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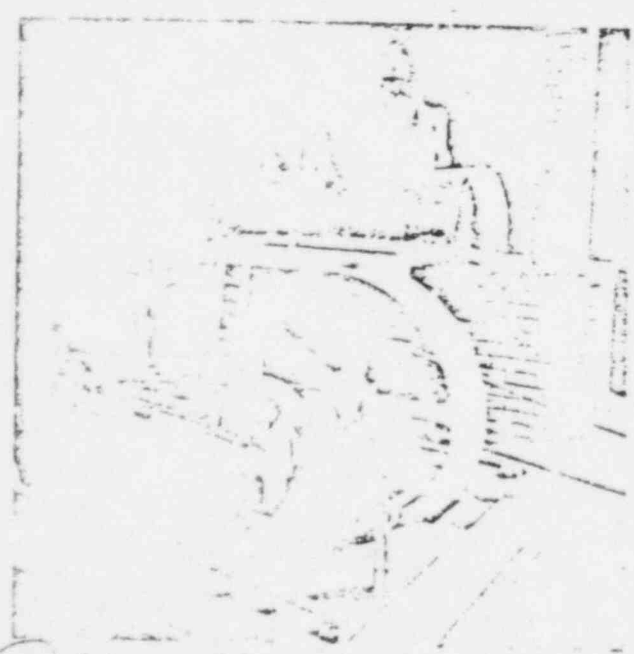

Instructor's Guide

Plant Performance

NUCLEAR ENERGY TRAINING

Instructor's Guide
Module 4
Plant Performance

NUS
CORPORATION

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GENERAL GUIDELINES FOR INSTRUCTOR

Each unit (one hour of videotape and corresponding text) requires about a four-hour block of time. The recommended sequence of instruction is as follows:

1. Introduce the unit of instruction.
2. Have the students read the objectives in the text for the first segment.
3. Add any other objectives that you wish to make.
4. Have the students view the first segment of videotape.
5. Have the students read the text corresponding to the first segment of videotape.
6. Amplify the key points of the segment.
7. Have the students answer the questions at the end of the segment. (The answers are provided at the end of the unit text.) While the students are writing their answers, walk around the room and render help as needed.
8. Before going on to the next segment, clear up any points of misunderstanding the class may have and ask if there are any questions.
9. WORK THROUGH ALL THE SEGMENTS IN THIS MANNER.
10. At the completion of the last segment, have the students work the problem set in their text. (This problem set is optional. The students may work all of the problems or only selected problems. The solution sheet is contained in the Instructor's Guide. It may be reproduced and passed out to the students.)
11. Have the students take the quiz. The quiz and the quiz solutions are contained in the Instructor's Guide. You must reproduce quizzes for distribution to the class.

This recommended sequence provides a great deal of flexibility for the instructor in adapting the instruction to the level of the students. Since the format for each segment is the same, it is not repeated in the presentation outline for each segment. The only portion of the recommended sequence that is expanded is the amplification of the key points. You should still follow the complete sequence indicated in these guidelines for each segment and simply interject and amplify key points for each segment in their proper order.

INSTRUCTOR'S GUIDE
A NOTE TO THE INSTRUCTOR

The decisions on the content of this module are based on three criteria:

(1) Is a particular item necessary for a competent operator to know?

(2) Is a particular item necessary knowledge for the NRC license exam?

(3) Is a particular item necessary for the understanding of later material?

With this philosophy in mind, much of the classical theory involved in physics and thermodynamics has been deleted. For example, in physics, the difference between a pound force and a pound mass and the derivation of the gravitational constant, g_c, are not taught. It is felt that an operator would never have to calculate values of kinetic energy, so the teaching of all the background is not necessary. The same philosophy is held in thermodynamics. For example, a carnot cycle is never mentioned.

Appendices have been included with the text for students who want more detail. These appendices include appropriate formulas, and it is recommended that a student who has a particular interest in the classical approach to physics and thermodynamics be directed to high school or lower-division college textbooks for further information.

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INSTRUCTOR'S GUIDE

Unit 1 - The Steam Power Cycle

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of the steam cycle and its components and the properties of steam and water. The concepts presented in this unit are essential to the understanding of the material covered in the remainder of this module. Specific objectives are given in the text for each segment.

2. Material Required

   a. Text - Unit 1 - The Steam Power Cycle
   b. Videotape - Unit 1 - The Steam Power Cycle
   c. Steam Tables booklet
   d. Problem set solutions (must be reproduced from the Instructor's Guide)
   e. Quizzes (must be reproduced from the Instructor's Guide)
   f. Viewgraphs:
      (1) 1.1-1 "Basic Steam - Water Cycle"
      (2) 1.1-2 "Using Boundaries to Study a Pump"
      (3) 1.1-3 "Using Boundaries to Study a Refrigerator"
      (4) 1.2-1 "Fahrenheit and Rankine Temperature Scales"
      (5) 1.2-2 "Pressure Scales"
      (6) 1.2-3 "U-Tube Manometer"
      (7) 1.3-1 "Specific Heat of Various Solids and Liquids"
      (8) 1.5-1 "Temperature-Entropy Diagram"

3. Unit 1 Presentation

   a. Tell the students the scope of the unit of instruction.
   b. Make sure that the students are aware that this is the first of a series of units on plant performance and that important basic concepts are being introduced.

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c. Remind the students that a glossary of new terms is included in their text.

d. Explain to the students the sequence of instruction you plan to use.

Segment 1 - The Basic Cycle

Key Points:

(1) Go over the definition of thermodynamics and discuss with the students the general idea of turning heat into useful work.

(2) Use Viewgraph 1.1-1 to discuss the basic components of the steam cycle. Have the students trace the path of water and steam through the system and discuss the changes that take place in each component.

(3) Make sure that the students understand where heat enters the system, where heat leaves the system, where work enters the system, and where work leaves the system.

(4) Use Viewgraph 1.1-2 to illustrate the use of boundaries as a means of studying a specific system or component. Emphasize the necessity of examining everything that crosses the boundary.

(5) Use Viewgraph 1.1-3 to illustrate the answers to question 1.1-6. The students may require guidance to fully understand the question.

Segment 2 - Temperature, Pressure, and Volume

Key Points:

(1) Briefly review the temperature and pressure changes that occur during the steam cycle to illustrate the importance of understanding these properties. Emphasize the fact that temperature, pressure, and volume can be used to fix all other properties of water.

(2) Discuss the definition of temperature. Use Viewgraph 1.2-1 to compare the Fahrenheit and Rankine temperature scales. Give examples of when the Rankine scale might be used.

(3) Discuss the definitions of pressure and atmospheric pressure. Use Viewgraph 1.2-2 to compare gauge pressure, absolute pressure, and inches of mercury vacuum.

(4) Use Viewgraph 1.2-3 to show how a manometer can be used to measure pressure.

(5) Work through some pressure calculations with the students. Use the examples in the text or some actual pressure readings taken in your plant.

(6) Make sure that the students understand the relationship between volume and specific volume.

(7) Use the Universal Gas Law to show how temperature, pressure, and specific volume are related. Use examples to show how various types of problems can be solved.

Segment 3 - Heat and Its Effects

Key Points:

(1) Review the definitions of heat and BTU, emphasizing that heat is the transfer of energy.

(2) Use Viewgraph 1.3-1 to discuss specific heat and compare the specific heats of various substances.

(3) Discuss change of phase with reference to the changes that water undergoes as it passes through the steam cycle.

(4) Discuss how latent heat of vaporization and boiling point vary with pressure.

Segment 4 - Enthalpy and Entropy

Key Points:

(1) Review the definitions of work and energy and relate them to the properties of enthalpy and entropy.

(2) Discuss how changes in enthalpy are used to determine how efficiently a component is operating.

(3) Go through some simple calculations involving changes in enthalpy and entropy to illustrate how these properties are used. At this point, the students must understand that entropy is a property of water, and is fixed for a specific temperature, pressure and specific volume. This is necessary for the next segment.

Segment 5 - Cycle Diagram

Key Points:

(1) Make sure that the students understand the purpose of a T-S diagram as a means of investigating plant processes.

(2) Use Viewgraph 1.5-1 to discuss the T-S diagram in detail. Make sure that the students understand the various lines on the diagram and that they know how to plot a process on it.

(3) Show the students what a Mollier Chart looks like.

Segment 6 - Steam Tables

Key Points:

(1) This segment is not included on the videotape, so make sure that the students have read and understood the text material.

(2) Discuss the reference point for the steam tables. Emphasize the fact that this is an arbitrary zero point, but that it works well for steam plant applications.

(3) Point out the similarities and differences in Tables 1 and 2. Make sure that the students understand how these two tables are set up.

(4) Discuss the concept of superheating and the organization of Table 3.

(5) Remind the students of the list of conversion factors in the back of the steam tables booklet.

4. Problem Set

You may assign any or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. As the students are working the problems, walk around the room and render help as needed.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 1 - Problem Set Solutions

1-1. First, find a boundary around whatever is being investigated, then see what changes occur in things as they cross the boundaries.

1-2. + 460°

1-3. psia = (30" - Hg vacuum) x ½
= (30" - 11") x ½
= 9.5 psia
yes

1-4. The British Thermal Unit (BTU): the heat required to raise one pound of water one degree F.

1-5. $\dot{Q} = \dot{m}\, C_p\, \Delta T$

$\dot{Q} = (1{,}000 \text{ gal} \times 8.33 \frac{\text{lb}}{\text{gal}}) \times (1 \frac{\text{BTU}}{\text{lb}^\circ F})\,(5^\circ F)$

$= 83{,}300$ BTU/min

Latent heat of vaporization @ 212°F = 970 BTU/lb

$\text{Steam} = \frac{83{,}300 \text{ BTU/min}}{970 \text{ BTU/lb}}$

$= 86.0 \frac{\text{lbs steam}}{\text{minute}}$

1-6. Work = force x distance
w = (50 lbs) x (20 feet)
= 1,000 ft-lbs work

1-7. a. The energy stored in water

b. If the pressure or temperature is known, enthalpy can be found from the steam tables. Enthalpy is defined for a particular temperature, pressure, and specific volume.

1-8. a. Specific volume of the saturated liquid

b. Specific entropy of the saturated steam

c. Specific enthalpy change from liquid to steam (also the latent heat of vaporization)

1-9. The pressure and temperature drop. As the steam drops inside the saturated steam dome, it becomes partly water. It crosses the saturation dome and becomes superheated until it gets to the 80°F line.

1-10. a. At higher temperatures and pressures, the molecules do not have to move as far apart.

b. The steam molecules are as close together as the water molecules. There is no difference, so no heat is required to cause boiling.

Unit I - The Steam Power Cycle

Quiz

Name: ______________________________ Date: ____________

Score: ________________

1. Convert 527°F to °R. (5)

2. What is the zero point for the Rankine scale? (10)

3. Calculate the force that would try to lift a containment building that is 100 feet in diameter and is pressurized to 60 psia. (15)

PLANT PERFORMANCE

1. The Steam Power Cycle (continued)

4. Define specific volume. (10)

5. Calculate the BTU's required to heat 3 pounds of a substance 250°F. (15)
The substance has a specific heat of .2 BTU/lb°F.

