PRESSURIZED WATER REACTOR OPERATOR
GENERIC FUNDAMENTALS
TEST ITEM CATALOG

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The National Academy for Nuclear Training operates under the auspices of the Institute of Nuclear Power Operations (INPO). The Academy provides a framework for a unified, coordinated industry approach to achieving and maintaining effective training and qualification. It also promotes pride and professionalism of nuclear plant personnel. The Academy integrates the training efforts of all U.S. nuclear utilities, the activities of the National Nuclear Accrediting Board, and the training-related activities of INPO.

FOREWORD

This test item catalog is intended to serve as a resource for use in training and examining candidates for licensed operator positions. The catalog encompasses selected topics in the fundamental subject areas of components, reactor theory, and thermodynamics. Subject areas and their topics are identical to those used in the U.S. Nuclear Regulatory Commission's *Knowledge and Abilities Catalog for Nuclear Power Plant Operators: Pressurized Water Reactors*, NUREG-1122. For each topic, supporting learning objectives, questions, answers, references, and explanations (if appropriate) are presented. Many branches of the National Academy for Nuclear Training contributed to the development and review of this catalog's content.

This catalog supersedes the version that was published in November 1992. It incorporates additional and modified questions. The scope of this catalog is limited to selected generic knowledge and ability subjects. Within each subject, questions generic to all PWRs have been developed. In a few instances, questions specific to nuclear steam supply system vendors have been written in order to address certain topics adequately. Questions addressing plant-specific topics are not within the scope of this catalog. Additionally, the catalog does not represent all the knowledge that a licensed operator candidate needs. That knowledge must be acquired by completion of performance-based, systematic training. This catalog may be used as an aid in training by instructors and candidates and is the primary source document used to examine candidates on generic fundamentals topics.

Users of this catalog might identify needed revisions of its content. Appendix C contains a feedback form for use in submitting suggested revisions.

Questions and comments concerning this catalog are welcomed and should be addressed to the manager, Training Activities (404) 644-8632.

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* No specific questions or learning objectives are given for this topic. These concepts are covered in other topics.

INTRODUCTION

This catalog contains questions, answers, references, and learning objectives for selected generic topics related to components, reactor theory, and thermodynamics. These test items were developed to measure student mastery of generic knowledge learning objectives.

The test items in this catalog are grouped by subject area: components in Section 1, reactor theory in Section 2, and thermodynamics in Section 3. Each subject area is further divided into specific topics, such as pumps, neutrons, or thermal hydraulics.

Within each of these topics, the order of presentation consists of consecutively numbered questions, answers, explanations (where appropriate), reference (s) (where available) and finally learning objectives. Learning objectives have been prepared which correspond to NUREG 1122 knowledge statements. The question sequence is in accordance with the knowledge statements and corresponding learning objectives. The learning objective pages can be used to locate questions covering specific knowledge statements.

Appendix A contains an equation and fact sheet for student use in studying and in undergoing practice examinations using these questions. Appendix B is a list of references and Appendix C is a feedback form that users may use to furnish comments and suggested revisions.

This catalog may be used as a stand-alone test item bank, or its contents may be incorporated into a utility's existing question bank. While the learning objectives and questions were developed to support training and examination of licensed operator candidates, some items may also be appropriate for other disciplines. Just as the answers provided for the multiple-choice questions often include explanations, the answers to the subjective questions often exceed the minimum acceptable response. Therefore, judgment should be exercised in adapting these answers for use as an examination answer key.

Utilities are encouraged to make the catalog contents available to students as a study aid. The catalog is offered in loose-leaf format to facilitate photocopying for individual student use. This format also allows students and instructors to subdivide the catalog into smaller documents for ease of handling.

The catalog has been provided to the U.S. Nuclear Regulatory Commission as the primary source of questions for future examinations on generic fundamentals.

The previous version of this catalog was published in November 1992. This revision of the catalog includes test items that were added or modified based on the questions used in recent generic fundamentals examinations.

VALVES
Questions

1. The primary purpose of a pressure relief safety valve is to

   A. reduce system energy
   B. reduce system pressure
   C. maintain system integrity
   D. maintain system mass

2. Which of the following valves is designed to maintain system integrity by opening if system pressure increases to a specific point, releasing a volume of steam or liquid, then closing at a pressure equal to or just below the setpoint?

   A. pressure control valve
   B. regulating valve
   C. check valve
   D. relief valve

3. The function of a relief valve is to

   A. cross-connect systems
   B. limit pressure of a system
   C. relieve excess heat from a system
   D. maintain constant flow in a system

4. The purpose of overpressure protection valves is to limit the internal pressure in vessels and thus protect personnel and equipment. The above statement best describes which of the following valves?

   A. safety
   B. control
   C. sentinel
   D. pressure regulating

5. Which of the following valves always functions as an overpressure protection valve?

   A. check valve
   B. safety valve
   C. pressure control valve
   D. spring-loaded reducing valve

6. The difference between the pressure at which a safety/relief valve begins to open and the pressure at which it is fully open is called

   A. blowdown
   B. accumulation
   C. setpoint tolerance
   D. setpoint deviation

7. The difference between the setpoint pressure at which a safety valve opens and the pressure at which it closes is called

   A. blowdown
   B. accumulation
   C. setpoint tolerance
   D. setpoint deviation

8. When a control valve at the outlet of a piping system is opened, flow will

   A. increase
   B. not change
   C. decrease
   D. fluctuate

9. When the pump discharge valve is opened on a constant speed pump with a fixed recirculation flow, pump suction flow will

   A. decrease
   B. increase
   C. fluctuate
   D. remain constant

10. In a closed system using a centrifugal pump to move a fluid, a manual throttle valve is closed one turn. What is the effect on system total flow?

    A. no change, only pressure is affected
    B. decreases due to increased resistance
    C. fluctuates due to decreased resistance
    D. increases to a value governed by the new system head

11. When a discharge valve is opened to atmosphere, the pressure on the upstream side of the valve will _______, and the pressure on the downstream side will _______.

    A. remain the same, increase
    B. increase, remain the same
    C. remain the same, decrease
    D. decrease, remain the same

12. When a discharge valve is opened to atmosphere, the pressure on the upstream side of the valve will

    A. remain the same, and the pressure on the downstream side will increase

    B. increase, and the pressure on the downstream side will remain the same

    C. remain the same, and the pressure on the downstream side will decrease

    D. decrease, and the pressure on the downstream side will remain the same

13. If a heat exchanger cooling water outlet valve is partially closed from the full open position, heat exchanger cooling water pressure upstream of the valve will

    A. increase
    B. not be affected
    C. decrease
    D. fluctuate

14. Which one of the following effects will result from manually closing the letdown control valve an additional 10%? Upstream pressure will _________ and letdown flow rate will _________.

    A. decrease, increase
    B. decrease, decrease
    C. increase, increase
    D. increase, decrease

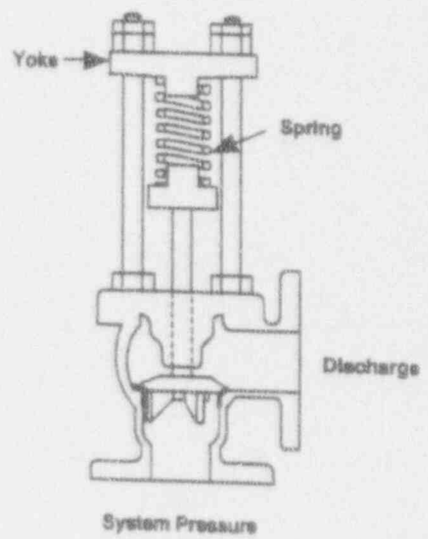
15. Which one of the following effects will result from manually opening the feedwater regulating/control valve an additional 10%? Upstream pressure will _________ and feedwater flow rate will _________.

    A. increase, increase
    B. increase, decrease
    C. decrease, increase
    D. decrease, decrease

16. Refer to the drawing of a spring-loaded valve (Figure 1.1-1). Upon a loss of system pressure, this valve will always move to (or remain in) the

    A. fully open position
    B. previous position
    C. fully closed position
    D. mid-position

FIGURE 1.1-1



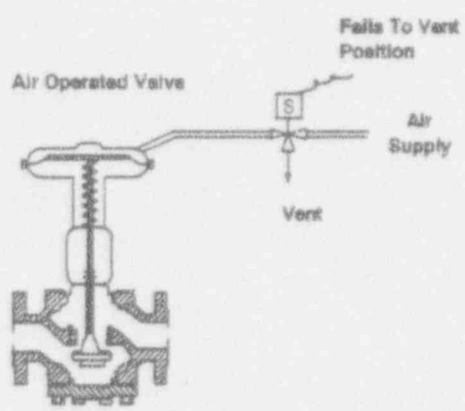
17. Refer to the drawing of a spring-loaded air-operated valve (see Figure 1.1-2). Upon a loss of air pressure, this valve will

    A. go to the fully open position
    B. remain at the current position
    C. go to the fully closed position
    D. go to the mid-position

18. Using the drawing of an air-operated valve (Figure 1.1-2), identify the valve position following a loss of electrical power.

    A. mid-position
    B. closed
    C. as is
    D. open

FIGURE 1.1-2



19. Using the drawing of an air-operated valve (Figure 1.1-2), identify the valve position following a diaphragm leak.

    A. open
    B. as is
    C. closed
    D. varies with system flow

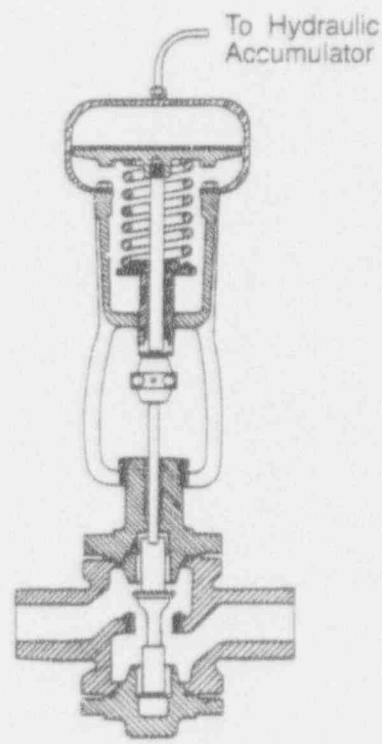
20. How would a motor-operated valve typically react to a loss of electrical power to the valve actuator?

    A. open fully
    B. close fully
    C. remain as is
    D. move to 50 percent open

21. Using the drawing of a hydraulically operated valve (Figure 1.1-3), identify the valve position following a loss of hydraulic pressure.

    A. open
    B. as is
    C. closed
    D. varies with pressure at the valve seat

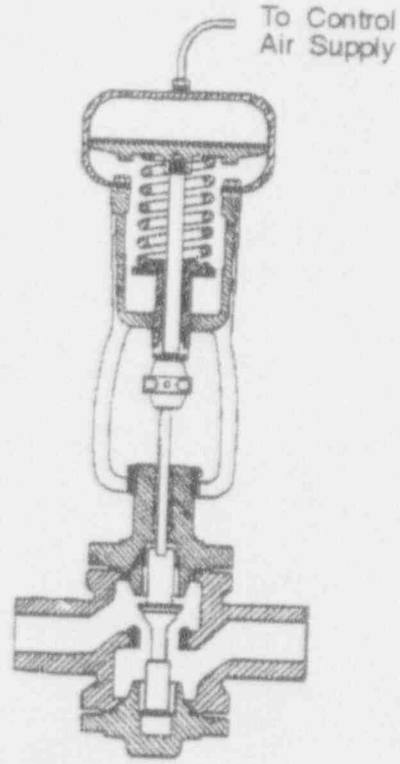
FIGURE 1.1-3



22. Refer to Figure 1.1-4 for the following question. Following a loss of controlling air pressure, the spring-loaded valve will fail

    A. open
    B. as is
    C. closed
    D. to mid-position

FIGURE 1.1-4



Spring-loaded Air-operated Valve

23. Operators should use <u>both</u> hands on valve handwheels when positioning manual valves to

    A. control the rate of valve motion to prevent water hammer

    B. overcome the resistance of installed locking devices

    C. control lateral force to prevent placing a bending force on the valve stem

    D. ensure system pressure, temperature, and flow are controlled during valve motion

24. Which of the following is <u>not</u> a technique normally used to prevent thermal binding and/or pressure locking of globe valves?

    A. Leave normally closed valves open one-quarter turn during heatup and cooldown.

    B. Use relief valves on valve bonnets to equalize pressure.

    C. Use proper closing torque to close manual valves.

    D. Cycle valves during a cooldown.

25. After an adjustment of the packing gland on a valve that had a minor packing leak, the operator attempts to operate the valve but finds that the valve is stuck. Select the most probable cause.

    A. The disk separated from the valve stem as a result of overtightening the packing.

    B. The operator placed the valve in the wrong position while adjusting the packing.

    C. Adjusting the packing overtorqued the valve in the closed direction.

    D. The operator overtightened the packing, causing the stem to bind.

26. An operator attempts to close a manual gate valve to isolate a pump in a shutdown system. However, no amount of manual force is able to rotate the handwheel. This condition can be caused by all of the following except

    A. The valve packing was improperly adjusted and is exerting excessive force on the valve stem.

    B. The system has cooled after shutdown and thermal contraction has resulted in binding of the valve stem.

    C. The system has been drained after shutdown and a hydraulic lock has formed under the valve disk.

    D. The valve was previously placed in the fully closed position and cannot be closed further.

27. The purpose of backseating a manual valve in an operating system is to

    A. isolate system pressure from the packing and stuffing box to minimize packing leakage

    B. fully remove the valve disk from the flow stream to minimize system head loss

    C. provide a backup means of flow isolation in the event of primary seat leakage

    D. provide a backup means of flow isolation in the event of a pipe break

28. The function of a valve backseat is to

    A. isolate system pressure from the packing and stuffing box to minimize packing leakage

    B. isolate system pressure from the packing and stuffing box for the purpose of valve repacking

    C. provide a means of flow isolation in the event of primary seat leakage

    D. provide a backup means of flow isolation in the event of a pipe break

29. If an operator attempts to operate a manual valve that appears to be stuck, either open or closed, he should

    A. strike the handwheel with a hammer to free the valve

    B. use an approved valve wrench to free the valve

    C. loosen the valve bonnet slightly to free the valve

    D. open the closest vent or drain valve to relieve pressure that could be causing the valve to stick

30. Prior to manually operating a motor-operated valve, it is good practice to

    A. stroke the valve electrically while depressing the manual clutch engaging lever to smoothly engage the clutch

    B. tag open the power supply to the valve motor

    C. pull up firmly on the declutch hand lever to reseat the clutch

    D. fully stroke the valve electrically to ensure that it moves freely with normal motor torque

31. After manually positioning a motor-operated valve, the valve actuator is reengaged by actuation of the

    A. manual declutch lever to the disengage position

    B. manual declutch lever to the engage position

    C. racked-in limit switch when the actuator motor breaker is racked in

    D. valve actuator motor in the open direction

32. Operation of the manual declutch lever (initially in the normal position) of a motor-operated valve __________ the motor and __________ the handwheel.

    A. disengages; engages
    B. deenergizes; engages
    C. engages; disengages
    D. reenergized; disengages

33. An operator should never attempt to manually disengage the motor on a motor-operated valve whose motor is operating because it might damage the

    A. worm gear pinion
    B. torque switches
    C. limit switches
    D. clutch

34. When manually positioning a motor-operated valve, why must the operator avoid using excessive valve seating/backseating force?

    A. Valve stem limit switch settings may become inaccurate.

    B. The valve may bind during subsequent operation.

    C. The clutch may not re-engage the valve motor when required.

    D. Stem position may no longer be an accurate indicator of valve position.

35. Which one of the following valves is used to control the direction of fluid flow and prevent backflow in a system?

    A. safety valve
    B. relief valve
    C. divert valve
    D. check valve

36. Check valves are used to

    A. permit flow in only one direction
    B. prevent system overpressure
    C. dampen flow oscillations
    D. prevent water hammer

37. Three common types of check valves used in power plants are

    A. swing, lift, and gate valves
    B. lift, ball, and needle valves
    C. ball, swing, and lift valves
    D. swing, lift, and diaphragm valves

38. A stop check valve is a modified check valve that

    A. cannot be shut remotely

    B. can be used to prevent flow in both directions

    C. can be opened manually to allow flow in both directions

    D. contains both a gate valve disk and a check valve disk

39. To verify the position of a closed manual valve, the operator should operate the valve

    A. to the fully open position, then reclose it using normal force

    B. in the closed direction using normal force

    C. in the open direction until flows sounds are heard, then close the valve using manual force

    D. in the closed direction until it stops, then close it an additional one-half turn using normal force

40. To verify a manual valve in an operating system is closed, the operator should operate the valve handwheel in the

    A. open direction until the valve is fully open, then reclose it using normal force

    B. close direction using normal force and verify there is no substantial handwheel movement

    C. open direction until flow sounds are heard, then reclose the valve using normal force

    D. close direction utilit it stops, then close it an additional one-half turn using additional force if necessary

41. To verify the position of fully-open manual valve, the operator should

    A. operate the valve handwheel in the open direction until handwheel motion stops, then operate the valve handwheel one turn in the closed direction

    B. operate the valve handwheel in the open direction until handwheel motion stops, then torque the handwheel an additional one-half turn in the open direction

    C. operate the valve handwheel in the closed direction to fully close the valve, then fully open the vlave

    D. operate the valve handwheel in the closed direction to partially close the valve, then fully open the valve

42. To verify the position of a fully open manual valve, the operator should

    A. fully close the valve, then reopen to the fully open position

    B. open the valve until it touches the back-seat, then close to the desired position

    C. operate the valve in the open direction until the valve is backseated one-half turn

    D. operate the valve in the closed direction, then reopen the valve to its previous open position

43. Which of the following types of valves are best designed to throttle flow?

    A. gate and diaphragm valves
    B. gate and globe valves
    C. gate and butterfly valves
    D. globe and diaphragm valves

44. In comparing a gate valve to a globe valve, which of the following statements is correct?

    A. A globe valve has a higher pressure drop when fully open and is better for throttling.

    B. A gate valve has a lower pressure drop when fully open and is better for throttling.

    C. A gate valve has a higher pressure drop when fully open and is better for throttling.

    D. A globe valve has a lower pressure drop when fully open and is better for throttling.

45. When comparing the characteristics of gate and globe valves in an operating system, a globe valve generally has the __________ pressure drop when fully open and is the better valve for __________ flow.

    A. lower; isolating
    B. higher; isolating
    C. lower; throttling
    D. higher; throttling

46. In comparison to a globe valve, a gate valve has a __________ pressure drop when fully open and is the __________ choice for throttling.

    A. higher; better
    B. lower; better
    C. higher; poorer
    D. lower; poorer

47. What is the major disadvantage of a globe valve as compared to a gate valve?

    A. Globe valves cannot be used to throttle flow.

    B. Globe valves are expensive and difficult to install.

    C. Globe valves have a relatively large pressure drop when fully open.

    D. Globe valves do not provide good control of flow or pressure.

48. Gate valves are designed to

    A. stop flow
    B. regulate flow
    C. prevent backflow
    D. regulate pressure

49. Gate valves should not be used to throttle fluid flow because

    A. the large D/P across a gate valve when throttled would cause erroneous flow indication

    B. all gate valves rely on backseats to prevent stem leakage and should not be throttled

    C. the turbulent flow created by a partially opened gate valve can cause extensive damage to the valve

    D. the large size of the valve gate would require an oversized actuator to position the valve accurately

50. A typical check valve is designed to:

    A. permit flow in only one direction
    B. prevent system overpressure
    C. isolate system components
    D. perform automatic pump venting

VALVES
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

While a pressure relief valve does reduce energy by reducing pressure, its purpose is to protect the system.

Reference 25, appendix A, pages 18 and 22.

2. D

Reference 25, appendix A, pages 18 and 22.

3. B

Reference 25, appendix A, pages 18 and 22.

4. A

Reference 25, appendix A, pages 18 and 22.

5. B

Reference 25, appendix A, pages 18 and 22.

6. B

7. A

Reference 23, pages 22-17.

8. A

Reference 14, chapter 7, pages 61 and 63.

9. B

Reference 25, appendix A.

10. B

Reference 25, appendix A, pages 18 and 22.

11. D

Reference 25, appendix A, pages 18 and 22.

12. D

Reference 25, appendix A, pages 18 and 22.

13. A

Reference 14, chapter 7, pages 61 through 90.

14. D

15. C

16. C

Without any system pressure to oppose spring pressure, the pressure exerted by the spring will close the valve.

Reference 23, page 22-17.

17. C

Reference 49, chapter 7, pages 130 through 132.

18. B

Reference 49, chapter 7, pages 130 through 132.

19. C

Reference 49, chapter 7, pages 130 through 132.

20. C

In motor-operated valves, an electric motor provides the motive force to both open and shut the valve. Upon a loss of electrical power, the valve remains in the last position.

Reference 25, appendix A, page 27.

21. A

Principle of operation is the same as that of an air-operated valve.

Reference 49, chapter 7, pages 130 through 132.

22. A

The spring will open the valve when air pressure is lost.

Reference 23, page 22-20.

23. C

Using two hands prevents excessive lateral force on the valve stem, which protects the valve stem from bending or binding.

Reference 49; and Reference 42, page 1.4-2.

24. A

Leaving a normally closed valve partially open is not an acceptable technique to prevent thermal binding or pressure locking of valves and defeats the purpose of closing the valve. B, C, and D all are examples of acceptable techniques.

Reference 25, appendix A, page 35.

25. D

Since the valve became stuck immediately following a packing adjustment and the packing is in direct contact with the valve stem, item D is the most logical response.

Reference 25, appendix A, page 35.

26. C

27. A

A backseat is provided in some valves to remove or reduce pressure from the valve packing and/or packing stuffing box. Backseating is not normally done to reduce wear on the backseat surfaces, thus allowing proper operation in the event of packing failure.

Reference 25, appendix A, page 35.

28. A

A backseat is provided in some valves to remove or reduce pressure from the valve packing and/or packing stuffing box. Backseating is not normally done to reduce wear on the backseat surfaces, thus allowing proper operation in the event of packing failure.

Reference 25, appendix A, page 35.

29. B

Operators should only use approved valve wrenches to free a stuck valve.

Reference 25, page 3.

30. B

The electrical power supply to the valve actuator should be isolated and tagged to prevent remote or automatic actuation during manual operation.

Reference 25, page 3.

31. D

During manual operation, the actuator motor is disengaged from the valve stem by a declutch lever and clutch ring. The declutch lever is held in place by trippers during manual operation. Upon actuation of the actuator motor, the trippers are released, freeing the declutch lever and engaging the motor.

Reference 25, appendix A, page 30.

32. A

The declutch lever is used to permit manual valve operation by disengaging the actuator motor and engaging the handwheel.

Reference 25, appendix A, page 30.

33. D

Attempting to manually disengage the motor during motor operation will result in damage to the clutch ring and declutch lever.

Reference 25, appendix A, pages 4 and 30.

34. B

Using excessive seating/backseating force results in the valve disk being pressed into the valve seat. The force required to unseat the valve may exceed torque switch settings, causing the valve to fail to operate on demand.

Reference 25, page 4.

35. D

Check valves are designed to limit flow to one direction by automatically shutting if flow reverses direction.

Reference 49, chapter 6, page 134.

36. A

Check valves are designed to limit flow to one direction by automatically shutting if flow reverses direction.

Reference 49, chapter 6, page 134.

37. C

There are three common types of check valves used in power plants:

- vertical or horizontal lift check
- swing check
- ball check

A gate valve is used to stop flow in a system and does not restrict direction of flow.

Reference 25, appendix A, page 13.

38. B

A stop check valve is a modified globe or angle valve with a modified valve disk that functions as a check valve when opened and can be closed to stop flow like a normal globe valve.

Reference 25, appendix A, page 13.

39. B

Valves should only be moved in the close direction to verify valve position. If the valve is open, this will close the valve. If the valve is closed, this will not exceed normal closure force.

Reference 25, page 3.

40. B

Valves should only be moved in the close direction to verify valve position. If the valve is open, this will close the valve. If the valve is closed, this will not exceed normal closure force.

Reference 25, page 3.

