S/U

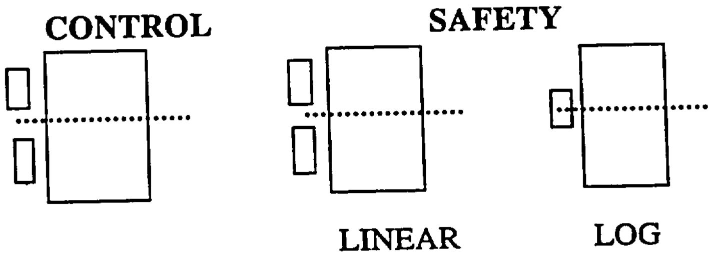
4.3 Detectors

9.1
Figure ~~2~~-2

4.3.1 Principal of operation
  a. count or measure charged particles
  b. neutrons produce charged particles for detection
  c. ion pairs collected = f(applied voltage)

9.1
Figure ~~2~~-3

4.3.2 Location
  a. wells external to reactor vessel
  b. radial and axial symmetry



COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 905-2C
Title: Excore Nuclear Instrumentation
Written by: Gage
Approved by:
Date: 10/27/92

4.4 Log Safety Channel

9.1
Figure ~~2~~-4

4.4.1 Proportional Detector
- a. neutron reaction

$$ {}_0n^1 + {}_5B^{10} = \underset{+++}{{}_3Li^7} + \underset{++}{{}_2\alpha^4} + \underset{---}{5\,e^{-1}} $$

- b. source level & low power ops
- c. secondary ionization in BF_3 gas
- d. large neg. charge collected by HV electrode
- e. γ reaction effects similar but smaller magnitude (allows for removal in disciminator)
- f. 2 assembly per channel
- g. 4 detectors per assembly
- h. enhances channel sensitivity

9.1
Figure ~~2~~-5

4.4.2 Fission Chamber
- a. U_3O_8 coats inner surface (90% U-235)
- b. high energy charged fission fragments ionize gas

$$ {}_0n^1 + {}_{92}U^{235} = X + Y + \text{energy} $$

- c. ions collected as a small electrical charge
- d. γ also ionizes Ar or N gas
- e. pulse amplitude α # ion pairs produced
- f. 1 per channel

9.1
Figure ~~2~~-6

4.4.3 Preamplifier
- a. located in containment building
- b. increases signal to noise ratio

4.4.4 Pulse counting
- a. discriminator elliminates γ signal (1/6 magnitude) set min. voltage level for filtration.
- b. audible count rate can be divided by freq. select sw.
- c. log cout rate amp converts ${}_0n^1$ pulses into log signal

4.4.5 Campbelling
- a. power α RMS (of random signal)
- b. bandpass amp (10^{-2}% - 150 %)
- c. RMS amp (signal α power)
- d. log amp (output α log of input)

4.4.6 Summing amp (combines pulse count and campbell)

4.4.7 Rate amp
- a. rate of change circuit
- b. pretrip & CWP @ 1.5 DPM (no credit in analysis)
- c. high SUR trip @ 2.6 DPM (10^{-4} % < power < 15 %)

4.4.8 Bistables

Level 1 (de-energize when power > 10^{-4} %)
- a. remove RPS zero power mode bypass
- b. clear ΔT power block
- c. enable TMLP CWP

Level 2 (de-energize when power > 10^{-4} %)
- a. enable SUR trip

Extended range (de-energizes at ~~200-500~~ 1000 cps)
- a. removes HV from B-10 proportional counter
- b. shifts WR indication from cps to % mode

4.5 Linear Safety Channel

Figure ~~2~~ 9.1-7

4.5.1 Detector (Uncompensated Ion Chamber)
- a. boron lined
- b. (n,α) reaction with B-10
- c. γ produces reactions also as before
- d. γ compensation NOT required
  - ${}_0n^1$ >> γ signal
  - γ α power (in the power range)
- e. 2 detectors per channel

Figure ~~2~~ 9.1-8

4.5.2 Linear Amp (increase signal magnitude) supplies:
- a. power summer (U + L)
- b. deviation comparator (L-U)
- c. subchannel comparator

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 905-2C	Title: Excore Nuclear Instrumentation	
Written by: Gage	Approved by:	Date: 10/27/92

4.5.3 Power summer supplies:
- a. rod drop bistable
- b. TMLP trip calculator
- c. axial power distribution trip circuitry
- d. VOPT circuitry
- e. comparator averager
- f. level 1 bistable ($\phi > 15$ %)

note: gain of summing amp adjusted based on sec. heat balance calculation

4.5.4 Bistables

Rod drop
compares power with power after a time delay circuit (if difference large enough ... AWP)

Level 1
de-energizes > 15 %
inhibits high SUR trip
enables loss of load & axial power dist. trip

HV decrease in HV or loss of low voltage supply

4.1
Figure ~~2~~-9

4.6 Linear Control Channel

4.6.1 Similar circuitry to safety channel

4.6.2 Channel outputs:
- a. RRS
- b. Recorder (control room)

4.6.3 Power ratio calculator (separate control signals, U & L) provided to control room recorder.

5.0 PWR Experiences

5.1 Davis Besse (April 85)

5.2 Millstone 2 (Jan 85)

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 325C - 9.2
Title: Incore Neutron Detection System
Written by: Gage
Approved by: Bell
Date: 3/23/93

p 9.2-1	**1.0 OBJECTIVES**
p 9.2-1	**2.0 FUNCTIONS**
	3.0 SELF POWERED NEUTRON DETECTOR
Figure 9.2-1	3.1 Operation Rh - 103 reaction with a neutron Beta emitted Insulator ... Al_2O_3 Charge deficiency proportional to neutron ϕ Measure charge flow through ammeter *note: External power connection NOT required*
Figure 9.2-2	3.2 Decay Scheme 93% ..... 42 seconds 7% ..... 4.4 minutes $T = 0.93\ (42\ \text{sec}) + 0.07\ (4.4\ \text{min}) \sim 1\ \text{min}$
Figure 9.2-3	3.3 Response Time apply step change input neutron power ~ 5 min to reach equilibrium output *note: slow response precludes use in RPS*
Figure 9.2-6	3.4 Detector Assembly 4 Rh detectors 1 Cromel-Alumel Themocouple 1 Background cable corrects for γ induced reactions which can produce electrons: Fission γ's Fission Product decay γ's no Rh

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.	Title: Incore Neutron Detection System	
Written by: Gage	Approved by: Bell	Date: 3/23/93

Figure 9.2-7

3.5 Detector Radial Location
    45 Fuel Assemblies
    Inserted through :
        nozzles
        guide tubes
        zircaloy thimbles (within FAs)

note: refuel ... assemblies withdrawn into their guide tubes and lifted out with UGS

Figure 9.2-5

3.6 Detector Axial Locations
    4 elevational planes within the core
        20%, 40%, 60%, and 80%
        Core bottom ... reference height
    Thermocouple ... core outlet temperature
        @ CEA guide tube exit
        ~ 1 foot above the active fuel height

note : under full RCS flow CETs read ~ 10-15°F less than Th due to influence by water that has NOT passed along the fuel rods i.e. bypass flow thru center guide thimble.

