



Condensate and Feedwater Systems

ACADs (08-006) Covered

1.2.1.3 3.1.1.3 3.1.1.8 4.2.7.5 4.2.7.14 5.2.2.6 5.3.2.9

Keywords

Condensate, feedwater, flowpath, turbine, air removal system, pumps, condenser.

Description

This document provides instructor notes and references to materials which can be used to develop a lesson on condensate and feedwater systems.

Supporting Material

Systems Training Manual Volume 19 "Condensate System"

Systems Training Manual Volume 20 "Feedwater / Feedwater Pump Turbine Systems"

Systems Training Manual Volume 18 "Air Removal System"

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***PALO VERDE
NUCLEAR GENERATING STATION***

Instrumentation & Controls Training

Classroom Lesson

I&C Program		Date: 07/12/2000
LP Number: NAI9902XC007	Rev. : 01	Rev Author: Norman R. Cooley
Title: Condensate And Feedwater Systems		Technical Review:Robin T. Meredith
Duration : 3 Hours		
		Teaching Approval:

INITIATING DOCUMENTS:

Site Maintenance Training Program Description

PROCEDURES

NONE

REQUIRED TOPICS

NONE

CONTENT REFERENCES

Systems Training Manual Volume 19 "Condensate System"

Systems Training Manual Volume 20 "Feedwater / Feedwater Pump Turbine Systems"

Systems Training Manual Volume 18 "Air Removal System"

Tasks Covered

The following tasks are covered in Condensate And Feedwater Systems:

Task Number*	Task Statement
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Total tasks: 0

TERMINAL OBJECTIVE:

- 1.0** Given the appropriate references,, the participant will be able to recognize the components, functions and operation of the Condensate and Main Feedwater Systems.
 - 1.1** Identify the functions associated with the Condensate System.
 - 1.2** Identify the functions associated with the Feedwater System.
 - 1.3** Identify the Condensate System flowpath and components.
 - 1.4** Identify the Feedwater System flowpath and components.
 - 1.5** Recognize the operation of the Condensate System.
 - 1.6** Recognize the operation of the Feedwater System.

Lesson Introduction:Condensate And Feedwater Systems

CLASSROOM GUIDELINES

- If applicable, remind students of class guidelines as posted in the classroom.
- Attendance Sheet
- Pass the attendance sheet around and have it signed in black ink.
- Materials
- Ensure that student materials needed for the class are available for each student. (For materials required, refer to the list of materials on the cover page.)
- Questions and Participation
- Emphasize student participation and remind them of your philosophy on asking and answering questions, if applicable.

ATTENTION STEP

- Give a brief statement or story to get student concentration focused on the lesson subject matter.

LESSON INTRODUCTION

- Give a brief statement which introduces the specific lesson topic. Should be limited to a single statement.

MOTIVATION

- Focus students attention on the benefits they derive from the training. At Instructors discretion. The need for remotivation in each succeeding lesson must be analyzed by the Instructor and presented as necessary.
- Instructor should include how the STAR process can be used to improve or enhance Operator Performance, if applicable.
- Lesson Terminal Objective
- Read and discuss lesson terminal objective and review lesson enabling objectives, if desired.
- Topic
- If applicable, briefly preview the lesson topic outline and introduce the major points to be covered. The objectives review may have been sufficient.
- REINFORCE the following PVNGS management expectations as opportunities become available
- Nuclear Safety
- Industrial Safety Practices
- STAR and Self-Checking
- Procedure Compliance
- Communication Standards
- ALARA
- Prevent Events

Course Terminal Objective

Given the appropriate references, the participant will be able to recognize the components, purposes and capabilities of the Plant Systems and Components as demonstrate by 80% overall proficiency on a series of three written examinations.

T.Obj 1.0	Given the appropriate references,, the participant will be able to recognize the components, functions and operation of the Condensate and Main Feedwater Systems.
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EO 1.1	Identify the functions associated with the Condensate System.
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1.1.1 Main Idea

A. System Functions

1. Condense Main Turbine and Feedwater Pump Turbine exhaust steam.
2. Provide (4) stages of feedwater heating.
3. Store deaerated condensate for reuse in the secondary cycle. (About 100,000 gallons.)
4. Provide required net positive suction head, NPSH, for the feedwater pumps.
5. Receive makeup from and discharge excess water to the condensate storage tank.
6. Discharge chemically contaminated condensate to the Circulating Water System (CW).
7. Cleanup Condensate via polishing demineralizers.