41. D

Fully open valves should only be operated in the close direction to verify valve position. If the valve is open, the valve will move slightly, indicating the valve is open.

Reference 25, section 6.6.

42. D

Fully open valves should only be operated in the close direction to verify valve position. If the valve is open, the valve will move slightly, indicating the valve is open.

Reference 25, section 6.6.

43. D

Gate valves are designed for systems where straight line flow and minimum flow restrictions are desired. Gate valves are not suitable for throttling due to poor flow control, and the turbulent flow created by a partially opened valve could seriously damage the valve.

Reference 14, pages 7-61 through 7-63.

44. A

A gate valve has a low pressure drop when fully open. Gate valves are best for flow isolation and should not be used for throttling.

Relative to a gate valve, a globe valve has a high pressure drop when fully open.

A globe valve is designed for use in throttling applications.

Reference 49, chapter 6.

45. D

A gate valve has a low pressure drop when fully open. Gate valves are best for flow isolation and should not be used for throttling.

Relative to a gate valve, a globe valve has a high pressure drop when fully open.

A globe valve is designed for use in throttling applications.

Reference 49, chapter 6.

46. D

A gate valve has a low pressure drop when fully open. Gate valves are best for flow isolation and should not be used for throttling.

Relative to a gate valve, a globe valve has a high pressure drop when fully open.

A globe valve is designed for use in throttling applications.

Reference 49, chapter 6.

47. C

Globe valves are designed to provide good flow and pressure control and are used extensively in throttling applications. Compared to gate valves, however, a globe valve has a higher pressure drop when the valve is fully opened.

Reference 49, chapter 6.

48. A

Gate valves are designed to start and stop flow.

Reference 49, chapter 6.

49. C

Gate valves are designed for systems where straight line flow and minimum flow restrictions are desired. Gate valves are not suitable for throttling due to poor flow control, and the turbulent flow created by a partially opened valve could seriously damage the valve.

Reference 49, chapter 6, page 131.

50. A

VALVES
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Question 1

State the purpose of pressure relief valves.

K1.01 Questions 2, 4, 5

Given a list of valves, select the overpressure protection valve (safety or relief).

K1.01 Question 3

State the function of a relief valve.

K1.02 Questions 6, 7

Define terminology associated with relief valves.

K1.03 Questions 8-15

Explain the effect of valve position on pressure and/or flow rate in piping systems.

K1.04 Question 16

Explain the operation of a spring-loaded valve.

K1.04 Questions 17-19, 22

Explain the operation of an air-operated valve.

K1.04 Question 20

Explain how a motor-operated valve (MOV) would react to a loss of electrical power.

K1.04 Question 21

Explain the operation of a hydraulically operated valve.

K1.05 Questions 23, 29

Identify the precautions an operator must observe while operating manual valves.

K1.05 Question 24

Identity three techniques used to prevent thermal binding and/or pressure locking of valves.

K1.05 Questions 25, 26

Given a potential problem encountered during valve operations and a list of possible causes, select the cause that best fits the problem described.

K1.05 Questions 27, 28

Identify the function and use of valve backseats.

K1.06 Questions 30, 33, 34

Explain the precaution(s) to be observed while manually operating a motor-operated valve (MOV).

K1.06 Questions 31, 32

Explain the operation of the manual declutch lever on a typical motor-operated valve (MOV).

K1.07 Questions 35, 36, 50

Explain the purpose of a check valve.

VALVES
Learning Objectives

K1.07 Question 37

Identify the three types of check valves used in power plants.

K1.07 Question 38

Given a specific type of check valve, describe its operation.

K1.08 Questions 39-42

Explain the proper method/technique used to verify or determine valve position (open, closed, throttled).

K1.09 Question 43

Given a list of valve types, identify those valves that are designed to be used for throttling flow.

K1.09 Questions 44-47

State the reasons for using globe valves versus gate valves for throttling flow.

K1.09 Question 48

State the application for which gate valves are best suited.

K1.09 Question 49

Explain why gate valves should not be used to throttle fluid flow.

SENSORS AND DETECTORS
Questions

1. If the density input to a density-compensated flow instrument fails high, the <u>indicated</u> flow will

    A. increase to a new higher value

    B. increase temporarily, then return to its initial value

    C. decrease to a new lower value

    D. decrease temporarily, then return to its initial value

2. The compensating input on a flow instrument is proportional to density. This input converts volumetric flow rate to

    A. velocity flow rate
    B. laminar flow rate
    C. mass flow rate
    D. differential flow rate

3. Density compensation is used in flow instruments to change __________ into __________.

    A. mass flow rate, volumetric flow rate
    B. volumetric flow rate, mass flow rate
    C. mass flow rate, differential pressure
    D. differential pressure, volumetric flow rate

4. The density compensating input to a steam flow instrument is used to convert volumetric flow rate to

    A. velocity flow rate
    B. gallons per minute
    C. mass flow rate
    D. differential flow rate

5. If the density input to a compensated flow instrument fails low, the <u>indicated</u> flow will

    A. increase to a new higher value

    B. increase temporarily, then return to its initial value

    C. decrease to a new lower value

    D. decrease temporarily, then return its initial value

6. With a constant velocity flow rate, an increase in the density input signal to a compensated flow instrument causes the indicated flow to increase. This occurs because <u>actual</u>

    A. volumetric flow rate decreases
    B. mass flow rate decreases
    C. volumetric flow rate increases
    D. mass flow rate increases

7. The most probable cause for fluctuating indication from a liquid flow rate differential pressure detector is

    A. gas or steam being trapped in the liquid

    B. unequal temperature gradients in the liquid

    C. vortexing of the liquid passing through the flow device

    D. the valve on the high pressure sensing line being partially closed

8. Gas or steam bubbles entrapped in a liquid flow detector cause fluctuations in indicated flow due to

   A. changes in temperature

   B. changes in volume flow rate

   C. plugging of the differential pressure detector taps

   D. changes in pressure sensed at the differential pressure detector taps

9. If the liquid flowing through a differential pressure liquid flow rate detector contains entrained voids (gas or steam), indicated flow rate will be

   A. erroneously high
   B. erroneously low
   C. unaffected
   D. fluctuating

10. If the high pressure sensing line on a differential pressure (D/P) flow detector develops a leak, what will happen to flow indication?

   A. increase
   B. decrease
   C. remain the same
   D. fluctuate

11. If the low pressure sensing line on a differential pressure (D/P) flow detector develops a leak, what will happen to flow indication?

   A. increase
   B. decrease
   C. remain the same
   D. fluctuate

12. If the diaphragm ruptures on a differential pressure (D/P) flow sensor, how will indicated flow respond?

   A. increase
   B. decrease
   C. remain the same
   D. fluctuate

13. A differential pressure (D/P) detector is being used to measure flow rate in a cooling water system. Flow rate is indicating 75% of scale. If the D/P detector diaphragm ruptures, indicated flow rate will

   A. go to 0% because low D/P is sensed

   B. go to 0% because high D/P is sensed

   C. go to 100% (full scale) because low D/P is sensed

   D. go to 100% (full scale) because high D/P is sensed

14. If the equalizing line on a differential pressure (D/P) flow detector is opened, the flow detector indication will

   A. increase slightly
   B. decrease slightly
   C. go to zero
   D. not change

15. If the orifice in a differential pressure (D/P) flow sensor wears so that the orifice or flow nozzle becomes larger, how will indicated flow rate be affected? Flow rate will

   A. read higher than normal
   B. read lower than normal
   C. not change
   D. fluctuate

16. If the steam pressure input to a density-compensated steam flow instrument fails high, the indicated flow rate will

   A. decrease, because the density input has decreased

   B. increase, because the density input has decreased

   C. decrease, because the density input has increased

   D. increase, because the density input has increased

17. Which one of the following will cause indicated volumetric flow rate to be lower than actual volumetric flow rate using a differential pressure (D/P) flow detector and a calibrated orifice?

A. debris becomes lodged in the orifice

B. a leak develops in the low pressure sensing line

C. the orifice erodes over time

D. system pressure decreases

18. Which of the following will cause indicated flow rate to be higher than actual flow rate using a differential pressure (D/P) flow detector and a calibrated orifice?

A. debris becomes lodged in the orifice

B. a leak develops in the high pressure sensing line

C. the orifice erodes over time

D. the flow detector equalizing valve is inadvertently opened

19. Flow detectors (such as an orifice, flow nozzle, and venturi tube) measure flow rate using the principle that flow rate is

A. directly proportional to the differential pressure squared

B. inversely proportional to the differential pressure squared

C. directly proportional to the square root of the differential pressure

D. inversely proportional to the square root of the differential pressure

20. A differential pressure steam flow measuring instrument uses density compensation and square root compensation to produce steam flow rate indication in lbm/hr. The purpose of square root compensation in this flow measuring instrument is to convert ________ to ________.

A. steam pressure; fluid velocity
B. steam pressure; fluid density
C. differential pressure; fluid velocity
D. differential pressure; fluid density

21. A cooling water system is operating at a steady-state flow rate of 700 gpm with 60 psid across the flow transmitter venturi. If cooling water flow rate is increased to 1000 gpm, differential pressure across the flow transmitter venturi will be approximately

A. 85.7 psid
B. 122.4 psid
C. 171.4 psid
D. 244.8 psid

22. A cooling water system is operating at steady-state conditions indicating 900 gpm with 60 psid across the flow transmitter venturi. If cooling water flow rate is increased to 1800 gpm, flow transmitter venturi differential pressure will be approximately

A. 85 psid
B. 120 psid
C. 175 psid
D. 240 psid

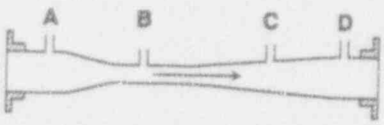
23. On the drawing of a venturi flow detection device (Figure 1.2-1) , identify where the low pressure tap is located.

A. point "A"
B. point "B"
C. point "C"
D. point "D"

24. On the drawing of a venturi flow detection device (Figure 1.2-1), identify where the high pressure tap should be located.

   A. point "A"
   B. point "B"
   C. point "C"
   D. point "D"

FIGURE 1.2-1



25. The differential pressure (D/P) across a flow measuring device doubles. By what factor has flow increased?

   A. 2^3
   B. 2^2
   C. 2
   D. $\sqrt{2}$

26. If the flow velocity through a differential pressure flow sensor doubles, by what factor will its differential pressure increase?

   A. square root of two
   B. two
   C. four
   D. eight

27. The flow rate of a fluid passing through a venturi can be determined by measuring the

   A. change in the pressure of the fluid as it passes through the venturi

   B. change in the density of the fluid as it passes through the venturi

   C. linear displacement of a metering plug installed in the throat of the venturi

   D. rotation of a paddle wheel type device installed in the throat of the venturi

28. A differential pressure level transmitter, with its Reference leg vented to atmosphere, was calibrated for use on an open tank at 100°F. If mass in the tank remains constant and the temperature is raised to 200°F, the <u>indicated</u> level will

   A. remain the same although actual level increases

   B. increase but remain less than actual level

   C. decrease but remain greater than actual level

   D. increase in direct proportion to the temperature rise

29. A differential pressure level transmitter, with a dry Reference leg vented to atmosphere, was calibrated for use on an open tank at 80°F. If the mass in the tank remains the same and the temperature is raised to 150°F, the <u>indicated</u> level will

   A. remain equal to actual level, since no water was added or drained

   B. increase above actual level due to the expansion of the water

   C. remain the same, but actual level would increase

   D. increase with actual level due to the expansion of the water

30. Refer to the drawing of a tank differential pressure level detector that was recently calibrated at a tank water temperature of 80°F (see Figure 1.2-2).

If the mass of the water in the tank remains the same while the tank water temperature is raised from 80°F to 150°F, the indicated level will

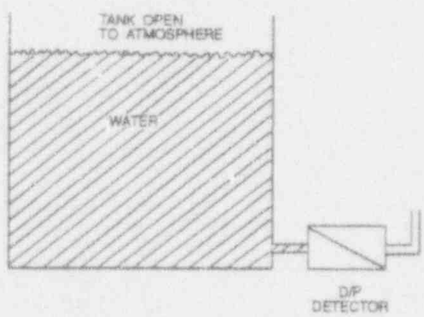
A. remain equal to actual level

B. increase due to the expansion of the water

C. remain the same

D. decrease due to the expansion of the water

FIGURE 1.2-2



Tank Differential Pressure Level Detector

31. Refer to the drawing of two tank differential pressure level indicators (see Figure 1.2-3).

Two differential pressure (D/P) level indicators are installed on a large water storage tank. Indicator 1 was calibrated at 100°F water temperature and indicator 2 was calibrated at 200°F water temperature. Assuming both are on scale, which indicator will indicate the higher level?

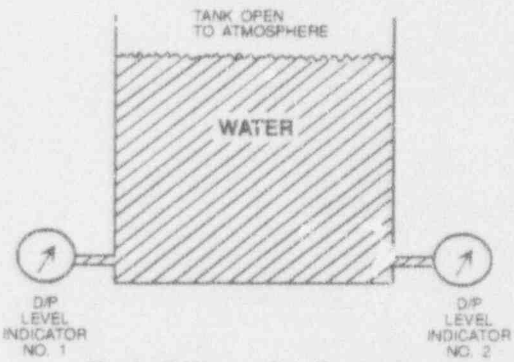
A. indicator 1 at all water temperatures

B. indicator 2 at all water temperatures

C. indicator 1 below 150°F, indicator 2 above 150°F

D. indicator 2 below 150°F, indicator 1 above 150°F

FIGURE 1.2-3



Tank Differential Pressure Level Detector

32. Refer to the drawing of a water storage tank with two differential pressure level indicators (see Figure 1.2-3).

Indicator 1 was calibrated at 200°F and indicator 2 was calibrated at 100°F. If tank water temperature is 150°F, then

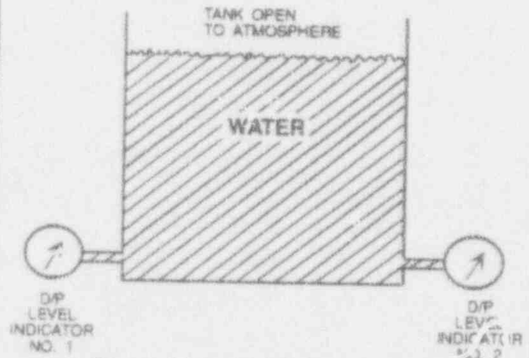
A. indicator 1 will read greater than indicator 2

B. indicator 2 will read greater than indicator 1

C. indicator 1 and 2 will read the same

D. both indicators will be inaccurate, but it is impossible to predict which indicator will read greater

FIGURE 1.2-3



Tank Differential Pressure Level Indicators

33. A differential pressure level transmitter is being used in a control loop to maintain a tank level at 50%. The transmitter's D/P cell uses a dry Reference leg that senses pressure at the top of the tank. The transmitter was calibrated at a tank temperature of 150°F. If the tank temperature fell to 100°F, the actual level would

A. be maintained at 50%

B. increase above 50%, due to the controller action

C. first increase, then decrease to 50%

D. decrease, due to increased density of the water

34. Two differential pressure level transmitters are installed in one large tank. Transmitter "I" is calibrated at a tank temperature of 100°F, and transmitter "II" is calibrated at 200°F. Which indicates higher?

A. transmitter I

B. transmitter II

C. transmitter I less than 150°F, transmitter II above 150°F

D. neither; both indicate the same

35. Two differential pressure level transmitters are installed in a large tank. If transmitter I is calibrated at 200°F and transmitter II is calibrated at 100°F, then at 150°F

A. transmitter I will read greater than transmitter II

B. transmitter II will read greater than transmitter I

C. transmitter I and II will read the same

D. it is impossible to predict how either transmitter will respond

36. Two differential pressure level transmitters are installed in a large tank. Transmitter I is calibrated at 200°F. Transmitter II is calibrated at 100°F. Which transmitter will read lower at 150°F?

A. transmitter I

B. transmitter II

C. must consult water density curve to accurately determine

D. neither, they will read the same

37. A closed tank uses a differential pressure level detector with a dry reference leg that senses pressure at the top of the tank. The instrument was calibrated at a tank temperature of 80°F. Explain how indicated level changes as tank temperature increases. Assume actual level remains constant.

38. The pressure differential between a reference leg and a variable leg is

A. directly proportional to the height of the variable leg

B. inversely proportional to the height of the variable leg

C. directly proportional to the density of the variable leg

D. directly proportional to the temperature of the Reference leg

39. Refer to the drawing of a tank differential pressure level detector (see Figure 1.2-4).

If the differential pressure detector equalizing valve is opened, level indication will

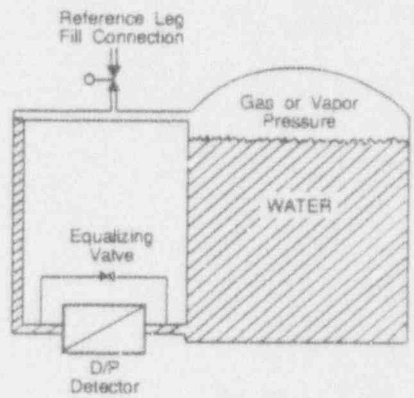
A. decrease and stabilize below actual level

B. increase and stabilize above actual level

C. oscillate above and below actual level

D. remain constant at the current level

FIGURE 1.2-4



Tank Differential Pressure Level Detector

40. Refer to the drawing of a tank differential pressure (D/P) level detector (see Figure 1.2-4).

The level detector is being used in a level control system that is calibrated to maintain tank level at 75% at the current water temperature of 90°F. If water temperature gradually increases and stabilizes at 120 °F, the level control system will cause actual tank level to

A. remain at 75%
B. increase and stabilize above 75%
C. oscillate around 75%
D. decrease and stabilize below 75%

41. Complete the following statement to describe the theory of operation of a differential pressure level detector using a wet reference leg.

The pressure differential between a ____________ height of liquid and the pressure sensed at the bottom of a tank is ________ ___ proportional to the height of liquid in the tank.

A known, directly
B. known, inversely
C. variable, directly
D. variable, inversely

42. A differential pressure level transmitter has been calibrated for a density of 62 lbm/ft^3. However, the actual tank liquid density is 40 lbm/ft^3. The indicated tank level will be

A. higher than actual level
B. lower than actual level
C. the same as actual level
D. erratic

43. A differential pressure level detector senses the differential pressure between a Reference height of liquid and the pressure at the bottom of a tank. This differential pressure is __________ the level of liquid in the tank.

A. an integral of
B. a differential of
C. directly proportional to
D. inversely proportional to

44. The differential pressure type level detector senses the differential pressure between a __________ height of liquid and a column of liquid at a fixed height.

A. programmed
B. backup
C. Reference
D. variable

45. A differential pressure type level detector senses the differential pressure between a Reference height of liquid and

A. atmospheric pressure
B. programmed pressure
C. the pressure at the top of a tank
D. the pressure at the bottom of a tank

46. A high ambient temperature at its Reference leg may cause a differential pressure type level indicator using a wet Reference leg to read

A. greater than actual level
B. less than actual level
C. at a constant level
D. at a fluctuating lower level

47. A differential pressure type level detector with a wet Reference leg is being used to measure level in a closed tank inside containment. If containment pressure increases with no appreciable change in containment temperature, the level indicator will read

A. greater than actual level
B. less than actual level
C. the actual level
D. at a fluctuating lower level

48. If the Reference leg of a differential pressure level indicator experiences high ambient temperature, indicated level will

A. read less than actual level
B. read greater than actual level
C. equal the actual level
D. slowly decrease to zero

49. A differential pressure type level detector with a wet Reference leg is being used to measure level in a closed tank inside containment. If a vacuum develops in containment without an appreciable change in containment temperature, the level indicator will

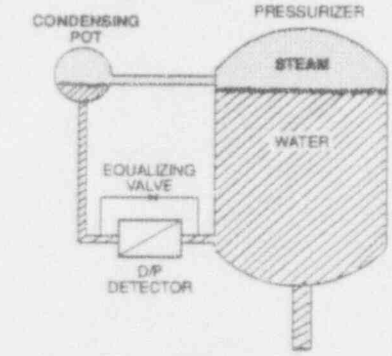
A. read greater than actual level
B. read less than actual level
C. read the actual level
D. fluctuate around actual level

50. Refer to the drawing of a pressurizer differential pressure level detector (see Figure 1.2-5).

With the plant at normal operating conditions, a pressurizer level differential pressure (D/P) instrument, that had been calibrated while the plant was in a cold condition, would indicate ________ than actual level because of a ______________ differential pressure sensed by the D/P detector at normal operating conditions.

A. lower; larger
B. lower; smaller
C. higher; larger
D. higher; smaller

FIGURE 1.2-5



Pressurizer Differential Pressure Level Detector

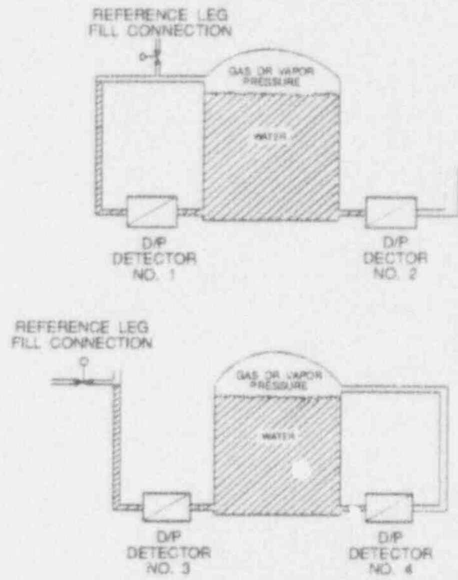
51. Refer to the drawing of four differential pressure level detectors (see Figure 1.2-6).

The tanks are identical and are being maintained at 17 psia and 70% water (calibration conditions). They are contained in a building that is open to atmospheric pressure.

Which of the level detectors will provide the lowest level indication if atmospheric pressure decreases?

A. 1 and 3
B. 1 and 4
C. 2 and 3
D. 2 and 4

FIGURE 1.2-6



Tank Differential Pressure Level Detectors

52. Refer to the drawing of four tank differential pressure level detectors (see Figure 1.2-6).

The tanks are identical with equal water levels and both are pressurized to 20 psig. All detectors were calibrated at the current water temperature and 70°F external (ambient) temperature.

Which detectors will provide the <u>most inaccurate</u> level indication following an increase in external (ambient) temperature from 70°F? (Assume water temperature and external pressure do not change.)

A. 1 and 3
B. 2 and 4
C. 1 and 4
D. 2 and 3

53. A differential pressure type level detector with a wet Reference leg is being used to measure level in a closed tank inside containment. If containment temperature decreases, the level indicator will read

    A. greater than actual level
    B. less than actual level
    C. at the actual level
    D. at a fluctuating higher level

54. The level indication for a reference leg differential pressure level instrument will fail low as a result of

    A. a break on the Reference leg

    B. rupture of the diaphragm in the differential pressure cell

    C. the Reference leg flashing to steam

    D. a break on the variable leg

55. A break in the wet Reference leg of a differential pressure type level detector will cause the indicated level to

    A. exceed the actual level
    B. be less than actual level
    C. remain constant at the actual level
    D. fluctuate around the actual level

56. A break in the variable leg of a wet Reference leg differential pressure type level indicator will cause the indicated level to

    A. be greater than actual level
    B. be less than actual level
    C. remain constant at the actual level
    D. fluctuate around the actual level

57. A rupture of the diaphragm in a wet Reference leg differential pressure level detector will cause the indicated level to

    A. read greater than actual level
    B. read less than actual level
    C. remain constant at the actual level
    D. fluctuate around the actual level

58. If the wet Reference leg of a differential pressure level detector flashes to steam, the indicated level will

    A. be greater than actual level
    B. be less than actual level
    C. remain constant at the actual level
    D. fluctuate around the actual level

59. Refer to the drawing of a steam generator differential pressure level detector (see Figure 1.2-7).

    Which one of the following failures will cause the associated steam generator level indicator to indicate the lowest level?

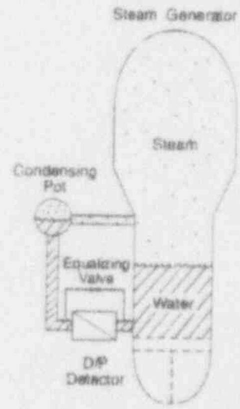
    A. The D/P detector diaphragm ruptures.