Figure 9.2-4

4.0 OUTPUTS

4.1 Thermocouple (CET)
    max temp range = 2300°F ~ 55 mv
    Three functions provided :
    (1) Proper core cooling (nat. circ)
    (2) Subcooling margin (LOCA)
    (3) Core uncovery (ICC)
            (superheated indication)

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.	Title: Incore Neutron Detection System	
Written by: Gage	Approved by: Bell	Date: 3/23/93

4.2 Neutron flux

$$\phi = \frac{I}{S\,L\,K_a K_b K_c}$$

L = length of detector

I = neutron current

S = neutron detector sensitivity

1.15×10^{-21} A/nv/cm

K_a = burnup correction

K_b = background correction

K_c = neutron energy change over core life correction

σ_a of Rh - 103 $\doteq$ f(energy)

4.3 Azimuthal Tilt (T_q)

defn = max of the following ratio :

$$\frac{[P_i - (\Sigma P_i)/4]}{(\Sigma P_i)/4}$$

Example: P_1 = 101%

P_2 = 99%

P_3 = 96.5%

P_4 = 99%

96-

P_{ave} = 98.875%

T_q = (98.875 - 96.5) / 98.875 = 0.024

note : symmetric detectors are used

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.	Title: Incore Neutron Detection System	
Written by: Gage	Approved by: Bell	Date: 3/23/93

4.4 Planar Radial Peaking Factor (F_{xy})

defn = max of (peak/ave) power density of the horizontal planes
(unrodded)
factor excludes tilt

4.5 Integrated Radial Peaking Factor (F_r)

defn = (peak pin power / ave pin power)
(unrodded)
factor excludes tilt

4.6 Total Peaking Factors

Planar Radial PF = $F_{xy} \times (1 + T_q)$

Integrated Radial PF = $F_r \times (1 + T_q)$

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. ~~905-9C~~ 225-C C 10.1	Title: Reactor Protection System

Written by: Gage	Approved by: Bell	Date: 10/28/92

1.0 Special Instructions and Training Aids

1.1 Viewgraphs for lesson R905P-9C
1.2 ANO2 control room slides
1.3 Calvert Cliffs simulator

2.0 References

2.1 CE systems manual - section 10.1
2.2 ANO2 PPS tech manual
2.3 Calvert Cliffs RPS tech manual
2.4 Calvert Cliffs system description - section 59
2.5 10 CFR 50
2.6 IEEE - 279
2.7 Information Notice 91-52
2.8 Training article NS-6
2.9 10 CFR 50.62

Page 5.1-1

3.0 Learning Objectives

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 905-9C | Title: Reactor Protection System

Written by: Gage | Approved by: | Date: 10/28/92

10.2-4 - 50 Pretrip
Pg 10.1-7 100psia
Fig 10.2-3 50psia

4.0 Presentation

4.1 Purpose = *insure safety limits NOT violated during AOO*
- 4.1.1 Safety limits = DNBR, LHR, RCS pressure
- 4.1.2 AOO = condition expected to occur during plant life (10 CFR 50 app A)

4.2 Design features
- 4.2.1 Single failure criterion (IEEE - 279)
  "single failure within the protection system shall not prevent proper protective action"
  (single failure defn in 10 CFR 50 app A)
  de-energize to actuate!
- 4.2.2 Redundancy (multiple channels)
- 4.2.3 Testibility (ensure reliability)
- 4.2.4 Trip logic
  - a. 1/1 fail non-conservative ... no trip when needed
  - b. 1/2 fail conservative ...
    unecessary trip &
    during testing, unreliable 1 sensor problem
  - c. 2/3 meets min. requirement of 1 failure
    note: some reliability lost during testing ... place tested channel trip condition, (ie back to 1/2 limitation)
  - d. 2/4 meets single failure &
    1 channel in test (bypass)
- 4.2.5 Separability (GDC 24)

Table 5.1

4.3 Reactor trips (include purposes of each)

Figure 5.1-1
Figure 5.1-2

4.4 Circuitry
- 4.4.1 Bistable trip unit
  - a. comparison of input parameter to setpoint
  - b. de-energize to actuate
  - c. one for each trip in each channel
  - d. 7 relays
    - 5 driven by trip comparator
      - 3 used in 2/4 logic matrices
      - 2 used for trip annuciation
    - 2 driven by pretrip comparator

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 905-9C	Title: Reactor Protection System	
Written by: Gage	Approved by:	Date: 10/28/92

Figure 5.1-3

4.4.2 Variable bistable trip unit
  a. high linear power
  b. sepoint = f(high select nuclear power and ΔT power)
  c. min setpoint = 30 %
  d. max setpoint = 106.5 %
  e. manual reset PB (one for each channel)

Figure 5.1-4

4.4.3 Auxiliary trip unit
  a. axial power distribution
  b. loss of load

Figure 5.1-5

4.4.2 Logic matrices
  a. 6 matrices - 2/4 logic
  b. coincidence logic (same parameter)
  c. 4 matrix relays - 1 per trip path

4.4.3 Logic matrix relays
  a. de-energize to actuate
  b. actuate contacts in each trip circuit breaker control relay

Figure 5.1-1

4.4.4 Trip circuit breaker control relay (trip path relay)
  a. de-energize to actuate
  b. 4 trip paths
  c. each trip path controls two circuit breakers
  d. UV coil ... de-energize to trip
  e. shunt trip ... energize to trip

Figure 5.1-6

4.5 CEA power supplies
  4.5.1 Non-vital powered MG sets
  4.5.2 8 breakers allows testing (without bypass)
  4.5.3 Trip breaker 9
    a. does NOT receive trip signal
    b. syncronization of MG buses
  4.5.4 2 "group" CEA power supplies
  4.5.5 UV coils
    a. RT to TT
    b. note: FWCS & SDBCS comes from a TT

Figure 5.1-7

4.6 Reactor trip circuit breakers
  4.6.1 1 x 2 x 2 logic
  4.6.2 Breaker operation (trip)
    a. UV coil OFF or shunt coil ON
    b. manual operation

Lesson No. 905-9C	Title: Reactor Protection System	
Written by: Gage	Approved by:	Date: 10/28/92

4.7 Bypasses

Figure 5.1-9

4.7.1 Trip channel inhibit
- a. removes a trip channel from service
- b. maintenance or testing usage
- c. manually initiated
- d. key operated switches (relay and contact operation)
- e. 2/3 logic for effected trip channel

Note: trip bypassing is channelized (i.e. all automatic bypasses operate on a 3/4 logic)

4.7.2 Automatic bypasses (power level dependent from excore NI)
- a. <u>high SUR</u> effective when:
  WR log safety > 10^{-4} % &
  linear safety < 15 %
  note: below 10^{-4} %...poor countint statistics while above 15% ... MTC, doppler, and high power level trips provide adequate reactivity excursion protection
- b. <u>axial power distribution</u>
  bypassed until linear safety channel > 15 %
  (Kw / ft limit can not be exceeded at low powers with worst case ASI)
- c. <u>loss of load</u>
  bypassed until linear safety channel > 15 %
  permits turbine startup

4.7.3 Zero power mode bypass
- a. allow TMLP & low RCS flow trips bypassed
  (permits CEA operation during S/D or C/D)
- b. manually actuated
- c. log power < 10^{-4} % + key lock switch to bypass
- d. TMLP calculation is prevented from using ΔT power (when in bypass mode)
- e. automatic removal when log power > 10^{-4} %

4.7.4 Low SG pressure
- a. permits cooldown without reactor trip
- b. manually actuated
- c. SG press < ~~550~~ psia + key lock switch to bypass
- d. automatic removal when SG press > ~~550~~ psia

785

Lesson No. 905-9C	Title: Reactor Protection System	
Written by: Gage	Approved by:	Date: 10/28/92

4.8 RPS Interfaces
  4.8.1 CWP
    a. high linear power
    b. high SUR
    c. TMLP pretrip
  4.8.2 PORV actuation
    a. operated in conjunction with high Pzr pressure trip
    b. 2/4 coincidence to actuate

Figure 5.1-8

5.0 Integrated Operation Scenarios

5.1 Demonstrate single failure design
5.2 Demonstrate 2/4 logic
5.3 Combination or individually use following examples:
  5.3.1 Reactor trip*
  5.3.2 Manual trip
  5.3.3 Loss of 120 Vac bus*
  5.3.4 Failure of trip circuit control relay (trip path relay)
  5.3.5 Trip circuit breaker failure
  5.3.6 Information notice 91-52
  * note: included in the manual

6.0 RPS Testing

6.1 Sensor checks
  6.1.1 Channel check
  6.1.2 Calibrated known standards

6.2 Trip bistable test (channel functional test)
  6.2.1 Place trip function in trip channel inhibit
  6.2.2 Manually vary trip test circuit input to comparator
    a. digital voltmeter
    b. test selector switches
    c. potentiometer
  6.2.3 Verify trip by logic matrix lamps

- 6.3 Logic matrix test (part of channel functional test)
  - 6.3.1 Actuate matrix relay hold PB
    - a. applies test voltage to hold coils
      - note: double coil matrix relays
    - b. maintains matrix relay energized
  - 6.3.2 Rotate channel trip select sw
    - a. one for each logic matrix to be tested
    - b. operates contacts in matrix under test
    - c. test voltage applied to B/S trip relay test coils
      - note: opposite polarity to primary coil
    - d. selected trip relay de-energizes
  - 6.3.3 Trip action observation
    - a. trip relay indications on front panel
    - b. loss of voltage to matrix relay
    - c. matrix relay hold lights remain ON (test voltage)