B. Condenser Air Removal System (AR).

1. Establish and maintain vacuum on the condenser shell side during plant startup.
2. Continuously remove air and non-condensable gases from the condenser shell side during power operation and plant shutdown.
3. In case of high radiation level in the condenser, reduce the amount of radioactivity released to the atmosphere by shifting discharge path automatically to a charcoal adsorption unit

EO 1.2	Identify the functions associated with the Feedwater System.
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1.2.1 Main Idea

- A. Main Feedwater System
 - 1. Supply feedwater from suction of the FW pumps to the FW regulating valves at required temp., pressure and flow rate.
 - 2. Provide final (3) stages of FW heating in (2) parallel heater trains.
 - 3. Main FW Pump Turbine System - convert high thermal energy from SG and low thermal energy from MSR or Aux. Steam into mechanical energy to drive the Main FW Pumps.

EO 1.3	Identify the Condensate System flowpath and components.
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1.3.1 Main Idea

- A. Systems Interactive Description.
 - 1. CW flowing through condenser tubes absorbs heat from:
 - a. L.P. turbine and FW pump turbine exhaust and LP FW heater drains during normal operations.
 - b. Turbine bypass system discharges up to (40%) full steam flow to condenser during abnormal conditions such as:
 - 1) Turbine Trips
 - 2) Load Rejections
 - 2. Steam gives up heat to CW, condenses and collects in hotwell.
 - a. Hotwell divided into (2) halves corresponding to (2) tube bundles.
 - b. (2) halves allow continued operation (at reduced power) while one CW flow path is isolated for maintenance such as to repair tube leaks.
 - 3. Vacuum maintained to maximize turbine output power and plant efficiency.
 - a. Created by condensation of turbine exhaust steam as it flows around tubes.
 - b. Air and non-condensable gases released in or leaking into condenser will cause loss of vacuum induced efficiency.
- B. Condenser Air Removal units, (4) installed to remove air and non-condensable gases.
 - 1. Take suction on main condenser shell side via core air off-take pipes.
 - 2. Discharge to a common exhaust header directed to atmosphere.
 - 3. Exhaust air filtering unit used when abnormally high radiation levels detected.
- C. Condensate pumps.
 - 1. Take suction off condenser hotwells
 - 2. Discharge to common supply header which distributes to:
 - a. LP FW heaters.
 - b. Various service loads.
 - 3. Directly or Via secondary chemical control system condensate polishing demineralizers
- D. LP FW heaters (12).
 - 1. (4) stages of (3) parallel trains.
 - 2. Maximize plant efficiency by preheating condensate with LP turbine extraction steam.

3. Arranged in series, located in upper condenser volume above tube bundles.
4. Heated condensate leaves via common header to FW pump suction.

EO 1.4	Identify the Feedwater System flowpath and components.
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1.4.1 Main Idea

- A. Main FW system receives water from CD.

T002.

1. Common header branches into (2) parallel networks supplying suction to (2) FW pumps.
2. Additional FW supplied by heater drains, each having an individual pump which injects water into FW pump suction.
3. FW pumps discharge to common header which branches to FW heater trains.
4. Heated FW flow returns to common header to mix FW
5. Mixed FW is then branched out again to the S/G's.

EO 1.5	Recognize the operation of the Condensate System.
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1.5.1 Main Idea

I. EO05 Recognize the operation of the Condensate System

A. Individual component descriptions

1. Main Condenser.

T003.

- a. Multi-pressure, radial-flow, single-pass, shell and straight-tube, reheat type. (Radial flow describes flowpath of exhaust steam from outer tubes to tube bundle center).
- b. Consists of (3) similar, separate sections.
- c. Floor supported, located beneath (3) LP turbines, each of which exhausts directly to its associated condenser section.
- d. Since CW flows through (3) sections in series condenser section pressure is progressively higher in each.
 - 1) A = 2.7 inches HgA.
 - 2) B = 3.3 inches HgA.
 - 3) C = 4.2 inches HgA.
- e. Has design heat rejection rate of 8.9×10^9 BTU/HR and total CW flow through tubes of approximately 560,000 GPM.
- f. Condenser shell, carbon steel, floor supported, connected to LP turbine exhaust hood by water-sealed, rubber belt type expansion joint.
 - 1) Seal prevents air leakage into condenser.
 - 2) Allows movement between turbines and condensers.
- g. (3) condenser sections cross-connected by a 120" x 72" wired duct located above tube bundles. To equalize pressure if an abnormal pressure/temperature differential occurs, a water seal will blow out. Blowout occurs at 30 degree differential temperature
- h. Two separate tube bundles in each condenser section.
 - 1) 25,426 titanium tubes provide total effective heat transfer area of approx. 1,123,000 square feet. Baffle plates prevent direct steam impingement on tubes.
 - 2) Arranged for optimum efficiency, supported throughout their length by support plates and welded at each end of their tube sheets.
 - 3) To compensate for progressively higher CW temperature tubes vary in length per condenser section (A, B, C).
 - a) Section A: 45.5 feet.
 - b) Section B: 50.0 feet.