    B. The Reference leg ruptures.

    C. The variable leg ruptures.

    D. The equalizing valve is opened.

FIGURE 1.2-7



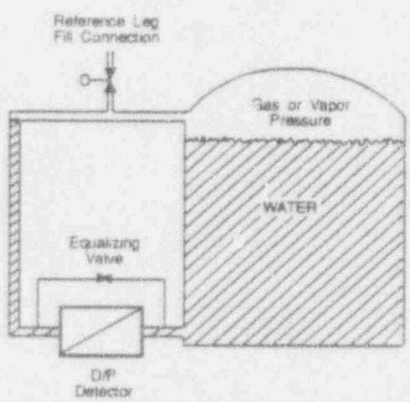
Steam Generator Differential Pressure Level Dector

60. Refer to the drawing of a tank differential pressure level detector (see Figure 1.2-8).

Tank water level indication will be <u>lower</u> than actual level when reference leg temperature is _______________ than calibration conditions or when there is a break in the ___________ leg of the D/P cell.

A. less, reference
B. less; variable
C. greater; reference
D. greater; variable

FIGURE 1.2-8



Tank Differential Pressure Level Detector

61. In a bourdon tube pressure detector, pressure is measured using

A. the distance moved by the tip of the tube

B. the change in length of the tube

C. the change in cross-sectional area of the tube

D. the change in volume of the tube

62. In a diaphragm type pressure detector, pressure is measured using diaphragm

A. radial deflection
B. axial deflection
C. temperature change
D. wall thickness

63. If the pressure sensed by a bourdon tube increases, the curvature of the detector will _____ because of the greatest force being applied to the ___________ curve of the detector.

A. increase; inner
B. decrease; inner
C. increase; outer
D. decrease; outer

64. Semiconductor strain gages are routinely used in transmitters for

A. RCS pressure instruments
B. RCS temperature instruments
C. control rod position instruments
D. steam generator level instruments

65. A simple bellows pressure detector is located in the reactor containment with its low pressure side vented to the containment. If a main steam line break raises containment pressure by 40 psi, the associated system pressure indication (disregarding any temperature effect on the bellows) will

A. increase by the square root of 40 psi
B. increase by 40 psi
C. decrease by 40 psi
D. stay constant

66. A system is monitored by a simple diaphragm pressure detector with its low pressure side vented to the containment. If a main steam break raises containment pressure by 20 psi, the system pressure indication (disregarding any temperature effect on the detector) will

A. increase by the square root of 20 psi
B. decrease by the square root of 20 psi
C. increase by 20 psi
D. decrease by 20 psi

67. A bellows pressure transmitter with its low-pressure side vented to containment atmosphere is being used to measure reactor coolant system (RCS) pressure. A decrease in the associated pressure indication could be caused by either a containment pressure __________ or a RCS pressure __________.

A. decrease, decrease
B. increase, increase
C. decrease, increase
D. increase, decrease

68. A bourdon tube pressure detector is located inside containment and vented to containment atmosphere. The detector is connected to a cooling water system and is currently indicating 100 psig (midscale).

Assuming actual cooling water system pressure does not change, a containment temperature increase of 100°F will cause a ____________ change in indicated pressure, and a containment pressure increase of 40 psi will cause a __________ change in indicated pressure.

A. significant, significant
B. negligible, significant
C. significant, negligible
D. negligible, negligible

69. A bourdon tube pressure detector that is indicating 50% of scale is suddenly exposed to a pressure transient that permanently distorts the detector. Actual pressure returns to its original value. Assuming the detector remains intact, the affected pressure indication will initially go offscale high and then

A. become unpredictable until the instrument is calibrated

B. return to a pressure lower than original

C. return to original pressure

D. return to a pressure greater than original

70. In a diaphragm detector with its Reference leg vented to atmosphere, which one of the following diaphragm-related problems is <u>not</u> a significant cause of failure during plant operation?

A. deflection
B. leakage
C. stiffening
D. overrange

71. A properly adjusted 0 to 200 psig diaphragm pressure detector that is reading 100 psig develops a leak in its diaphragm. The most likely final pressure indication observed by an operator would be

A. offscale low
B. 0 psig
C. 200 psig
D. offscale high

72. Refer to the drawing of a bellows-type differential pressure detector (see Figure 1.2-9).

The spring in this detector (shown in a compressed state) has weakened from long-term use. If the actual differential pressure is constant, how will indicated differential pressure respond as the spring weakens?

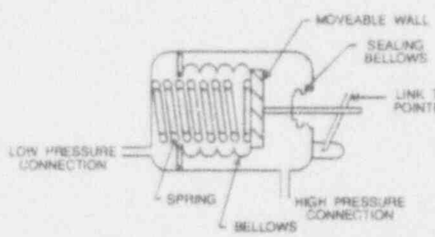
A. no change unless the pressure at the low pressure tap exceeded the pressure at the high pressure tap

B. increase, because the high pressure will compress the spring more

C. decrease, because the high pressure will compress the spring more

D. increase, because the spring will expand more

FIGURE 1.2-9



Bellows - Type Differential Pressure Detector

73. If a bourdon tube pressure detector is over-ranged sufficiently to permanently distort the bourdon tube, subsequent pressure measurement will be inaccurate because the ________________ of the detector tube will be inaccurate.

A. distance moved by the tip
B. change in the length
C. expansion of the cross-sectional area
D. change in the volume

74. A resistance temperature detector (RTD) operates on the principle that the change in electrical resistance of

A. two dissimilar metals is directly proportional to the temperature change measured at their junction

B. two dissimilar metals is inversely proportional to the temperature change measured at their junction

C. a metal is directly proportional to its change in temperature

D. a metal is inversely proportional to its change in temperature

75. A resistance temperature detector (RTD) operates on the principle that a change in metal resistance is _________ proportional to the change in __________.

A. inversely; metal temperature
B. inversely; metal temperature squared
C. directly, metal temperature
D. directly; metal temperature squared

76. When comparing a thermocouple to a resistance temperature detector (RTD), the thermocouple

A. measures temperature less accurately

B. requires an external power supply for operation

C. is unable to withstand high temperatures

D. responds much slower to a temperature change

77. Which of the following constitutes an advantage of a resistance temperature detector over other temperature measurement devices?

    A. rapid response time
    B. low cost
    C. high accuracy
    D. simplicity

78. A thermocouple operates on the principle that a voltage is generated in a closed circuit of

    A. two similar metals when their junctions are at the same temperature

    B. two similar metals when their junctions are at different temperatures

    C. two dissimilar metals when their junctions are at the same temperature

    D. two dissimilar metals when their junctions are at different temperatures

79. The output voltage of a thermocouple is ________ proportional to the ________. (Assume reference junction temperature remains constant.)

    A. directly; measuring junction temperature

    B. directly; square of measuring junction temperature

    C. inversely; measuring junction temperature

    D. inversely; square of measuring junction temperature

80. If a resistance temperature detector (RTD) develops an open circuit (bridge circuit remains intact), indication will fail

    A. high
    B. low
    C. as is
    D. to mid-scale

81. If shorting occurs within a resistance temperature detector (RTD), indication will fail

    A. to mid-scale
    B. as is
    C. high
    D. low

82. An open circuit in a thermocouple detector causes the affected temperature indication to fail

    A. high
    B. low
    C. to reference junction temperature
    D. as is

83. A correct statement regarding thermocouples is that they

    A. will indicate low offscale with an open circuit at the sensing junction

    B. are more accurate than resistance temperature detectors

    C. are made up of two similar metals in contact at one end, called the hot junction

    D. are based on the following characteristics of metals: a change in electrical resistance occurs when a change in temperature occurs

84. What is the most common type of position sensor used to provide remote indication of a valve that is normally fully open or fully closed?

A. limit switch

B. reed switch

C. linear variable differential transformer (LVDT)

D. servo transmitter

85. A certain application requires that a valve's position be remotely indicated in units of "percent of full open." What kind of position sensor would be used?

A. limit switch
B. reed switch
C. LVDT
D. RTD

86. An automatic tank level controller uses a potentiometer for manual adjustment of the level setpoint which is currently 60%. An operator increases the potentiometer setting to lower the level setpoint signal to a value previously known to maintain tank level at 50%. However, actual tank level stabilizes at 40%. The most likely cause is that

A. the potentiometer slide bar has developed a thin film of corrosion, thereby increasing the resistance of the potentiometer

B. the potentiometer wiper has lost contact with the slide bar, thereby allowing only fine setpoint adjustments

C. the potentiometer wiper and slide bar have developed a short circuit, thereby decreasing the resistance of the potentiometer

D. the potentiometer locking device has not been released, thereby allowing only coarse setpoint adjustments

87. The plant has experienced a loss of coolant accident with degraded safety injection flow. One reactor coolant pump is being operated continuously for core cooling. Core voiding is homogeneous and is currently 20%.

Which one of the following describes excore source/startup range neutron level indication as homogeneous core voiding increases from 20% to 100% of the core? (Assume neutron detectors are located adjacent to the bottom portion of the core.)

A. increases continuously
B. increases, then decreases
C. decreases continuously
D. decreases, then increases

88. In an ion chamber radiation detector, if the electric field strength is increased from the low to high end of the ion chamber region, the total number of ions collected
, and the ions collected in the ion chamber are
________ incident gamma radiation level.

A. increases, independent of

B. stays essentially the same, independent of

C. increases, proportional to

D. stays essentially the same, proportional to

89. A gas-filled radiation detector that is operating in the ionization region is exposed to a gamma radiation field. If the gamma radiation field is constant and the applied voltage is increased but maintained within the ionization region, the detector output will:

A. increase, because of an increase in secondary ionizations.

B. remain the same, because detector output is not affected by a change in voltage in this region.

C. increase, because of a decrease in recombination of primary ions.

D. remain the same, because the detector is already producing its maximum output.

90. Which one of the following materials is installed inside an ion chamber that is typically used for thermal neutron detection and reactor power indication?

A. polyethylene
B. boron-10
C. uranium-238
D. rhodium-103

91. The detection of neutrons with an ion chamber requires some type of special feature within the detector because neutrons are not directly ionizing particles. Which of the following is the special feature used to allow ion chamber neutron detection?

A. Line the inside of the detector with polyethylene.

B. Line the inside of the detector with boron-10.

C. Encapsulate the detector with polyethylene.

D. Encapsulate the detector with boron-10.

92. Which of the following describes the reason for the high sensitivity of a Geiger-Mueller tube radiation detector?

A. Changes in applied detector voltage have little effect on detector output.

B. Geiger-Mueller tubes are longer than other radiation detector types.

C. Any incident radiation event causing primary ionization results in ionization of the entire detector gas volume.

D. Geiger-Mueller tubes are operated at relatively low detector voltages, allowing detection of low energy radiation.

93. Geiger-Mueller tube radiation detectors are able to

A. discriminate between neutron and gamma radiation

B. discriminate between gammas of differing energies in the Mev range

C. provide increased output when applied voltage is increased

D. make use of gas amplification

94. Draw the gas-filled detector characteristic curve. Label the axes and identify each of six regions.

95. Describe how and why detectors operating in the ionization chamber region, the proportional region, and the Geiger-Mueller region respond to incident radiation. Explain the effect of increasing applied voltage within each region.

96. Scintillation detectors convert radiation energy into light by a process know as

A. gas amplification
B. space charge effect
C. luminescence
D. photoionization

97. Which of the following statements best describes how a proportional counter functions?

    A. Some of the ions from primary ionization are collected. No secondary ionizations take place.

    B. All of the ions from primary ionization are collected. No secondary ionizations take place.

    C. All of the ions from primary ionization along with some ions from secondary ionization are collected.

    D. All of the ions from primary ionization, secondary ionization, and Townsend avalanche are collected.

98. What design feature allows neutron detection by a proportional counter?

    A. detector outer surface lined with boron-10

    B. detector filled with BF_3 gas

    C. detector anode made of B_4C

    D. detector encased in borated polyethylene

99. A BF3 proportional counter detects both neutrons and gammas. Which of the following best describes the method used to eliminate the gamma contribution from the detector output?

    A. Two counters are used, one sensitive to neutron and gamma and the other sensitive to gamma only. The outputs are electrically opposed to cancel the gamma-induced currents and yield a neutron-only signal for indication use.

    B. The BF3 proportional detector records neutron flux of sufficient intensity that the gamma signal is insignificant compared to the neutron signal and yields a neutron-only signal for indication use.

    C. Gamma-induced detector pulses are of insufficient width to generate a significant log-level amplifier output. Neutron pulses are the only ones with sufficient width to yield a neutron-only signal for indication use.

    D. Neutron-induced current pulses are significantly larger than those from gamma. The detector signal is applied to a circuit which filters out the smaller gamma pulses yielding a neutron-only signal for indication use.

100. A BF_3 proportional counter can be used to measure the strength of a single kind of radiation even in a field with multiple kinds of radiation. This is done by applying the detector output signal to a circuit that filters out the smaller ______ pulses, yielding a _______-only signal for indication.

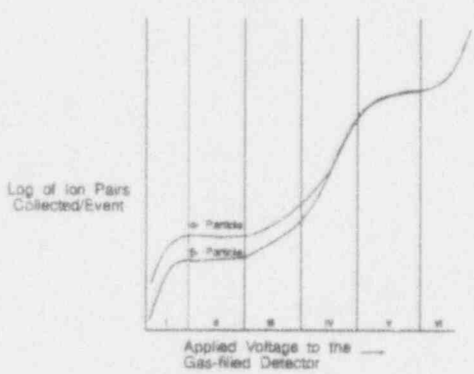
    A. gamma, neutron
    B. neutron, gamma
    C. beta, neutron
    D. neutron, beta

101. Refer to the drawing of a gas-filled detector characteristic curve (see Figure 1.2-10).

In a gas-filled radiation detector, operating in the "proportional" region, essentially ________ of the ions caused by incident radiation are collected and the number of ions collected from secondary ionizations is ______________ applied voltage.

A. all; independent of
B. none; related to
C. all; related to
D. none; independent of

FIGURE 1.2-10



Gas-filled Detector Characteristic Curve

102. The inner surface of a fission chamber is lined with ______ which allows neutron detection.

A. U_3O_8 - 90% enriched in U235

B. U_3O_8 - natural enrichment

C. Pu_3O_8 - 90% enriched in Pu239

D. Pu_3O_8 - natural enrichment

103. A fission chamber operates in which region of the gas-filled detector curve?

A. recombination
B. ion chamber
C. limited proportionality
D. Geiger-Mueller

104. Most of the electrons collected in a fission chamber are released as a result of ionizations caused directly by

A. fission fragments
B. fission gammas
C. fission betas
D. fissionable materials

105. Before using a portable survey instrument, four checks should be performed. Which of the following is not one of the typical pre-operational checks?

A. battery check
B. leak check
C. visual inspection
D. calibration date check

106. Which type of radiation detector should be used for a survey in a low gamma radiation area?

A. ion chamber
B. Geiger-Mueller tube
C. proportional counter
D. fission chamber

107. Which type of radiation detector is the most sensitive to low level gamma radiation?

A. ion chamber
B. Geiger-Mueller
C. proportional
D. fission chamber

108. Which of the following types of radiation is the major contributor to the dose indication on a self-reading pocket dosimeter (SRPD)? (also called SRD, PIC, and direct reading dosimeter)

A. alpha
B. beta
C. gamma
D. neutron

109. What method is used to determine the dose recorded by a thermoluminescent dosimeter (TLD)?

A. Hold the TLD up to the light and, through the lens, check the position of the fiber against an internal transparent scale.

B. Press the "read" button on the TLD and read the dose directly on the external digital readout.

C. Insert the TLD into a TLD reader which heats the TLD and measures the light emitted from the dosimeter.

D. Hold the TLD up to the light, and measure the degree of darkening of the TLD crystal.

110. Which of the following statements describes the use of a self-reading pocket dosimeter (SRPD)?

A. The indication from an SPRD is a dose rate in mr/hr.

B. SPRDs can be used to record beta and gamma radiation.

C. SRPDs hold their charge indefinitely when removed from a radiation field.

D. SRPD readings must be considered inaccurate when SRPDs are dropped.

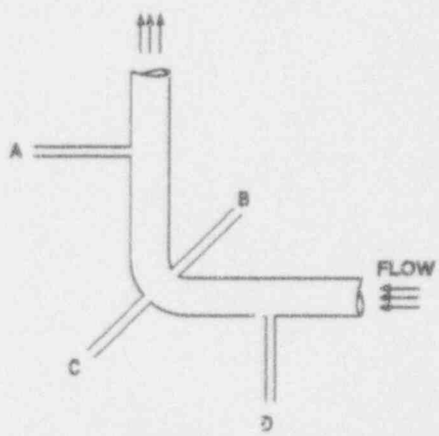
111. Refer to the drawing of a pipe elbow used for flow measurement in a cooling water system (see Figure 1.2-11).

A differential pressure (D/P) flow detector is connected to instrument lines B and C. Instrument lines A and D are sealed.

If instrument line B develops a leak, indicated flow rate will ____________ due to a ___________ measured D/P.

A. increase; larger
B. increase; smaller
C. decrease; larger
D. decrease; smaller

FIGURE 1.2-11



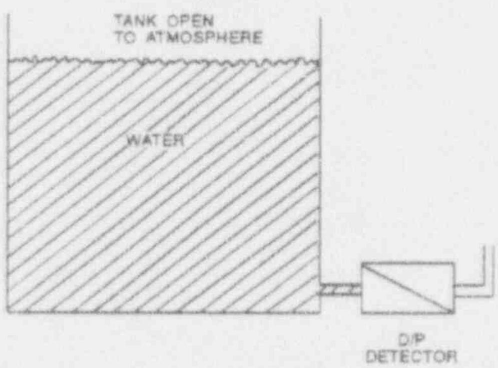
Pipe Elbow

112. Refer to the drawing of a tank differential pressure (D/P) level detector (see Figure 1.2-12).

The level detector is being used in a level control system that is calibrated to maintain tank level at 75% at the current water temperature of 120°F. If water temperature gradually decreases and stabilizes at 90°F, the level control system will cause actual tank level to:

A. remain at 75%
B. increase and stabilize above 75%
C. oscillate around 75%
D. decrease and stabilize below 75%

FIGURE 1.2-12



Tank Differential Pressure
Level Detector

113. A properly calibrated 0 to 100 psia diaphragm pressure detector is connected to a pressurized system and is vented to the atmosphere. It is currently producing a system pressure indication of 75 psia.

If the diaphragm ruptures, indicated pressure will be:

A. 0 psia
B. 15 psia
C. 60 psia
D. 100 psia

114. An automatic tank level controller uses a potentiometer for manual adjustment of the level setpoint which is currently 40 percent. An operator lowers the potentiometer setting to raise the level setpoint signal to a value previously known to maintain tank level at 50 percent. However, actual tank level stabilizes at 60 percent.

The most likely cause is that the potentiometer:

A. slide bar has developed a thin film of corrosion, thereby increasing the resistance of the potentiometer

B. wiper has lost contact with the slide bar, thereby allowing only fine setpoint adjustments

C. wiper and slide bar have developed a short circuit, thereby decreasing the resistance of the potentiometer

D. locking device has not been released, thereby allowing only coarse setpoint adjustments

115. A differential (D/P) detector is being used to measure main steam flow rate. At a steam flow rate of 10^6 lbm/hr measured D/P is 40 psid.

If steam flow changes such that current D/P is 30 psid, what is the current steam flow rate?

A. 4.79×10^5 lbm/hr
B. 5.63×10^5 lbm/hr
C. 7.52×10^5 lbm/hr
D. 8.66×10^5 lbm/hr

116. Which one of the following flow devices produces a relatively large differential pressure and is used in an operating fluid system when the resulting flow restriction is not a major concern?

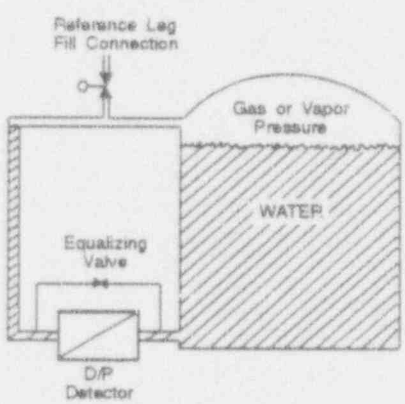
A. venturi
B. flow nozzle
C. pipe elbow
D. orifice

117. Refer to the drawing of a tank differential pressure (D/P) level detector (see figure 1.2-13):

The D/P sensed by the detector is __________ proportional to the __________of the water in the tank. (Assume a constant mass in the tank.)

A. directly; height
B. inversely; height
C. directly; temperature
D. inversely; temperature

FIGURE 1.2-13



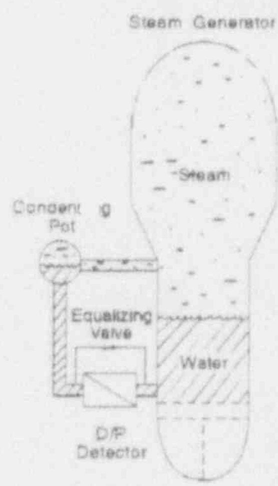
Tank Differential Pressure Level Detector

118. Refer to the drawing of a steam generator differential pressure level detector (see figure 1.2-14).

If reference leg flashing occurs during a rapid depressurization of the steam generator, indicated level will:

A. be greater than actual level
B. be less than actual level
C. remain constant at the actual level
D. slowly decrease to zero

FIGURE 1.2-14



Steam Generator Differential Pressure Level Dector

119. Refer to the drawing of a tank differential pressure level detector (see figure 1.2-15).

A calibrated differential pressure level detector is being used to measure level in a vented tank inside the auxiliary building. If building pressure increases with no change in temperature, the associated level indication will:

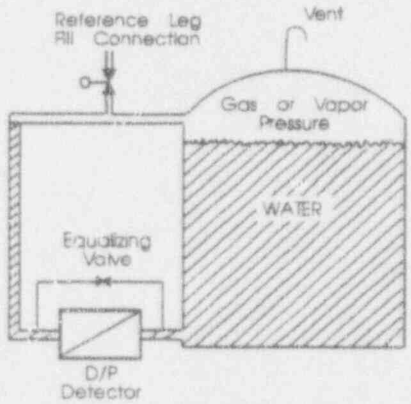
A. remain at the actual level

B. increase and stabilize above the actual level

C. decrease and stabilize below the actual level

D. decrease, then increase and stabilize at the actual level.

FIGURE 1.2-15



Tank Differential Pressure Level Detector

120. Refer to the drawing of a tank differential pressure level detector (see figure 1.2-16).

With a wet reference leg differential pressure level detector, which of the following occurrences will cause its level indicator to indicate the lowest level?

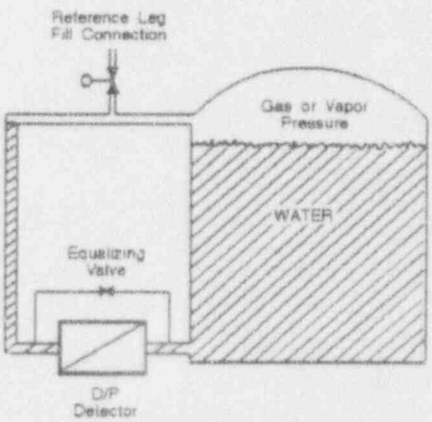
A. A break on the variable leg.

B. A break on the reference leg.

C. Reference leg flashing to steam.

D. Rupture of the diaphragm in the differential pressure cell.

FIGURE 1.2-16



Tank Differential Pressure Level Detector

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

If the density input to a density-compensated flow detector fails high, the instrument will see a higher flow for the same D/P across the flow restriction.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

2. C

Taking into account the density of a substance will allow a mass flow rate to be derived from a volumetric flowrate.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

3. B

Taking into account the density of a substance will change a volumetric flow rate to a mass flow rate calculation.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

4. C

Taking into account the density of a substance will change a volumetric flow rate to a mass flow rate calculation.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

5. C

If the density input on a density compensated flow detector fails low, the flow indicated by the detector will be less than actual flow.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

6. D

An increase in the density of a fluid at a given volumetric flow rate equates to an increase in mass flow rate.