6. What is the specific heat of water? (10)

7. Define work. (5)

98. Draw a T-S diagram. Label the axes, place a saturation dome, and show constant pressure and constant enthalpy lines. (10)

99. Find the changes in enthalpy, entropy, and specific volume when water is boiled at 255 psig. (10)

PLANT PERFORMANCE
I. The Steam Power Cycle (continued)

10. Indicate on a simple T-S diagram the area in which the superheated steam tables apply. (10)

Unit 1 - Quiz Solutions

1. $527^{\circ}F + 460^{\circ} = 987^{\circ}R$

2. The temperature at which there is no molecular motion in matter: $0^{\circ}R$

3. $\text{Pressure} = \frac{\text{force}}{\text{area}}$

   $\text{Force} = P \times A$

   $\text{Force} = (60 \text{ psia} - 15 \text{ psi}) \left(\frac{\pi (100 \text{ ft}) \times \left(144 \frac{in^2}{ft^2}\right)}{4} \right)$

   $\text{Force} = 7.3 \times 10^9$ pounds
   or
   3.6 million tons

4. The volume of one pound of a substance

5. $Q = m C_p \Delta T$

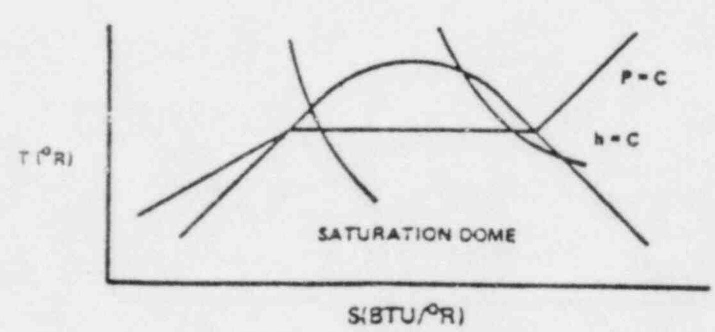
   $Q = (3 \text{ lbs}) (.2 \text{ BTU/lb}^{\circ}F) (250^{\circ}F)$

   $Q = 150$ BTU

6. $1 \text{ BTU/lb}^{\circ}F$

7. Force acting through a distance

8.



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PLANT PERFORMANCE

1. The Steam Power Cycle

9. psia = psig + 15 psi

psia = (255 psig) + 15 psi

psia = 270 psia

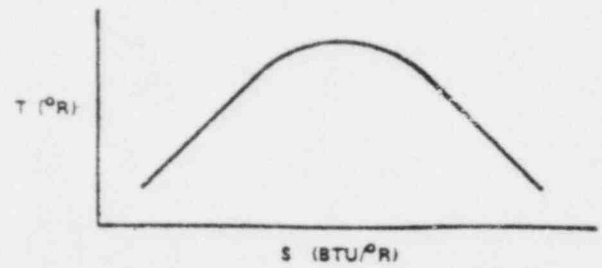
From the steam tables

$h_{(fg)} = 825.0$

$s_{(fg)} = 0.9585$

$(v_{fg}) = 1.82452$

10.



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INSTRUCTOR'S GUIDE

Unit 2 – Thermodynamics: Heat at Work

I. Objective

At the conclusion of this unit, the students should know the first and second laws of thermodynamics, have an understanding of the energy equation and the various types of energy included in it, and be able to work simple problems involving energy conversions and efficiency.

II. Materials Required

a. Text - Unit 2 - Thermodynamics: Heat at Work
b. Videotape – Unit 2 - Thermodynamics: Heat at Work
c. Steam Tables booklet
d. Problem set solutions (must be reproduced from the Instructor's Guide)
e. Quizzes (must be reproduced from the Instructor's Guide)
f. Viewgraphs

(1)	2.1-I	"Energy Equation"
(2)	2.2-I	"Energy Changes in the Turbine"
(3)	2.3-I	"Pipe Schematic"
(4)	2.4-I	"Efficiency Equation"
(5)	2.5-I	"Refrigeration Cycle"
(6)	2.5-I	"Refrigeration Cycle T-S Diagram"

III. Unit 2 Presentation

a. Tell the students the unit objective.
b. Remind the students of the list of new terms that is included in their text.
c. Explain to the students the sequence of instruction you plan to use.

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Segment 1 - The First Law of Thermodynamics: Potential and Kinetic Energy

Key Points:

(1) Make sure that the students understand the basic principle of the first law of thermodynamics, that energy can neither be created nor destroyed, but the form can change.

(2) Use Viewgraph 2.1-1 to introduce the energy equation. Tell the students what the symbols stand for and that they will be defined in this unit.

(3) Refer to plant startup and shutdown as examples of changes in stored energy.

(4) Make sure that the students understand that potential energy is the energy of position. Refer them to Appendix A of their text for addtional information on potential energy calculations.

(5) Review the definition of kinetic energy, emphasizing that kinetic energy is proportional to velocity squared. Additional information is included in Appendix A.

(6) Water hammer is an illustration of kinetic energy in action. You may want to draw on your own experience for additional examples.

Segment 2 - Internal Energy, Flow Work, Mechanical Work, and Heat

Key Points:

(1) Make sure that the students understand the concepts that make up the last four terms of the energy equation - internal energy, flow work, mechanical work, and heat.

(2) Review enthalpy as the sum of internal energy and flow work.

(3) Use Viewgraph 2.2-1 and the energy equation to analyze how energy is changed in the turbine phase of the steam-water cycle.

Segment 3 - Energy Conversion

Key Points:

(1) Remind the students of the conversion factors that are included in the Steam Tables booklet.

(2) Make sure that the students understand the relationship between heat and work.

(3) Use Viewgraph 2.3-1 and the energy equation to show the changes in energy that take place as water flows through a pipe. Discuss the terms pressure head and velocity head.

Segment 4 - The Second Law and Efficiency

Key Points:

(1) Make sure that the students know the two parts of the second law of thermodynamics and how they relate to plant efficiency.

(2) Use examples such as the one in the text (Example 2.4-1) to illustrate how heat is wasted in the plant.

(3) Use Viewgraph 2.4-1 to discuss how efficiency is related to temperature.

Segment 5 - Vapor Compression Refrigeration Cycle

Key Points:

(1) Use Viewgraph 2.5-1 to discuss the operation of the refrigeration cycle. Show how the components are comparable to the components of the steam-water cycle.

(2) Use Viewgraph 2.5-2 to analyze the refrigeration cycle by means of a T-S diagram. Make comparisons to the steam-water cycle where appropriate.

(3) Make sure that the students understand how the free expansion of steam affects the efficiency of the plant.

4. Problem Set

You may assign some or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. As the students are working problems, walk around the room and render help as needed.

5. Quiz

A short review should be conducted before the quiz is given, but the review should not preview the quiz questions. Simply cover key points and ask the class if there are any questions.

Unit 2 - Problem Set Solutions

2-1. No, it would continue on the stored energy in the plant.

2-2. a. The kinetic energy of the flywheel will keep the pump running. As the pump moves additional water, the energy of the flywheel will decrease.

b. To store energy as kinetic energy

2-3. a. W = P x V

W = (962 psia - .5 psia) (.016 ft^3/lb)

W = 15.384 ft-lbs

b. W = P x V

W = (962 psia) (V_{fg})

W = (962 psia) (~.44)

W = ~424 ft-lbs

c. Increasing the internal energy of the water

2-4. Mechanical work and heat are energy in motion, while flow work and internal energy are stored in the water.

2-5. 1st Law:

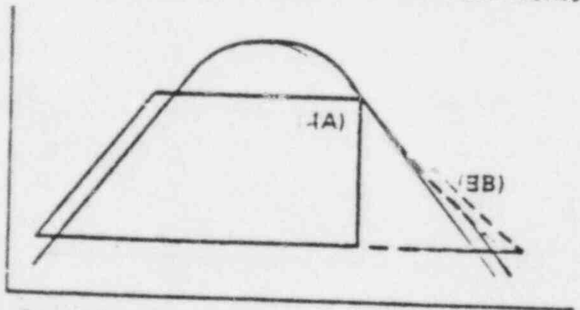
BTU's wasted will increase and BTU's converted to work will decrease.

2nd Law:

BTU's out will increase, so ΔS_{out} will be larger than ΔS_{in}.

2-6. No, because work has to be done to make it work.

2-7.



c. The Second case would be more of a load on the condenser.

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Unit 2 - Thermodynamics: Heat at Work

Quiz

Name: ______________________ Date ______________

Score: ______________________

1. What effect does increasing the energy stored in the plant have?

2. What is a water hammer?

3. Define flow work and give its units.

4. a. What parameter is actually measured to find flow through a flow-measuring device?

   b. How does that parameter vary with flow?

5. State the two parts of the second law of thermodynamics:

   a.

   b.

6. a. What is efficiency?

b. How can efficiency be defined mathmatically?

Unit 2 - Quiz Solutions

1. It increases the temperature of the plant.
2. High-velocity water is suddenly stopped or turned. It then gives up its energy to the pipes or valves and can damage them.
3. Flow work is the energy of pressure times volume, and its units are foot-pounds.
4. a. ΔP
   b. It varies as the square of the flow.
5. a. Heat flows from a high temperature to a low temperature.
   b. Not all heat can be turned into work.
6. a. A measure of how well a system uses the energy put into it
   b. $E = \frac{\text{work out}}{\text{energy in}}$

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INSTRUCTOR'S GUIDE

Unit 3 - Steam Boilers

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of how heat is transferred, what factors affect heat transfer, how to draw a heat transfer curve, what is involved in boiling heat transfer, and how a steam boiler operates.

2. Material Required

a. Text - Unit 3 - Steam Boilers

b. Videotape - Unit 3 - Steam Boilers

c. Problem set solutions (must be reproduced from the Instructor's Guide)

d. Quizzes (must be reproduced from the Instructor's Guide)

e. Viewgraphs:

(1)	3.1-1	"Heat Conduction"
(2)	3.2-1	"Heat Transfer Curve"
(3)	3.2-2	"Convection Heat Transfer"
(4)	3.3-1	"Boiling Heat Transfer"
(5)	3.3-2	"Transition Boiling"
(6)	3.4-1	"Effect of a Pressure Increase on Boiling Heat Transfer"
(7)	3.4-2	"Effect of a Pressure Decrease on Boiling Heat Transfer"
(8)	3.4-3	"Effect of a Flow Increase on Boiling Heat Transfer"
(9)	3.5-1	"Steam Boiler Schematic"
(10)	3.5-2	"Cyclone-Type Moisture Separator"
(11)	3.5-3	"Chevron-Type Moisture Separator"

3. Unit 3 Presentation

a. Tell the students the scope of the unit of instruction.

b. Remind the students that a glossary of new terms is included in their text.

c. Explain to the students the sequence of instruction you plan to use.

Segment 1 - Basic Heat Transfer Principles

Key Points:

(1) Use Viewgraph 3.1-1 to discuss conduction as the basic means of heat transfer across metal surfaces.

(2) Make sure that the students understand the importance of a temperature difference in conduction heat transfer.

(3) Discuss convection as a means of getting heat from the wall of the steam boiler into the water. Emphasize the role of water flow.

(4) Briefly discuss what radiation heat transfer is.

(5) Discuss heat transfer coefficients and how they are used in your plant.

Segment 2 - Physical Parameters of Basic Heat Transfer

Key Points:

(1) Make sure that the students understand the relationship between heat flow and ΔT. It might be helpful to go through Example 3.2-1 with the class.

(2) Make sure that the students understand the relationship between heat transfer rate and area, including ΔT.

(3) Have the students give examples in the plant of materials that are good conductors and materials that are poor conductors and tell how these materials are used.

(4) Discuss the effect of the buildup of deposits on heat transfer surfaces.

(5) Use Viewgraph 3.2-1 to introduce the heat transfer curve.

(6) Use Viewgraph 3.2-2 to illustrate the effect of a flow increase on convection heat transfer.

Segment 3 - Boiling Heat Transfer

Key Points:

(1) Use Viewgraph 3.3-1 to show where boiling heat transfer appears on the heat transfer curve. Discuss why this portion of the curve is steeper than the convection portion.

(2) Make sure that the students understand the concepts of nucleate boiling, sub-cooled nucleate boiling, bulk boiling and film boiling.

(3) Use Viewgraph 3.3-2 to discuss transition boiling and critical heat flux.

(4) Make sure that the students were able to follow the videotape demonstration and that they understood why the wire might have burned out.