- c) Section C: 55.25 feet.
 - i. Air off-take pipes, installed at each tube bundle center remove air and non-condensable gases, are slotted and extend the entire tube bundle length.
 - 1) Air and steam vapors are drawn into pipes and exhausted to atmosphere via Condenser Air Removal System.
 - 2) Air/vapor cooled by CW prior to laving condenser.
 - j. Hotwell provides condensate storage, reheat and deaeration, detention time and leak detection.
 - 1) Each shell has an inner bottom (above actual bottom) where condensate falls and flows to a sump for reheat.
 - 2) Longitudinal divider plate at centerline allows continued operation if a tube leak occurs in one CW flowpath. Isolated hotwell half can be pumped out to CW via one of the CD pumps.
 - 3) Provides for 100,000 gallon condensate storage volume; sufficient for (4) minutes "valves wide open" operation.
 - 4) Condensate leaves via two (36) inch lines and is supplied via CST (10) inch line which branches into four (8) inch lines.
 - k. Each condenser section protected for over-pressurization by associated LP turbine rupture disc.
 - l. Vacuum breaker on each condenser section to allow rapid turbine slowing under emergency conditions and condenser pressure equalization during normal plant shutdown.
 - m. (4) LP FW heaters are installed in the neck area above the tube bundles in each condenser section.
2. Condenser Air Removal Units.

T004 and T004A

- a. Four identical units installed to remove air and non-condensable gases from the main condenser shell side. (3) in service, (1) in standby for power generation ("HOLDING"); (4) operated in high capacity startup ("HOGGING").

Average condenser pressure with 3 units is 3.4 in. HgA.

- 1) Vacuum pumps.
 - a) One-third capacity, (2)-stage, water-ring type, (150) HP electric motor-driven.
 - b) Capacity vary's with inlet pressure, though designed to remove (37.5) lb/hr. gas, (81.5) lb/hr associated water vapor at (1) inch HgA inlet condition.
 - c) Two stage compression used during plant normal operations ("holding mode"); single stage for startup ("hogging").
- 2) Exhaust Air Filtering Unit (1).
 - a) Normally Bypassed, will go in to operation if radioactivity is detected on Plant Vent

- b) Removes moisture, particulate contamination, gaseous iodine and methyl iodine from exhaust.
 - c) Consists of:
 - (i) (2) moisture separators capable of removing up to (650) lbs. water/hr at (1600) CFM.
 - (ii) (1) electric heating coil to reduce exhaust relative humidity below (70)% to prevent charcoal filter adsorption ability damage.
 - (iii) (1) exhaust HEPA (high efficiency particulate air) prefilter.
 - (iv) (1) activated charcoal filter for carbon adsorption of iodine and methyl iodide.
 - (v) (1) exhaust HEPA post-filter.
 - (vi) HEPA filters capable of (99.97)% efficiency for greater than (0.3) micron particles.
3. Condensate Pumps (3).
- a. (50)% capacity provides head necessary to maintain flow from condenser hotwell to FW pump suctions.
 - b. Vertical, six-stage, canned, mixed-flow type with (9100) GPM capacity driven by (3500) HP electric motor.
 - c. Motor upper bearings oil lubricated, oil cooling water supplied by turbine cooling water system.
 - d. A pump takes suction on 1A, 1B and 1C hotwells.
 - e. C pump takes suction on 2A, 2B and 2C hotwells.
 - f. B pump can be aligned to:
 - 1) Take suction on both sides of hotwell (normal lineup).
 - 2) Take suction on either side of hotwell (abnormal lineup).
 - g. All (3) pumps normally operating though (2) are capable of meeting full-power condensate flow requirements.

Provided that minimum FW pump suction pressure requirements are met with only 2 CD pumps.

- h. Pump overheating protection provided by mini-flow recirculation line used at reduced pump discharge (less than 3400 GPM).
 - i. All pumps discharge to a common header.
4. Condensate Demineralizer System.
- a. Functions to maintain required water chemistry during upset (circulating water in leakage) or abnormal conditions, plant startup or shutdown.
 - b. When necessary condensate flow is directed from CD pump discharge to an array of (6) polishing demineralizers (ion exchangers).
 - 1) Spherical service vessels containing a mixed-bed regenerative-type resin.
 - 2) Each holds (312) cubic feet of resin.