Reference 02, pages 105 through 107; reference 30, chapter 25, pages 16 and 17.

7. A

Gas or steam bubbles in a liquid flow detector will cause fluctuations in the pressure which will be felt in the D/P cell. These fluctuations will be indicated as flow fluctuations.

Reference 31, chapter 12, page 197.

8. D

Gas or steam bubbles in a liquid flow detector will cause pressure fluctuations which will be felt by the D/P cell and indicated by fluctuations in indicated flow.

Reference 31, chapter 12, page 199.

9. D

Gas or steam bubbles in a liquid flow detector will cause pressure fluctuations which will be felt by the D/P cell and indicated by fluctuations in indicated flow.

Reference 31, chapter 12, page 199.

10. B

If the high pressure sensing line on a D/P flow detector leaks, the D/P between the high and low pressure tap will decrease indicating less flow.

Reference 31, chapter 12, page 199.

11. A

If the low pressure sensing line on a D/P flow detector leaks, the D/P between the high and low pressure taps will increase. This is due to the fact that the low pressure tap will read lower than normal. This increase in D/P will cause an indicated increase in flow.

Reference 31, chapter 12, page 199.

12. B

The rupture of the diaphragm in a D/P flow sensor will decrease the sensed D/P to zero. This will cause an indication of less flow.

Reference 31, chapter 12, page 198.

13. A

The differential pressure across the ruptured diaphragm will be zero, indicating zero flow.

14. C

Opening the equalizing line on a D/P flow detector will cause sensed D/P to go to zero. Therefore the indicated flow will be zero.

Reference 40, page 1-4-3.

15. B

If the orifice or flow nozzle in a D/P flow detector wears to a larger size, then the indicated flow will decrease slightly and level off due to the decrease in D/P across the orifice.

Reference 31, chapter 5, page 59.

16. D

The higher steam pressure input indicates that the steam's density has increased. For the same volume flow rate, a higher density results in a higher mass flow rate

17. C

A lower D/P will be generated across the eroded orifice, resulting in a lower indicated flow rate.

18. A

Debris lodged in the orifice will cause a greater pressure drop for a given flow. Therefore, a greater flow rate will be indicated.

19. C

A flow detector has a high pressure tap and a low pressure tap which develops a D/P. The flow velocity is directly proportional to the square root of the D/P.

Reference 31, chapter 5, page 198.

20. C

21. B

D/P is proportional to flow rate squared:

$$\frac{D/P_2}{D/P_1} = \frac{(flow_2)^2}{(flow_1)^2}$$

$$\frac{D/P_2}{60\ psid} = \frac{(1000\ gpm)^2}{(700\ gpm)^2}$$

$$= 2.04$$

$$D/P_2 = (60\ psid)\ (2.04)$$

$$= 122.4\ psid$$

22. D

The differential pressure across a venturi is proportional to the square of the flow. Because flow doubled, DP increased by two-squared, or a factor of four.

23. B

The low pressure tap in a venturi flow detector is located at the throat.

Reference 31, chapter 5, page 59.

24. A

The high pressure tap is located upstream of the convergent part of the nozzle.

Reference 31, chapter 5, page 59.

25. D

The increase in flow velocity is proportional to the square root of the D/P.

Reference 31, chapter 5, page 198.

26. C

The relationship for a D/P flow sensor is that D/P is proportional to V^2; therefore, if the velocity doubles, D/P would increase by 4.

Reference 31, chapter 12, page 197.

27. A

Reference 31, chapter 5.

28. A

Since no water was added or drained, the D/P cell sees no more mass (pressure) due to the fluid above it. The actual level surely goes up due to the decrease in density resulting from the higher temperature; however, the indicated level remains the same.

Reference 31, chapter 5, page 59.

29. C

Since no water was added or drained, the D/P cell sees no more mass (pressure) due to the fluid above it. The actual level surely goes up due to the decrease in density resulting from the higher temperature; however, the indicated level remains the same.

Reference 31, chapter 5, page 59.

30. C

Since no water was added or drained, the D/P cell sees no more mass (pressure) due to the fluid above it. The actual level surely goes up due to the decrease in density resulting from the higher temperature; however, the indicated level remains the same.

Reference 31, chapter 5, page 59.

31. B

Reference 31, chapter 5, page 59.

32. A

Reference 31, chapter 5, page 59.

33. D

Reference 31, chapter 5, page 59.

34. B

Reference 31, chapter 5, page 59.

35. A

Reference 31, chapter 5, page 59.

36. B

Reference 31, chapter 5, page 59.

37.

As tank temperature increases, liquid density decreases, resulting in decreasing pressure at the variable tap of the DP cell. In a dry reference leg detector, a decreasing variable leg pressure produces a decreasing level signal. Therefore, indicated level will decrease as tank temperature increases.

38. B

The D/P cell is the n ost commonly used level sensor. If the pressure generated by a known (fixed) height of liquid is compared to the pressure generated at the bottom of a tank, the difference of these pressures is inversely proportional to level of liquid in the tank.

Reference 53, chapter 2, page 87.

39. B

Opening the equalizing valve will cause the differential pressure across the D/P cell to fall to zero. A zero D/P is interpreted by the level instrument to mean tank level is the same as reference leg level. Therefore, indicated level would become greater than actual level.

Reference 53, chapter 2, page 87.

40. B

If tank temperature rises, the density of the water in the tank decreases, causing indicated level to decrease below 75%. The level control system will respond to the indicated level decrease by raising level. At the new steady-state, actual level will be greater than 75% while indicated level will equal 75%.

41. B

The wet reference leg provides a known height of liquid whose pressure is applied to one side of the DP cell. Tank level exerts a pressure on the other side of the cell. As tank level falls, the pressure decreases, causing the differential pressure to increase.

42. B

If the density of a liquid in a tank is less than one, then more water (volume) is needed in the tank as compared to liquid with a density of one to have the same level indication.

Reference 53, chapter 2, page 88.

43. D

The D/P cell is the most commonly used level sensor. The pressure generated by a known (fixed) height of liquid is compared to the pressure generated at the bottom of a tank (variable).

Reference 53, chapter 2, page 87.

44. D

The D/P cell is the most commonly used level sensor. The pressure generated by a known (fixed) height of liquid is compared to the pressure generated at the bottom of a tank (variable).

Reference 53, chapter 2, page 87.

45. D

The D/P cell is the most commonly used level sensor. The pressure generated by a known (fixed) height of liquid is compared to the pressure generated at the bottom of a tank (variable).

Reference 53, chapter 2, page 87.

46. A

An increase in ambient temperature will cause the density of the Reference leg of a D/P cell to decrease. This results in a lower D/P sensed by the D/P cell which results in a higher indicated level.

Reference 53, chapter 2, page 87.

47. C

Increasing ambient pressure has no effect on D/P cell level instruments because they are sealed.

Reference 53, chapter 2, page 88.

48. B

An increase in ambient temperature will cause the density of the Reference leg of a D/P cell to decrease. This results in a lower D/P sensed by the D/P cell which results in a higher indicated level.

Reference 53, chapter 2, page 87.

49. C

Decreasing ambient pressure has no effect on D/P cell level instruments because they are sealed.

Reference 53, chapter 2, page 87.

50. A

The density of the pressurizer water is less at normal operating temperature than when cold. Therefore, a given tank level produces less pressure on the variable leg side of the D/P cell, resulting in a larger differential pressure and lower indicated level.

51. B

Decreased atmospheric pressure results in lower pressures at the reference leg side of detectors 2 and 3, resulting in an increase in indicated level. Therefore, detectors 1 and 4 will indicate lower levels than detectors 2 and 3.

52. A

The elevated ambient temperature raises the temperature and decreases the density of the water in the reference legs, causing a reduction in accuracy of detectors 1 and 3.

53. B

A decrease in ambient temperature will cause the density of the Reference leg of a D/P cell to increase. This results in a higher D/P sensed by the D/P cell which results in a lower indicated level.

Reference 53, chapter 2, page 87.

54. D

A break in the variable leg of a D/P cell will result in a maximum D/P being sensed by the D/P cell. Therefore, the level instrument will indicate a low level.

Reference 53, chapter 2, page 87.

55. A

A break in the Reference leg of a D/P cell will result in a minimum D/P being sensed by the D/P cell and therefore the level instrument will indicate a level higher than actual level.

Reference 53, chapter 2, page 87.

56. B

A break in the variable leg of a D/P cell will result in an increase in the D/P being sensed by the D/P cell; therefore, the level instrument will indicate a level that is lower than actual level.

Reference 53, chapter 2, page 87.

57. A

A ruptured diaphragm of a D/P cell will result in a decrease in the D/P being sensed by the D/P cell; therefore, the level instrument will indicate a level that is higher than actual level.

Reference 53, chapter 2, page 87.

58. A

The density of the Reference leg fluid decreases when it flashes to steam. This results in a decrease in D/P as sensed by the D/P cell which results in a higher indicated level.

Reference 53, chapter 2, page 88.

59. C

A break in the variable leg of a D/P cell will result in a maximum D/P being sensed by the D/P cell; therefore, the level instrument will indicate a low level. All other choices result in a minimum D/P being sensed by the D/P cell; therefore, the level instrument would have indicated a high level.

Reference 53, chapter 2, page 87.

60. B

A decrease in reference leg temperature causes the density of the reference leg water to increase, thereby increasing the differential pressure and causing indicated level to fall.

A break in the variable leg reduces pressure on the low-pressure side of the D/P detector, increasing the differential pressure and causing indicated level to fall.

Reference 53, chapter 2, pages 87 and 88.

61. A

When an internal pressure is applied, the tip of the tube will straighten out. The motion of the tip varies with the exerted pressure and is calibrated in terms of pressure.

Reference 63, page 11-14.

62. B

The amount of expansion of the element is proportioned to the applied pressure. The axial deflection of the detector is used to generate meter movement.

Reference 63, pages 11-12 and 11-13.

63. D

Pressure is exerted evenly on the inside walls of a bourdon tube. However, because the area of the outer curve wall is greater than the inner curve wall area, more force is applied to the outer wall. Therefore, a pressure increase will tend to straighten the bourdon tube, decreasing its curvature.

64. A

65. C

If containment pressure rises by 40 psi, the detector responds as if system pressure had dropped by approximately 40 psi.

Reference 57, chapter 7, pages 14 and 15.

66. D

If containment pressure rises by 20 psi, the detector responds as if system pressure had dropped by approximately 20 psi.

Reference 57, chapter 7, pages 14 and 15.

67. D

If containment pressure increases, the detector responds as if process pressure had dropped.

Reference 57, chapter 7, page 15.

68. B

Bourdon tube pressure transmitters are usually made of materials with a very low temperature coefficient of expansion, hence a high temperature condition does not cause any variance in the dimensions of the bourdon tube. If containment pressure rises 40 psi, the detector indication drops by 40 psi. This error could be large at reduced system pressure (e.g. 100 psig). The detector output in this case is significantly reduced.

Reference 57, chapter 7, pages 14 and 15.

69. D

If the bourdon tube is overranged, pressure is applied to the point where it can no longer return to its original shape. Most gauges are designed to handle approximately 35% beyond upper range as overrange without damage. If a gauge is deformed, it does not return to its original shape; thus, the indication would return to some value greater than original.

Reference 02, chapter 2, page 47.

70. A

A diaphragm type pressure detector is extremely sensitive to overrange. The other long term difficulties occur when the diaphragm becomes stiff or develops leaks resulting in error.

Reference 02, chapter 2, page 46.

71. B

If a leak develops in the diaphragm, pressure across the diaphragm equalizes. This yields zero diaphragm deflection and zero pressure reading, assuming proper zero adjustment with both high and low pressure chambers vented to atmosphere.

Reference 02, chapter 2, pages 45 and 46.

72. B

73. A

Reference 02, chapter 2, page 47.

74. C

Resistance temperature detectors (RTDs) operate on the principle that the electrical resistance of a metal changes as the metal's temperature changes. Answers A and B introduce the concept of dissimilar metals, which has nothing to do with an RTD. Answer D is incorrect since electrical resistance increases with increasing molecular activity (directly related).

Reference 26, chapter 4.3, pages 118 through 128.

75. C

Resistance versus temperature curves for metals typically used in RTDs are very nearly linear; thus, directly proportional is the correct answer.

Reference 26, chapter 4.3, page 120.

76. A

77. C

RTDs are not simple to install because they require protection from rapidly moving fluids and a bridge circuit must be used to determine temperature with an RTD. RTDs are usually the most expensive of temperature measurement systems. RTDs have at best a 0.5 -5 second response time with considerably longer times in some applications. RTDs are, however, very accurate.

Reference 02, chapter 5, pages 126 through 148.

78. D

Thermocouples consist of two dissimilar metals, joined to produce a voltage or electromotive force when the junctions are at different temperatures.

Reference 02, chapter 5, pages 130 and 131.

79. A

Thermocouple EMF or voltage is directly proportional to the temperature difference between junctions. If the Reference junction temperature is held constant, then EMF is directly proportional to measuring junction temperature.

Reference 02, chapter 5, pages 132 and 133.

80. A

If an RTD fails open, the bridge develops a maximum output and indicates a maximum temperature.

Reference 57, chapter 6, page 10.

81. D

If an RTD shorts to ground, the bridge develops a minimum output and indicates a minimum temperature.

Reference 57, chapter 6, page 10.

82. B

If an open develops in a thermocouple circuit, no path for current flow exists. No current means failed low temperature indication.

Reference 02, chapter 5, pages 130 through 134.

83. A

A thermocouple operates on the principle that a voltage is developed when two dissimilar metals are joined and there is a temperature difference between that junction and a reference junction. The voltage produces a current, which falls to zero if an open circuit occurs.

Reference 02, pages 130 through 134.

84. A

The simplest and most common position sensor for full-open and full-shut indication is a pair of limit switches.

85. C

A linear variable-differential transformer (LVDT) uses an extension of the valve stem as an armature inside the transformer coils. Movement of the valve (and armature) changes the output voltage by changing the inductances of the coils, giving an analog position indication.

86. A

87. B

The number of neutrons reaching the excore detectors depends on two factors: neutron flux in the core, and neutron leakage from the core.

As voiding begins and progresses, the leakage of neutrons is increased by the removal of water from the core. This causes an increase in neutron level indication. However, as voiding progresses toward 100%, the core effective multiplication factor is reduced, causing a reduction of neutron flux and a corresponding decrease in neutron level indication.

88. D

In an ion chamber, the output signal is a function of the amount of primary ionization produced by the incident radiation. As the voltage is increased, detector output remains consta-'

Reference 60, pages 5-8, 5-13, and 5-14.

89. B

In an ion chamber, the output signal is a function of the amount of primary ionization produced by the incident radiation. As the voltage is increased, detector output remains constant.

Reference 60, pages 5-8, 5-13, and 5-14.

90. B

The detector must contain a material with which the neutron interacts and results in the production of ions. The most common target material is Boron. The Boron-10 component of an ion chamber detector is typically in the form of a coating on the inner wall of the detector.

Reference 60, pages 5-28 and 5-29.

91. B

The detector must contain a material with which the neutron interacts and results in the production of ions. The most common target material is boron. The boron-10 component of an ion chamber detector is typically in the form of a coating on the inner wall of the detector.

Reference 60, pages 5-28 and 5-29.

92. C

Any incident radiation event causing primary ionization in the tube results in the ionization of the entire gas volume. This characteristic makes the detector highly sensitive.

Reference 60, pages 5-28 and 5-29.

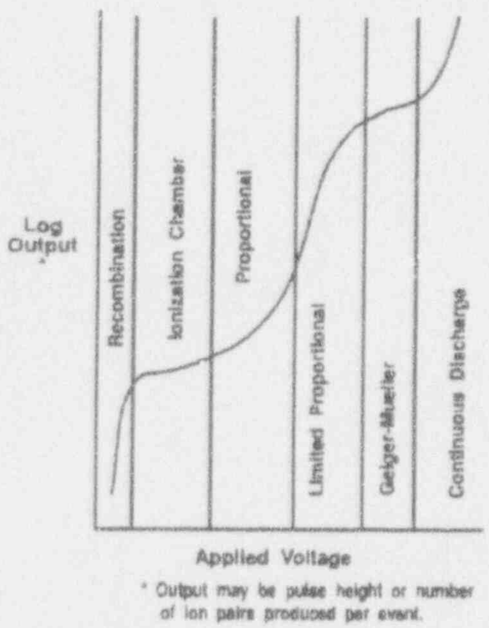
93. D

Answers A, B, and C are all just the opposite of actual G-M tube characteristics. Although it is very sensitive to radiation, a G-M tube cannot discern the energy of the radiation event. The tube simply counts events.

Reference 60, pages 5-28 and 5-29.

94. B

FIGURE 1.2-17



Reference 60, page 5-7.

95.

In all regions, incident radiation interacts with the gas in the detector to produce ion pairs.

Ionization Chamber Region - The ion pairs produced by the incident radiation are all collected on the detector electrodes. However, the applied voltage and resultant ion acceleration are too low to cause secondary ionization. Therefore; increasing voltage will not affect detection output.

Proportional Region - The voltage applied to the detector is adequate to accelerate primary ion pairs enough to cause additional (secondary) ionization. This results in "gas amplification," in which each primary ion pair creates additional ions, amplifying the resultant output. The higher the applied voltage, the greater the gas amplification.

Geiger-Mueller Region - The applied voltage is so high that any ionizing event caused by incident radiation results in complete ionization of the detector gas. Further increases in voltage in the G-M region therefore produces no additional output.

Reference 60, pages 5-8 and 5-9.

96. C

Scintillation detectors operate on the principle of luminescence.

Reference 60, page 5-45.

97. C

Secondary ionization occurs in a proportional counter. The production of secondary ions adds to the total charge collected on the electrodes.

Townsend avalanche is a phenomenon occurring in the limited proportional and Geiger-Muller regions of the gas-filled detector curve and does not apply to a proportional counter.

Reference 60, pages 5-8 and 5-9.

98. B

The BF3 proportional counter operates in the proportional region of the gas-filled detector characteristic curve. It employs a cylindrical detector filled with BF3 gas. Neutrons interact with boron atoms to produce charged particles which produce gas ionization inside the detector.

Reference 60, page 5-21.

99. D

Answer A describes a compensated ion chamber.

Answer B applies to an uncompensated ion chamber.

Answer C is not applicable to any detector.

In a BF3 proportional counter, neutron-induced pulses have a greater amplitude than gamma-induced pulses. To accurately measure neutron flux only, the gamma pulses are electronically removed with a discriminator circuit allowing pulses greater than some minimum limit to pass through the circuitry.

Reference 60, pages 5-22 and 5-23.

100. A

In a BF3 proportional counter, neutron-induced pulses have a greater amplitude than gamma-induced pulses. To accurately measure neutron flux only, the gamma pulses are electronically removed with a discriminator circuit allowing pulses greater than some minimum limit to pass through the circuitry.

Reference 60, pages 5-22 and 5-23.

101. C

Reference 60, page 5-8.

102. A

The fission chamber employs U_3O_8 enriched to about 90% U-235.

Reference 60, page 5-43.

103. B

A fission chamber operates in the ion chamber region.

Reference 60, page 5-43.

104. A

The major source of ionization in a fission chamber is the charged fission fragments produced when an incident neutron causes fission of the uranium in the fission chamber.

105. B

Prior to using a portable survey instrument, four checks should be performed: battery check, calibration date check, visual inspection, and source check.

Reference 60, page 5-57.

106. B

Answers A B, & C are all gas-filled detectors of which the G-M tube is the most sensitive. A fission chamber is clearly unacceptable for portable radiation monitor use. The most widely used survey meter for low intensity beta and gamma radiation fields is a G-M tube.

Reference 60, page 5-34.

107. B

Reference 60, page 5-34.

108. C

Reference 60, pages 5-32 and 5-33.

109. C

The TLD crystal is heated under controlled conditions and the amount of light emitted is measured. This process is performed by a TLD reader providing a digital display of the radiation exposure and a strip chart recording of the reading process.

Reference 60, pages 5-50 and 5-51.

110. D

SRPDs are subject to discharge and erroneous readings if dropped or jarred.

Reference 60, pages 5-32 and 5-33.

111. A

112. D

Since there is no mass change, the level detector senses no change in water level. However, due to increasing water density, actual level decreases.

113. B

114. C

115. D

$(D/P_2) / (D/P_1) = (flow_2)^2 / (flow_1)^2$

$30 / 40 = (flow_2)^2 / (10^6)^2$

$30 / 40 \times (10^6)^2 = (flow_2)^2$

$[30 / 40 \times (10^6)^2]^{1/2} = flow_2$

$flow_2 = 8.66 \times 10^5$

116. D

117. B

118. A

119. A

120. A

SENSORS AND DETECTORS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.02 Questions 1,2

Describe the operation of density compensating flow detectors.

K1.02 Questions 3,4

State the reason for using density compensation in flow detectors.

K1.02 Questions 5,6

Describe the operation of density compensating flow detectors.

K1.03 Questions 7-9

Identify the effects of vapor or gas in a liquid D/P detector on liquid flow rate indication.

K1.04 Questions 10-18, 111

Identify the possible causes and effects on indication of flow detector or sensor failures.

K1.05 Questions 19-27, 115-116

Explain the operation of a D/P type flow detector.

K1.06 Questions 28-37, 112

Describe the effects of varying temperature on level indication from a differential pressure level transmitter.

K1.07 Questions 38-45, 117

Describe the theory and operation of level detectors.

K1.08 Questions 46-53, 118-119

Identify the effects of environmental operating conditions (pressure/temperature) on various types of level indications.

K1.09 Questions 54-60, 114, 120

Identify the cause of failures of level detectors and the effects on level indication.

K1.10 Questions 61,63

State the basic principles of operation of bourdon tube pressure detectors.

K1.10 Question 62

State the basic principles of operation of a diaphragm type pressure detector.

K1.10 Question 64

Identify an application of semiconductor strain gages.

K1.11 Questions 65-68

State the effects of an adverse operating environment on pressure detectors.

K1.12 Questions 69-73, 113

Given a normally operating pressure detector, identify the potential causes and effects on indication of pressure detector failure.

K1.13 Questions 74-77

State the basic principles of operation of a resistance temperature detector (RTD), including its advantages and disadvantages.

K1.13 Questions 78,79

State the basic principles of operation of a thermocouple including its advantages and disadvantages.

K1.14 Questions 80-83

State the effect on indicated temperature of various thermocouple and resistance temperature detector malfunctions.

K1.16 Questions 84-86

Select the appropriate position-indicating sensor for a particular application.

K1.17 Question 87

Describe effects of core voiding on neutron detection.

K1.18 Questions 88-93

State the basic principles of operation of an ion chamber radiation detector.

K1.18 Questions 94,95

Draw, label, and explain the gas-filled detector characteristic curve.

K1.18 Question 96

State the basic principles of operation of a scintillation radiation detector.

K1.18 Questions 97-101

State the basic principles of operation of a proportional counter radiation detector.

K1.18 Questions 102-104

State the basic principles of operation of a fission chamber radiation detector.

K1.19 Questions 105-110

State the proper methods for using portable/personal radiation monitoring instruments.

K1.20 No questions

Principles of operation of failed-fuel detectors are addressed under K1.18.

CONTROLLERS AND POSITIONERS
Questions

1. Flow controllers use the _______ method of control.

   A. open-loop
   B. on-off
   C. closed-loop
   D. external regulating

2. The difference between setpoint and the measured parameter value in an automatic flow controller is called

   A. gain
   B. bias
   C. feedback
   D. error

3. An automatic flow controller is being used to position a valve in a cooling water system. The controller demand signal is being increased in magnitude to drive the valve operator.

   The factor by which the magnitude of the demand signal is increased is referred to as

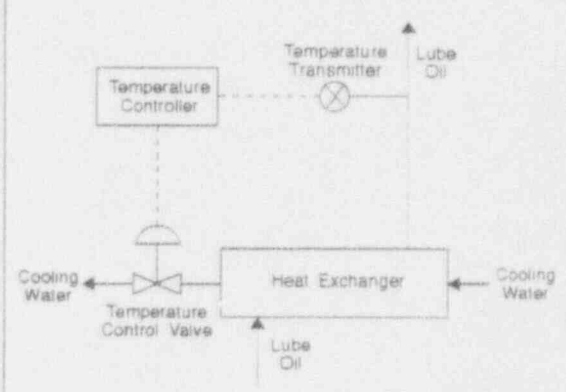
   A. gain
   B. bias
   C. feedback
   D. error

4. Refer to the drawing of a lube oil temperature control system (see figure 1.3-1)

   If the temperature transmitter fails high (high temperature output signal), the temperature controller will __________ the temperature control valve, causing the actual heat exchanger lube oil outlet temperature to __________.