- 6.4 Trip path / circuit breaker test (part of channel functional test)
  - 6.4.1 Depress matrix hold PB
  - 6.4.2 Select trip pos on channel trip select sw
    - (opening the matrix)
  - 6.4.3 Select matrix relay on matrix relay trip select sw
    - a. de-energizes 1/4 matrix relays
    - b. opens two RTCBs
    - c. CEDMs remain energized
  - 6.4.4 Rotate matrix relay trip select sw to next pos.
    - a. re-energize tested matrix relay
    - b. allows manual reset of RTCBs
  - 6.4.5 Test observations
    - a. drop out lamps (matrix relay de-energized)
    - b. trip path lamp (test status panel)
    - c. no current through RTCBs
  - 6.4.6 Repeat sequence of all trip paths and matrices

- 6.5 Manual trip test
  - 6.5.1 Depress 1/4 manual PB
  - 6.5.2 Observe two RTCBs open
  - 6.5.3 Reset RTCBs
  - 6.5.4 Repeat process for each PB

COMBUSTION ENGINEERING LESSON PLAN		
Lesson No. 905-9C	Title: Reactor Protection System	
Written by: Gage	Approved by:	Date: 10/28/92

7.0 PRA Insights (Calvert Cliffs)

7.1 ATWS statistics
- 7.1.1 Core melt frequency contribution ... 33%
- 7.1.2 Risk reduction factor ... 1.53
- 7.1.3 Risk achievement factor ... 11,539
  - note: small prob. of RPS failure

7.2 Dominant accident sequence
- 7.2.1 Transient (LOOP, LOFW, TT, etc)
- 7.2.2 Failure of RTCBs to open on valid Rx trip signal
- 7.2.3 MFW pumps trip / runback (low flow)
- 7.2.4 RCS fails (overpressure)
- 7.2.5 Core melt

7.3 No credit
- 7.3.1 Initiation of feed and bleed core cooling
- 7.3.2 Manual trip of reactor

7.4 ATWS operator expected actions
- 7.4.1 Manually trip Rx
- 7.4.2 De-energize MG sets to CEAs
- 7.4.3 Emergency borate

7.5 Methods to reduce frequency or mitigate results
- 7.5.1 Reduce # transients
- 7.5.2 Improve RPS reliability
- 7.5.3 Qualify RCS and valve operability at high pressures
  - a. vessel head lift & likely fail to reseat (> 3500 psia)
  - b. SG tubes under high Δp (rupture)
  - c. check valve operability (CVCS, HPSI, etc)
- 7.5.4 Improve analysis to show peak pressure < prediction
- 7.5.5 Change fuel load (ensure more neg. MTC)

7.7 10 CFR 50.62
- 7.7.1 Initiate AFW & TT.
- 7.7.2 Additional scram system
  - a. 2/4 pressurizer pressure channels (> 2450 psia)
  - b. interrupt output of CEDM MG sets

325C - 10.2

1.0 Training Aids
  - 1.1 Transparency Package for TM/LP and ASI trips
  - 1.2 Lesson Plan for TM/LP and ASI trips

2.0 References
  - 2.1 Calvert Cliffs System Description
  - 2.2 Calvert Cliffs Technical Specifications

3.0 Objectives

- 3.1 State the purposes of the the Thermal Margin/Low Pressure and Axial Power Distribution trips.
- 3.2 List the inputs to the TM/LP and ASI trips
- 3.3 State the plant conditions used to determine when these trips are in effect.

4.0 Presentation

- 4.1 General Introduction
  - 4.1.1 The TM/LP and ASI trips function that DNBR and kW/ft. limits are not exceeded.
  - 4.1.2 Maintenance of limits ensure that cladding integrity is maintained during anticipated operational occurrences.
- 4.2 Trip Inputs
  - 4.2.1 TM/LP
    - 4.2.1.1 Cold Leg Temperature
    - 4.2.1.2 Hot Leg Temperature
    - 4.2.1.3 Linear Power Safety Channel
    - 4.2.1.4 Pressurizer Pressure
    - 4.2.1.5 Axial Shape Index
    - 4.2.1.6 RCS Flow
    - 4.2.1.7 SG Pressure
    - 4.2.1.8 *General Operation - the TM/LP trip unit combines the inputs into an allowable operating pressure (setpoint). If actual pressure equals setpoint, a trip signal is generated.*
  - 4.2.2 ASI
    - 4.2.2.1 Upper and Lower Detector from linear safety channel.
    - 4.2.2.2 Plant power from TM/LP calculation
    - 4.2.2.3 *General Operation - The ASI trip unit calculates an allowable ASI as a function of power and compares the allowable ASI with actual ASI. If actual ASI equals or exceeds allowable ASI, a trip signal is generated.*

4.3 Thermal Margin/Low Pressure Trip Unit

- 4.3.1 TM/LP Functions
  - 4.3.1.1 To prevent DNBR
  - 4.3.1.2 To provide asymetric steam generator protection.
- 4.3.2 DNBR Parameters
  - 4.3.2.1 Temperature
  - 4.3.2.2 Pressure
  - 4.3.2.3 RCS Flow
  - 4.3.2.4 Total Power
    - a. Axial component
    - b. Radial component .
- 4.3.3 Power Calculations
  - 4.3.3.1 Excore Nuclear Power
  - 4.3.3.2 Delta T Power
- 4.3.4 Delta T Power
  - 4.3.4.1 Delta T power is the product of mass flow rate, specific heat, and (T_H-T_C).
  - 4.3.4.2 T_H is the average of both loops.
  - 4.3.4.3 T_C is the maximum of both loop cold leg temperatures.
  - 4.3.4.4 The mass flow rate is a contant - unity for four pumps and less than unity for less than four pumps.
  - 4.3.4.5 Calculator generates terms that are proportional to:
    - a. coolant density - affects mass flow rate.
    - b. specific heat - varies with temperatue
    - c. flow rate variations
    - d. rate of change of delta T power
  - 4.3.4.6 Delta T power is compared with excore power, and the higher of the two signals is sent to the pressure (setpont) calculator. The higher of the two signals is called Q power.
- 4.3.5 Q Power Modifications
  - 4.3.5.1 CEA Position - provides radial flux component. Assumptions
    - a. Maximum CEA deviation
    - b. CEA sequencing
    - c. CEAs are at the transient insertion limit.
    - d. The output of this modification is called Q_{R1}.

4.3.5.2 ASI - a set of limiting ASIs that represent the minimum DNBR with all other factors held constant. This power correction is called Q_A.

4.3.5.3 The product of Q_{R1} and Q_A is called Q_{DNB} and is used as the power input into the pressure setpoint calculation.

4.3.6 Cold Leg Input

4.3.6.1 Compensated for differences in inputs in less than full RCS flow conditions - called T_{CAL}.

4.3.6.2 Less than 4 RCP operation is not permitted.

4.3.7 Flow Dependent Setpoint

4.3.8 Cover Sample Setpoint Calculation - P_{VAR}.

4.3.9 Setpoint Selection

4.3.9.1 P_{var}.

4.3.9.2 P_{Min}

4.3.9.3 Asymetric SG input

4.3.9.4 1, 2, and 3 are supplied to a high select unit.