Segment 4 - Physical Parameters of Boiling Heat Transfer

Key Points:

(1) Use Viewgraph 3.4-1 to discuss the effect of a sudden pressure increase on boiling heat transfer. Make sure that the students understand what is taking place and why the curve shifts to the right.

(2) Use Viewgraph 3.4-2 to discuss why a sudden pressure drop may cause serious problems in the plant.

(4) Use Viewgraph 3.4-3 to discuss the effects of a flow increase on boiling heat transfer. Have the students draw a curve to illustrate the effects of a decrease in flow.

Segment 5 - Steam Boiler Characteristics

(1) Use Viewgraph 3.5-1 to discuss water circulation in a steam boiler. Emphasize the type of circulation used in your plant.

(2) Use Viewgraphs 3.5-2 and 3.5-3 to discuss the two types of moisture separators. Discuss how and when either or both are used in your plant.

(3) Make sure that the students understand the concepts of quality and carryover. Only two causes of carryover were mentioned in the text. You may want to add to this list.

(4) Discuss swell and shrink and make sure that the students understand the causes and effects of each.

4. Problem Set

You may assign any or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. Problem 1.5 is especially recommended. As the students are working the problems, walk around the room and render help as needed.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

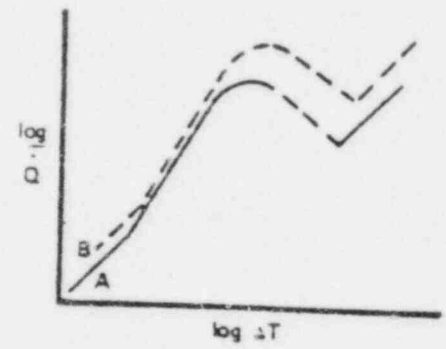
Unit 3 - Problem Set Solutions

3-1. $\dot{Q} = K\Delta T$

$$\frac{10^6 \text{ BTU's}}{\text{hr}} = K\,(60\,^{\circ}F)$$

$$K = 1.66 \times 10^4 \frac{\text{BTU}}{\text{hr} - {}^{\circ}F}$$

3-2. a. and b.



c. Increased flow will cause a decreased layer of water, which improves heat transfer. This means that more heat can be transferred for a smaller ΔT.

3-3. The one with saturated steam, because the heat transfer will be condensation. In the case with superheated steam, the steam temperature has a drop $10^{\circ}F$ before condensation can start.

3-4. (a) ↓

(b) ↓

(c) ↑

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3.5 Burnup refers to the depletion of the uranium fuel due to power operations, while burnout is damage due to high temperatures.

Unit 3 - Steam Boilers

Quiz

Name: ______________________ Date______________

Score: ________________

1. a. What are the three basic methods of heat transfer? (10)

   b. Which play a significant role in heat transfer in your plant? (5)

   c. Which method of basic heat transfer is of little use in plant operations? Why? (5)

2. Draw and label the heat transfer curve. Label the different modes of heat transfer as represented by each portion of the curve. (15)

3. Define "critical heat flux." (10)

4. What is "swell"?

5. a. A heat exchanger transfers 110,000 BTU/hr with an average temperature differential of 20 °F. What will happen to the heat flow if scale builds up and the temperatures remain constant? (10)

b. What will happen to the temperature differential if the heat flow remains the same? (5)

6. Why is boiling heat transfer so efficient? (10)

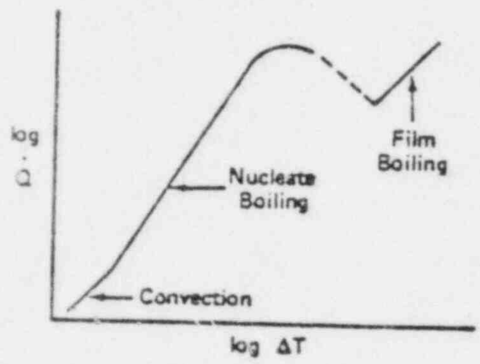
7. What is the basic principle involved in cyclone and chevron-type moisture separators? (15)

8I. A sudden pressure decrease can cause nucleate boiling to turn into film boiling. Can a sudden <u>increase</u> in pressure also cause a negative effect with respect to nucleate boiling? Why or why not? (15)

Unit 3 - Quiz Solutions

1. a. Conduction, convection, radiation
   b. Conduction and convection
   c. Radiation - It requires very high temperatures, which could damage the plant components.

2.



3. The heat flux ($\dot{Q}$) that would cause DNB

4. An increase in the level of the steam boiler due to a decrease in pressure

5. a. Heat flow will decrease
   b. It will increase

6. The water absorbs a lot of heat as it changes to steam, so this is much faster that conduction/convection.

7. The water is denser than the steam, so a change in direction will cause the water to be thrown out.

8. Yes, an increase in pressure will also cause a corresponding increase in saturation temperature. This will suppress nucleate boiling and a larger ΔT would be required for the same $\dot{Q}$.

INSTRUCTOR'S GUIDE

Unit 4 - Turbine Generator

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of how steam flows through the turbine, how the energy in steam is converted into useful work, how superheating and reheating can increase the efficiency of the turbine process, and what precautions must be taken to prevent or minimize turbine damage. Specific objectives are given in the text for each segment.

2. Material Required

   a. Text - Unit 4 - Turbine Generator
   b. Videotape - Unit 4 - Turbine Generator
   c. Steam Tables booklet
   d. Problem set solutions must be reproduced from the Instructor's Guide)
   e. Quizzes (must be reproduced from the Instructor's Guide)
   f. Viewgraphs:

(1)	4.1-1	"Turbine Generator Arrangement"
(2)	4.1-2	"T-S Diagram of the Turbine Process"
(3)	4.1-3	"Simplified T-S Diagram"
(4)	4.2-1	"Nozzle Schematic"
(5)	4.2-2	"Plain Orifice"
(6)	4.2-3	"Convergent Nozzle"
(7)	4.2-4	"Convergent-Divergent Nozzle"
(8)	4.2-5	"Impulse Turbine"
(9)	4.2-6	"Reaction Turbine"
(10)	4.3-1	"Effect of Superheating on the Turbine Process"
(11)	4.3-2	"The Reheat Cycle"

3. Unit 4 - Presentation

a. Tell the students the scope of the unit of instruction.

b. Remind the students that a glossary of new terms is included in this text.

c. Explain to the students the sequence of instruction you plan to use.

d. Remind the students to use the steam tables for plant cycle calculations.

Segment 1 - Turbine Cycle

Key Points:

(1) Use Viewgraph 4.1-1 to follow the flow of steam through the turbine. Make sure that the students understand the changes that occur in the steam.

(2) Make sure that the students understand the general purpose of the moisture separator/reheater. This device is covered in more detail later in this unit.

(3) Use Viewgraph 4.1-2 to discuss the turbine process in detail. Make sure that the students understand why the real turbine process and the ideal turbine process are different. Reinforce the concepts with the assistance of Viewgraph 4.1-3.

(4) Discuss the reasons for turbine inefficiency. Emphasize problems that have occurred in your plant.

Segment 2 - Energy Conversion

Key Points:

(1) Use Viewgraph 4.2-1 to show the relationship between downstream pressure and upstream pressure. Make sure that the students understand the meaning of the critical pressure ratio.

(2) Use Viewgraphs 4.2-2 through 4.2-4 to discuss the various types of orifices and nozzles. Include in the discussion how each nozzle operates, what its advantages are, where it might be used in the plant, and the effect of the critical pressure ratio.

(3) Use Viewgraphs 4.2-5 and 4.2-6 to discuss the operation of impulse turbines and reaction turbines, including similarities, differences, and advantages of each type.

Segment 3 - Superheat and Reheat Cycles

Key Points:

(1) Briefly review the steam cycle to show where superheat is added.

(2) Use Viewgraph 4.3-1 to illustrate the effects of superheating on the turbine process. Make sure that the students understand how superheating increases the efficiency of the steam.

(3) Discuss the advantages and disadvantages of using superheaters in nuclear plants. Relate these to your plant's decision to use or not use superheaters.

(4) Remind the students that Table 3 of the steam tables contains values for calculations involving superheated steam.

(5) Use Viewgraph 4.3-2 to discuss the effects of reheating steam and the role of moisture separator/reheaters in the plant. Include advantages and disadvantages.

Segment 4 - Turbine Precautions

Key Points:

(1) Review the ways in which moisture in the steam can damage the turbine blades and discuss the more serious damage that can result from water induction.

(2) Make sure that the students understand that a turbine trip by itself does not damage the turbine. Damage occurs when water or steam re-enters the turbine in an attempt to fill the vacuum that is created.

(3) Discuss the ways in which excess heat can build up in the turbine and how heat can cause damage.

(4) Make sure that the class understands what is meant by breaking vacuum in the condenser and how and why this might be done.

(5) Discuss the cause and effect of static electricity and the precautions that are taken to keep it from building up in the turbine.

4. Problem Set

You may assign some or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. As the students are working the problems, walk around the room and render help as needed.

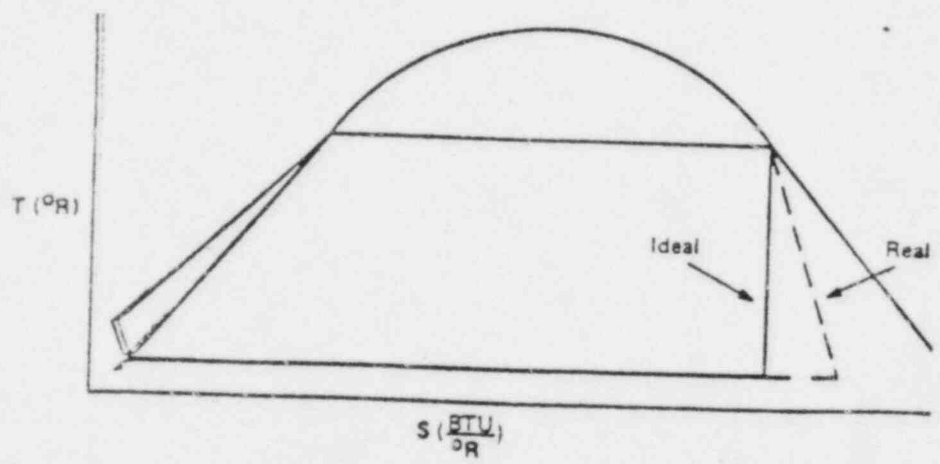
5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the class if there are any questions.

Unit 4 - Problem Set Solutions

1. (Answers may be in either order.)
   a. Remove moisture
   b. Reheat steam

2.



3. Reaction turbines have a pressure drop across stationary blades and moving blades. The drop across the moving blades causes a velocity increase and a reaction force. Impulse turbines have a pressure drop only across the nozzles and use the direct impingement of steam to create a force.

4. Option 2 is much more efficient.

Unit 4 - Turbine Generator
Quiz

Name: ______________________ Date ____________

Score: ______________

1. What is the function of a turbine? (Use thermodynamic terms) (10)

2. Turbine inefficiencies decrease the work we get from each BTU added to the plant. Are there any positive benefits derived from turbine inefficiencies? (15)

3. Define "critical pressure ratio." (10)

4. Under what steam conditions would you expect (a) a reaction turbine, and (b) an impulse turbine to be used? (High/low pressure)

   a. Reaction - (10)

   b. Impulse - (10)

5. Why are many stages of blades used in large turbines? (15)

6. What is the source of heat for a moisture separator/reheater? (10)

7. a. Would you ever break vacuum before the turbine stops rotating? (10)

b. Is this a good routine procedure? Why? (10)

Unit 4 - Quiz Solutions

1. To convert the enthalpy in the steam into useful work
2. Yes - Decreased moisture in the steam
3. $CPR = \frac{\text{Downstream Pressure}}{\text{Upstream Pressure}} = 58\%$
4. a. Low steam pressure
   b. High steam pressure
5. To get the maximum amount of work out of the steam
6. Steam from the main steam system or extraction steam from the high-pressure turbine
7. a. In an emergency to stop the turbine rapidly
   b. No. It places severe stresses on the turbine.