   A. open; decrease
   B. open; increase
   C. close; decrease
   D. close; increase

FIGURE 1.3-1



Lube Oil Temperature Control System

5. If a flow controller is in manual, the flow is controlled by the

   A. operator
   B. setpoint
   C. gain
   D. error

6. If the turbine shaft speed signal received by a typical turbine governor control system fails low during turbine startup, the turbine governor will cause turbine speed to

   A. increase, until an upper limit is reached or the turbine trips on overspeed

   B. decrease, until the mismatch with demanded turbine speed is nulled

   C. increase, until the mismatch with demanded turbine speed is nulled

   D. decrease to a minimum speed setpoint

7. The range of values around the setpoint of a measured variable where no action occurs in an automatic flow controller is defined as

   A. deviation
   B. error
   C. deadband
   D. bias

8. The purpose of a valve positioner in a typical pneumatic control system is to

   A. provide feedback to determine actual valve position

   B. position the controlling solenoid valve

   C. compare control output signal and setpoint error, and adjust valve operator air supply to position the valve

   D. compare control output signal and valve position and adjust valve operator air supply to position the valve

9. Refer to the drawing of a pneumatic control system (see figure 1.3-2). The purpose of the valve positioner is to convert

   A. a small control air pressure into a proportionally larger air pressure to adjust valve position

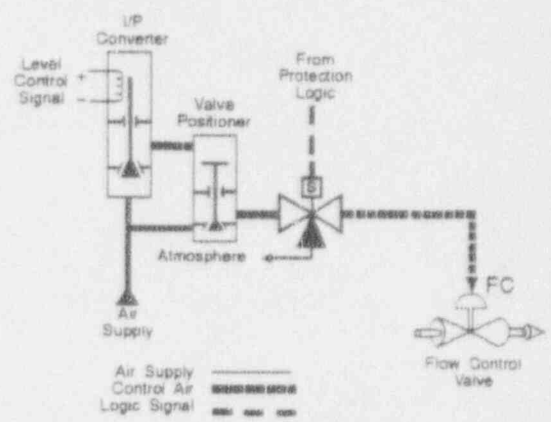
   B. a large control air pressure into a proportionally smaller air pressure to adjust valve position

   C. pneumatic force into mechanical force to adjust valve position

   D. mechanical force into pneumatic force to adjust valve position

10. Refer to the drawing of a pneumatic control system (see figure 1.3-2).

FIGURE 1.3-2



Pneumatic Control System - PWR

An increasing steam generator (S/G) level will decrease the S/G level control signal and reduce the control air pressure applied to the feed control valve which reduces feedwater flow to the S/G. If the control signal is manually increased, how will the pneumatic control system affect steam generator level?

   A. Level will increase because the valve positioner will open more.

   B. Level will decrease because the valve positioner will open more.

   C. Level will increase because the valve positioner will close more.

   D. Level will decrease because the valve positioner will close more.

11. The position of a typical air-operated isolation valve changes by energizing a solenoid that:

    A. energizes an air motor to open or close the valve

    B. lines up or removes control air to a pilot valve

    C. lines up or removes control air to a modulating manifold

    D. lines up or removes control air to the valve operator

12. Pneumatic valve positioners

    A. apply air pressure to controllers to operate valves in response to auto and manual demands

    B. supply air pressure to operate valves in response to a control signal

    C. can either receive or supply air to controllers, depending on the direction of valve travel

    D. act independently of the controller, in order to prevent pressure transients on the actuator diaphragm

13. The output pressure of a pneumatic controller is typically insufficient to drive a valve actuator accurately. To overcome this problem, a control loop would normally employ a

    A. valve actuating lead/lag unit
    B. pressure regulator
    C. valve positioner
    D. pressure modulator

14. An emergency diesel generator (D/G) is the only power source connected to its emergency bus. The governor of the D/G directly senses D/G __________ and directly adjusts D/G __________ flow to maintain a relatively constant D/G frequency.

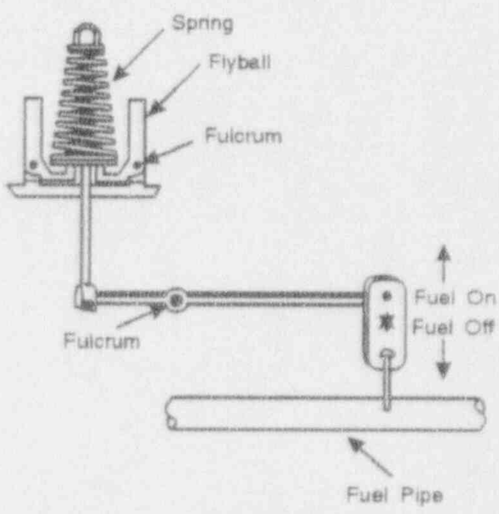
    A. load; air
    B. speed; fuel
    C. load; fuel
    D. speed; air

15. Refer to the drawing of a flyball-weight mechanical speed governor (see figure 1.3-3)

    In a flyball-weight mechanical speed governor, the purpose of the spring on the flyball mechanism is to __________ centrifugal force by driving the flyballs __________.

    A. counteract; apart
    B. aid; together
    C. counteract; together
    D. aid; apart

FIGURE 1.3-3



Flyball Weight Mechanical Speed Governor

16. An automatic tank level controller uses a potentiometer for manual adjustment of the level setpoint which is currently 60 percent. An operator increases the potentiometer setting to lower the level setpoint signal to a value previously known to maintain tank level at 50 percent. However, actual tank level stabilizes at 40 percent. The most likely cause is that

    A. the potentiometer slide bar has developed a thin film of corrosion, thereby increasing the resistance of the potentiometer

    B. the potentiometer wiper has lost contact with the slide bar, thereby allowing only fine setpoint adjustments

    C. the potentiometer wiper and slide bar have developed a short circuit, thereby decreasing the resistance of the potentiometer

    D. the potentiometer locking device has not been released, thereby allowing only coarse setpoint adjustments

17. The output signal from a proportional controller is proportional to the

    A. bias
    B. deadband
    C. deviation
    D. setpoint

18. In describing a proportional controller, the term "offset" refers to the difference between the

    A. setpoint and deadband
    B. control point and setpoint
    C. proportional band and control point
    D. deadband and proportional band

19. Which one of the following describes the response of a direct acting proportional-integral controller, operating in automatic, to an increase in the controlled parameter above the controller setpoint?

    A. The controller will develop an output signal that continues to increase until the controlled parameter equals the controller setpoint, at which time the output signal becomes constant.

    B. The controller will develop an output signal that will remain directly proportional to the difference between the controlled parameter and the controller setpoint.

    C. The controller will develop an output signal that continues to increase until the controlled parameter equals the controller setpoint, at which time the output signal becomes zero.

    D. The controller will develop an output signal that will remain directly proportional to the rate of change of the controlled parameter.

20. The level in a tank is controlled by an automatic control system. Level is initially at its setpoint. A drain valve is then opened, causing tank level to begin to decrease. The decreasing level causes the controller to begin to open a makeup supply valve. After a few minutes, a new, steady-state tank level below the original level is observed, with the supply rate equal to the drain rate.

    The controller in this system uses ______ control.

    A. on-off
    B. proportional
    C. derivative (rate)
    D. integral (reset) plus derivative (rate)

21. The level in a tank is controlled by an automatic control system. Level is initially at its setpoint. A drain valve is then opened, causing tank level to begin to decrease. The decreasing level causes the controller to begin to open a makeup supply valve. After a few minutes, with the drain valve still open, level is again constant at the setpoint.

    The controller in this system uses ______ control.

    A. on-off
    B. proportional
    C. integral (reset)
    D. derivative (rate)

22. What precaution must be observed when transferring a valve controller from the automatic mode to manual mode of control?

    A. ensure that the proper offset is established between the automatic mode and manual mode

    B. ensure that the valve controller output signals are matched between automatic mode and manual mode

    C. ensure that the automatic valve controller signal is decreasing before transferring to the manual mode of control

    D. ensure that the automatic valve controller signal is increasing before transferring to manual mode of control

23. A transfer that avoids a perturbation during an automatic-to-manual or manual-to-automatic transfer by matching the controller output signals between automatic and manual control is called

    A. a minimum offset transfer
    B. a deadband transfer
    C. an analog to digital transfer
    D. a bumpless transfer

24. Why must an operator pay particular attention to auto/manual valve controllers placed in the manual mode?

    A. Manual valve controller operation can result in excessive valve cycling.

    B. Valve position will no longer automatically change in response to changes in system parameters.

    C. System parameters will no longer automatically change in response to changes in valve position.

    D. The valve can only be operated locally during manual controller operation.

25. When shifting from automatic to manual valve control, the manual and automatic output signals should be matched to

    A. prevent a sudden valve repositioning upon the transfer

    B. ensure the valve will operate upon demand

    C. move the valve to the new position prior to the transfer

    D. ensure valve position indication is accurate

26. Which one of the following describes the response of a direct acting derivative controller, operating in automatic, to an increase in the controlled parameter above the controller setpoint?

    A. The controller will develop an output signal that continues to increase until the controlled parameter equals the controller setpoint, at which time the output signal becomes constant.

    B. The controller will develop an output signal that will remain directly proportional to the difference between the controlled parameter and the controller setpoint.

    C. The controller will develop an output signal that continues to increase until the controlled parameter equals the controller setpoint, at which time the output signal becomes zero.

    D. The controller will develop an output signal that will remain directly proportional to the rate of change of the controlled parameter.

27. An air-operated isolation valve requires 4,800 lbf from its diaphragm actuator and 4 inches of stem travel for proper operation. The air supply system can provide up to 80 psig of air pressure to the actuator.

    What is the minimum surface area of the actuator diaphragm required for proper valve operation?

    A. 15 square inches
    B. 60 square inches
    C. 120 square inches
    D. 240 square inches

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

Most controllers use a feedback circuit from the sensor to tell the controller when the setpoint is reached. This is called a closed loop.

Reference 02, chapter 1, page 3.

2. D

Reference 02, chapter 1, page 3.

3. A

Reference 02, chapter 1, page 3.

4. A

Reference 02, chapter 1, page 3.

5. A

If a controller is in manual, the operator will control the process by opening or closing the valve in manual.

Reference 02, chapter 1, page 4.

6. A

Reference 02, chapter 1, pages 3,4.

7. C

Reference 02, chapter 1, page 3.

8. D

Control air does not move the diaphragm directly, but controls application of a higher volume source of air.

Reference 02, chapter 10, page 261.

9. A

Reference 02, chapter 10, pages 261-263.

10. A

Reference 02, chapter 10, pages 261-263.

11. D

Solenoid air-operated valves are positioned using electric current to a coil to move a slug that lines up air to open or close the valves.

Reference 02, chapter 10, page 261.

12. B

Positioners apply varying pressures to the diaphragm of the valve actuators in direct response to the output of controllers. They do not drive controllers. Pressure variations on the valve actuator diaphragm are the basis of valve motion.

Reference 02, chapter 10, page 261.

13. C

Valve positioners can be used to reposition actuators with higher driving requirements than a controller's normal output pressure or pressure range.

14. B

The frequency of the electric power produced in a diesel generator depends on the speed of the generator (and, hence, of the diesel). The governor controls fuel flow to maintain the correct diesel speed.

15. C

16. A

17. C

Reference 02, page 20, and reference 40, page 5.2-3.

18. B

Reference 02, page 20, and reference 40, page 5.2-3.

19. A

Reference 02, chapter 1, pages 18-30.

20. B

An on-off controller would not attain a steady-state level as long as the demand existed. A reset (or rate plus reset) controller would return the level to the setpoint.

Reference 40, page 5.2-3 through 5.3-3.

21. C

Of the choices, only reset control results in returning the parameter to its setpoint while demand continues.

Reference 02, pages 23 through 25.

22. B

A bumpless transfer is the avoidance of a bump or shock during an automatic-to-manual or manual-to-automatic transfer by matching the controller signals between automatic and manual control.

Reference 40, chapter 5, page A-3.

23. D

A bumpless transfer is the avoidance of a bump or shock during an automatic-to-manual or manual-to-automatic transfer by matching the controller signals between automatic and manual control.

Reference 40, chapter 5, page A-3.

24. B

In manual, the valve will only respond to manual demands. The system parameters will have no effect on the valve controls. However, the system, of course, will be affected by position of the valve.

Reference 02, chapter 9, page 247.

25. A

Reference 55, chapter 16, page 20.

26. D

27. B

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01, 1.02, 1.03, 1.04 Questions 1-7

Explain the function and operation of a flow controller when in manual and automatic modes.

K1.05 Questions 8-13, 27

Describe the function and characteristics of valve positioners.

K1.06, 1.02 Question 14, 15

Explain the operation of diesel generator governors.

K1.08 Question 16

Explain failure and degradation modes of level controllers.

K1.09 Questions 17-19

Identify terms used in describing controllers.

K1.09 Questions 20, 21, 26

Differentiate between the response of proportional, integral (reset), and derivative (rate) controllers.

K1.10 No questions

Questions related to air-operated valves are located under "Valves."

K1.11, 1.03, 1.07 Questions 22-25

Describe the precautions associated with transferring a valve controller from automatic to manual, or manual to automatic.

1. Which of the following is an indicator of pump cavitation?

   A. Pump motor amps are pegged high.
   B. Pump discharge pressure indicates zero.
   C. Pump motor amps are oscillating.
   D. Pump discharge pressure indicates shut-off head.

2. An indication of centrifugal pump cavitation is

   A. pump motor amps high with discharge pressure low

   B. pump motor amps high with discharge pressure high

   C. pump flow low with discharge pressure low

   D. pump flow low with discharge pressure high

3. The formation of vapor bubbles that subsequently collapse and cause pitting to a pump's impeller is known as

   A. vapor binding
   B. overheated bearings
   C. water hammer
   D. cavitation

4. Pump cavitation occurs when vapor bubbles are formed at the eye of a pump impeller

   A. when the localized flow velocity exceeds sonic velocity for the existing fluid temperature

   B. when the localized pressure exceeds the vapor pressure for the existing fluid temperature

   C. and enter a high pressure region of the pump where they collapse causing damaging pressure pulsations

   D. and are discharged from the pump where they collapse in downstream piping causing damaging pressure pulsations

5. Which one of the following is a symptom associated with cavitation of a centrifugal pump?

   A. decreased motor current and pump speed

   B. decreased pump and motor temperature

   C. steadily increasing discharge pressure

   D. increased noise and vibration

6. Select the statement that describes pump cavitation.

   A. Vapor bubbles are formed when the enthalpy difference between pump discharge and pump suction exceeds the latent heat of vaporization.

   B. Vapor bubbles are formed and enter a high pressure region where they collapse.

   C. Vapor cavities are produced when the localized pressure exceeds the vapor pressure at the existing temperature.

   D. Vapor bubbles are discharged from the pump where they impinge on downstream piping and cause a water hammer.

7. Which of the following changes in pump operating parameters will lead to pump cavitation in a centrifugal pump that is operating at rated conditions in an open system?

   A. steadily increasing pump inlet temperature

   B. steadily decreasing pump speed

   C. steadily increasing pump suction pressure

   D. steadily decreasing pump recirculation flow

8. To minimize the possibility of cavitation when starting a centrifugal pump,

   A. ensure net positive suction head is adequate

   B. ensure the discharge valve is open

   C. ensure the pump has been adequately vented

   D. ensure the pump suction valve is closed

9. The presence of air in a pump casing may result in ___________ when the pump is started.

   A. vortexing
   B. pump runout
   C. pump overspeed
   D. gas binding

10. Air binding in a centrifugal pump is an undersirable condition which may be avoided by

   A. opening the pump constant vent valve when the pump is secured

   B. closing the pump constant vent valve when the pump is in operation

   C. opening the pump casing vent valve, while priming the pump, until a steady stream of water appears

   D. opening the pump suction vent valve just prior to starting the pump and then closing it after the pump is running

11. Gas binding in a centrifugal pump can be prevented by

   A. venting the pump prior to pump start

   B. lowering suction pressure prior to pump start

   C. increasing pump speed gradually during pump start

   D. shutting the discharge valve prior to pump start

12. A centrifugal pump is started and the following indications are observed: oscillating flow, oscillating discharge pressure, and oscillating amps. This indicates that the pump is experiencing

   A. excessive thrust
   B. cavitation
   C. runout
   D. wear ring failure

13. A centrifugal pump is being returned to service after maintenance. The operator fails to vent the pump properly. When the pump is started the operator should see ___________ capacity and _______ discharge head.

   A. lower; lower
   B. lower; higher
   C. higher; lower
   D. higher; higher

14. Gas binding in a centrifugal pump is a condition in which the pump:

    A. is operating at maximum capacity

    B. volute is filled with steam or air

    C. rotor is locked in place by the buildup of gases in the pump casing

    D. available net positive suction head (NPSH) exceeds required NPSH

15. Which of the following conditions describes shutoff head for a centrifugal pump?

    A. The volumetric flow rate at a given pump differential pressure has been maximized.

    B. Cavitation will occur upon reaching shut-off head.

    C. Available net positive suction head is at a maximum level.

    D. Pump differential pressure is at a maximum value.

16. A centrifugal pump may have to be shut off when system pressure is above pump shut-off head to prevent

    A. bursting of the pump casing by subjecting it to high pressure

    B. possible overheating of the pump due to insufficient flow through it

    C. water hammer in downstream lines when system pressure drops to a value where the pumps can inject water

    D. inadvertent injection of fluid if system pressure decreases

17. Operating a centrifugal pump at shutoff head without recirculation flow can directly result in

    A. discharge piping overpressurization
    B. suction piping overpressurization
    C. excessive pump leakoff
    D. pump overheating

18. A motor-driven centrifugal pump is operating under no flow conditions. Which of the following damaging conditions will first occur during pump operation with no flow?

    A. pump failure from overspeed
    B. pump failure from overheating
    C. motor failure from overspeed
    D. motor failure from overheating

19. A centrifugal pump with no recirculation flow path must be stopped when discharge pressure reaches pump shutoff head to prevent

    A. bursting of the pump casing by subjecting it to excessively high pressure

    B. water hammer in downstream lines when system pressure drops to a value where the pumps can inject water

    C. overheating of the motor

    D. overheating of the pump

20. In Figure 1.4-1, the flowpath through valve "A" is designed to

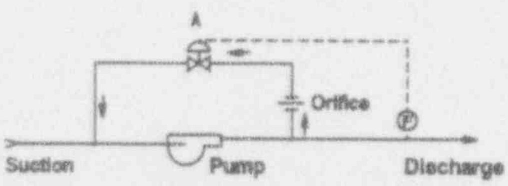
    A. provide minimum recirculation flow through the pump during shutoff head conditions

    B. prevent pump runout by creating a recirculation flowpath

    C. direct a small amount of water to the pump suction to raise available net positive suction head

    D. prevent discharge piping from exceeding pressure limits during no-flow conditions

FIGURE 1.4-1

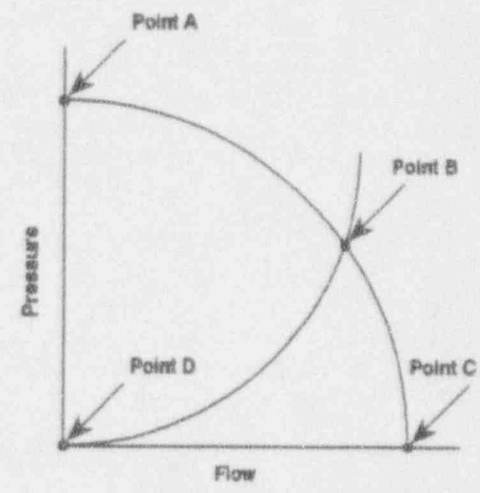


Centrifugal Pump

21. Refer to the drawing of the centrifugal pump and system characteristic curves (see Figure 1.4-2). Which point represents the pump's shutoff head?

    A. point A
    B. point B
    C. point C
    D. point D

FIGURE 1.4-2



Centrifugal Pump and System Characteristic Curves

22. When a centrifugal pump is opeating at shutoff head, it is pumping at ________ capacity and ________ discharge head.

    A. maximum, minimum
    B. maximum, maximum
    C. minimum, maximum
    D. minimum, minimum

23. Shutting the discharge valve on an operating centrifugal pump will cause the motor amps to ________ and the pump discharge pressure to ________.

    A. increase, increase
    B. decrease, increase
    C. increase, decrease
    D. decrease, decrease

24. An operator is sent to make an inspection of a service water pump 5 minutes after starting. He notices the pump casing is extremely hot, pump noise level is abnormally high, and pump flow rate is erratic and lower than expected. Which of the following could not cause these indications?

    A. cavitation of the pump

    B. operation with discharge valve closed and recirculation line isolated

    C. air binding of the pump

    D. operation at pump runout

25. In Figure 1.4-3, the available net positive suction head for a centrifugal pump may be increased by

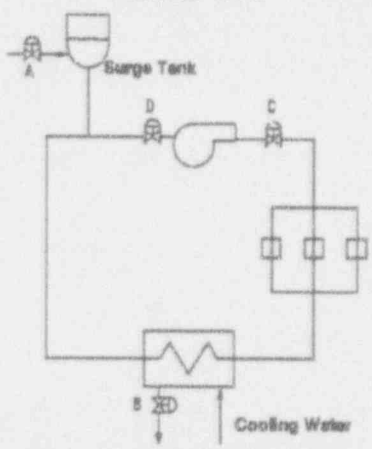
    A. opening surge tank makeup valve "A" to raise tank level

    B. throttling heat exchanger cooling water valve "B" closed

    C. throttling pump discharge valve "C" open

    D. throttling pump suction valve "D" closed

FIGURE 1.4-3



Basic System

26. Which one of the following operations will cause a decrease in available net positive suction head for a centrifugal pump?

    A. decreasing the inlet fluid temperature
    B. increasing the pump discharge pressure
    C. throttling shut the pump discharge valve
    D. throttling open the pump discharge valve

27. A motor-driven centrifugal pump is operating at rated flow, then the discharge valve is throttled shut. Which of the following parameters will increase as a result of this action?

    A. volumetric flow
    B. NPSH available
    C. motor current
    D. NPSH required

28. The net positive suction head for a pump may be expressed as

    A. discharge pressure minus saturation pressure of the fluid being pumped

    B. discharge pressure minus suction pressure

    C. suction pressure minus saturation pressure of the fluid being pumped

    D. suction pressure plus fluid vapor pressure

29. When a centrifugal pump is started, the response of motor current should be

    A. low starting amps, increasing to a higher equilibrium running amperage

    B. low starting amps, remaining at a low equilibrium running amperage

    C. high starting amps, decreasing to a lower equilibrium running amperage

    D. high starting amps, remaining at a high equilibrium running amperage

30. A pump is circulating 200°F water in a closed system equipped with a surge tank. Several hours later, after system cooldown and no lineup changes, the pump is circulating 120°F water.

    During the system cooldown, pump motor current has:

    A. decreased because water density has increased

    B. increased because water density has increased

    C. increased because pump motor efficiency has decreased

    D. increased because pump motor efficiency has decreased

31. Which of the following operating conditions for a centrifugal pump would require the most amperage?

    A. Discharge head is at shutoff head.
    B. The pump is operating at minimum flow.
    C. Discharge head is at design head.
    D. The pump is at runout.

32. A constant-speed centrifugal pump motor draws the <u>least</u> current when the pump is

    A. at runout conditions
    B. at operating conditions
    C. accelerating to normal speed during start
    D. at shutoff head

33. Throttling closed the discharge valve of an operating centrifugal pump will cause motor current to

    A. increase

    B. decrease

    C. increase briefly, then return to original value

    D. decrease briefly, then return to original value

34. A centrifugal pump is circulating water at 100°F in a cooling water system. After several hours the water temperature has increased to 150°F. Assuming system flow rate (gpm) is constant, pump motor amps will have __________ because __________ .