4.3.10 P_{Min} - ensures a reactor trip will occur even if P_{var} calculates a lower setpoint. (PERHAPS A DNBR CORRELATION LIMIT)

4.3.11 Asymetric Steam Generator Input

4.3.11.1 Flux tilt can occur because of incomplete mixing.

4.3.11.2 Input of SG pressures

4.3.11.3 Comparison

4.3.11.4 135 psid limit

4.3.11.5 Results in 2500 psia setpoint

4.3.12 PreTrip Functions

4.3.12.1 Bias added to setpoint

4.3.12.2 If pressure equals setpoint + bias, a pretrip signal is generated.

4.3.12.3 CWP on pretrip

4.3.12.4 Disabled if in "Zero Mode Bypass" or if wide range power is $< 10^{-4}\%$.

- 4.3.13 Trip Functions
    - 4.3.13.1 Input to matrix ladders
    - 4.3.13.2 Disabled if in "Zero Mode Bypass" or if wide range power is < 10^{-4}%.
- 4.3.14 TM/LP Indications
    - 4.3.14.1 Pressure Input
    - 4.3.14.2 Setpoint
    - 4.3.14.3 Q Power

4.4 Axial Shape Index

- 4.4.1 Purposes
    - 4.4.1.1 Linear Heat Rate trip
    - 4.4.1.2 High linear heat rates can be caused by:
        - a. Xenon oscillations
        - b. CEA mispositioning
- 4.4.2 Inputs
    - 4.4.2.1 Power - Q power from TM/LP
    - 4.4.2.2 ASI - from excore linear power (Y_E)
    - 4.4.2.3 F_{xy} - amplifier gains
- 4.4.3 Shape Annealing
    - 4.4.3.1 Corrects excore signal
    - 4.4.3.2 Correction is least squares linear fit from incore data.
    - 4.4.3.3 $Y_I = AY_E + B$
- 4.4.4 Power Signal Modifications
    - 4.4.4.1 Modified by CEA position
    - 4.4.4.2 Q(CEA position) is called Q_{R2}.
- 4.4.5 Trip and Pretrip Limits
    - 4.4.5.1 Function Generators generate Y_P and Y_n.
    - 4.4.5.2 Limits are compared to ASI
    - 4.4.5.3 Trips and pretrip signals generated if limits are exceeded.
- 4.4.6 ASI Indications
    - 4.4.6.1 Limits meters
    - 4.4.6.2 ASI
- 4.4.7 Bypassed < 15% power

10.3 ESF Actuation

Objectives

10.3.1 Intro

1) Pzr Press }
2) Cont Press }
3) Cont Rad } LOCA
4) S/G Press }

5) S/G Level } AFW
6) 4160 Vac ESF Voltage } DG
7) RWT Level } RAS

1) SIAS
2) CSAS
3) CIS
4) RWS
5) CRS
6) SGIS
7) AFAS
8) DG Seq. Sig

10.3.2 System Description

Table 10.3-1

4 sensor subsystems monitor redundant & independent process measurements

2 Redundant & Independent actuation subsystems (Fig 10.3-1)

10.3.3.1 SIAS

Fig 10.3-2

~~[illegible]~~ 1740 psia - SI ← 2.8 psig → CIS.
1785 psia = SI Block

|1| ECCS
1) Start 2 HPSI
2) Open 8 HPSI inj valves
3) Open the HPSI aux hdr isolation valve
4) start 2 LPSI
5) Open 4 LPSI inj valve
6) Open 4 SIT outlet Isol (if closed)

|2| BA
1) Start 2 BA
2) " 3 Chg Pmps
3) Open Gravity feed
4) " BA add

|3| RCS & Cont Press
1) Close Ltdn isol
2) Close RCP CBO
3) Close RCDT cont. isol
4) Close RCS sample v/vs

|4| Cooling Wtr Sys Realignment
1) Starts 2 Service Wtr Pmps
2) Isolates SW to Turb Bldg
3) Start 2 CCW Pmps
4) Opens CCW Supply to S/D Clr
5) Start 2 Salt Wtr Pmps

|5| Emerg. D.G. started

|6| Open spray hdr isolation valves

10.3.3.2 CIS (Fig 10.3-3) 2-8psig

1) CCW isol to RCPs
2) Cont Pent Rm Vent. starts
3) Cont Iodine Removal systems is placed in service
4) Cont Inst Air Supply is isolated

Can reset by "CIS RESET" push button, equipment operated manually
↳ after condition cleared

10.3.3.3 CSAS (Fig 10.3-4) 4.25psig

1) starts 2 CS pmps
2) Starts the cont. cooling fans
3) Opens service water outlets from the containment building cooling fans
4) Close MSIU, MFIV, trips secondary plant pumps

SIAS will open isolation valves in spray header

10.3.3.4 RAS (Fig 10.3-5) Low RWT 2/4

1) Cont. sump suctions open
2) LPSI pumps stopped
3) LPSI, HPSI, CS pmp minimum flow/recirculation valves close
4) CCW HX Salt Wtr valves open

10.3.3.5 Cont. Radiation Signal 2/4

Isolates Cont. Purge
Limit release of fission products

10.3.3.6 SGIS (Fig 10.3-6)
703 psia$^{2/4}$ 767psia$^{3/4}$ Blockable

Fig 10.3-7 SGIS & CSAS operated equipment

10.3.3.7 DG Sequencing Signal
5 sec intervals reenergize selected essential loads
Service Wtr, Salt Wtr, Inst Air Comp
w/ SIAS
include safety related pumps - HPSI, LPSI

10.3.3.8 AFW AFAS (Fig 10.3-8)

40% Wide Range 2/4

10.3.3.9 Diverse Scram Inputs

ATWAS issue Diverse Scram System DSS
Calvert Cliffs ES[illegible]F wide range per press input for Hi Press

10.3.4 ESFAS Design Basis

IEEE 279 Criteria for Protection for Nuc Pw Generating Stations

1) Single Failure - won't prevent ESFAS
2) Quality of components and modules - 40yr design life
3) Channel independence - between redundant subsystems
~~Electrical isolation~~
Electrical isolation
Physical separation

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. ~~305-24~~B 325C-11.5	Title: AUXILIARY FEEDWATER SYSTEM	
Written by: Loren F. Donatell	Approved by: Larry Bell	Date: 01/12/93

1.0 TRAINING AIDS/SPECIAL INSTRUCTIONS
- 1.1 Transparency Package for 305-24
- 1.2 Lesson Module for 305-24

2.0 REFERENCES
- 2.1 CE Systems Manual, Chapter 5.8
- 2.2 CCNPP System Description No. 34

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 305-24
Title: AUXILIARY FEEDWATER SYSTEM

Written by: Loren F. Donatell
Approved by: Larry Bell
Date: 01/12/93

3.0 PRESENTATION

3.1 Learning Objectives

3.1.1 Cover Objectives in manual

3.2 Introduction

3.2.1 System Purposes

a. Ensure a heat sink is available for removal of decay heat
  1. Normal operation
  2. Emergency operation such as SBLOCA

b. Cooldown primary plant if no MFW is available

c. Maintain S.G. levels during plant start-ups and shutdowns

Figure 5.8-1
Page 5.8-9

3.3 AFW System Description

Figure 5.8-2
Page 5.8-11

3.3.1 Major Components

3.3.1.1 Condensate Storage Tank (CST) 12

a. Supply both Unit-1 and Unit-2

b. 350,000 gallons

c. Class I concrete structure

d. Protected against tornadoes and missiles

e. CSTs 11 and 21 lined up to their respective Condensate Systems

f. Minimum volume by T.S.
  1. 150,000 gallons
  2. Maintain RCS in hot standby for six hours while dumping steam to the atmosphere with a concurrent loss of offsite power

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 305-24	Title: AUXILIARY FEEDWATER SYSTEM	
Written by: Loren F. Donatell	Approved by: Larry Bell	Date: 01/12/93

3.3.1.2 Other AFW Supplies

a. From other Unit to motor driven pump discharge lines
b. Plant fire main to suction of the motor driven pump

Table 5.8-1
Page 5.8-6

3.3.1.3 Electric Driven AFW Pump

a. Class 1E, 4.16 kVAC, 500 hp
b. Multistage, horizontal, centrifugal
c. 450 gpm design flowrate
d. 140 gpm minimum for pump cooling
    1. Controlled by automatic recirculation valves
e. Reserved for emergency use only

Table 5.8-2
Page 5.8-7

3.3.1.4 Turbine Driven AFW pump

a. Terry Steam Turbine
    1. Single stage, non-condensing
    2. 600 hp at 3990 rpm
    3. Normal supply from Main Steam
    4. Can be supplied from Aux. Steam
    5. Steam supply valves powered from Instrument Air System
b. Byron - Jackson pumps
    1. Six stage, horizontal, centrifugal
    2. 700 gpm
    3. 80 gpm min. flow - controlled by an orifice

3.3.1.5 Blocking Valves

a. Eight valves
b. Each line has two, in series
c. Shut and isolate flow to a ruptured S.G.
d. Block signal comes from AFAS

3.3.1.6 Flow Control Valves

- a. Four valves
- b. Regulate AFW flow to S.G.s

3.3.1.7 AFAS

- a. Automatically starts AFW on low S.G. level
- b. Identifies a ruptured S.G. and blocks flow to that S.G.
- c. Four sensor subsystems
    1. Monitor redundant and independent S.G. parameters
    2. Four channels of W.R. level
    3. Four channels of S.G. pressure
- d. Two actuation subsystems
    1. Monitor the sensor subsystems
    2. Coincidence logic
    3. 2/4 level low (40% W.R.) generates a START signal
    4. 2/4 dp at 115 psid generates a BLOCK signal
- e. AFAS Block
    1. Prevents continued feedwater addition to a ruptured S.G.
    2. RCS cooldown adds positive reactivity
    3. Continued steaming from a ruptured S.G. adds energy to containment
    4. Only the affected S.G. is blocked, other S.G. receives normal feed for decay heat removal

3.3.2 System Operation

3.3.2.1 Steam Generator Level Control

- a. Start-ups to ~ 5% reactor power
- b. Shutdowns
- c. Cooldowns

COMBUSTION ENGINEERING LESSON PLAN

Lesson No. 305-24	Title: AUXILIARY FEEDWATER SYSTEM	
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3.3.2.2 Power Operation

a. Lined up to CST 12
b. Auto start on S.G. low level of 40% W.R.