5

INSTRUCTOR'S GUIDE

Unit 5 - Condenser

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of why the condenser is needed, how it operates, and how it affects cycle efficiency. They should also understand the effects on the plant cycle of turbine extraction, feedwater heating, and the particular condenser cooling system in use for their plant. Specific objectives are given in the text for each segment.

2. Material Required

   a. Text - Unit 5 - Condenser
   b. Videotape - Unit 5 - Condenser
   c. Steam Tables booklet
   d. Problem set solutions (must be reproduced from the Instructor's Guide)
   e. Quizzes (must be reproduced from the Instructor's Guide)
   f. Viewgraphs:

(1)	5.1-1	"Effect of Pumping Steam from Turbine to Boiler"
(2)	5.1-2	"Condenser Diagram"
(3)	5.1-3	"The Condensing Process on a T-S Diagram"
(4)	5.2-1	"Steam Driven Air Ejector"
(5)	5.3-1	"Air Ejector Draining Through a Loop Seal"
(6)	5.4-1	"Feedwater Heating"
(7)	5.4-2	"Cascading Drains"
(8)	5.5-1	"Operation of a Wet Cooling Tower"
(9)	5.5-2	"Forced Draft Cooling Tower"
(10)	5.5-3	"Natural Draft Cooling Tower"

3. Unit Presentation

a. Tell the students the scope of the unit of instruction.
b. Remind the students that a glossary of new terms is included in their text.
c. Remind the students to use the steam tables to find the values needed for plant calculations.
d. Explain to the students the sequence of instruction you plant to use.

Segment 1 - Condenser Theory

Key Points:

(1) Make sure that the students understand what the condenser does and why it is needed. Use Viewgraph 5.1-1 to show why steam is not pumped directly from the turbine to the boiler.

(2) Use Viewgraph 5.1-2 to identify the various parts of the condenser and discuss the function of each part. Have the students trace the flow of steam and water through the condenser.

(3) Use Viewgraph 5.1-3 to show how the condensing process looks on a T-S diagram. Make sure that the students understand why there is no change in temperature.

Segment 2 - Condensers and Cycle Efficiency

Key Points:

(1) Make sure that the students understand why the condenser operates at a vacuum and how the condenser allows the steam temperature in the turbine to drop to 80°F.

(2) Discuss with the students the ways in which the vacuum is created and maintained in the condenser. Make sure that they understand how the condensing process helps in maintaining the vacuum.

(3) Use Viewgraph 5.2-1 to discuss the general operation of a steam driven air ejector. Expand the discussion to include the particular types of steam driven air ejectors or electrically driven mechanical pumps that are used in your plant.

Segment 3 - Improving Condenser Efficiency

Note: This segment discusses many ways that the operator can affect condenser operation. In some plants, however, equipment or procedures will not allow for some of the operations that are included. For example, there may be no means to control the flow of cooling water through the condenser. In some plants, the ΔT of the cooling water through the plant is required to be kept at a minimum, so flow cannot be reduced during the winter. It is recommended that you find what procedures apply in your plant and stress them in class. Also explain why some of the suggestions made in the videotape cannot be implemented.

Key Points:

(1) Discuss the differences between efficiency in the turbine and efficiency in the condenser, emphasizing how each affects the overall efficiency of the plant cycle.

(2) Discuss the factors that affect condenser efficiency. Stress those that an operator in your plant has some control over.

(3) Use Viewgraph 5.3-1, if this arrangement applies to your plant, to show how plant design might affect condenser efficiency.

Segment 4 - Turbine Extraction and Feedwater Heating

Key Points:

(1) This segment continues with the idea of overall cycle efficiency. Make sure that the students understand where turbine extraction and feedwater heating fit into the cycle and how they affect cycle efficiency.

(2) Use Viewgraph 5.4-1 to discuss how the regeneration process works. Make sure that the students understand why turbine extraction is an effective use of heat.

(3) Use Viewgraph 5.4-2 to illustrate the system of cascading drains. Emphasize how these drains help to make the use of heat more effective.

Segment 5 - Condenser Cooling Systems

Key Points:

(1) In this segment, emphasize the type of cooling system used for your plant, but let the students be aware of the other types that are available. The students should know why a particular system was chosen for their plant.

(2) Use Viewgraph 5.5-1 to illustrate the operation of a wet-type cooling tower. If your plant uses a dry-type tower or a combined wet/dry system, point out the differences in design and operation.

(3) Use Viewgraphs 5.5-2 and 5.5-3 to discuss the operation of forced draft and natural draft cooling towers, including the advantages and disadvantages of each. Again, stress the system used by your plant.

4. Problem Set

You may assign some or all of the problems in the problem set. It may also be helpful to include problems characteristic to your own plant.

As the students are working the problems, walk around the room and render help as needed.

5. <u>Quiz</u>

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 5 - Problem Set Solutions

5-1. Steam @ 540°F: $v = .47\ ft^3/lb$ $s_g = 1.40\ BTU/°R$

Steam @ 80°F: $v_f = .02\ ft^3/lb$ $s_f = .09\ BTU/°R$

$v_g = 633.3\ ft^3/lb$ $s_g = 2.04\ BTU/°R$

$s_{fg} = 1.94\ BTU/°R$

Find the percent of the exhaust that is still steam.

$$\% = \frac{(1.40\ BTU/°R) - (.09\ BTU/°R)}{1.94\ BTU/°R}$$

% = 67% steam

The volume of steam left from each pound that enters the turbine is $v_g \times 67\%$, or $424\ ft^3$.

The increase in volume is 424 ÷ .02, or 21,200 times

5-2. 29 in. Hg ≅ .5 psia

28 in. Hg ≅ 1 psia

saturation temperature @ .5 psia = 80°F

@ 1 psia = 102°F

$$E = 1 - \left(\frac{80 + 460}{540 + 460}\right) = 46\%$$

$$E = 1 - \left(\frac{102 + 460}{540 + 460}\right) = 43.8\%$$

5-3. Steam @ 540°F: $s_g = 1.40\ BTU/°R$ $h_g = 1194\ BTU/lb$

Steam @ 212°F: $s_f = .31\ BTU/°R$ $h_f = 180\ BTU/lb$

$s_g = 1.75\ BTU/°R$ $h_g = 1150\ BTU/lb$

$s_{fg} = 1.44\ BTU/°R$ $h_{fg} = 970\ BTU/lb$

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Steam at 80°F: s_f = .09 BTU/°R h_f = 48 BTU/lb

s_g = 2.04 BTU/°R h_g = 1096 BTU/lb

s_{fg} = 1.94 BTU/°R h_{fg} = 1048 BTU/lb

% steam @ 212°F: s_g @ 540°F = 1.4[illegible]

$-s_f$ @ 212°F = .3[illegible]

1.0[illegible]

s_{fg} @ 212°F = 1.44, so % = 76%

h of steam/water @ 212°F: (.76 x h_{fg}) + h_f

(.76 x 9[illegible]) + 180 = 917 BTU/lb

change in enthalpy between 540°F and 212°F:

1194 - 917 = 277 BTU/lb

% steam @ 80°F s_g @ 540°F = 1.4[illegible]

$-s_f$ @ 80°F = .09

1.3[illegible]

s_{fg} @ 80°F = 1.94, so % = 68%

h of steam/water @ 80°F: (.68 x h_{fg}) + h_f

(.68 x 104[illegible]) + 48 = 761 BTU/lb

change in enthalpy between 212°F and 80°F:

917 - 761 = 156 BTU/lb

5-4. No. If it were operated at a vacuum, the temperature would be less than even 75°F and it would be almost impossible to reject the latent heat of vaporization to the atmosphere except in cold weather.

K3 6590

1085 0078

Unit 5 - Condenser

Quiz

Name: ______________________ Date: ______________

Score: ______________

1. Describe the changes to cycle temperatures and efficiency as the condenser becomes fouled. (15)

2. Define condensate depression. (10)

3. How does a reheating hotwell actually reheat the condensate? (15)

PLANT PERFORMANCE

E. Condenser (continued)

4. Operation of a steam plant without the installed regenerative feedwater heaters will adversely affect the cycle efficiency in two ways. Describe these two ways. (20)

5. Describe how air flow is created in a natural draft cooling tower. (15)

5. Condenser (continued)

6. Why are feedwater heater drains cascaded? (15)

7. What causes condenser fouling? (10)

Unit 5 - Quiz Solutions

1. The condenser temperature increases and the cycle efficiency decreases.

2. Condensate depression is cooling of the condensate below its saturation temperature.

3. Steam lanes direct steam down to the hotwell area. There the condensate drips from the tubes through the steam and into the hotwell. The condensate is reheated as it drips through the steam.

4. a. The average temperature at which heat is added to the cycle will be decreased.
   b. The turbine will no longer be operating at designed steam flows and pressures.

5. Air is heated by hot cooling water in the base of the tower. The heated air is less dense, so it rises up in the tower. The shape of the tower is designed to act like a chimney and give the air additional velocity.

6. To utilize the heat in the high temperature drains by heating feed-water at lower temperatures.

7. A buildup of mud, chemicals, and growth of algae causes condenser fouling.

6

INSTRUCTOR'S GUIDE

Unit 6 - Pumps and Fluid Flow

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of the principles involved in the operation of hydraulic systems, including the characteristics of positive displacement pumps, jet pumps, and centrifugal pumps, and the concept of net positive suction head. Specific objectives are given in the text for each segment.

2. Material Required

   a. Text - Unit 6 - Pumps and Fluid Flow
   b. Videotape - Unit 6 - Pumps and Fluid Flow
   c. Steam Tables booklet
   d. Problem set solutions (must be reproduced from the Instructor's Guide)
   e. Quizzes (must be reproduced from the Instructor's Guide)
   f. Viewgraphs:

(1)	6.1-1	"T-S Diagram of the Plant Cycle"
(2)	6.1-2	"Closeup of the Pumping Process"
(3)	6.1-3	"Plot of Pressure Head vs. Flow"
(4)	6.2-1	"Positive Displacement Pump Components"
(5)	6.2-2	"Pump Laws"
(6)	6.3-1	"Jet Pump Components"
(7)	6.3-2	"Jet Pump Principles"
(8)	6.4-1	"Radial Flow Pump"
(9)	6.4-2	"Axial Flow Pump"
(10)	6.4-3	"Mixed Flow Pump"
(11)	6.4-4	"Pressure vs. Flow Graph for Centrifugal Pumps"
(12)	6.5-1	"NPSH Calculation"

3. Unit 6 Presentation

a. Tell the students the scope of the unit of instruction.

b. Remind the students that a glossary of new terms is included in their text.

c. Remind the students to refer to the Steam Tables booklet for values needed in plant calculations.

d. Explain to the students the sequence of instruction you plan to use.

Segment 1 - Hydraulic Systems

Key Points:

(1) Use Viewgraph 6.1-1 to briefly review the plant cycle and to show where the pump fits into the cycle.

(2) Use Viewgraph 6.1-2 to discuss in general terms how the pump performs work and the effects of inefficiencies on this work. Use the energy equation to discuss the energy changes that occur during the pumping process.

(3) Make sure that the students understand the difference between laminar flow and turbulent flow and the effects of friction losses and shock losses on pump efficiency. Introduce the general concept of a Reynolds number.

(4) Use Viewgraph 6.1-3 to illustrate the relationship between pressure head and flow. Point out how the system response changes if the system constant is changed.

Segment 2 - Positive Displacement Pumps

Key Points:

(1) Use Viewgraph 6.2-1 to discuss the operation of a positive displacement pump in terms of what each component does and how this type of pump moves water.