    A. decreased; water density has decreased
    B. increased; water density has decreased
    C. decreased; water volume has increased
    D. increased; water volume has increased

35. Many large centrifugal pumps are started with their discharge valves closed in order to prevent

    A. loss of recirculation (mini flow)
    B. overloading the pump motor
    C. cavitation in the pump
    D. lifting the discharge relief valve

36. Explain why some centrifugal pumps are typically started only when their discharge valves are closed.

37. The major effect of operating centrifugal pumps in parallel is

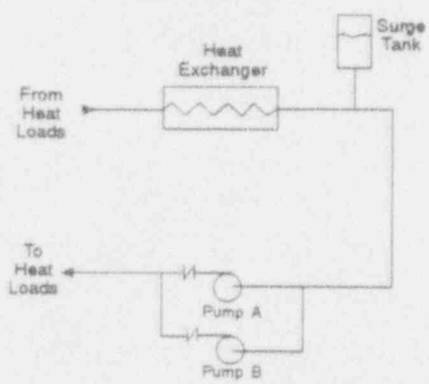
    A. increased system pressure
    B. increased system flow rate
    C. decreased system pressure
    D. decreased system flow rate

38. Refer to the drawing of a cooling water system and the associated centrifugal pump operating curve (see Figure 1.4-4) in which pumps A and B are identical single-speed centrifugal pumps and only pump A is operating.

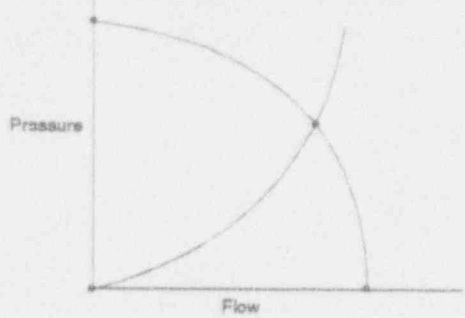
    If pump B is started, system flow rate will be __________ and common pump discharge pressure will be __________ .

    A. the same; higher
    B. higher; the same
    C. the same; the same
    D. higher; higher

FIGURE 1.4-4



Cooling Water System



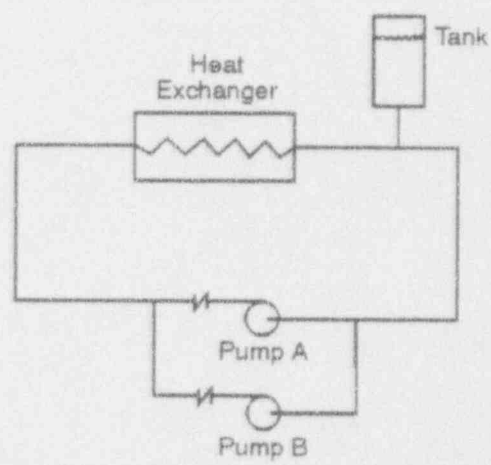
Centrifugal Pump and System Characteristic Curves

39. Refer to the drawing of a cooling water system (see Figure 1.4-5) in which pumps A and B are identical single-speed centrifugal pumps.

    Compared to system operating conditions with only pump A operating, after pump B is started, system flow rate will be approximately __________ and pump discharge pressure will be approximately __________ .

    A. constant; double
    B. double; constant
    C. constant; constant
    D. double; double

FIGURE 1.4-5



Cooling Water System

40. Given a closed plant system with two identical centrifugal pumps in parallel, one of which is running. Describe the effect on system flow and pump head when the second pump is started. Contrast the final, steady-state conditions to the initial conditions.

41. Which of the following is an indication of pump runout?

    A. high discharge pressure
    B. low pump motor current
    C. high pump flow rate
    D. pump flow reversal

42. Which statement below describes centrifugal pump runout conditions?

    A. high discharge pressure, low flow, high power demand

    B. high discharge pressure, high flow, high power demand

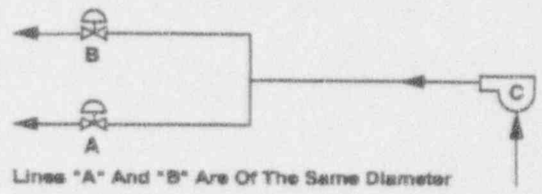
    C. low discharge pressure, high flow, high power demand

    D. low discharge pressure, high flow, low power demand

43. In Figure 1.4-6, a centrifugal pump is operating at maximum design flow delivering water through fully open valve "A" and half-open valve "B". If valve "B" is now opened fully, the result could be

    A. pump at shutoff head
    B. pump suction pressure increasing
    C. pump NPSH increasing
    D. pump in runout condition

FIGURE 1.4-6



Centrifugal Pump

44. Pump runout is undesirable because

    A. it indicates a loss of back pressure caused by excessive flow

    B. the motor can be damaged from high running current

    C. it leads to an increase in condensate depression due to decreased suction pressure

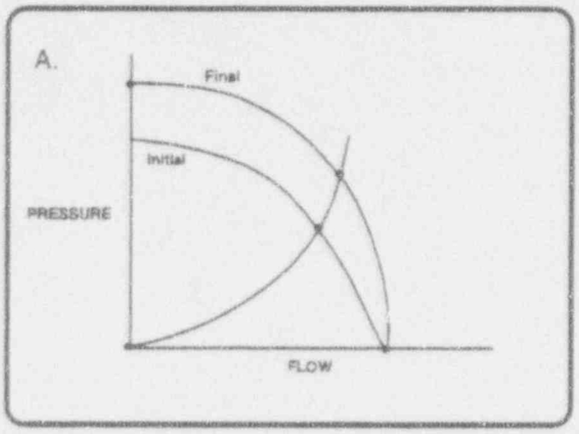
    D. water hammer may be caused by pressure surges in the discharge piping

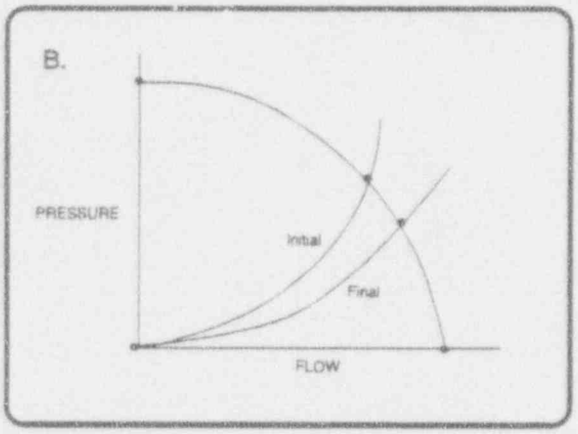
45. Which one of the following is an indication of pump runout?

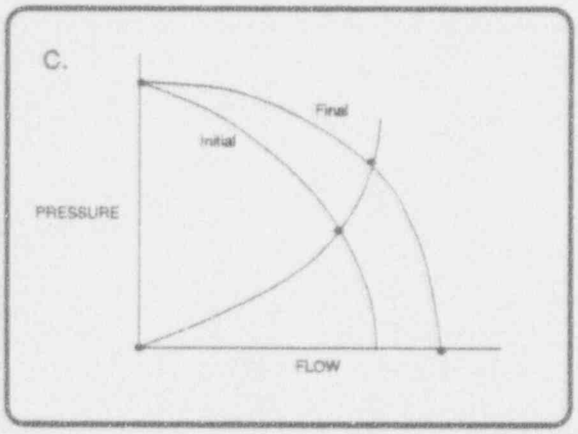
    A. high pump discharge pressure
    B. low pump motor current
    C. high pump vibration
    D. low pump flow rate

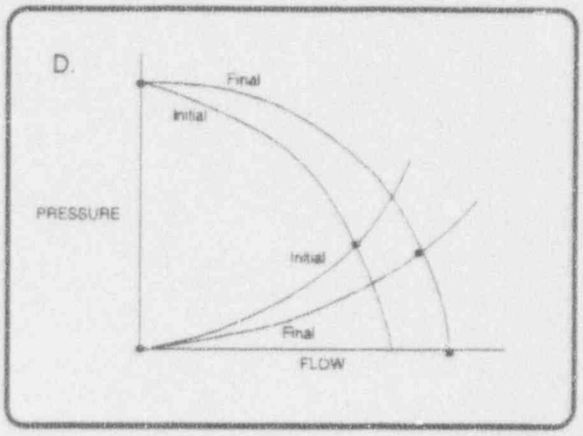
46. Draw a typical pump operating curve and system operating curve. Label the curves, the axes, and the system operating point.

47. A centrifugal pump in a closed system is operating with a partially open discharge valve. The discharge valve is then opened fully. Which set of curves illustrates the resulting change?





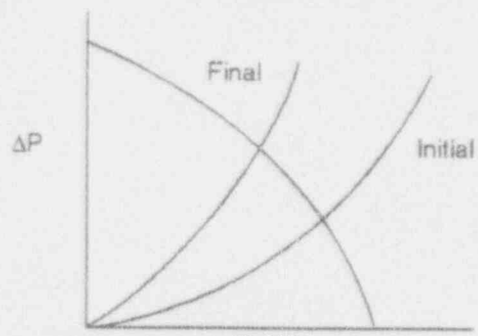




48. Given a closed system in which a centrifugal pump is supplying flow through two heat exchangers in parallel. What operating change would cause the shift in the pump and system operating curves shown in Figure 1.4-7?

A. further opening of pump discharge valve
B. decrease in pump speed
C. increase in system pressure
D. valving out one heat exchanger

FIGURE 1.4-7



Centrifugal Pump and System Characteristic Curves

49. Given a closed system in which a centrifugal pump is supplying flow through two heat exchangers in parallel. Which of the following operating changes would have <u>no effect</u> on the point where the pump and system characteristic curves intersect?

A. further opening of pump discharge valve

B. increase in pump speed

C. increase in system pressure

D. valving out one heat exchanger

50. Refer to the drawing of a lube oil temperature control system and the associated centrifugal pump operating curve (see Figure 1.4-8).

If the pump is operating at point B on the operating curve, how will the operating point change if the temperature control valve modulates further open?

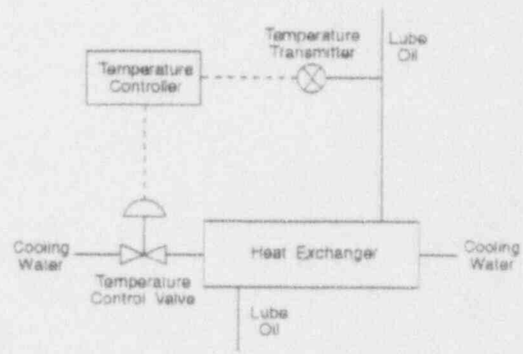
A. Operating point B will be located on curve 1 closer to point D.

B. Operating point B will be located on curve 2 closer to point A.

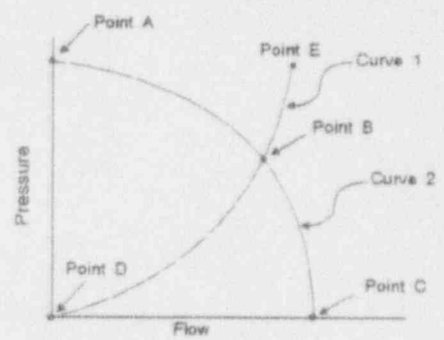
C. Operating point B will be located on curve 1 closer to point E.

D. Operating point B will be located on curve 2 closer to point C.

FIGURE 1.4-8



Lube Oil Temperature Control System



Centrifugal Pump and System Characteristic Curves

51. Refer to the drawing of a lube oil temperature control system and the associated centrifugal pump operating curve (see Figure 1.4-8).

    The pump is operating at point B on the operating curve. If the temperature control valve modulates farther closed, operating point B will be located on curve _________, closer to point __________. (The options below assume that curves 1 and 2 are exactly as shown in Figure 1.4-8)

    A. 1; D
    B. 2; A
    C. 1; E
    D. 2; C

52. A centrifugal pump is operating at rated conditions in an open system. If the pump recirculation valve is opened farther, pump discharge pressure will __________ and pump flow rate will __________.

    A. increase; decrease
    B. decrease; increase
    C. increase; increase
    D. decrease; decrease

53. When flow from a centrifugal pump is increased by throttling open the discharge valve, AVAILABLE net positive suction head (NPSH) _______, and REQUIRED NPSH ________.

    A. decreases, decreases
    B. decrease, increases
    C. increases, increases
    D. increases, decreases

54. Increasing the flow rate from a centrifugal pump by throttling open the discharge valve will cause pump head to

    A. increase and stabilize at a higher value

    B. decrease and stabilize at a lower value

    C. remain constant because pump head is a design parameter

    D. increase, then decrease following the pump's efficiency curve

55. Select the statement about a single-speed, motor-driven, centrifugal pump that is correct.

    A. Upon throttling open the discharge valve, total developed head and motor amps decrease.

    B. When the discharge valve is throttled open, required net positive suction head increases, and pump differential pressure decreases.

    C. Upon throttling open the discharge valve, total developed head increases and available net positive suction head decreases.

    D. When the discharge valve is throttled open, pump cavitation is reduced and total developed head decreases.

56. Which one of the following specifies the proper pump discharge valve position and the basis for that position when starting a large centrifugal pump?

    A. discharge valve fully open to reduce motor power requirements

    B. discharge valve throttled to reduce motor power requirements

    C. discharge valve fully open to ensure adequate pump net positive suction head

    D. discharge valve throttled to ensure adequate pump net positive suction head

57. An increase in positive displacement pump speed will cause the available net positive suction head for the pump to

    A. decrease due to the increase in fluid flow

    B. decrease due to the increase in fluid discharge pressure

    C. increase due to the increase in fluid discharge pressure

    D. increase due to the increase in fluid flow

58. If the speed of a positive displacement pump is increased, the available net positive suction head (NPSH) will ____________ and the probability of cavitation will __________.

    A. increase, increase.
    B. decrease, decrease
    C. increase, decrease
    D. decrease, increase

59. Available net positive suction head for a positive displacement pump will increase if the pump's

    A. discharge pressure increases
    B. motor speed decreases
    C. suction temperature increases
    D. discharge valve is throttled closed

60. Available net positive suction head is defined as

    A. the sum of the fluid head, velocity head, and elevation head

    B. the minimum suction head necessary to prevent cavitation

    C. the difference between the total suction head and the saturation pressure of the fluid at the pump suction

    D. the difference between the suction pressure and discharge pressure of the pump

61. When starting a positive displacement pump, why must the pump discharge valve be fully open?

    A. prevents rupturing the pump casing
    B. prevents pump cavitation
    C. reduces motor starting current
    D. reduces pressure fluctuations in discharge piping

62. What effect would fully closing the discharge valve have on an operating positive displacement pump?

    A. The pump would overheat due to lack of adequate pump flow.

    B. The current drawn by the pump motor would decrease to minimum.

    C. The flow stoppage would allow dissolved gasses to come out of solution, possibly gas-binding the pump.

    D. The pump or piping would fail due to excessive pressure being generated.

63. The discharge valve of an ideal reciprocating positive displacement pump is throttled toward the closed direction. This causes pump flow to _________ and pump head to ___________.

    A. remain constant; remain constant
    B. decrease; remain constant
    C. remain constant; increase
    D. decrease; increase

64. Which of the following describes the operating characteristics of a pump?

    A. Centrifugal pumps deliver a variety of flows at a constant head.

    B. Positive displacement pumps deliver a constant head over a variety of flows.

    C. Centrifugal pumps deliver extremely high flows at high heads.

    D. Positive displacement pumps deliver a constant flow over a variety of heads.

65. Which of the following conditions will result in the greatest change in the volumetric flow rate through a positive displacement pump?

    A. doubling the pump speed

    B. throttling the discharge valve from full open to half open

    C. doubling pump net positive suction head

    D. halving downstream system pressure

66. A closed system has one operating positive displacement pump in service. A second positive displacement pump is subsequently placed into service. If the pumps are in parallel, the system flow rate will __________ and the system discharge pressure will __________.

    A. stay approximately the same; stay approximately the same

    B. approximately double; increase slightly

    C. increase slightly; approximately double

    D. approximately double, approximately double

67. As the speed of a positive displacement pump increases, the pump's

    A. available net positive suction head increases

    B. probability of cavitation decreases

    C. volumetric flow rate increases

    D. discharge head decreases

68. A positive displacement pump (PDP) is operating in an open system. PDP parameters are as follows:

PDP speed	=	1000 rpm
PDP discharge pressure	=	2000 psig
PDP suction pressure	=	50 psig
PDP flow rate	=	150 gpm

Which one of the following changes will cause PDP flow rate to exceed 200 gpm?

    A. A second identical discharge path is opened.

    B. PDP speed is increased to 1500 rpm.

    C. PDP suction pressure is increased to 120 psig.

    D. Downstream system pressure is decreased to 1000 psig.

69. When starting a positive displacement pump, why must the pump discharge valve be fully open?

    A. ensures integrity of the pump and system piping

    B. prevents pump cavitation

    C. reduces motor starting current

    D. minimizes the potential for water hammer

70. What is the purpose of the safety/relief valve located between the pump outlet and discharge isolation valve of most positive displacement pumps?

    A. Provide recirculation of pump discharge back to the pump suction if pump discharge pressure approaches shutoff head.

    B. Protect the pump, discharge piping, and suction piping from overpressure if the suction valve is closed during operation.

    C. Protect the pump and discharge piping from overpressure if the discharge valve is closed during pump operation.

    D. Protect the pump and discharge piping from overpressure due to thermal expansion of pump contents when the pump is shutdown with its suction valve closed.

71. Which of the following changes in pump operating parameters could lead to pump cavitation in a centrifugal pump that is operating in a closed-loop system?

    A. steadily increasing system pressure

    B. steadily increasing pump suction pressure

    C. steadily increasing pump inlet temperature

    D. steadily decreasing pump flow rate by reducing pump speed

72. Which one of the following will result in immediate cavitation of a centrifugal pump operating at normal rated flow?

    A. recirculation flow path is aligned
    B. recirculation flow path is isolated
    C. pump suction valve is fully closed
    D. pump discharge valve is fully closed

73. A motor-driven centrifugal pump is operating in an open system. If the discharge valve is fully opened from a throttled position, available NPSH will ______________ and required NPSH will ________________.

    A. increase; increase
    B. increase; decrease
    C. decrease; increase
    D. decrease; decrease

74. Minimum required net positive suction head for an ideal positive displacement pump will increase if the pump:

    A. motor speed increases
    B. discharge pressure decreases
    C. suction temperature increases
    D. discharge valve is throttled open

75. A variable speed positive displacement pump is operating at 60 gpm in an open system. To decrease pump flow rate to 30 gpm, pump speed must be decreased by a factor of:

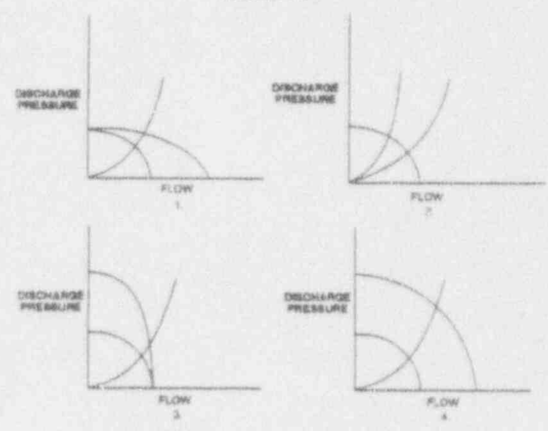
    A. 1.44
    B. 2
    C. 2.88
    D. 4

76. Refer to the drawing of 4 centrifugal pump operating curves (see figure 1.4-9).

    Two identical constant speed centrifugal pumps are operating in series in an open system when one pump trips. Which set of operating curves depicts the "before" and "after" conditions described above?

    A. 1
    B. 2
    C. 3
    D. 4

FIGURE 1.4-9



Centrifugal Pump Operating Curves

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

Cavitation is characterized by inconsistent or oscillating amperage on the pump motor and oscillating pump discharge flow rate.

All other choices imply that the pump experiences a constant change to a maximum or minimum value for either flow or discharge pressure.

Reference 44.

2. C

Reference 29, pages 2.213 through 2.215.

3. D

Cavitation is defined as the formation and subsequent collapse of vapor bubbles on the pump impeller.

Reference 44.

4. C

Reference 29, pages 2.213 through 2.215.

5. D

Reference 29, pages 2.213 through 2.15.

6. B

Reference 44.

7. A

If pump inlet temperature is increased steadily, the water is that much closer to saturation temperature for any given pressure. Maintaining that margin is what prevents cavitation.

Reference 44.

8. A

Ensuring adequate NPSH provides a margin against cavitation.

Reference 44.

9. D

Reference 22, part B, chapter 1, page 320.

10. C

The common practice for removing air or trapped gases (steam, etc.) from a pump casing is to open the pump casing vent valve as the pump is being filled. As the pump fills, the operator should wait until no visible signs of air (bubbles) remain before closing the vent.

None of the other choices would accomplish this.

Reference 29, page 2-191.

11. A

Reference 22, part B, chapter 1, page 320.

12. B

Reference 12.

13. A

Air entrapped in the pump casing can cause gas binding, reducing the flow and pressure developed by the pump.

14. B

Reference 22, part B, chapter 1, page 320.

15. D

Shutoff head is generally defined as the maximum value of head (DP) that a pump can produce.

Reference 22, part B, chapter 1, page 320.

16. B

Overheating of a pump is a likely consequence of inadequate flow through a pump.

Reference 23, chapter 19, and Reference 44.

17. D

Fluid flowing through a centrifugal pump serves to cool it. Inadequate flow can lead to pump overheating.

18. B

Fluid flowing through a centrifugal pump serves to cool it. Inadequate flow can lead to pump overheating.

19. D

Fluid flowing through a centrifugal pump serves to cool it. Inadequate flow can lead to pump overheating.

20. A

Normal design of pumps often includes a minimum flow recirculation flowpath from discharge back to suction through an orifice. This will ensure a minimum flow through the pump.

Reference 23, chapter 19; and Reference 44.

21. A

Reference 63, page 10-43.

22. C

Shutoff head is a term that describes a centrifugal pump in a condition where discharge flow is zero and discharge head is at maximum.

Reference 22, part B, chapter 1, pages 320, 326, and 328.

23. B

As resistance to flow increases, the pump's discharge pressure increases. However, with the discharge valve shut, no useful work is done, and current consumption is minimal.

24. D

When pump runout occurs the volumetric flow rate reaches a maximum, high level.

Reference 63, pages 10-43 through 10-45.

25. A

Opening valve A raises surge tank level, creating greater static head at the pump suction.

All other choices would decrease available NPSH.

Reference 35, pages 34 through 36.

26. D

A, B, and C are incorrect because they all actually increase NPSH. D is correct due to the increased flow through the pump resulting in a lower suction pressure.

Reference 63, chapter 10, page 56.

PUMPS
Answers

27. B

Reference 63, chapter 10, page 43.

28. C

Mathematical expression of NPSH is

$P_{suction} - P_{sat}$

Reference 35, pages 34 through 36.

29. C

Reference 35, pages 34 through 36.

30. B

Motor amps will decrease due to the pump moving less mass per unit volume. This means less work is required to move a less dense fluid.

Reference 35, page 26.

31. D

Runout would create the greatest current draw on the pump motor.

Reference 35, pages 34 through 36.

32. D

A pump running at shutoff head is producing no work (other than overcoming friction losses). Therefore, the power and current consumed by its motor is minimal.

33. B

As discharge valve is throttled, pump discharge head increases, pump flow decreases and required pump power decreases.

Reference 22, part B, chapter 1, pages 326 and 328.

34. A

The water density will decrease when the temperature increases. Since the volumetric flow rate is constant, less work is required to move the water through the system reducing the pump motor amps.

Reference 35, page 26.

35. B

The amount of current a pump draws while starting depends on the amount of work being done. With the discharge valve shut, work is at a minimum, so starting current is minimized.

Reference 35, pages 17 through 20.

36.

Starting currents for pump motors are typically five-to-six times the running current. With the pump discharge valve closed, running current will be at a minimum. Therefore, starting the pump with the discharge valve closed will minimize starting current, thus avoiding the possibility of motor damage or supply breaker tripping.