3.3.2.3 Emergency Operation

a. Used with atmospheric dumps to cooldown the plant following a loss of offsite power
b. Vital for core safety if a SBLOCA occurs
c. Cover basic scenario from section 5.8.5, PRA Insights

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.~~905-10C~~ 325C - 12	Title: CPC - CEAC - COLSS	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/23/92

1.0 TRAINING AIDS - NONE

2.0 REFERENCES

2.1 Technical Managers Manual - Sections 6.1, 6.2, and 6.3
2.2 Waterford Training Manual

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.905-10C | Title: CPC - CEAC - COLSS

Written by: Larry Bell | Approved by: Larry Bell | Date: 10/23/92

3.0 OBJECTIVES

3.1 To aquaint the Technical Manager with digital protection systems

3.2 To aquaint the Technical Manager with the COLSS program.

4.0 CPC PRESENTATION

4.1 CPC Purposes - to provide protection for the specified acceptable fuel design limits during anticipated operational occurrences.

- 4.1.1 Specified Fuel Design Limits
  - 4.1.1.1 DNBR
  - 4.1.1.2 kW/ft.
- 4.1.2 Anticipated Operational Occurrence - an event that is likely to occur once in the forty year life of the plant.

Figure 6.1-1 4.2 System Description

Page 6.1-7

- 4.2.1 Reactor Power
  - 4.2.1.1 Raw inputs for each of 3 detectors
  - 4.2.1.2 Shape Annealing Corrections
    - Corrects detector output fro flux shape affects
    - Determined during testing by inducing axial xenon oscillations.
  - **Figure 6.1-2** 4.2.1.3 Rod Shadowing - target rods used.
  - **Page 6.1-9** 4.2.1.4 Colder T_c - more moderation
- 4.2.2 3D Power Calculations
  - 4.2.2.1 Target Rods
    - 1/4 of total CEAs
    - All CEAs in <u>core quadrant</u>.
  - 4.2.2.2 Radial Distribution
    - Table Lookup
    - Peaking Factors - function of CEA position.
  - 4.2.2.3 Axial Peaking Calculations
    - Three detector inputs corrected for shape annealing and rod shadowing
    - Curve fit into 20 axial planes
  - 4.2.2.4 Azimuthal Tilt Input
    - Addressable constant
    - Value is obtained from COLSS and manually input.

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.905-10C | Title: CPC - CEAC - COLSS

Written by: Larry Bell | Approved by: Larry Bell | Date: 10/23/92

- 4.2.3 Hot Pin Calculation
  - 4.2.3.1 Axial Power Distribution
  - 4.2.3.2 Radial Power Distribution
  - 4.2.3.3 Azimuthal Tilt
  - 4.2.3.3 The above are combined to calculate the psuedo hot pin. The output of the hot pin calculation is sent to the DNBR and LPD calculations.
- 4.2.4 RCS Flow Input
  - 4.2.4.1 RCP speed
  - 4.2.4.2 Converted into a mass flow rate signal by temperature
  - 4.2.4.3 Mass Flow rate supplied to:
    - DNBR Calculation
    - ΔT power calculation
- 4.2.5 Pressurizer Pressure
  - 4.2.5.1 One transmitter per CPC
  - 4.2.5.2 Pressure is supplied to:
    - DNBR Calculation
    - Quality Calculation
- 4.2.6 Temperature Inputs
  - 4.2.6.1 Both hot and cold leg temperatures are inputs
  - 4.2.6.2 Hot leg temperature is used to :
    - Calculate mass flow rate
    - Calculate ΔT power
  - 4.2.6.3 Cold Leg Temperature is used to:
    - Calculate mass flow rates
    - Calculate ΔT power
    - Calculate temperature shadowing
    - Calculate DNBR
- 4.2.7 ΔT Power Calculation
  - 4.2.7.1 $Q = mC_p(\Delta T)$
  - 4.2.7.2 Calibration constant
  - 4.2.7.3 High Select

Pressure drop calculation in hot legs

Pressure drop calculation in cold legs

Temperatures and pressures are combined into enthalpy.

COMBUSTION ENGINEERING LESSON PLAN		
Lesson No.905-10C	Title: CPC - CEAC - COLSS	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/23/92

4.3 Local Power Density Calculation and Trip Generation

4.3.1 Local Power Density is a function of:
  4.3.1.1 Hot Pin Power
  4.3.1.2 Total Power

4.3.2 Calculated LPD is compared to LPD pre-trip and trip setpoints.

4.3.3 If either limit is exceeded, the appropriate signal is sent to thePPS

4.3.4 Two out of four CPCs calculating that LPD is at the trip setpoint will result in a reactor trip.

4.4 DNBR Calculation and Trip Generation

4.4.1 DNBR is a function of:
  4.4.1.1 Hot Pin Power
  4.4.1.2 Total Power
  4.4.1.3 RCS Flow
  4.4.1.4 Pressurizer Pressure
  4.4.1.5 Temperature

4.4.2 Calculated DNBR is compared to DNBR pre-trip and trip setpoints.

4.4.3 If either limit is exceeded, the appropriate signal is sent to thePPS

4.4.4 Two out of four CPCs calculating that DNBR is at the trip setpoint will result in a reactor trip.

Calculates quality using enthalpies.

4.4.5 Coolant Quality
  4.4.5.1 Temperature and pressure dependent
  4.4.5.2 15% Limit
  4.4.5.3 Generates DNBR trip

Figure 6.1-3
Page 6.1-11

4.4.6 DNBR Update Program
  4.4.6.1 Normal DNBR calculation takes 50 milliseconds, the update program updates DNBR between calculations.
  4.4.6.2 Accounts for changes between calculations
  4.4.6.3 Derivatives of DNBR inputs
  4.4.6.4 RCS Flow - negative derivatives only.
  4.4.6.5 Point out boundaries

4.5 Auxiliary Trips
  - 4.5.1 Normal CPC Operating Space
    - 4.5.1.1 $2 \leq$ RCPs Operating ≤ 4
    - 4.5.1.2 1750 psia $\leq$ Pzr Press $\leq$ 2400 psia
    - 4.5.1.3 $465°F \leq T_c \leq 580°F$
    - 4.5.1.4 $1.28 \leq$ Radial Peaking ≤ 4.28
    - 4.5.1.5 $-17° F \leq \Delta T_c \leq 17°F$
    - 4.5.1.6 $0 \leq$ Quality
    - 4.5.1.7 $-0.6 \leq$ ASI ≤ 0.6
  - 4.5.2 If parameters are outside of the boundaries above, an auxiliary trip will be generated.
  - 4.5.3 ΔT_c trip function protects against large radial tilts due to assymetric steam generators.

5.0 Control Element Assembly Calculators

5.1 Purpose of CEACs - to supply CEA misalignment information to the CPCs.

Figure 6.2-1
Page 6.2-3

5.2 CEAC Inputs
  - 5.2.1 All CEAs provide a position input to the CEACs
  - 5.2.2 Target Rods to CPC and CEAC
  - 5.2.3 Optical Isolation

Figure 6.2-2
Page 6.2-5

5.3 Software
  - 5.3.1 CEARSPT converted to a digital signal
  - 5.3.2 Signal converted to 0 to 100% withdrawn signal
  - 5.3.3 Sensor Failure
  - 5.3.4 CEA Reference Position - lowest CEA in subgroup
  - 5.3.5 Individual CEAs are compared to reference position to determine deviation.
  - 5.3.6 5.6% deadband (8.4 inches)
  - 5.3.7 Case Determination

5.4 Deviation Cases
  - 5.4.1 Case 1:
    - 5.4.1.1 Deviation of 1 CEA
    - 5.4.1.2 3 CEAs deviated
    - 5.4.1.3 Uncontrolled CEA withdrawal.