(2) Use Viewgraph 6.2-2 to discuss the pump laws. Show on the graph how flow, pressure, and power vary with pump speed.

(3) Make sure that the students understand why the discharge valve should be open when a positive displacement pump is to be started. Mention the function of safety relief valves.

Segment 3 - Eductors and Jet Pumps

Key Points:

(1) Use Viewgraph 6.3-1 to discuss the operation of a jet pump in terms of what each component does and how this type of pump moves water.

(2) Use Viewgraph 6.3-1 to discuss the changes in pressure that occur as water moves through a jet pump.

(3) This segment must be stressed for boiling water reactors. You may want to expand on the concepts presented in this segment or relate them to your particular applications.

Segment 4 - Centrifugal Pumps

Key Points:

(1) Use Viewgraph 6.4-1 to discuss the operation of a radial flow pump in terms of what each component does and how this type of pump moves water. Make sure that the students understand the concept of centrifugal force.

(2) Use Viewgraph 6.4-2 to discuss the operation of an axial flow pump in terms of what each component does and how this type of pump moves water.

(3) Use Viewgraph 6.4-3 to discuss how a mixed flow pump combines features of the radial flow pump and the axial flow pump.

(4) Make sure that the students understand why a radial flow pump is started with the discharge valve closed, while a positive displacement pump is started with the discharge valve open.

(5) Use Viewgraph 6.4-4 to illustrate the relationships of pressure, flow, and speed for centrifugal pumps. Show how the system curve on the graph identifies the operating point of the system. Make sure that the students are aware that the pump laws apply to radial pumps.

Segment 5 - Net Positive Suction Head

Key Points:

(1) Use Viewgraph 6.5-1 to go through a simple NPSH calculation. Make sure that the students understand what NPSH is and why it is important.

(2) Discuss the causes of pump cavitation and the problems that it can cause in the plant.

(3) Make sure that the students understand why a series of pumps is used to gradually increase water pressure.

4. Problem Set

You may assign any or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. As the students are working problems, walk around the room and render help as needed.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 6 - Problem Set Solutions

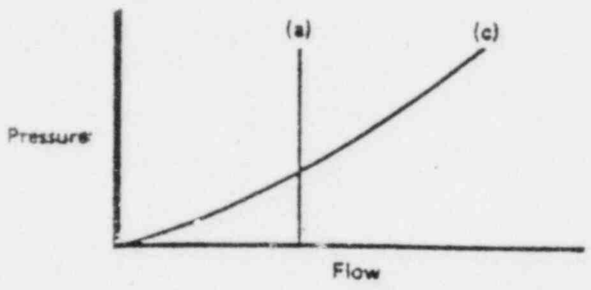
6-1. Total pressure developed:

psia discharge	(200 psig) + 14.7
- psia suction	-(30" - 28") x 1/2
total developed head	213.7 psi developed

Given: 1 ft of water = .43 psi

$$\text{feet of water} = \frac{213.7 \text{ psi}}{.43 \frac{\text{psi}}{\text{ft}}} = 497 \text{ feet of water}$$

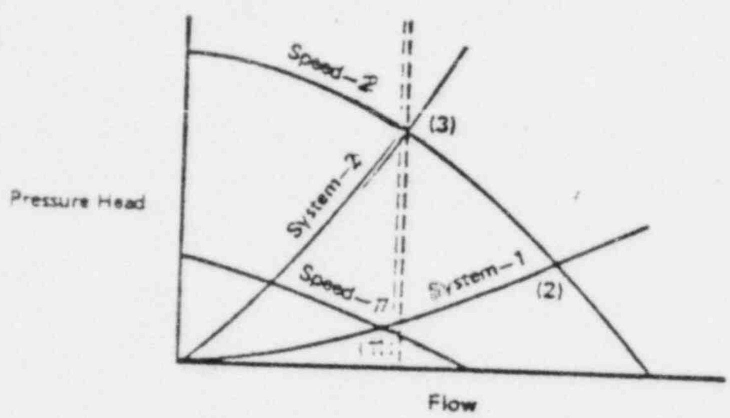
6-2.



b. The discharge is constant, no matter what the pressure, if there is no speed change or leakage.

6-3. Flow work is provided by the driving nozzle, which converts pressure to velocity (kinetic energy), and thus reduces the pressure of the driving flow. The reduced pressure causes the suction water to flow, and the driving water transfers some of its kinetic energy to the suction water. The kinetic energy of the combined flow is converted back to pressure by the diffuser.

6.4



The plant is originally operating at point (1). When the speed of the pump is doubled, pressure and flow are increased to point (2), and the level starts to increase. The flow control valves start to close, thereby changing the system characteristics until operation is at point (3), with an increased pressure, but the same flow.

6-5. Saturation pressure @ 500°F = 680 psia

NPSH = suction pressure − saturation pressure

NPSH = 1000 psia − 680 psia

NPSH = 320 psia

Unit 6 - Pumps and Fluid Flow

Quiz

Name: ______________________ Date: ______________

Score: ______________

1. Basically, how does a positive displacement pump perform work as it pumps water? (15)

2. The suction pressure of a pump is 2,100 psig and the discharge pressure is 2,400 psig.
   a. Calculate the "total developed head." (10)
   b. What would the total developed head be if the speed of the pump were doubled? (15)

3. A centrifugal radial pump is controlled by throttling on the discharge valve.

a. Can a positive displacement pump be controlled this way? Explain. (15)

b. Would there be any possible problems if flow were controlled by the suction valve? Explain. (15)

c. Compare the pump power requirements for a positive displacement pump and a radial flow centrifugal pump as the discharge valves are shut. (20)

4. Define "cavitation." (10)

Unit 6 - Quiz Solutions

1. A part of the pump actually pushes the water out of the pump against the discharge pressure.

2. a. 2,400 psig
   -2,100 psig
   300 psi

   b. Heat α speed^2
   Speed is 2 x $\therefore$ heat is 4 x
   4 (300) = 1200 psi

3. a. No. Excessive pressure may be created and the pump damaged.
   b. Yes. Possible to have cavitation.
   c. Power to the positive displacement pump would increase, while the other would decrease.

4. The process by which local areas on a pump impeller drop below saturation pressure and bubbles form and then collapse.

7

INSTRUCTOR'S GUIDE

Unit 7 - Steam Plant Calculations

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of how to calculate steam cycle efficiency by temperature and heat balance methods, how to improve cycle efficiency, and how to avoid wasting heat. Specific objectives are given in the text for each segment.

2. Material Required

   a. Text - Unit 7 - Steam Plant Calculations
   b. Videotape - Unit 7 - Steam Plant Calculations
   c. Steam Tables booklet
   d. Problem set solutions (must be reproduced from the Instructor's Guide)
   e. Quizzes (must be reproduced from the Instructor's Guide)
   f. Viewgraphs: none

3. Unit 7 - Presentation

   a. Tell the students the scope of the unit of instruction.
   b. Remind the students that a glossary of new terms is included in the text.
   c. Explain to the students the sequence of instruction you plan to use.

Segment I - Steam Cycle Efficiency

Key Points:

(1) Review the calculation of efficiency with the equation $E = 1 - \frac{T_{out}}{T_{in}}$. Make sure that the students understand how T_{out} and T_{in} are obtained.

(2) Make sure that the students understand why a plant cannot be 100% efficient and why the actual efficiency of a plant is always less than its optimum efficiency.

(3) Work through a sample heat balance with the students using the equation $E = \frac{\text{work out}}{\text{heat in}}$. Emphasize the difference in terms between this equation and the temperature equation, but show how the results are almost the same.

(4) Give examples to show how refinements such as feedwater heating can increase cycle efficiency.

Segment 2 - Heat Balances

Key Points:

(1) Show the students samples of computer heat balance printouts that are used in your plant. Point out the various factors that are used in heat balance calculations.

(2) Take the students through a reactor power heat balance step by step, pointing out where the computer obtains the data that is needed for calculations.

(3) Make sure that the students understand the terms and units that appear on the computer printout. These should include megawatts thermal, generator gross megawatts, unit net megawatts, and net heat rate.

Segment 3 - Improving Cycle Efficiencies

Note: This segment includes operating tips to improve plant efficiency. Be sure to explain to the students which tips are applicable to your plant and why some cannot be used.

Key Points:

(1) Emphasize the central point of this segment - that the best way to improve cycle efficiency is to operate the plant the way it was designed to run.

(2) Show the class a sample of a heat balance provided by the manufacturer of your plant. Emphasize that plant components should usually be operated at the levels suggested.

(3) Review the causes of condensate depression and poor condenser vacuum. Point out specific steps that an operator in your plant can take to reduce or eliminate problems in these areas.

(4) Use the water level in the feedwater drain system as an example of how an operator should be alert to changes in plant systems and how his actions can have an impact on plant efficiency.

Segment 4 - Reducing Heat Waste

Key Points:

(1) Make sure that the students understand the importance of reducing losses of heat, steam, and water. Emphasize that these losses may create hazards in the plant, may necessitate additional maintenance, and may increase operating costs.

(2) Review the operation of steam traps and stress the importance of checking steam traps frequently for proper operation.

(3) Discuss the use of lagging in your plant for systems where heat is to be kept in and systems where heat is to be kept out.

4. Problem Set

You may assign any or all of the problems in the problem set. It may also be helpful to introduce problems characteristic to your own plant. As the students are working the problems, walk around the room and render help as needed.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 7 - Problem Set Solutions

7-1. The plant that operates between 540°F and 80°F (plant b) would need a larger condensate cooling system, because it is less efficient, and it will have to reject more heat to provide 1000 Mw.

7-2. Yes. The plant was apparently designed to run at maximum efficiency with a cooling water temperature of 50°F.

7-3. Yes. The plant is designed for 100% power, and running it at any other level will adversely affect efficiency.

Unit 7 - Steam Plant Calculations

Quiz

Name: ______________________ Date: ______________________

Score: ____________________

1. Give the basic formula for efficiency used in calculating a heat balance. (20)

2. Why must calorimetrics (heat balance for reactor power) be done if nuclear instruments give a direct readout of power? (20)

3. What is the approximate efficiency of a power plant? (20)

PLANT PERFORMANCE

7. Steam Plant Calculations (continued)

4. List three causes of poor condenser vacuum. (20)

a. ______________________

b. ______________________

c. ______________________

5. How do steam traps contribute to plant safety? (20)

Unit 7 - Quiz Solutions

1. $E = \frac{\text{useful work out}}{\text{required heat in}}$

2. Nuclear instruments tend to drift, so calorimetrics are necessary for accurate power levels.

3. 10,000 to 10,500 BTU/kw hr

   or

   30% to 35%

4. (Answers may be in any order.)
   a. Low cooling water flow
   b. High cooling water temperature
   c. Condenser fouling
      Air leaking
      Air binding

5. By draining water from the piping, they keep water out of the turbine.

8

INSTRUCTOR'S GUIDE

Unit 8 - Reactor Thermal and Hydraulic Performance

1. Objectives

At the conclusion of this unit, the students should have a very general understanding of the basic objectives and considerations involved in reactor thermal and hydraulic performance. The concepts presented in this unit are essential to the understanding of the specific details covered in the special sessions that follow.

2. Material Required

   a. Text - Unit 8 - Reactor Thermal and Hydraulic Performance
   b. Videotape - Unit 8 - Reactor Thermal and Hydraulic Performance
   c. Problem set solutions (must be reproduced from the Instructor's Guide)
   d. Quizzes (must be reproduced from the Instructor's Guide)
   e. Viewgraphs:
      (1) 8.1-1 "Fuel Arrangement Showing Centerline"
   f. "Thermal and Hydraulic Evaluation of the Reactor" section of the facility Final Safety Analysis Report.