37. B

Two identical pumps operating in parallel can deliver almost twice the flow of a single pump.

Reference 63, page 10-45 and 10-46.

38. D

Reference 63, pages 10-45 and 10-46.

39. B

Reference 63, pages 10-45 and 10-46

40.

The second pump will attempt to double system flow. However, the increased system head loss resulting from the higher flow will prevent flow from doubling. Pump head for each pump will increase to match the (increased) system head loss. Final flow will be greater than but not twice initial flow; pump head will increase somewhat.

Reference 63, pages 10-45 and 10-46.

41. C

Low discharge pressure, high current, and high pump flow would be seen during runout conditions.

Reference 35, pages 18 through 20.

42. C

Reference 22, part B, chapter 1, pages 326 and 328.

43. D

If the pump is already at maximum rated flow, then opening another similarly sized flow path may result in runout.

Reference 35, page 30.

44. B

B is correct because current flow in the pump motor increases in response to the increase in pump speed resulting in excessive heat generation on motor winding.

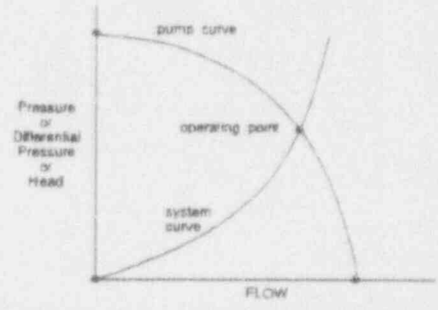
Reference 63, page 10-44.

45. C

Reference 63, pages 10-43 through 10-45.

46.

FIGURE 1.4-10



47. B

The system curve rotates clockwise because the system head loss for any given flow has been reduced.

Reference 63, page 10-41.

48. D

When the heat exchanger is valved out of the system, the flow rate at any differential pressure is reduced. This causes the system curve to rotate counterclockwise.

Reference 63, page 10-41.

49. C

Changes in pump speed would shift the pump characteristic curve. Changes in the system (opening or closing valves) would shift the system characteristic curve. If either curve shifts, the system operating point changes. Because changes in system pressure do not affect either curve, the operating point is unaffected.

Reference 63, pages 10-20 through 10-25, and 10-41 through 10-42.

50. D

The opening of the control valve decreases system flow resistance, increasing flow and decreasing pressure head.

Reference 63, pages 10-20 through 10-24 and 10-41 through 10-45.

51. B

Reference 63, pages 10-20 through 10-24 and 10-41 through 10-45.

52. B

A decrease in pump discharge pressure causes an increase in flow rate through the system with pump work being held constant.

Reference 63, page 10-41.

53. B

Available NPSH will decrease as the increased flow reduces suction pressure. Required NPSH as specified by the pump manufacturer will increase as flow increases.

Reference 35, pages 34 through 36.

54. B

Basic centrifugal pump characteristics.

Reference 22, part B, chapter 1, pages 320-325.

55. B

A is incorrect because motor amps will increase. C is incorrect because total developed head decreases. D is incorrect because pump cavitation would increase.

Reference 63, chapter 10, page 37.

56. B

Reference 63, page 10-43.

57. A

A is correct because an increase in pump flow will lower pump suction pressure causing available NPSH to decrease.

B, C, and D are incorrect because:

B. NPSH is not a function of discharge fluid temperature

C. NPSH is not a function of pump discharge pressure.

D. NPSH decreases with increased flow as described for A above.

Reference 63, chapter 10, pages 53 through 61.

58. D

D is the only correct answer. As volumetric flow increases, pressure at the suction of the pump decreases. As suction pressure decreases, available net positive suction head decreases and the probability of cavitation increases.

Reference 63, chapter 10, pages 53 through 61.

59. B

A and D are incorrect because they have no effect on the flow rate through the pump. Since flow rate is not affected, NPSH is not affected.

C decreases net positive suction head due to the decrease in the margin to saturated conditions at the pump suction.

B is correct because if flow increases, pump suction pressure will decrease, moving the pump closer to saturation.

Reference 63, chapter 10, pages 53 through 61.

60. C

A, B, and D are incorrect because:

A. incomplete - does not include saturation head

B. minimum NPSH definition

D. differential pressure definition

Reference 63, chapter 10, page 54.

61. A

Reference 63, page 10-52.

62. D

Reference 63, page 10-52.

63. C

Positive displacement pumps are designed to ensure a set, positive flowrate, unless their speed or stroke is changed. In an ideal positive displacement pump, repositioning the discharge valve will change head only.

Reference 22, part B, chapter 1, page 320.

64. D

Positive displacement pumps deliver constant flows regardless of head.

Reference 22, part B, chapter 1, page 320.

65. A

Reference 63, chapter 10, page 52.

66. B

The two pumps will each deliver almost as must flow as a single pump; thus flow will double. Discharge pressure will rise slightly due to increased head loss resulting from the increased flow.

67. C

Reference 63, chapter 10, pages 53 through 61.

68. B

The PDP flow rate can only be increased by increasing its speed.

Reference 63, pages 10-49 through 10-53.

69. A

Reference 63, page 10-53.

70. C

Reference 63, page 10-53.

71. C

72. C

73. C

Increased flow will result in lower suction pressure resulting in decreased NPSH. Therefore, required NPSH will increase.

74. A

Increased flow will result in lower suction pressure ıesulting in decreased NPSH. Therefore, required NPSH will increase.

75. B

76. C

PUMPS
Learning Objectives

Each learning objective listed below is preceded by the associated question number (s) and by the number of its related knowledge statement.

K1.01 Questions 1-6

Identify the symptoms associated with pump cavitation.

K1.01 Questions 7, 8, 71, 72

Describe the conditions associated with pump operation which may lead to cavitation in the pump.

K1.02 Question 9

Define the term gas binding as it relates to a pump.

K1.02 Questions 10, 11

Explain how gas binding in a pump is avoided prior to pump start.

K1.02 Questions 12, 13

Identify the symptoms associated with gas binding in centrifugal pumps.

K1.02 Question 14

Define the term gas binding as applied to centrifugal pumps.

K1.04 Questions 15, 16

Describe the conditions associated with pump shutoff head.

K1.04 Questions 17-19

State the consequences of operating a centrifugal pump without adequate flow.

K1.04 Question 20

Explain how centrifugal pumps are protected from shutoff head conditions.

K1.04 Question 21

Define pump shutoff head.

K1.04 Question 22

Define the term "shutoff head" as applied to a centrifugal pump.

K1.04 Questions 23, 24

Relate pump motor current and/or discharge pressure to operating conditions.

K1.06 Questions 25-27, 73, 74

Identify the response of the available NPSH for a centrifugal pump to changes in fluid parameters.

K1.06 Question 28

Define net positive suction head (NPSH).

K1.07 Questions 29-34

Identify the effects of various operating conditions of a centrifugal pump on motor current.

K1.08 Questions 35, 36

Explain why some centrifugal pumps are started with their discharge valves closed.

K1.09 Questions 37-40

State the major effect of operating centrifugal pumps in parallel.

PUMPS
Learning Objectives

K1.12 Questions 41-43

Identify pump operating conditions associated with pump runout.

K1.12 Questions 44, 45

Describe the adverse consequences of operating centrifugal pumps in a "runout" condition.

K1.14 Questions 46-51, 76

Draw and explain changes in pump and system characteristic curves due to system changes.

K1.15 Questions 52-55

Explain the relationship between pump flow and pump head for centrifugal pumps.

K1.16 Question 56

Describe the proper conditions and bases for starting a large centrifugal pump.

K1.20 Questions 57, 58

Describe the relationship of positive displacement pump speed to available NPSH and cavitation.

K1.20 Question 59

Describe the effect of fluid parameters on the available net positive suction head of a positive displacement pump.

K1.20 Question 60

Define available net positive suction head (NPSH).

K1.21 Questions 61, 62

Explain why a positive displacement pump's discharge valve must be open when the pump is running.

K1.22 Questions 63-68, 75

Explain the relationship between pump flow and pump head for positive displacement pumps.

K1.23 Question 69

Explain why the positive displacement pump discharge valve must be open when starting the pump up.

K1.24 Question 70

Describe the purpose of the relief valve in the discharge line of a positive displacement pump.

MOTORS AND GENERATORS
Questions

1. Which one of the following is not an indication of a locked reactor coolant pump rotor?

   A. reactor coolant system pressure transient

   B. increased reactor coolant pump amps followed by a breaker trip

   C. decreased flow in unaffected loop(s)

   D. low reactor coolant system flow trip

2. During a locked reactor coolant pump (RCP) rotor event, RCP amps will change. Which of the following best describes how and why the affected RCP amps change?

   A. increase due to mechanical binding

   B. increase due to the increase in stator counter electromotive force (CEMF)

   C. decrease due to the decrease in pump flow

   D. decrease due to the increase in rotor counter electromotive force (CEMF)

3. Which of the following describes the initial reactor coolant pump ammeter response to a locked rotor event?

   A. increases
   B. decreases
   C. remains the same
   D. fluctuates

4. An operator can differentiate a locked reactor coolant pump (RCP) rotor from a sheared RCP rotor 30 seconds after the event by observing (Assume no operator action.)

   A. loop flow indications
   B. RCP ammeter indications
   C. loop differential temperatures indications
   D. reactor trip status

5. Reactor coolant pump motor amps will _______ if the rotor is locked, and the motor speed will _______ if the rotor shears.

   A. increase, increase
   B. increase, decrease
   C. decrease, increase
   D. decrease, decrease

6. Which of the following is <u>not</u> a possible consequence of overheating motor and generator electrical insulation?

   A. discoloration of parts
   B. blown fuses
   C. bearing damage
   D. electrical grounds

7. Which of the following consequences results from motor and generator electrical insulation overheating?

   A. decreased electrical current demand
   B. decreased equipment life
   C. increased plant efficiency
   D. decreased power interruptions

8. Decreased bearing life for motors and generators may result from

   A. overheating
   B. overvoltage
   C. overcurrent
   D. nominal loading

9. Overheating of motor and generator bearings or insulation may cause equipment life expectancy to

   A. increase continually
   B. increase briefly, then level off
   C. decrease continually
   D. remain unchanged

10. Which of the following is not a possible consequence of motor and generator electrical insulation overheating?

    A. decreased plant efficiency
    B. increased power interruptions
    C. increased electrical current demand
    D. increased equipment life

11. If the generator bearings on a motor generator overheat then

    A. the generator voltage will increase
    B. the generator windings will overheat
    C. the motor current will decrease
    D. the motor windings will overheat

12. Which one of the following will provide motor protection against electrical damage caused by a gradual increase in bearing degradation?

    A. thermal overload device
    B. reverse power relay
    C. underfrequency relay
    D. undervoltage device

13. Excessive A.C. motor currents can be caused by

    A. overvoltage
    B. undervoltage
    C. low slip ratio
    D. low ambient temperatures

14. Excessive A.C. motor currents <u>cannot</u> be caused by which of the following simultaneous conditions?

    A. overvoltage while overloading
    B. overvoltage while underloading
    C. undervoltage while overloading
    D. undervoltage while underloading

15. Which of the following is <u>not</u> a cause of excessive A.C. motor current?

    A. undervoltage
    B. overload
    C. mechanical binding
    D. low ambient temperatures

16. Excessive AC motor current can be caused directly by operating the motor

    A. completely unloaded
    B. at full load
    C. with open-circuited windings
    D. with short-circuited windings

17. If the voltage supplied by an AC generator in an isolated electrical system is held constant while real load (Kw) is increased, the current supplied by the generator will increase in direct proportion to the __________ of the change in real load. (Assume power factor does not change.)

    A. square root
    B. amount
    C. square
    D. cube

18. Excessive A.C. generator currents can <u>not</u> be caused by operating the generator in an ______ condition.

    A. overvoltage
    B. undervoltage
    C. overload
    D. underloaded

19. A main generator is operating on the grid with the following indications:

    100 MWe
    0 MVAR
    2,800 amps
    20,000 volts

    If main generator excitation is reduced, amps will ______ and MWe will ______.

    A. decrease; decrease
    B. increase; decrease
    C. decrease; remain the same
    D. increase; remain the same

20. A main generator is operating on the grid with the following indications:

    500 MWe
    300 MVAR (VARs out)
    2,800 amps

    If main generator excitation is reduced slightly, amps will ______ and MWe will ______.

    A. decrease; decrease
    B. increase; decrease
    C. decrease; remain the same
    D. increase; remain the same

21. A centrifugal pump is operating with the following parameters:

    Speed = 1,800 rpm
    Current = 40 amperes
    Pump Head = 20 psi
    Pump Flow Rate = 400 gpm

    What will be the new value of pump head and current if the speed is increased to 2,000 rpm?

    A. 22 psi, 44 amps
    B. 25 psi, 44 amps
    C. 22 psi, 55 amps
    D. 25 psi, 55 amps

22. A centrifugal pump has a flow rate of 3,000 gpm and a current requirement of 200 amperes. If the pump speed is reduced such that the flow rate is 2,000 gpm, what is the final current requirement at the new lower speed? (Assume a constant motor voltage.)

    A. 59 amperes
    B. 89 amperes
    C. 133 amperes
    D. 150 amperes

23. A centrifugal pump is operating at 600 rpm with the following parameters:

    Current = 10 amperes
    Pump Head = 50 psi
    Pump Flow Rate = 200 gpm

    What will be the new value of pump head if the flow is increased such that the current requirements are now 640 amperes?

    A. 400 psi
    B. 600 psi
    C. 750 psi
    D. 1,200 psi

24. A centrifugal pump is operating at 1,800 rpm, pump head is 100 psid, and pump current is 10 amperes. What will be the new value of pump head if the speed is increased such that the current requirements are now 640 amperes?

    A. 400 psid
    B. 800 psid
    C. 1,200 psid
    D. 1,600 psid

25. If the speed of a variable speed centrifugal pump is increased to cause pump flow rate to double, pump motor current will

    A. remain constant
    B. increase two-fold (double)
    C. increase four-fold
    D. increase eight-fold

26. An increase in the stator temperature of a centrifugal pump motor can be caused by the motor current

    A. increasing
    B. decreasing
    C. remaining constant
    D. fluctuating

27. A motor-driven centrifugal pump is operating at a low flow condition in an open system. The throttled discharge vlave is then fully opened to increase system flow rate.

    Which one of the following will increase?

    A. pump discharge pressure
    B. available net positive suction head
    C. motor amps
    D. pump speed

28. A centrifugal pump has been running at an elevated temperature due to insufficient ventilation when an operator changes the ventilation lineup to cool the pump motor. Assuming pump flow rate and applied voltage remain constant, how will decreasing motor temperature affect the motor current?

    A. increase, because motor efficiency decreases

    B. decrease, because motor efficiency increases

    C. increase, because stator resistance decreases

    D. decrease, because stator resistance increases

29. The average starting current for an alternating current motor is approximately

    A. the same as its normal running current

    B. two to three times its normal running current

    C. five to six times its normal running current

    D. 10 to 15 times its normal running current

30. When starting a centrifugal pump, the response of motor current should be

    A. low starting amps, increasing to a higher equilibrium running amperage

    B. low starting amps, remaining at a low equilibrium running amperage

    C. high starting amps, decreasing to a lower equilibrium running amperage

    D. high starting amps, remaining at a high equilibrium running amperage

31. The starting current in an A.C. motor is significantly higher than the full-load running current because

    A. starting torque is lower than running torque

    B. starting torque is higher than running torque

    C. rotor current during start is higher than running current

    D. rotor current during start is lower than running current

32. Starting current in a squirrel cage induction motor is typically ______ times full-load rated current.

    A. 1/4 to 1/2
    B. 2 to 3
    C. 5 to 6
    D. 10 to 12

33. The starting current in an A.C. motor is significantly higher than the full-load running current because

    A. little current is induced onto the rotor because of the slow rotor speed

    B. higher torque is required during a starting event, thus requiring high currents

    C. little counter electromotive force is induced onto the stator to limit stator current during start

    D. A.C. motors are started under load and the starting current reflects this

34. Which of the following describes the motor current indications that would be observed during the start of a large AC motor at full load?

    A. Amps increase immediately to more than three times the full-load value and then decrease to the full-load value.

    B. Amps increase immediately to approximately twice the full-load value and then decrease to the full-load value.

    C. Amps increase immediately to the full-load value

    D. Amps slowly increase to the full-load value

35. Which one of the following describes the motor current indications that would be observed during the start of a large AC motor connected to a load?

    A. Amps slowly increase to the normal operating value over a pe.iod of five time constants.

    B. Amps immediately increase to the normal operating value and stabilize.

    C. Amps immediately increase to many times the normal operating value and then decrease to the normal operating value.

    D. Amps immediately increase to the full-scale value and then decrease rapidly to zero due to overload protection.

36. High induced rotor currents due to maximum slip and accompanied by motor currents 5 to 6 times normal best describes the response of a large AC motor during which of the following events?

    A. motor start
    B. motor at breakdown torque
    C. motor in thermal overload
    D. motor with commutator flashover

37. If the discharge valve of a large AC motor-driven centrifugal pump remains closed during a normal pump start, the motor ammeter indication will rise to:

    A. several times the full-load current value and then decrease to the no-load current value

    B. approximately the full-load current value and then decrease to the no-load current value

    C. several times the full-load current value and then decrease to the full-load value

    D. approximately the full-load current value and then stabilize at the full-load current value

38. If the discharge valve of a large AC motor-driven centrifugal pump remains closed during a normal pump start, the motor ammeter indication will rise to

    A. several times the full-load current value and then decrease to the no-load current value

    B. approximately the full-load current value and then decrease to the no-load current value

    C. several times the full-load current value and then decrease to the full-load value

    D. approximately the full-load value and then stabilize at the full-load current value

39. Which of the following is the reason for limiting the number of motor starts in a given time period?

    A. minimizes pitting of starter contacts

    B. prevents excessive torsional stresses on motor shaft

    C. prevents overheating of motor windings

    D. minimizes axial stresses on motor bearings

40. The number of starts for an electric motor in a given period of time should be limited because

    A. overheating of the windings can occur due to a high starting current

    B. rotor damage can occur due to excessive cyclic stresses on the shaft

    C. overheating of the windings can occur due to shorting within the stator

    D. rotor damage can occur due to excessive axial displacement of the shaft

41. The number of starts for an electrical motor in a given period of time should be limited because

    A. overheating of the windings can occur

    B. excessive electromotive force is generated during motor startup

    C. running current is much higher than starting current

    D. motors are normally started under full-load conditions

42. Explain why a limit exists on the frequency of starts of large A.C. induction motors.

43. Which of the following is not a reason for limiting the number of motor starts in a given time period?

    A. Overheating of windings may occur.

    B. Excessive torque generated during startup causes increased bearing wear.

    C. Starting current is much higher than running current.

    D. Too many motor starts in a short period increases the possibility of insulation failure.

44. Which of the following is the best reason for limiting the number of motor starts in a given time period?

    A. Running current is higher than starting current.

    B. Motors are normally started under full-load conditions.

    C. This requirement is strictly a technical manual restriction.

    D. This practice prevents overheating of windings.

45. The frequency of large AC motor starts should be limited to prevent excessive

    A. torsional stresses on the motor shaft

    B. wear of internal pump components

    C. arcing and degradation of motor breaker contacts

    D. heat buildup within the motor windings

46. Motor winding overheating may be reduced by

    A. increasing the reactive current flow in the stator windings

    B. limiting the number of motor starts allowed in a given time period

    C. decreasing the number of stator poles during the start sequence

    D. limiting the inductive reactance of the motor during the start sequence

47. Reactive power is the portion of the apparent power that is

    A. effectively returned to the source and is measured in KVAs

    B. actually dissipated in the load and is measured in watts

    C. effectively returned to the source and is measured in KVARs

    D. obtained by multiplying applied voltage and line current and is measured in watts-reactive

48. True power is that portion of apparent power that is

    A. effectively returned to the source and is measured in KVAs

    B. actually dissipated in the load and is measured in watts

    C. effectively returned to the source and is measured in KVARs

    D. obtained by multiplying applied voltage and line current and is measured in watts-reactive

49. Voltage (volts) best be defined in terms of

    A. an electrical potential difference
    B. the rate of doing electrical work
    C. coulombs of charge
    D. cycles per second

50. Current (amps) can best be defined in terms of

    A. electrical work
    B. electrical potential difference
    C. coulombs per second
    D. cycles per second

51. Frequency (Hz) can best be defined in terms of

    A. electrical work
    B. electrical potential difference
    C. coulombs of change
    D. cycles per second

52. Which one of the following will result from prolonged operation of AC motor windings at excessively high temperatures?

    A. Decreased electrical current demand due to reduced counter electromotive force.

    B. Increased electrical current demand due to reduced counter electromotive force.

    C. Decreased electrical ground resistance due to breakdown of winding insulation.

    D. Increased electrical ground resistance due to breakdown of winding insulation.

53. The number of starts for an electric motor in a given period of time should be limited because overheating of the ____________ can occur due to the ______________ counter electromotive force experienced at low rotor speed.

    A. windings; low
    B. commutator and/or slip rings; low
    C. windings; high
    D. commutator and/or slip rings; high

54. A main generator is operating in parallel with the power grid. If the voltage supplied to the generator field is slowly and continuously decreased, the generator will experience high current due to: (Assume no generator protective actuation occur.)

    A. excessive MWe
    B. excessive KVAR
    C. generator pole slippage
    D. generator reverse power

55. The starting current in an AC induction motor is much higher than the full-load running current because:

    A. The rotor does not develop maximum induced current flow until it has achieved synchronous speed.

    B. Resistance is added to the electrical circuit after motor start to limit running current.

    C. The stator is essentially a short circuit until a voltage is developed in the rotor.

    D. A large amount of electrical power is required to initially establish a rotating magnetic field.

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

In the event of a locked RCP motor, the flow will decrease in the affected loop, causing core delta-pressure to decrease. Due to the decrease in core delta-pressure, the flow in the unaffected loops will <u>increase</u>.

Reference 27, chapter 11, page 193.

2. A

A locked RCP rotor will cause pump amps to increase as the mechanical binding causes the motor's load to increase.

Reference 27, chapter 11, page 193.

3. A

A locked RCP rotor will cause pump amps to increase as the mechanical (binding) load causes rotor speed to decrease.

Reference 27, chapter 11, page 193.

4. B

The RCS response to a sheared or locked RCP rotor event will be the same. The primary indicator will be the effect on RCP amps. If the rotor shears, the motor amps will decrease to a minimum. If the rotor locks, motor amps will increase.

Reference 27, chapter 11, page 193.

5. A

A locked rotor requires the motor to produce maximum torque, thus drawing maximum current. If the rotor shears, the suddenly unloaded motor will speed up.

6. C

Overheating of equipment results in decreased equipment life due to the physical breakdown of any insulation material.

Reference 54, chapter 3, page 1:3.16; and Reference 48, lesson 5, page 72.

7. B

Overheating of equipment results in decreased equipment life due to the physical breakdown of any insulation material.

Reference 54, chapter 3, page 1:3.16; and Reference 48, lesson 5, page 72.

8. A

Overheating of bearings due to improper lubrication, undervoltage (which increases the torque loading of the machine), or abnormal (excessive) loading will result in decreased equipment life expectancy.

Reference 54, chapter 9, page 1:9.47; and Reference 48, lesson 5, page 72.

9. C

Bearing overheating will result in decreased life expectancy.

Reference 54, chapter 3, page 1:3.16; and Reference 48, lesson 5, page 72.

10. D

Overheating of equipment results in decreased equipment life due to the physical breakdown of insulation material.

Reference 54, chapter 3, page 1:3.16; and Reference 48, lesson 5, page 72.

11. D

The overheated bearing will increase the drag on the motor, causing motor current to increase.. The increased current would result in excess heat in the motor windings.

12. A

Reference 54, chapter 3, page 1:3.16; and Reference 48, lesson 5, page 72.

13. B

An undervoltage condition will cause excessive current because, to supply a constant torque (load), current must increase as voltage decreases.

Reference 27, chapter 11, page 194.