5.4.2 Case 2 - Deviation of 2 CEAs
5.4.3 Case 3 - dropped CEA in a 4 CEA subgroup
5.4.4 Case 4 - Dropped CEA in a 5 CEA subgroup

Figure 6.2-3
Page 6.2-7

5.5 CEAC Outputs
5.5.1 Penalty Factor to CPCs
5.5.2 CEA Position Indication

6.0 Core Operating Limits Supervisory System

6.1 COLSS Design Requirements - COLSS is designed to assist the operator in implementing the follwing sections of technical specifications:
6.1.1 Licensed Power LCO
6.1.2 DNBR LCO
6.1.3 LPD LCO
6.1.4 Azimuthal Tilt LCO
6.1.5 Axial Shape Index LCO

Figure 6.3-1
Page 6.3-17

6.2 COLSS Inputs
6.2.1 Hot and Cold Leg Temperatures
  6.2.1.1 Delta T power
  6.2.1.2 DNBR
6.2.2 Pressurizer Pressure
6.2.3 RCP Speed and delta P
  6.2.3.1 RCS Flow Calculation
  6.2.3.2 RCS Flow used in:
    - Delta T Power
    - DNBR
6.2.4 Incore Flux - power distribution
6.2.5 CEA Position
  6.2.5.1 From plant computer calculation of CEA position
  6.2.5.2 Used in the calculation of power distribution
6.2.6 FW Flow and Temperature - Secondary Calorimetric
6.2.7 Steam flow and pressure - Secondary Calorimetric
6.2.8 Turbine first stage pressure - Proportional to power

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.905-10C	Title: CPC - CEAC - COLSS	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/23/92

- 6.2.7 Steam flow and pressure - Secondary Calorimetric
- 6.2.8 Turbine first stage pressure - Proportional to power

6.3 COLSS Outputs
- 6.3.1 Core Power
- 6.3.2 DNBR Power Margin
- 6.3.3 kW/Ft Power Margin
- 6.3.4 Power Margin
  - 6.3.4.1 Margin to closest limit
  - 6.3.4.2 Limits are:
    - Licensed Power
    - DNBR
    - LPD
- 6.3.5 Power Margin Alarm
- 6.3.6 Azimuthal Tilt Alarm
  - 6.3.6.1 CPC Tilt Allowance alarm
  - 6.3.6.2 Technical Specifications Limit
- 6.3.7 Axial Shape Index

Figure 6.3-2
Page 6.3-19

6.4 COLSS Power Calculations
- 6.4.1 Secondary Calorimetric Power
- 6.4.2 Primary Delta T Power Calculation
- 6.4.3 Turbine First Stage Pressure

6.5 Secondary Calorimetric Power
- 6.5.1 Heat Balance across the SG
- 6.5.2 SG Power = Power out - power in
  - 6.5.2.1 P_{out} = (mass flow rate) (h_{out})
  - 6.5.2.2 P_{in} = (mass flow rate) (h_{in})
- 6.5.3 Power Out
  - 6.5.3.1 h_{out} is determined from steam pressure
  - 6.5.3.2 mass flow rate = feedwater flow - blowdown flow
- 6.5.4 Power In
  - 6.5.4.1 h_{in} is determined by feedwater temperature
  - 6.5.4.2 mass flow rate = feedwater flow
- 6.5.5 Energy Gains
  - 6.5.5.1 RCP Heat
  - 6.5.5.2 Charging Flow
  - 6.5.5.3 Pressurizer Heaters

COMBUSTION ENGINEERING LESSON PLAN

Lesson No.905-10C	Title: CPC - CEAC - COLSS	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/23/92

6.5.6 Energy Losses
- 6.5.6.1 Letdown Flow
- 6.5.6.2 CBO
- 6.5.6.3 Heat losses to containment

6.5.7 Secondary Calorimetric Power is used for:
- 6.5.7.1 Selection of power
- 6.5.7.2 Calibration of ΔT power and turbine power
- 6.5.7.3 Secondary calorimetric power is calculated every 30 seconds if plant power is ≥15%.

6.6 Turbine Power Calculation

6.6.1 Turbine First Stage Pressure
- 6.6.1.1 Proportional to load
- 6.6.1.2 Relatively fast changing indication of power when load is being changed.

6.6.2 Calculated once per second

6.6.3 Calibrated to secondary calorimetric power

6.7 ΔT Power

6.7.1 $Q = mC_p(\Delta T)$

6.7.2 Mass flow rate derived from:
- 6.7.2.1 RCP Speed
- 6.7.2.2 RCP ΔP
- 6.7.2.3 Temperatures

6.7.3 Hot and cold leg RTDs provide required ΔT input.

6.7.4 ΔT power is calculated once per second

6.7.5 ΔT is very accurate at steady state and the higher of ΔT power or turbine power is used below 15%.

6.7.6 ΔT is calibrated by secondary calorimetric power.

Figure 6.3-3
Page 6.3-21

6.8 Power Selection

6.8.1 Power selection is the highest of:
- 6.8.1.1 Secondary Calorimetric Power
- 6.8.1.2 Calibrated Turbine Power
- 6.8.1.3 Calibrated ΔT Power

6.8.2 The selected power is sent to:
- 6.8.2.1 Comparison with lowest operating limit
- 6.8.2.2 PDIL Alarm generation

Figure 6.3-4
Page 6.3-23

6.8.3 Alternate Power Selections
- 6.8.3.1 If secondary calorimetric power is BAD or if power ≤ 15%, the higher of uncalibrated ΔT or turbine power is selected.

Lesson No.905-10C	Title: CPC - CEAC - COLSS	
Written by: Larry Bell	Approved by: Larry Bell	Date: 10/23/92

Figure 6.3-5
Page 6.3-25

6.8.3.2 If ΔT is BAD, the higher of secondary calorimetric power or turbine power is selected.
6.8.3.3 If turbine power is BAD, the higher of secondary calorimetric or ΔT power is selected.

6.9 Operating Limits Selection
- 6.9.1 Licensed Power Limit
  - 6.9.1.1 A constant equal to the licensed power of the plant
  - 6.9.1.2 Usually the most limiting of all power limits
- 6.9.2 DNBR Limit
  - 6.9.2.1 Pressurizer Pressure
  - 6.9.2.2 RCS Flow
  - 6.9.2.3 Axial Flux from Incores
  - 6.9.2.4 Radial flux from table lookup and CEA positions
    - Calculation too time consuming
    - CEA position used by COLSS is more accurate than CPC CEA position
  - 6.9.2.5 Cold Leg Temperature
  - 6.9.2.6 Azimuthal Tilt
- 6.9.3 LPD Limit
  - 6.9.3.1 Total Power
  - 6.9.3.2 Axial Power Distribution
  - 6.9.3.3 Azimuthal Tilt

Detailed discussion can be found on page 6.3-13

Figure 6.3-6
Page 6.3-27

6.10 Power Distribution Calculations
- 6.10.1 Axial Power Distribution
  - 6.10.1.1 Calculated from incore detectors
  - 6.10.1.2 Curve fit of average value of signals at one location.
  - 6.10.1.3 Used for ASI, DNBR, and LPD
- 6.10.2 Azimuthal Tilt
  - 6.10.2.1 4 detectors (one in each quadrant) - 9 sets of symmetrical detectors
  - 6.10.2.2 CPC Az tilt alarm
  - 6.10.2.3 Tech Spec Az tilt alarm

Plant Differences

TLB
2/22/79

1.0 TRAINING AIDS - NONE

2.0 References
  2.1 USARs for CE Units
  2.2 Waterford 3 Training Manual (FWCS, SDBCS, RPCS)
  2.3 CE Low Power Feedwater Control

3.0 Objectives
  No formal objectives are listed in the text; however, this presentation is presented to:
  3.1 Provide a background for plant events discussions.
  3.2 Discuss "System 80" Control Systems
  3.3 Fulfill student feedback comments

4.0 Presentation
  4.1 CE Plant Classifications
    4.1.1 Divided into 6 Categories based on fuel assembly configuration & MW(t)
    4.1.2 Category 1 - Palisades
      4.1.2.1 204 fuel assemblies - 2530 MW(t)
      4.1.2.2 15X15 fuel assemblies
      4.1.2.3 Cruciform CEAs - motor driven
    4.1.3 Category 2 - Fort Calhoun
      4.1.3.1 133 Fuel assemblies - 1500 MW(t)
      4.1.3.2 14X14 fuel assemblies
      4.1.3.3 motor driven CEAs

Plant Differences

TLB
2/22/94

4.2.2 Thermal Shields
    4.2.2.1 Minimizes radiation damage to vessel
Palisades
    4.2.2.2 Figure 30-2
    4.2.2.3 Fort Calhoun and Maine Yankee
    4.2.2.4 Saint Lucie used to have thermo shields, but it failed and was removed.