3. Unit 8 - Presentation

   a. Tell the students the scope of the unit of instruction.
   b. Remind the students that a glossary of new terms is included in their text.
   c. Explain to the students the sequence of instruction you plan to use.

Segment 1 - Performance Objectives

Key Points:

(1) Remind the students that the material presented in this unit is very general and that they will be given more details later.

(2) Review with the students the methods of heat generation and removal in the core. Relate these methods to the ways that damage might occur to the fuel and the clad.

(3) Use Viewgraph 8.1-1 to discuss peak centerline temperature and the importance of insuring that the fuel does not melt and the clad is not damaged. Discuss the causes of excessive heat in the fuel.

(4) Give the students the following problem and provide them with the necessary plant-specific information.

Calculate your plant's peak local power from the design thermal power, the design peaking factor, and core construction.

Answer: peak power = $\frac{\text{(thermal power in Mw)} \times 1000}{\text{(no. of rods)} \times \text{(length of rods)}} \times \text{P.F.}$

How does the peak local power calculated compare with the limitations as given by your Technical Specifications?

Answer: They should be the same.

Segment 2 - Departure from Nucleate Boiling

Key Points:

(1) Review the explanation of film boiling given in Unit 3. Make sure that the students understand that this segment is concerned with additional ways that film boiling can occur.

(2) Discuss with the students the meaning and use of DNBR.

(3) Trace the flow of water and steam up past the fuel rods, making sure that the students understand the concepts of bubbly flow, slug flow, annular flow, and dryout.

(4) Briefly discuss the effects of a sudden pressure drop or an increase in the inlet temperature on DNB and/or dryout.

Segment 3 - Temperature and Pressure Limitations

Key Points:

(1) Discuss with the students the effects of sudden temperature changes in metals. Refer to the videotape demonstration.

(2) Discuss the concept of critical areas in terms of temperature changes and thermal stresses. Inform the students of where to find the maximum temperature change rate for their plant.

(3) Discuss the effects of pressure changes when metals are at low temperatures. Make sure that the students understand brittle failure, ductile behavior, and nil ductility transition temperature.

4. Problem Set

Due to the introductory nature of this material, only the problem in segment one of these notes is given. We recommend that at this point, each student be given a copy of the Reactor Thermal and Hydraulic Evaluation from the facility FSAR. Read through it and explain the material in terms of the material in this unit.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 8 - Quiz

1. Define DNBR. (15)

2. Why is a DNBR specified as larger than 1 used as a limit? (20)

3. Define dryout. (15)

PLANT PERFORMANCE

E. Reactor Thermal and Hydraulic Performance (continued)

4. Define "NDTT." (15)

5. List two undesirable effects of heating or cooling a large component rapidly.

a. ______________________________________ (10)

b. ______________________________________ (10)

6. What limits insure that the reactor vessel will not undergo brittle failure? (15)

Unit 8 - Quiz Solutions

1. DNBR = $\frac{\text{critical local heat flux}}{\text{actual local heat flux}}$

2. As long as the DNBR is larger than one, the actual heat flux will not cause film boiling.

3. Dry out is process that may occur during accident conditions. The heat flux into the water may be sufficient to convert all the water to steam so that only steam is available to accept the heat from the last length of the heat transfer surface.

4. "NDTT" stands for nil-ductility transition temperature and is the temperature below which a metal exhibits brittle behavior.

5. a. Immediate failure
   b. Metal fatigue

6. Limiting the pressure while the vessel is below the NDTT will insure that there is no brittle failure.

9

PLANT PERFORMANCE

INTRODUCTION TO THE SPECIAL SESSIONS

Units 9 and 10 of this module are special sessions that introduce a certain amount of plant-specific material. Because the NET program has been designed to fit into an overall training program prior to systems training, the students are not expected to know a great deal about the plant at this point in their training.

The segments on the nuclear fuel systems and reactor components are intended to give an overview of these systems so that the students can understand the bases of the limits that are discussed later. These segments also introduce some of the material that the students will have to learn in depth during their systems training.

The segments on heat balances, peaking factors, and thermal limits are designed to cover topics that are sometimes not heavily stressed in operator training. It is important that operators understand the thermal limits and their bases, so these sections should be stressed.

Problem sets have not been included in these special sessions. Instead, it is recommended that the instructor furnish related plant-specific material for class exercises. One suggested format is to provide the students with plant-related material the parallels the text. After they have completed a segment of text, they can then look over the corresponding plant-specific material. The students will eventually have to understand and be familiar with the plant-specific material as it is written for the plant, but it is difficult for a student with little background in nuclear power to understand material extracted directly from FSAR's, Technical Specifications, and Operating Procedures. The text can provide the basis for understanding the plant-related material.

The following are some specific suggestions for material and methods that can be used with the special sessions.

1. Obtain the following illustrations from your FSAR or systems descriptions.
   - Fuel assembly
   - Reactor vessel and internals
   - Reactor coolant system flow path

   Use the illustrations to show the specific arrangements and nomenclature that are specific for your plant. Make sure that the students understand the coolant flow paths.

2. Obtain a blank reactor heat balance form from your plant operating procedures and a completed form from the station logs. Give each student a copy of the blank form, and work through an example with information from the completed form.

3. Obtain information on your plant's thermal and hydraulic design features from your FSAR. The description of these features typically centers on a discussion of various peaking factors. Distribute a copy of the information to each student and make sure that everyone understands the definitions and the bases of the factors.

4. Obtain information on your plant's specific thermal limits from your Technical Specifications. Give each student a copy of the relevant limits and their bases as stated in the Technical Specifications. Include limits on peaking factors, heatups and cooldowns, flux distribution, and power to flow. Also provide the students with copies of the log sheets used to verify the limiting conditions for operation. The students must understand each limit and its basis, so be sure that any additional limits are fully defined. Information in the Technical Specifications and the FSAR is typically

unexplained and undefined, so the students should not be directed to this type of material until after they have read the text. Be sure to go through the plant-specific material point by point with the students to insure that every point is understood.

5. The unit computer is often a source of printed data relating to the heat balance and thermal limits. Provide each student with a copy of the computer printout, preferably one taken at a high power level. The students should be able to define each term on the printout that relates to thermal limits. This activity also provides a convenient means of introducing all of the items on the printout.

INSTRUCTOR'S GUIDE

Unit 9 - Reactor Fuel and Core Design (BWR)

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of how reactor fuel is arranged in the core, the purposes of the reactor vessel and the reactor internals, the purpose of core orificing, the operation of the Reactor Recirculation System, and the use of a reactor heat balance.

2. Material Required

   a. Text - Unit 9 - Reactor Fuel and Core Design (BWR)
   b. Quizzes (must be reproduced from the Instructor's Guide)
   c. Viewgraphs:

(1)	9.1-1	"Fuel Rod"
(2)	9.1-2	"Fuel Assembly"
(3)	9.2-1	"Change in NDTT with Core Life"
(4)	9.2-2	"Reactor Vessel with Internals"
(5)	9.2-3	"Steam Separators"
(6)	9.2-4	"Peripheral Fuel Support Piece"
(7)	9.2-5	"Four-Lobed Fuel Support Piece"
(8)	9.4-1	"Reactor Recirculation System"
(9)	9.4-2	"BWR Vessel Arrangement for Jet Pump Recirculation System:
(10)	9.4-3	"Jet Pumps"

3. Unit 9 Presentation

   a. Tell the students the scope of the unit of instruction.
   b. Remind the students that a glossary of new terms is included in the text.

c. Explain to the students the sequence of instruction you plan to use. There is no videotape for this unit. It is suggested that the students read one text segment at a time, answer the questions at the end of that segment, and then participate in a class discussion on the material.

Segment 1 - The Nuclear Fuel System

Key Points:

(1) Use Viewgraph 9.1-1 to point out the components of a fuel rod. Discuss the composition and purpose of the fuel and the clad.

(2) Discuss the particular fuel rod arrangement used in your plant and give the students any plant-specific data that they might need in this area.

(3) Use Viewgraph 9.1-2 to discuss the composition of an individual fuel assembly.

Segment 2 - Reactor Vessel and Internals

Key Points:

(1) Use Viewgraph 9.2-1 to review the change in NDTT over core life that was discussed in Unit 8. Also review the importance of closely observing plant heatup and cooldown rates.

(2) Use Viewgraph 9.2-2 to show the arrangement of the reactor internals and to point out specific components.

(3) Use Viewgraph 9.2-3 to illustrate the path of the steam/water mixture through the steam separators.

(4) Use Viewgraphs 9.2-4 and 9.2-5 to show the two types of fuel support pieces. Make sure that the students understand the similarities and differences between the two types.

Segment 3 - Thermal and Hydraulic Considerations

Key Points:

(1) Discuss the concept of critical power in relation to its effect on heat transfer. Make sure that the students understand that each value of critical power depends on a specific set of operating conditions.

(2) Relate the discussion of inlet orificing to what the students have learned about nozzles. Make sure that the students understand how nozzles can be used to change the velocity of water.

(3) Provide the students with specific information on the normal operating conditions for your plant and review it with them.

Segment 4 - Reactor Recirculation System

Key Points:

(1) Use Viewgraph 9.4-1 to show the general layout of a typical Reactor Recirculation System. Make sure that the students know which components apply to your plant.

(2) Use Viewgraph 9.4-2 to discuss the positions of the jet pumps in the reactor vessel and their connections as part of the Reactor Recirculation System.

(3) Use Viewgraph 9.4-3 to discuss jet pump operation. Trace the flow of water through the jet pump and point out where energy changes occur.

(4) Discuss the method used to control core flow in your plant - variable speed pump or variable position valve.

Segment 5 - Reactor Heat Balance

Key Points:

(1) If possible, work through a reactor heat balance with the students, using actual data obtained in your plant.

(2) Point out which factors in the reactor heat balance equation are the most significant and which can be treated as constants.

(3) Go through the three simplified methods for determining approximate core power. Emphasize any that are used in your plant.

4. Problem Set

A problem set is not included with this unit. It is recommended that you provide the students with applicable plant-specific training material and information on your plant's Reactor Recirculation System. Have them read through the material and then discuss it with them.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not review the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 9 - Reactor Fuel and Core Design (BWR)

Quiz

Name: ______________________ Date: ________________

Score: ________________

1. List three inside components of a fuel rod.
   a. ____________________ (5)
   b. ____________________ (5)
   c. ____________________ (5)

2. List two functions of the fuel channel.
   a. ____________________ (10)
   b. ____________________ (10)

3. a. What is the reactor vessel made of? (10)

   b. What is the reactor vessel lined with? (5)

4. State two functions of core orificing.
   a. ____________________ (10)
   b. ____________________ (10)

5. Describe the flow control method used in your plant's Reactor Recirculation System. (10)

6. Suppose that a significant amount of moisture were being carried over from the reactor with the steam. Would a reactor heat balance obtain a result different from true power? Why? (20)

Unit 9 - Quiz Solutions

1. (These answers may be in any order.)
   a. Fuel pellets
   b. Plenum spring
   c. Helium (in the plenum)

2. (Any two of the following)
   a. Directs coolant flow
   b. Guides control rods
   c. Protects the fuel assembly during handling

3. a. Low alloy steel
   b. Stainless steel

4. (These answers may be in any order.)
   a. Reduce flow cutback as power is increased.
   b. Distribute the flow so that the highest flow is directed to the fuel assemblies with the highest power production.

5. Either a or b is acceptable, depending upon plant arrangement.
   a. Variable speed pumps are used.
   b. Two-speed pumps with variable throttle valves are used.

6. Yes. A heat balance assumes that the water is turned into steam. If part is not, the heat balance will not reflect true reactor power. In this case, it would be lower than true power.

INSTRUCTOR'S GUIDE

Unit 9 - Reactor Fuel and Core Design (PWR)

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of how reactor fuel is arranged in the core, the purposes of the reactor vessel and internals, the operation of the Reactor Coolant System, and the use of a reactor heat balance.