- c. System normally in standby, designed to treat normal condensate at (24,800) GPM, at (450) psig and (120)°F when placed in service. (Normal Delta-P = 20 psid across demineralizers.)
 - d. Three operational modes for a demineralizer:
 - 1) Service: condensate flows from CD pump discharge header through a maximum of (5) polishers to the LP FW Heaters.
 - 2) Resin transfer: Moving a resin bed from its service vessel to regenerating equipment for processing and back.
 - 3) Regeneration Mode: Resin rinsed to remove particulates and crud, regenerated using acid and caustic solutions and rinsing.
5. Low Pressure Feedwater Heaters.
- a. (3) sets of four LP FW heaters arranged in series located in condenser upper volume above tube bundles.
 - b. Shell and straight-tube heat exchangers with condensate flowing through the tubes and LP turbine exhaust steam on the shell sides.
 - c. Heated condensate enters common header, is directed to FW pump suctions where header branches into (2) parallel networks.

EO 1.6	Recognize the operation of the Feedwater System.
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1.6.1 Main Idea

- A. Main FW Pumps (2).
1. Single-stage, horizontal, double suction, turbine driven, provide Main FW system driving force.
 2. Each has (65)% capacity, designed to handle 22,314 gpm at (348)°F 4000-6000 RPM pump speed based on speed of turbine powering the pump.
 3. Basically consist of an impeller within a double volute casing.
 - a. Liquid directed to center of impeller via (2) suction chambers, thrown to rim by centrifugal force at high velocity.
 - b. High velocity converted to static pressure as liquid leaves pump discharge casing.
 4. Supported by tilting pad radial bearings and full Kingsbury double-acting thrust bearing.
 5. Bearing lube oil supplied by FW pump turbine lube oil system.
 6. Shaft seals are packless serrated bushings with water supplied by CD system.
 7. (12) inch bypass line assures recirculation at minimum flow through pumps to prevent overheating.
 8. Motor operated valve on discharge, manual valve on suction allow for pump isolation and removal.
 9. If one pump is lost, other can handle (27,933) gpm, (65)% of system capacity, for extended time without cavitation and excess noise and vibration.
 10. Main FW pump turbines
 - a. Convert thermal energy of SG system, Aux. Steam or MSR's into mechanical energy to drive main FW pumps.
 - b. Six-stage condensing steam turbine, (16,555) HP at (5640) RPM.
 - c. Exhaust to Main Condenser.
 - d. Speed of turbine, and thus pump, controlled by positioning steam admission control valves.
 - 1) Speed control necessary to maintain required FW pressure through steady state and transient plant operation.
 - 2) Steam admission control valve position set by speed governor which receives speed demand signals from Feedwater Control System.
- B. High Pressure Feedwater Heaters (6).
1. (2) trains, each with (3) stages of HP heaters.
 2. Heat FW pump discharge water approximately (101)°F prior to being sent to S/G's.
 3. (18) inch bypass line on each train provides for (25)% of flow when one train out of service.

4. Combine with (75)% capacity of (1) heater train, bypass allows operation up to (90)% generated power during single train failure
5. Each supplied with heating steam extracted from main turbine.
6. Heater condensate drains to heater drain tank.
7. Feedwater discharge via common heater to two (24) inch headers to S/G's.

C. S/G economizer control valves.

T005 and T005A

1. Economizer section of S/G uses portion of cold leg half of S/G to preheat incoming FW to saturation temperature.
2. Economizer preheating capability is insufficient during low power operations and thus economizer is shut.
3. Valves, one per generator, are (16) inch high capacity, cage-guided valves.
4. Design flow rate is (25,200) GPM at (1240) PSIG.
5. Though normally automatically operated, may be manually controlled; fails, as is, on loss of electrical power or air pressure.

D. S/G Downcomer Control Valves.

1. During low power operations, (100)% of all flow passes through the downcomer control valves.
2. At (15)% power, valve shuts and all flow is through the economizer.
3. At (50)% steam flow (power), valve reopens and supplies (10)% of rated FW flow.
4. Valves are direct acting globe valves, designed for (3,485) GPM at (1245) PSIG.
5. Normally automatically operated, may be operated manually; fails, as is, on loss of electrical power or air pressure.

SUMMARY OF MAIN PRINCIPLES

Objectives Review

Review the Lesson Objectives

Topic Review

Restate the main principles or ideas covered in the lesson. Relate key points to the objectives. Use a question and answer session with the objectives.

Questions and Answers

Oral questioning

Ask questions which implement the objectives. Discuss students answers as needed to ensure the objectives are being met.

Problem Areas

Review any problem areas discovered during the oral questioning, quiz, or previous tests, if applicable. Use this opportunity to solicit final questions from the students (last chance).

Concluding Statement

If not done in the previous step, review the motivational points which apply this lesson to students needs. If applicable, end with a statement leading to the next lesson.

You may also use this opportunity to address an impending exam or practical exercise.

Should be used as a transitional function to tie the relationship of this lesson to the next lesson. Should provide a note of finality.