4.3 Incore Instrumentation
  4.3.1 Detector Assemblies
    4.3.1.1 5 detectors (instead of 4) + C.E.T.
    4.3.1.2 10, 30, 50, 70, 90% of active core height
    4.3.1.3 Contains calibration tube for movable incore
    4.3.1.4 Applicable to 150" fuel - categoric 4, 5, and 6.

igure 30-3
  4.3.2 Movable Incore System
    4.3.2.1 System consists of:
      (a) two drive machines
      (b) transfer machines (2)
      (c) Passive wye
      (d) Purge gas system
      (e) Leak detection system
      (f) Plant computer interface
      (g) calibration tubes in Incore Instrument Assembly

Plant Differences

TLB
2/23/94

- 4.6 Rack-and-Pinion CEA Mechanism
  - 4.6.1 Installed @ Fort Calhoun and Palisades
    - 4.6.1.1 Drives "conventional" CEA at Fort Calhoun
    - 4.6.1.2 Drives cruciform CEA at Palisades
  - 4.6.2 Drive Motor
    - 4.6.2.1 120Vac, 60 hz, single phase
    - 4.6.2.2 Drives rack via brake and magnetic clutch
  - 4.6.3 Brake
    - 4.6.3.1 Functions to hold CEA when CEA isn't moving
    - 4.6.3.2 De-energized when the drive motor is energized and visa versa
  - 4.6.4 Magnetic Clutch
    - 4.6.4.1 Controls the coupling of the CEA to the motor
    - 4.6.4.2 When de-energized, the CEA drops into the core
  - 4.6.5 Motor Drive Shaft
    - 4.6.5.1 Extends from clutch to drive gear
    - 4.6.5.2 Positions "rack"
  - 4.6.6 Rack
    - 4.6.6.1 Connects to the CEA via a bayonet coupling

Plant Differences

TLB
2/23/94

4.7.4 Upper Guide Structure modifications
- figure 30-10 & contrast 30-11

4.7.5 CEA designs require a CEA mask on refueling machine

IGURE
30-12

4.7.6 Part-length CEAs
  4.7.6.1 Partial poison section - 16" of B_4C
  4.7.6.2 Trippable
  4.7.6.3 ANO2, Waterford 3, SONGS, and Palo Verde

4.8 Power Operated Relief Valves
  4.8.1 Not installed at ANO2, Waterford 3, SONGS or Palo Verde
    4.8.1.1 Larger steam dump capacity
    4.8.1.2 No feed-bleed capability
    4.8.1.3 ECCS vents @ ANO2

4.9 System 80 steam Generators
  4.9.1 Two feed rings
    4.9.1.1 Economizer - 14" lines - 2 nozzles
    4.9.1.2 Downcomer - 6" - similar to conventional design

4.9 SYSTEM 80 STEAM GENERATORS

- 4.9.1 Two feed rings
  - 4.9.1.1 Economizer - 14" -2 nozzles
  - 4.9.1.2 Downcomer - 6" -similar to conventional design
- 4.9.2 Define Economizer
- 4.9.3 Flowpath - in the economizer feedring, downward direction-flow . distribution plate-up past the tubes -counter flow heat exchanger
- 4.9.4 6 inch feedring
  - 4.9.4.1 Used during AFW operations - cold FW
  - 4.9.4.2 Used during low power operations (< 15%)
  - 4.9.4.3 Used above 50% (provides 10% flow) to provide subcooling to recirculation water and to improve recirculation ratio.

4.10 RPS/ESFAS Interfaces

- 4.10.1 Block Diagram
  - 4.10.1.1 Shared transmitter input
  - 4.10.1.2 CPC Input
- 4.10.2 Bistable Relay Card
  - 4.10.2.1 ESF + RPS relays
  - 4.10.2.2 Variable Setpoint Generator

4.10.2.3 Pzr and log pwr bypass

4.10.3 ESF Matrix - explain

4.10.4 Variable setpoint for SG press and pzr press

4.10.4.1 Pzr bypass logic

4.10.4.2 SG press actually goes to zero - no bypass needed

4.10.5 Excore input

4.10.5.1 3 fission chambers per channel

4.10.5.2 Power range (CPC) input

4.10.5.3 log channel input

4.10.5.4 log channel trip bypass

4.11 SIS Differences

4.11.1 HPSI

4.11.1.1 3rd pump as a backup

4.11.1.2 Explain that 3rd pump on category 4-6 plants may be valved to either header

4.11.1.3 Two pumps at Palo Verde

4.11.1.4 Maine Yankee has Centrifugal charging pumps instead of HPSI

4.11.1.5 Discharge pressures of 1250 to 1600 psi

4.11.1.6 flow rates vary from 150 to 700 gpm

- 4.11.2 SITs
  - 4.11.2.1 200 psig SITs - category 1 thru 3 units
  - 4.11.2.2 600 psig SITs - category 4-6 units
- 4.11.3 LPSI
  - 4.11.3.1 Split discharge headers at Palo Verde and Waterford.

4.12 Reactor Power Cutback System

- 4.12.1 The RPCS functions to rapidly reduce reactor power by dropping CEAs during:
  - 4.12.1.1 Load Rejections
  - 4.12.1.2 Loss of MFP
  - 4.12.1.3 Restoration of heat generation and heat removal during load rejections prevents high pzr pressure trips
  - 4.12.1.3 Reduction of power during MFP trips prevents low SG lvl trips
- 4.12.2 RPCS Inputs
  - 4.12.2.1 Feedpump control oil pressure switches (2/2 logic)
  - 4.12.2.2 Load Rejection signal from SBDCS

- 4.12.2.3 Runback signal consisting of P_{TFS} and P_{SG} biased by T_{AVE}. This signal is used to runback the turbine at 200%/minute to avoid low steam generator pressures.

4.12.3 Arm Command

- 4.12.3.1 Generated by the plant computer when plant power is ≥ 75%
- 4.12.3.2 Calculation of negative reactivity required to reduce reactor power to ~75% based upon power and temperature.
- 4.12.3.3 Chooses subgroups of CEAs to drop.
- 4.12.3.4 Arm command is <u>one of two</u> signals required to drop CEAs

4.12.4 Drop Command

- 4.12.4.1 Generated by loss of MFP or load rejection inputs
- 4.12.4.2 Drop command is the <u>2nd of two</u> signals required

FWCS will cover event

- 4.12.7 RPCS actions 50% - 75%
  - 4.12.7.1 Initiating event
  - 4.12.7.2 Drop signal is generated, <u>but</u> no arm signal is generated
  - 4.12.7.3 Turbine setback signal is generated
  - 4.12.7.4 If loss of MFP, RRS inserts CEAs to match 50% turbine power. FWCS maintains level.
  - 4.12.7.5 If load rejection, SDBCS + RRS will restore heat removal and heat generation balance and FWCS will maintain SG lvl.
- 4.12.8 RPCS actions ≥ 75%
  - 4.12.8.1 Drop signal generated by initiating event
  - 4.12.8.2 Plant computer selects subgroups and initiates arm command
  - 4.12.8.3 Drop command + arm command allows CEAs to drop
  - 4.12.8.4 RRS + SDBCS restores heat

Lesson Title: COLSS	Date: 11/7/86 Rev.: 0
Program: R-205P-17	Author: T. L. Bell
	Reviewed By: T. L. Bell

1.0 Special Instructions and Training Aids

- 1.1 R-205P-17 Viewgraph Package
- 1.2 R-205P-17 Course Module

2.0 References

- 2.1 CE Systems Manual - Section 15.2
- 2.2 Waterford 3 Training Manual
- 2.3 ANO2 Procedure