2. Material Required

   a. Text - Unit 9 - Reactor Fuel and Core Design (PWR)
   b. Quizzes (must be reproduced from Instructor's Guide)
   c. Viewgraphs:

(1)	9.1-1	"Fuel Assembly"
(2)	9.1-2	"Rod Control Cluster Assembly"
(3)	9.2-1	"Reactor Vessel and Internals"
(4)	9.2-2	"Reactor Vessel Flow Path"
(5)	9.3-1	"Reactor Coolant Loop"
(6)	9.3-2	"Steam Generator - Type A"
(7)	9.3-3	"Steam Generator - Type B"
(8)	9.3-4	"Reactor Coolant Pump Schematic"
(9)	9.4-1	"Reactor Heat Balance"

3. Unit 9 Presentation

   a. Tell the students the scope of the unit of instruction.
   b. Remind the students that a glossary of new terms is included in the text.
   c. Explain to the students the sequence of instruction you plan to use. There is no videotape for this unit. It is suggested that the students read one text segment at a time, answer the questions at the end of that segment, and then participate in a class discussion on the material.

Segment 1 - The Nuclear Fuel System

Key Points:

(1) Discuss the composition of the fuel and clad, and point out the importance of the spring and the helium.

(2) Use Viewgraph 9.1-1 to demonstrate a typical fuel assembly. Discuss the particular fuel rod arrangement used in your plant and give the students plant-specific data that they might need.

(3) Use Viewgraph 9.1-2 to demonstrate a rod control cluster assembly. Discuss the construction and composition of the type of rod used in your plant.

Segment 2 - Reactor Vessel and Internals

Key Points:

(1) Use Viewgraph 9.2-1 to familiarize the students with the reactor components and their functions. The objective here is only to familiarize the student: in-depth knowledge of components will be obtained in systems training. If your reactor vessel and internals are significantly different from the typical example, provide the students with a handout of the plant-specific information.

(2) Use Viewgraph 9.2-2 to demonstrate the flow of coolant through the reactor vessel and the core.

Segment 3 - Reactor Coolant System

Key Points:

(1) Use Viewgraph 9.3-1 to demonstrate a typical reactor coolant loop. Discuss the specific arrangement of loops, steam generators, and pumps used in your plant.

(2) Use Viewgraph 9.3-2 or 9.3-3, if applicable, to illustrate your steam generator. (Both of these types are recirculating

steam generators. Plants with once-through steam generators should refer to Appendix C on once-through steam generators.)

(3) Use Viewgraph 9.3-4 to illustrate a typical reactor coolant pump. Discuss the importance of seal injection.

Segment 4 - Heat Balance Calculations

Key Points:

(1) Viewgraph 9.4-1 has been provided to illustrate a typical heat balance form. It is recommended, however, that each student be given a copy of the form used by your plant. A calculation can be performed using data from the station logs.

(2) Discuss any particular information, such as methods used to find approximate power, that are plant-specific.

(3) Emphasize the importance of the correct performance of heat balances.

4. Problem Set

A problem set is not included with this unit. It is recommended that you provide the students with applicable plant-specific training material. Have them read through the material and then discuss it with them.

5. Quiz

A short review may be conducted before you give the quiz. The review, however, should not preview the quiz questions. Simply cover key points and ask the students if there are any questions.

Unit 9 - Reactor Fuel and Core Design (PWR)

Quiz

Name: ______________________ Date: ______________

Score: ______________

1. List three inside components of a fuel rod.
   a. ______________________ (5)
   b. ______________________ (5)
   c. ______________________ (5)

2. State two functions of the thimbles in a fuel assembly.
   a. ______________________ (10)
   b. ______________________ (10)

3. What is the function of the diffuser plate in the core? (15)

4. Is boiling in a PWR core expected? If so, what are the limitations on the amount? (20)

5. How is the leakage of reactor coolant along the reactor coolant pump shaft eliminated? (10)

6. Suppose that a significant amount of moisture were being carried over out of the steam generators. Would a reactor heat balance obtain a result different from true power? Why? (20)

Unit 9 – Quiz Solutions

1. (Answers may be in any order.)

   a. Fuel pellets

   b. Spring

   c. Helium gas

2. (Any two of the following)

   a. Structural support of the fuel assembly

   b. Guide for control rods

   c. House neutron sources

   d. House burnable poison

3. The diffuser plate distributes flow to the core so that the high power areas have high flow.

4. Yes. There is some boiling in the hot channels, but it must be limited so that there will be no steam in the upper plenum.

5. Leakage is eliminated by injecting high-pressure cool water into the pump seal.

6. Yes. The reactor heat balance assumes that all the water is converted to steam. If it is not, the heat balance will be off. In this case, the heat balance would indicate a power level higher than true power.

PLANT PERFORMANCE

EXAM 1

UNITS 1 - 4

NAME ______________________ DATE ______________

SCORE ______________

1. State the function of each of the following components in the steam-water cycle. (5)

   a. Steam Boiler

   b. Pump

   c. Turbine

   d. Condenser

2. Briefly explain the following pressure scales and state the units used with each. (5)

   a. Absolute pressure scale

b. Gauge pressure scale

c. Mercury vacuum scale

d. Mercury absolute scale

3. Briefly define what heat is and state its units. (5)

4. What is the relation between heat and temperature? (5)

5. What is enthalpy a mesure of? (5)

6. Find the following values in your steam tables: (5)

   a. Pressure of 300°F saturated steam

   b. The energy required to boil one pound of water at 835 psig.

7. State the first law of thermodynamics. (5)

8. Briefly define the following forms of energy. (5)

   a. Potential energy

   b. Kinetic energy

   c. Internal energy

   d. Flow work

9. Water is flowing through a system at 30 gallons per minutes (gpm). It has a certain kinetic energy. How will its kinetic energy change if the flow is increased to 60 gpm? (5)

10. State the two parts of the second law of thermodynamics. (5)

11. A refrigeration cycle moves heat from a cold area to a warm area. Does this violate the second law of thermodynamics? Why? (5)

12. List and define the three basic mechanisms of heat transfer. (5)

13. List a mathematical relationship between: (5)

    a. Heat flow and temperature difference

    b. Heat flow and area

14. What is required for nucleate boiling? (5)

15. Define critical heat flux (CHF). (5)

16. What is the DNB point? (5)

17. Define "shrink" and "swell." (5)

K3 664

1073 013

18. What is the difference between impulse and reaction turbines? (5)

19. Why are multi-stage turbines used for the main power producing turbine in the plant? (5)

20. Why would you ever want to "break vacuum" while the turbine is still rotating? (5)

PLANT PERFROMANCE

EXAM 1 - SOLUTIONS

UNITS 1 - 4

1. a. Convert water to steam by taking heat into the cycle.
   b. Pump water from a low pressure to a high pressure. This puts work into the cycle.
   c. Convert heat energy in the steam into useful work. Work leaves the cycle.
   d. Convert the steam coming from the turbine into water and remove heat from the cycle.

2. a. Starts at absolute 0 pressure, with 14.7 at atmospheric pressure. Units are psia.
   b. Starts with 0 at atmospheric pressure. Absolute 0 equals -14.7 on this scale. The units are psig.
   c. Starts at atmospheric and increases as pressure decreases. Absolute 0 equals 30" on this scale. The units are "Hg.
   d. This is the inverse of the preceding scale. The units are "Hg abs.

3. Heat is the transfer of internal energy and its units are BTU's.

4. One effect heat has is to change the temperature of a substance by increasing the molecular vibration. This effect is set for any particular substance and is called the "specific heat" of a substance.

5. It is a measure of energy stored in a substance.

6. 67.000 <u>psia</u>

   h_{fg} @ (835 psig + 14.7)

   $\approx h_{fg}$ @ 850 psia

   $\approx$ 679.5 BTU/lb

7. Energy cannot be created or destroyed, but remains constant.

8. a. The energy of position.
   b. The energy of motion.
   c. Energy of molecular motion and molecular bonds.
   d. Energy of a substance due to pressure multiplied by its volume.

9. It will go up by a factor of four.

10. 1. Heat naturally flows from a high temperature to a low temperature.
    2. Not all heat can be turned into work; depends upon the temperatures in the cycle.

11. No. Because work is put into the cycle to make it happen.

12. a. Conduction - heat transfer through solid material by vibration of molecules.
    b. Convection - heat transfer by bulk movement of a fluid.
    c. Radiation - heat transfer by direct emission.

13. a. $\dot{Q} \propto \Delta T$

    or

    $\dot{Q} = K \Delta T$

    b. $\dot{Q} \propto A \Delta T$

    or

    $\dot{Q} = K A \Delta T$

14. Nucleating points and a surface temperature $8^{\circ} - 10^{\circ}$ higher than saturation temperature.

15. The amount of heat flux required to cause a transition to film boiling.

16. It is the point at which a departure from nucleate boiling occurs. It occurs at the critical heat flux.

17. These are processes that happen in the steam boiler. Shrink occurs during a pressure increase when the apparent level drops because the steam bubbles in the water collapse. Swell occurs during a pressure decrease when the apparent level increases because the steam bubbles expand and new bubbles form.

18. An impulse turbine converts the kinetic energy of the steam into work by changing the direction of the steam in the moving blades. There is a pressure drop across the nozzles and not across the moving blades. In a reaction turbine, on the other hand, work is obtained by allowing the steam to expand across the moving blades and create a reaction force. There is a pressure drop across both the moving blades and the stationary blades.

19. Multi-stages turbines are used to get the maximum amount of work out of the steam.

20. To rapidly stop the turbine in an emergency.

INSTRUCTOR'S GUIDE

Unit 10 - BWR Performance

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of the information shown on a power-flow operating map, the bases for various operating limits, the role of thermal limits in protecting the integrity of the fuel, the use of peaking factors in power distribution calculations, the methods used to assess the probability of film boiling, and the steps that have been taken to minimize specific types of fuel failures.

2. Material Required

   a. Text - BWR Performance

   b. Quizzes (must be developed and reproduced locally)

   c. Viewgraphs:

(1)	10.1-1	"Power-Flow Map for Constant Recirculation Pump Speed"
(2)	10.1-2	"Power-Flow Map - Flow Control Lines"
(3)	10.1-3	"Simplified Power-Flow Map"
(4)	10.1-4	"Power-Flow Map with Minimum Power Line and Rod Block Line"
(5)	10.1-5	"Power-Flow Map Normal Operating Conditions"
(6)	10.1-6	"BWR-5/6 Power-Flow Map"
(7)	10.2-1	"Steam Quality vs. Boiling Length"
(8)	10.2-2	"Steam Quality vs. Boiling Length: Operating Conditions"

3. Unit 10 Presentation

   a. Tell the students the scope of this unit of instruction.

   b. Remind the students that a glossary of new terms is included in the text.

c. Explain to the students the sequence of instruction you plan to use. There is no videotape for this unit. It is suggested that the students read one text segment at a time, answer the questions at the end of the segment, and then participate in a class discussion. The discussion should include related plant-specific material.

Segment 1 - Boiling Water Reactor Power-Flow Map

Key Points:

(1) Note that the illustrations used in this segment refer to a typical BWR plant. Provide the students with related plant-specific material and point out differences between the typical plant and your plant as each topic is covered.

(2) Use Viewgraph 10.1-1 to introduce the power-flow map. Review the meaning of each of the lines and discuss the ways in which power is controlled in your plant.

(3) Use Viewgraph 10.1-2 to discuss flow control lines. Make sure that the students understand the difference between this power-flow map and the one shown in Viewgraph 10.1-1.

(4) Use Viewgraph 10.1-3 to show how plant operations can be mapped. Discuss the considerations and procedures that your plant uses.

(5) Use Viewgraph 10.1-4 to discuss operating limits. Provide the students with specific information on your plant's operating limits.

(6) Use Viewgraph 10.1-5 to discuss normal operating conditions for a typical BWR plant. Obtain or develop a similar power-flow map that defines the normal operating conditions for your plant. Point out areas in which operation is restricted, and discuss the bases for these restrictions.

(7) Use Viewgraph 10.1-6 to discuss power-flow considerations for a BWR-5/6 plant, if applicable.

Segment 2 - Reactor Plant Thermal Limits

Key Points:

(1) Discuss the design limit for fuel failures in your plant. Include a review of your plant's fuel performance record and the potential effects of fuel failures.

(2) Review the three basic types of thermal limits. Discuss the bases of specific limits in your plant that protect the fuel under various conditions.

(3) Make sure that the students understand the meaning and purpose of each of the various peaking factors and heat generation rates. Discuss the ways in which power distribution calculations are made in your plant.

(4) Use Viewgraphs 10.2-1 and 10.2-2 to illustrate how the relationship between steam quality and boiling length can be used to assess the probability of film boiling. Discuss the use of this concept and others in setting thermal limits to prevent film boiling.

Segment 3 - Nuclear Fuel Performance

Key Points:

(1) Review the units of fuel burnup and make sure that the students understand the meanings of the terms.

(2) Discuss the mechanisms of fuel failure described in the text. Stress any that have caused problems in your plant.

(3) Discuss the steps that have been taken to minimize specific types of fuel failures. Point out any design features of your plant's fuel system or any of your plant's operating procedures that deal specifically with minimizing fuel failures.

4. Problem Set

A problem set is not included with this unit. You may wish to develop problems on plant-specific material and work through them with the students.

5. Quiz

A quiz is not included with this unit. You may wish to develop a quiz on plant-specific material and administer it to the students.

INSTRUCTOR'S GUIDE

Unit 10 – PWR Performance

1. Objectives

At the conclusion of this unit, the students should have a basic understanding of pressure-temperature limits, heatup and cooldown stresses, the purpose and use of thermal limits, PWR peaking factors, the methods used to decrease the probability of film boiling, and the steps that have been taken to minimize specific types of fuel failures.

2. Material Required

   a. Text – PWR Performance
   b. Quizzes (must be developed and reproduced locally)
   c. Viewgraphs:
      (1) 10.1-1 "The Shift of RT_{NDT} Due to Fast Neutrons"
      (2) 10.1-2 "Locations for Analyzing the Shift in RT_{NDT}"
      (3) 10.1-3 "Neutron Fluence vs. Time"
      (4) 10.1-4 "Tension and Compression"
      (5) 10.1-5 "Composite of Heatup and Pressure Stresses"
      (6) 10.1-6 "Composite of Cooldown and Pressure Stresses"
      (7) 10.1-7 "Typical PWR Heatup and Criticality Limits"
      (8) 10.1-8 "Typical PWR Cooldown Limits"
      (9) 10.2-1 "Heat Production vs. Core Position"
      (10) 10.2-2 "Total Enthalpy Rise vs. Core Position"
      (11) 10.2-3 "Critical Heat Flux vs. Core Position"
      (12) 10.2-4 "DNBR vs. Core Position"

3. Unit 10 Presentation

   a. Tell the students the scope of this unit of instruction.
   b. Remind the students that a glossary of new terms is included in the text.

c. Explain to the students the sequence of instruction you plan to use. There is no videotape for this unit. It is suggested that the students read one text segment at a time, answer the questions at the end of the segment, and then participate in a class discussion. The discussion should include related plant-specific material.

Segment 1 - Pressurized Water Reactor Operating Curves

Key Points:

(1) Note that the illustrations used in this segment refer to a typical PWR plant. Provide the students with related plant-specific material and point out differences between the typical plant and your plant as each topic is covered.

(2) Review the types of metal failure that were introduced in an earlier unit. Emphasize the role of temperature and the meaning of NDTT and RT_{NDT}.

(3) Use Viewgraph 10.1-1 to discuss the effect of fast neutrons on RT_{NDT}. Use Viewgraph 10.1-2 to show where this effect is analyzed (if such analyses apply to your plant), and use Viewgraph 10.1-3 to show the change in this effect with time.

(4) Use Viewgraph 10.1-4 to make sure that the students understand the meaning of tension and compression. Then use Viewgraphs 10.1-5 and 10.1-6 to discuss the effects of various types of stresses on the pressure vessel. Emphasize what occurs during heatup and cooldown.

(5) Use Viewgraphs 10.1-7 and 10.1-8 as a basis for introducing PWR heatup and cooldown curves. If possible, provide the students with actual curves for your plant and relate the general information in the text to specific data for your plant. Discuss what these curves mean to the operator.

(6) Discuss the specific thermal limits that apply to your plant's pressurizer.

Segment 2 - Reactor Plant Thermal Limits

Key Points:

(1) Discuss the design limit for fuel failures in your plant. Include a review of your plant's fuel performance record and the potential effects of fuel failures.

(2) Review the three basic types of thermal limits. Discuss the bases of specific limits in your plant that protect the fuel under various conditions.

(3) Make sure that the students understand the meaning and use of each of the peaking factors discussed in the text.

(4) Discuss the methods used in your plant to perform DNBR calculations. Include the use of hot channel factors, as applicable. Point out differences between the general information provided in the text and the specific material used in your plant.

(5) Use Viewgraphs 10.2-1 through 10.2-4 to illustrate how DNBR calculations can be graphed. If possible, provide or develop similar graphs using plant-specific data.

Segment 3 - Nuclear Fuel Performance

Key Points:

(1) Review the units of fuel burnup and make sure that the students understand the meanings of the terms.

(2) Discuss the mechanisms of fuel failure described in the text. Stress any that have caused problems in your plant.

(3) Discuss the steps that have been taken to minimize specific types of fuel failures. Point out any design features of

your plant's fuel system or any of your plant's operating procedures that deal specifically with minimizing fuel failures.

4. Problem Set

A problem set is not included with this unit. You may wish to develop problems on plant-specific material and work through them with the students.

5. Quiz

A quiz is not included with this unit. You may wish to develop a quiz on plant-specific material and administer it to the students.

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PLANT PERFORMANCE

EXAM - 2

UNITS 5 - 8

NAME ______________________ DATE ______________

SCORE ______________

1. What are the two functions of the condenser? (15)

2. Why does the condenser operate at a vacuum? (5)

3. Briefly describe how too much flow and not enough flow through the condenser may adversely affect plant efficiency. (10)

4. How does heating the feedwater with turbine bleed steam increase plant efficiency? (5)

5. List one side benefit derived from using a steam extraction system. (5)

6. Make a simple graph of how pressure loss (head loss) varies in a system as the flow increases. Label both axes and also state a proportionality that defines the graph. (10)

7. State the pump laws as simple proportionalities. (5)

8. Draw a simplified cross section of a jet pump (or eductor) and explain how it works. (5)

9. Make a simple graph of how pressure and flow vary with a centrifugal pump. Plot the variables at speed 1 and at some speed 2 that is twice speed 1. (10)

10. Explain briefly how a calorimetric (heat balance) is performed to find reactor power. (5)

11. Why are calorimetrics performed? (5)

12. Define the following terms as they are used in relation to the production of power in a nuclear plant. (5)

a. Megawatts, thermal

b. Net megawatts

c. Net heat rate

13. Name the plant component with which the operator can have the greatest effect on plant efficiency. (5)

14. There are two objectives to the thermal and hydraulic design to protect the fuel from damage. List the two objectives. (5)

15. Why is pressure in the reactor vessel limited when the temperature is low? (5)

16. Why are very rapid changes in plant temperature prohibited? (5)

17. While reading an analysis of a hypothetical accident, you find this statement: (5)

"There is then a rapid drop in reactor pressure and the DNBR drops to less than one."

What would you expect the consequences of this to be?

PLANT PERFORMANCE

EXAM 2 - SOLUTIONS

UNITS 5 - 8

1. To remove heat from the steam cycle and to conserve the water

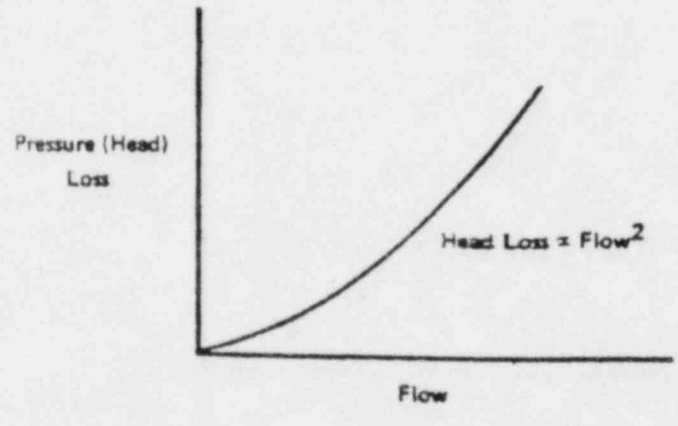
2. The temperature of the steam coming from the turbine is reduced by operating with the condenser at a vacuum. This increases plant efficiency.

3. Too much flow may create condensate depression, which would represent wasted heat. Too little flow would cause a decrease in vacuum, which, in itself, would cause a loss in efficiency.

4. It utilizes the latent heat in the steam to preheat the feedwater. This, in turn, increases the average temperature at which heat is added to the system.

5. Smaller low pressure turbines

6.



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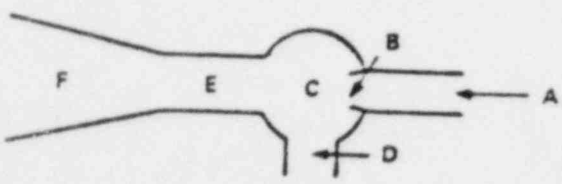
7. Flow α pump speed

Pressure α (pump speed)^2

Power α (pump speed)^3

8.



a. High pressure driving water enters the nozzle.

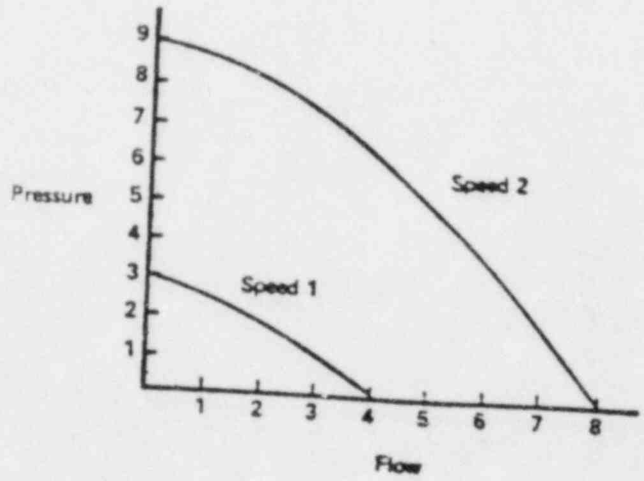
b. In the convergent nozzle, pressure head is changed to velocity head.

c. The low pressure area pulls water from the suction-D

e. The driving water and the suction water mix.

f. The velocity of the mixed driving water and suction water is converted to pressure head.

9.



10. The feedwater inlet enthalpy is subtracted from the steam outlet enthalpy. The difference is then multiplied by the feedwater flow rate.

11. To correct the accuracy of nuclear instrumentation

12. a. The heat energy that the reactor actually produces.
    b. The electrical power produced that is available to sell to customers
    c. The number of BTU's that the plant takes to make one KWHR of electricity

13. The condenser

14. (1) Limit fuel strain to less than 1%
    (2) Prevent the fuel from melting

15. To avoid brittle failure

16. To avoid excessive stresses that would be caused by extreme temperature differences. These would, in turn, cause metal fatigue or even damage.

17. Expect film boiling to occur and probable fuel damage