Notes	Lesson Plan (Continuation Sheet)

3.0 Objectives

- 3.1 Cover objectives on page 15.2-1

4.0 Presentation

- 4.1 Core operating limit supervisory system purposes
  - 4.1.1 To accurately calculate plant operating limits and to alert the operator if these limits are exceeded.
  - 4.1.2 Limits monitored
    - 4.1.2.1 DNBR core power limit
    - 4.1.2.2 Licensed power limit
    - 4.1.2.3 Local power density core power limit
    - 4.1.2.4 Azimuthal tilt limits
  - 4.1.3 General COLSS facts
    - 4.1.3.1 COLSS is a computer (software) program
    - 4.1.3.2 COLSS is <u>not</u> safety related
    - 4.1.3.3 If plant limits are less than COLSS limits - plant within initial conditions assumed in Safety Analysis.
    - 4.1.3.4 Within limits ensures protection during Anticipated Operational Occurrences
  - 4.1.4 COLSS Inputs
    - 4.1.4.1 Steam pressure
    - 4.1.4.2 Feedwater flow
    - 4.1.4.3 Feedwater temperature
- 4.2 COLSS Algorithms
  - 4.2.1 Plant Power Calculations
    - 4.2.1.1 Secondary power

Notes	Lesson Plan (Continuation Sheet)

- 4.2.1.2 Heat Balance across SG
- 4.2.1.3 SG power = energy in - energy out
- 4.2.1.4 Energy out
  - (a) steam pressure
  - (b) steam flow = feedwater flow - blowdown flow
  - (c) steam flow signal is noisy
- 4.2.1.5 Energy In
  - (a) feedwater flow
  - (b) feedwater temp
  - (c) blowdown flow
- 4.2.1.6 Losses/Gains
  - (a) pump heat
  - (b) letdown
  - (c) charging
  - (d) losses to containment
- 4.2.1.7 Calculated every 30 seconds if >15%

4.2.2 Turbine power

- 4.2.2.1 Turbine first stage press
- 4.2.2.2 Calibrated during testing
- 4.2.2.3 Once per second
- 4.2.2.4 Calibrated to secondary power
- 4.2.2.5 Improves transient response

4.2.3 RCS volumetric flow

- 4.2.3.1 Pump speed
- 4.2.3.2 Pump Delta P

4.2.4 Delta T Power

- 4.2.4.1 Core power = (flow rate) x specific

Notes	Lesson Plan (Continuation Sheet)

4.2.4.2 Used primarily below 15% power
4.2.4.3 Calculated once per second
4.2.4.4 Calibrated to secondary power
4.2.5 Power Selection
4.2.5.1 Highest power selected
4.2.5.2 Compared with lowest limit
4.2.5.3 Power margin = power limit - actual power
4.3 Power Limit Calculations
4.3.1 Licensed Power
4.3.1.1 Constant = 2815 MW(t)
4.3.1.2 Usually most limiting limit
4.3.2 3-D power
4.3.2.1 Radial - from CEA position - table lookup
4.3.2.2 Axial - Incore
4.3.2.3 LPD
4.3.2.4 DNBR
4.3.3 LPD Limit
4.3.3.1 3D power and Az tilt
4.3.3.2 Heat Generation Limit
4.3.4 DNBR
4.3.4.1 Pzr press
4.3.4.2 RCS flow
4.3.4.3 3D power
4.3.4.4 Az tilt
4.3.5 Limit selection
4.3.5.1 Low select
4.3.5.2 Lowest limit
4.4 Auxiliary calculations
4.4.1 Az tilt
4.4.2 ASI

Notes	Lesson Plan (Continuation Sheet)
	5.0 Tech Specs 6.0 Summary 6.1 Review Objectives

Notes | Lesson Plan (Continued)

- 6.0 Core Protection Calculators
    - 6.1 CPC Purposes
        - 6.1.1 Prevents exceeding DNBR and LPD during anticipated operational occurrences
    - 6.2 Inputs
        - 6.2.1 Reactor Power
            - 6.2.1.1 Raw input from each of 3 detectors
            - 6.2.1.2 Shape annealing corrections
                - (a) Corrects detector output for flux shape affects
                - (b) Determined during testing by inducing axial xenon oscillation
                - (c) incore data
            - 6.2.1.3 Rod Shadowing
                - (a) target rods used
            - 6.2.1.4 Temp Shadowing
                - (a) Colder Tc - less moderation
            - 6.2.1.5 Total power to high select
        - 6.2.2 3D Power Calculations
            - 6.2.2.1 Target Rods
                - (a) 20 CEAs
            - 6.2.2.2 Radial Distribution f(CEA)
                - (a) table lookup
            - 6.2.2.3 Misalignment Information from CEAC
            - 6.2.2.4 Azmuthal Tilt
                - (a) constant input
                - (b) .1 limit
            - 6.2.2.5 Hot Pin Calculation
                - (a) DNBR - localized effect
                - (b) Kw/Ft - localized

Notes	Lesson Plan (Continued)

6.2.3 RCS Flow
  6.2.3.1 Calculated from pump speed
  6.2.3.2 Supplied to:
    (a) DNBR
    (b) ΔT power calculation
6.2.4 Pressurizer Pressure
  6.2.4.1 Supplied to DNBR
  6.2.4.2 Quality Calculation
6.2.5 Temperature inputs
  6.2.5.1 T_h and T_c
  6.2.5.2 Delta T Power
    (a) Very accurate during steady state
    (b) Hi selected with Excore Power
    (c) Supplied to Kw/Ft and DNBR
  6.2.5.3 Highest T_c to DNBR
  6.2.5.4 Lowest T_c to temp shadowing

6.3 CPC Calculations
  6.3.1 Kw/Ft
    6.3.1.1 Hot Pin
    6.3.1.2 Total Power
    6.3.1.3 1&2 = heat generation
  6.3.2 DNBR
    6.3.2.1 Flow
    6.3.2.2 Pressure
    6.3.2.3 Power
    6.3.2.4 Temperature
    6.3.2.5 3-D power

Notes	Lesson Plan (Continued)

6.3.3 Coolant Quality
    6.3.3.1 Temp and Press dependent
    6.3.3.2 15% limit
    6.3.3.3 DNBR calculations problems
6.3.4 DNBR Update
    6.3.4.1 Normal DNBR calculation - 50 msec
    6.3.4.2 Accounts for changes during "lag"
    6.3.4.3 Flow - negative rates only
    6.3.4.4 derivatives of inputs
6.3.5 Trip Output
    6.3.5.1 Contact opens in Digital Bistable Cards
6.3.6 Aux Trips
    6.3.6.1 Internal Processor Faults
    6.3.6.2 <4 RCPs (>30%)
    6.3.6.3 Region 3 parameters
    6.3.6.4 ΔT_c

7.0 Control Element Assembly Calculators
    7.1 Purpose
        7.1.1 Supply misalignment information to CPCs
    7.2 CEAC Inputs
        7.2.1 Dual RSPT/CEA
        7.2.2 20 CEA Inputs to CPCs
        7.2.3 Optical Isolation to CEACs
    7.3 Software
        7.3.1 CEA Reference Position - lowest CEA in subgroup
        7.3.2 5.6% deadband
        7.3.3 Case conditions

Notes	Lesson Plan (Continued)

7.3.3.1 Case 1
    (a) deviation of 1 CEA
    (b) uncontrolled rod withdrawal
    (c) 3 CEAs deviated
7.3.3.2 Case 2
    (a) 2 CEAs misaligned
7.3.3.3 Case 3
    (a) Dropped CEA in 4 CEA subgroup
7.3.3.4 Case 4
    (a) Dropped CEA in 5 CEA subgroup

7.4 CEAC Outputs
    7.4.1 Penalty factor to CPCs
    7.4.2 CEA position indication

8.0 Engineered Safety Features
    8.1 Purpose
        8.1.1 To actuate equipment to mitigate consequences of an accident
    8.2 Systems
        8.2.1 SIAS
            8.2.1.1 LOCA
            8.2.1.2 Low Pressurizer Pressure
            8.2.1.3 High Containment Pressure
            8.2.1.4 HPSI - LPSI - Chg., etc.
        8.2.2 MSIS
            8.2.2.1 Steambreak
            8.2.2.2 Steam/feedwater isolation
        8.2.3 CIS
            8.2.3.1 Isolates non-safety related containment penetrations