14. B

Excessive motor currents cannot be developed in an A.C. motor experiencing overvoltage and an underloading condition. Overloading can cause a high current condition regardless of the voltage. Undervoltage could also cause excessive current even if the motor is underloaded.

Reference 27, chapter 11, page 194.

15. D

The causes of excessive motor currents are undervoltage, overload, and mechanical binding.

Reference 27, chapter 11, page 194.

16. D

Short-circuited windings provide a very low resistance path, resulting in excessive current.

17. B

By the definition of true power, a decrease in voltage must be accompanied by an increase in current.

Reference 47, lesson 8, page 124.

18. D

Excessive generator currents can be caused by overload, overvoltage, or undervoltage. In the case of overvoltage or undervoltage, the high currents result from the positive or negative MVARs provided by the generator.

Reference 19, Electrical Science, chapter 5.

19. D

Reference 19, Elec[illegible]al Science, chapter 5.

20. C

Reference 19, Electrical Science, chapter 5.

21. D

Flow is proportional to speed.
Head is proportional to speed squared.
Power and current are proportional to speed cubed.

Reference 63, chapter 10, page 36.

22. A

Pump flow is proportional to pump speed. Pump current is proportional to pump speed cubed.

$current_2 = current_1 \ (speed_2)^3 / (speed_1)^3$

$current_2 = current_1 \ (flow_2)^3 / (flow_1)^3$

$current_2 = 200 \text{ amps } (2000 \text{ gpm})^3 / (3000 \text{ gpm})^3$

$current_2 = 59 \text{ amperes}$

Reference 63, chapter 10, page 36.

23. B

$current_2 = current_1 \ (speed_2)^3 / (speed_1)^3$

$(speed_2)^3 = (current_2) \ (speed_1)^3 / (current_1)$

$(speed_2)^3 = \frac{(640)\ (600)^3}{10}$

$speed_2 = 2{,}400 \text{ rpm}$

$head_2 = head_1 \ (speed_2)^2 / (speed_1)^2$

$head_2 = 50 \text{ psi } (2{,}400)^2 / (600)^2$

$head_2 = 800 \text{ psi}$

Reference 63, chapter 10, page 36.

24. D

$current_2 = current_1 \ (speed_2)^3 / (speed_1)^3$

$(speed_2)^3 = (current_2) \ (speed_1)^3 = (current_1)$

$= (640 \text{ amps}) \ (1{,}800 \text{ rpm})^3 / (10 \text{ amps})$

$(speed_2) = 7{,}200 \text{ rpm}$

$head_2 = head_1 \ (speed_2)^2 / (speed_1)^2$

$= (100 \text{ psid}) \ (7{,}200 \text{ rpm})^2 / (1800 \text{ rpm})^2$

$= 1{,}600 \text{ psid}$

Reference 63, chapter 10, page 36.

25. D

Pump flow is proportional to pump speed. Speed must be doubled to double flow. Motor current is proportional to pump speed cubed. If speed doubles, current increases by 2 cubed or a factor of 8.

Reference 63, chapter 10, page 36.

26. A

As motor current increases, stator temperature will increase due to I^2R losses.

Reference 31, chapter 1, page 27; and reference 63, chapter 10, page 36.

27. C

28. C

A decrease in motor temperature will increase its efficiency. Since it is assumed that the pump flow rate and applied voltage to the motor remain constant, the motor current must be lower.

Reference 63, page 10-27.

29. C

30. C

31. C

Reference 63, page 10-43.

32. C

Observed/measured parameter.

Reference 27, chapter 11, page 194.

33. C

Induction motor starting impedance is a combination of D.C. resistance and stator impedance. The stator impedance is affected by the counter electromotive force induced onto it by the rotor.

Reference 27, chapter 11, page 194.

34. A

Starting current is typically more than three times the full-load rated current.

Reference 27, chapter 11, page 194.

35. C

Reference 27, chapter 11, page [illegible].

36. A

Motor starting currents are typically five to six times full-load current with maximum (100%) slip.

Reference 27, chapter 11, page 194.

37. A

Motor starting currents are typically five to six times full-load current (2/3 of meter range). Thus, amps will go off scale high and then return to the no-load value since the pump is operating at shutoff head.

Reference 27, chapter 11, page 194.

38. A

Reference 27, chapter 11, page 194.

39. C

Due to starting current typically being five to six times higher than normal running current, excessive heating of windings will result because of I^2R losses in windings. As windings increase in temperature, starting resistance will increase. This will result in further increasing the overheating problem.

Reference 27, chapter 11, page 194; and Reference 55, chapter 4, page 20.

40. A

Due to starting current typically being five to six times higher than normal running current, excessive heating of windings will result because of I^2R losses in windings. As windings increase in temperature, starting resistance will increase. This will result in further increasing the overheating problem.

Reference 27, chapter 11, page 194; and Reference 55, chapter 4, page 20.

41. A

Due to starting current typically being five to six times higher than normal running current, excessive heating of windings will result because of I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist. This will result in increasing the overheating problem.

Reference 27, chapter 11, page 194; and Reference 55, chapter 4, page 20.

42.

The starting current for an A.C. induction motor is five to six times greater than the running current. The relatively large starting current produces relatively large I^2R losses in the stator windings, resulting in heating of the windings. If adequate time is not allowed for this heat to dissipate between motor starts, the windings can overheat, possibly damaging the motor.

43. B

Starting current typically is five to six times greater than normal running current, and this high current can cause winding overheating and insulation damage.

Reference 27, chapter 11, page 194, and Reference 55, chapter 4, page 20.

44. D

Due to starting current typically being five to six times higher than normal running current, excessive heating of windings will result because of I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist. This will result in increasing the overheating problem.

Reference 27, chapter 11, page 194; and Reference 55, chapter 4, page 20.

45. D

The high starting current generates heat in the motor windings. Frequently repeated starts could result in overheating the windings.

46. B

Due to starting current typically being five to six times higher than normal running current, excessive heating of windings will result because of I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist. This will result in increasing the overheating problem.

Reference 27, chapter 11, page 194; and Reference 55, chapter 4, page 20.

47. C

Reference 36, chapter 4, page 49.

48. B

Reference 36, chapter 4, page 49.

49. A

Reference 36, chapter 2, page 53.

50. C

Reference 36, chapter 2, page 53.

51. D

Reference 36, chapter 3, page 23.

52. C

53. A

Initially low counter EMF allows high starting current that causes increased heating.

54. C

55. C

MOTORS AND GENERATORS
Learning Objectives

Each learning objective listed below is preceded by the associated question number (s) and by the number of its related knowledge statement.

K1.01 Questions 1-3

State the indications of a locked reactor coolant pump (RCP) rotor.

K1.01 Questions 4, 5

Differentiate between the indications of a locked reactor coolant pump (RCP) rotor and a sheared RCP rotor.

K1.02 Questions 6-12, 52

Identify the potential consequences of overheating motor and generator electrical insulation or bearings.

K1.03 Questions 13-16

State the causes of excessive current in motors.

K1.03 Questions 17,18

State the causes of excessive current in generators.

K1.03 Questions 19,20, 54

Determine the effects when the main generator excitation is changed.

K1.04 Questions 21-24

Perform calculations involving the relationship between centrifugal pump motor current and changes in the following associated parameters:

1) pump fluid flow rate
2) pump head
3) pump speed

K1.04 Questions 25-28

Identify the relationship that exists between centrifugal pump motor current and changes in the following associated parameters:

1) pump fluid flow rate
2) pump head
3) pump speed
3) stator temperature

K1.05 Questions 29-31, 34

Describe the relationship between starting and running current for an A.C. motor.

K1.05 Questions 32-38, 55

Explain the reason for differences between starting and running currents in an A.C. induction motor.

K1.06 Questions 39-46, 53

Identify the reasons for limiting the number of motor starts allowed in a given time period.

K1.07 Questions 47-51

Define the following terms and state their typical units of measurement: current, voltage, reactive power, true power, and frequency.

1. Refer to Figure 1.6-1 for the following question:

   All valves are identical and are initially 50% open. The temperature at point 7 is exceeding operating limits. To lower the temperature at point 7, the operator could adjust valve ____ in the _______ direction.

   A. A, open
   B. B, open
   C. C, shut
   D. D, shut

2. Refer to Figure 1.6-1 for the following question:

   Valves A, B, and C are fully open. Valve D is 20% open. All temperatures are as shown. Valve D is then quickly opened to 100%. The temperature at

   A. point 3 will increase
   B. point 4 will increase
   C. point 5 will decrease
   D. point 7 will decrease

3. Refer to Figure1.6-1 for the following question:

   Valve A is throttled at 40% open. All temperatures are as shown. If valve A is then throttled to 10% open, the temperature at

   A. point 2 will increase
   B. point 4 will increase
   C. point 5 will decrease
   D. point 7 will decrease

4. Refer to Figure 1.6-1 for the following question:

   All valves are identical and are initially 50% open. To lower the temperature at point 4, the operator should adjust valve ______ in the ______ direction.

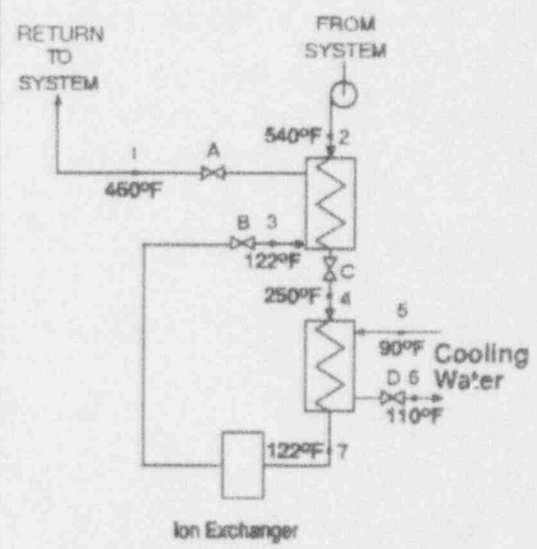
   A. A, open
   B. B, shut
   C. C, open
   D. D, shut

5. Refer to Figure 1.6-1 for the following question:

   All valves are identical and are initially 50% open. The temperature at point 7 is exceeding operating limits. To lower the temperature at point 7, the operator should adjust valve _____ in the open direction.

   A. A
   B. B
   C. C
   D. D

FIGURE 1.6-1



Water Cleanup System

6. Refer to the drawing of a water cleanup system (see Figure 1.6-1).

   Valves A, B, and C are fully open. Valve D is 80 percent open. All temperatures are as shown. If valve D is then throttled to 50 percent, the temperature at

   A. point 3 will decrease
   B. point 4 will increase
   C. point 5 will increase
   D. point 6 will decrease

7. To equal the heat transfer capabilities of a counter-flow heat exchanger, a parallel-flow heat exchanger must

   A. maintain a large ΔT throughout its length

   B. have more heat transfer area

   C. have a lower cooling water inlet temperature

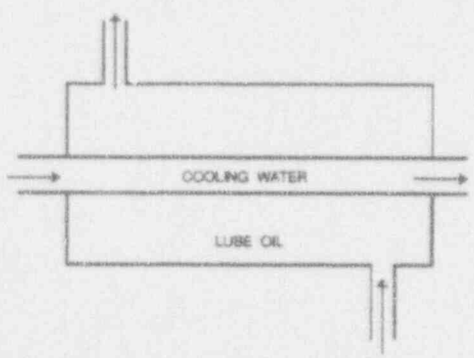
   D. have a higher cooling water inlet temperature

8. Refer to the drawing of a lube oil heat exchanger (see Figure 1.6-2).

   Increasing the oil flow rate through the heat exchanger will cause the oil outlet temperature to __________ and the cooling water outlet temperature to __________. (Assume cooling water flow rate remains the same.)

   A. increase; increase
   B. increase; decrease
   C. decrease; increase
   D. decrease; decrease

FIGURE 1.6-2



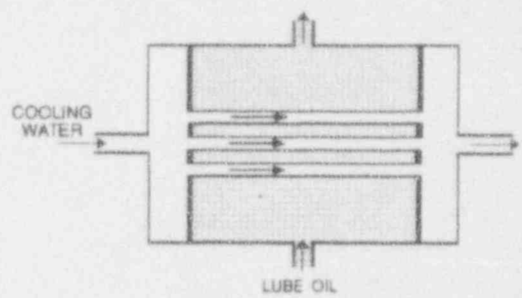
Lube Oil Heat Exchanger

9. Refer to the drawing of a lube oil heat exchanger (see Figure 1.6-3).

   Decreasing the oil flow rate through the heat exchanger will cause the oil outlet temperature to __________ and the cooling water outlet temperature to __________. (Assume cooling water flow rate remains the same.)

   A. decrease; decrease
   B. increase; decrease
   C. decrease; increase
   D. increase; increase

FIGURE 1.6-3



Lube Oil Heat Exchanger

10. Thermal shock, as applied to heat exchangers, is best defined as

    A. a change in temperature that induces excessive thermal stresses on heat exchanger components

    B. overexposure of heat exchanger components to thermal neutrons

    C. exposing heat exchanger components to a temperature increase greater than 50°F in one hour

    D. exposing heat exchanger components to a temperature decrease of greater than 50°F in one hour

11. Severe stress in a mechanical component, induced by a sudden, unequally distributed temperature change, is a description of

    A. thermal stress
    B. thermal shock
    C. brittle fracture
    D. pressurized thermal shock

12. Which of the following will result in thermal shock to a pressure vessel?

    A. a vessel "soak"
    B. severe overcooling
    C. rapid change in pressure
    D. rapid change in flow

13. The major thermodynamic concern resulting from rapidly cooling a pressure vessel is

    A. loss of subcooling margin
    B. thermal shock
    C. loss of shutdown margin
    D. condensation

14. Whenever possible, a heat exchanger should be placed in service by introducing both fluids gradually and simultaneously to

    A. prevent excessive thermal stresses in the heat exchanger

    B. maximize the heat transferred across the heat exchanger tubes

    C. minimize boiling of the cooling water in the heat exchanger tubes

    D. provide maximum temperature control of the system being cooled

15. Scale buildup on heat exchanger tubes will cause the heat transfer coefficient to

    A. increase
    B. decrease
    C. vary erratically
    D. remain the same

16. Tube fouling inside a heat exchanger will cause the heat transfer coefficient to

    A. increase
    B. decrease
    C. vary erratically
    D. remain the same

17. During normal steady-state plant operation with a constant generator load, plugging of one percent of the tubes in the main condenser will cause absolute pressure in the condenser to _________ and hotwell temperature to __________.

    A. increase; increase
    B. decrease, increase
    C. increase, decrease
    D. decrease; decrease

18. Tube scaling in a parallel flow heat exchanger will cause heat transfer to decrease because

    A. flow through the heat exchanger increases

    B. surface area of the tubes decreases

    C. heat transfer coefficient decreases

    D. inlet temperature of the cooling fluid increases

19. Tube fouling in a heat exchanger causes heat transfer to decrease by

    A. reducing fluid velocity on the shell side of the exchanger and reducing heat transfer area

    B. increasing flow rate through the tube side of the exchanger and increasing heat transfer area

    C. reducing the overall (total) heat transfer coefficient and reducing tube-side flow

    D. increasing the overall (total) heat transfer coefficient and increasing shell-side flow

20. Which one of the following effects will occur as a result of increased fouling of the main condenser tube bundles? Assume cooling water flow rate remains constant.

    A. Cooling water outlet temperature will decrease.

    B. Condenser hotwell temperature will decrease.

    C. Condensate depression will increase.

    D. Condenser heat rejection rate will increase.

21. Refer to the drawing of a lube oil heat exchanger (see Figure 1.6-3).

    If scaling occurs inside the cooling water tubes, cooling water outlet temperature will __________ and oil outlet temperature will __________. (Assume oil and cooling water flow rates remain the same.)

    A. decrease; decrease
    B. increase; increase
    C. decrease; increase
    D. increase; decrease

22. Borated water is flowing through the tubes of a heat exchanger being cooled by fresh water. The shell side pressure is less than tube side pressure. What will occur as a result of a tube failure?

    A. Shell side pressure will increase and the borated water system will be diluted.

    B. Shell side pressure will decrease and the borated water inventory will be depleted.

    C. Shell side pressure will increase and the borated water inventory will be depleted.

    D. Shell side pressure will decrease and the borated water system will be diluted.

23. Which of the following is always a direct consequence of a heat exchanger tube failure?

    A. chemical dilution/pollution
    B. system contamination
    C. loss of fluid separation
    D. subcooling reduction

24. Refer to the drawing of an operating cooling water system (see Figure 1.6-4).

    Which of the following effects would occur as a result of a tube failure in the heat exchanger?

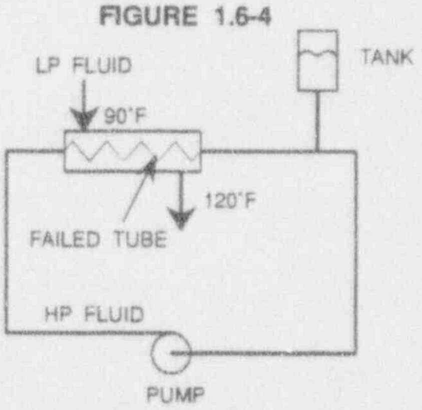
    A. pressure in the low pressure system decreases

    B. flow in the low pressure system reverses

    C. temperature in the low pressure system increases

    D. level in the tank increases

FIGURE 1.6-4



Cooling Water System

25. Using Figure 1.6-5, determine which of the following effects would occur as a result of a tube failure in the heat exchanger.

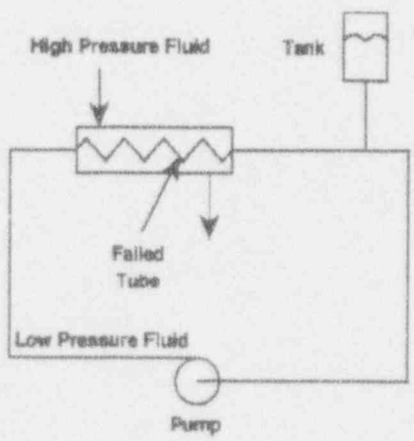
    A. High pressure fluid inventory increases.

    B. Flow in the low pressure system reverses.

    C. Temperature in the low pressure system increases.

    D. Level in the tank increases.

FIGURE 1.6-5



Basic Fluid System

26. Which of the following is not a possible consequence of a heat exchanger tube failure?

    A. shell rupture
    B. radioactive release
    C. fluid mixing
    D. increased vacuum

27. Which one of the following effects will occur as a result of multiple tube failures in the main condenser with the plant at 50% power?

    A. Condensate conductivity will increase.

    B. Condenser cooling water outlet temperature will decrease.

    C. Condensate chloride concentration will decrease.

    D. Condensate makeup rate will increase.

28. The plant is operating normally at 50 percent power. Which one of the following will result from a cooling water tube rupture in the main condenser?

    A. increased condenser vacuum

    B. increased conductivity of the condensate

    C. decreased condensate pump net positive suction head

    D. decreased condensate pump flow rate

29. Which of the following is not true concerning heat exchanger performance?

    A. Scale buildup on heat exchanger tube surfaces decreases the heat transfer coefficient.

    B. Tube fouling on the heat exchanger tubes will reduce the overall (total) heat transfer coefficient (U).

    C. Laminar flow is less effective than turbulent flow for heat transfer in a heat exchanger.

    D. Introduction of small amounts of air or non-condensible gases improves heat exchanger performance.

30. During normal plant operation at power, a crack in the shell of the main condenser, that results in a decreased condenser vacuum (higher absolute pressure), will cause cooling water outlet temperature to __________ and hotwell temperature to __________.

    A. increase; decrease
    B. decrease; decrease
    C. increase; increase
    D. decrease; increase

31. Borated water is flowing through the tubes of a heat exchanger being cooled by fresh water. The shell side pressure is less than tube side pressure. What will occur as a result of a tube failure?

    A. Shell side pressure will decrease and the borated water system will be diluted.

    B. Shell side pressure will decrease and the borated water inventory will be depleted.

    C. Fresh water inventory will be depleted and the borated water system will be diluted.

    D. Fresh water will become boron-contaminated and the borated water inventory will be depleted.

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

Throttling valve C in the shut direction will lower the tube-side flow rate through the non-regenerative heat exchanger. This will cause the cooling water to remove more heat, reducing temperatures at points 7, 3, and 1.

Reference 22, section III, part B, chapter 2, pages 337-350.

2. D

Opening valve D provides additional cooling water flow to the non-regenerative heat exchanger, reducing the temperature at point 7.

Reference 22, section III, part B, chapter 2, pages 337-350.

3. D

Throttling the system flow will increase the time both tube-side and shell-side water spends in the regenerative heat exchanger. This will cause a greater temperature drop on the tube side, reducing the temperature at point 4. Additionally, the reduced tube-side flow through the non-regenerative heat exchanger will result in a greater temperautre drop there as well. Therefore, the temperature at point 7 will decrease.

Reference 22, section III, part B, chapter 2, pages 337-350.

4. B

Throttling the system flow will increase the time both tube-side and shell-side water spends in the regenerative heat exchanger. This will cause a greater temperature drop on the tube side, reducing the temperature at point 4.

Reference 22, section III, part B, chapter 2, pages 337-350.

5. D

Opening valve D will increase cooling water flow rate through the heat exchangers. More heat will therefore be transferred out to the cooling water, reducing the temperatue at point 7.

Reference 22, section III, part B, chapter 2, pages 337-350.

6. B

Closing valve D reduces cooling water flow to the non-regenerative heat exchanger. The water returning through the regenerative heat exchanger to the system is warmer. This causes the water from the system to be hotter at point C as it leaves the regenerative heat exchanger.

Reference 22, section 111, part B, chapter 2, pages 337-350.

7. B

Reference 63, pages 5-8 through 5-10.

8. A

Reference 63, page 5-12.

9. A

Reference 63, page 5-12.

10. A

Thermal shock occurs when heat exchanger components are exposed to rates of temperature change that result in excessive stresses being induced.

11. B

Reference 52, pages 1,063 and 1,201.

12. B

Reference 64, overview, page 1.

13. B

Reference 65, overview, page 5.

14. A

Reference 63, pages 5-4 through 5-7.

15. B

Scale buildup creates an insulating layer on the heat exchanger tubes. The heat transfer coefficient decreases as the scale layer increases in thickness.

Reference 63, pages 9-18 and 9-19.

16. B

Tube fouling reduces the heat transfer rate in a heat exchanger by reducing the effective heat transfer coefficient and disrupting flow through the heat exchanger tubes.

Reference 63, pages 9-18 and 9-19.

17. A

Tube plugging results in reduced circulating water flow, which causes reduced vacuum (increased pressure) and higher hotwell temperature.

18. C

Tube scaling causes the effective heat transfer coefficient to decrease.

Reference 63, pages 9-18 and 9-19.

19. C

Tube fouling causes partial blockage of heat exchanger tubes and reduces the flow of cooling fluid through the tubes. The net heat transfer coefficient (U) is reduced; therefore, the heat transfer rate is reduced.

Reference 63, pages 9-18 and 9-19.

20. A

21. C

Since scaling occuring inside the cooling tubes will reduce the ability for heat transfer across the tubes, a reduction in heat exchange occurs. With flow rates remaining constant, the oil outlet temperature will be higher and the cooling water outlet temperature lower since it has not absorbed as much heat from the oil.

Reference 63, pages 5-10 through 5-12.

22. C

23. C

24. C

Reference 63, pages 5-10 through 5-12.

25. D

26. D

27. A

28. B

Reference 63, pages 9-3 through 9-24.

29. D

Air and non-condensible gases reduce the total heat transfer rate inside a heat exchanger.

Reference 63, pages 9-24 and 9-25.

30. C

Reference 63, pages 9-24 and 9-25.

31. D

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.04, 1.07 Questions 1,4,5

Discuss effects of heat exchanger flow rates that are too high or too low and methods of proper flow adjustment.

K1.04, 1.07 Questions 2,3, and 6-9

Discuss the effects of adjusting heat exchanger flow rates.

K1.09 Questions 10, 11

State the definition of "thermal shock" as it applies to heat exchangers.

K1.09 Questions 12-14

Identify operational activities that affect the possiblity of thermal shock.

K1.12 Questions 15-17

State the effects of tube fouling and tube scaling on heat exchanger operation.

K1.12 Questions 18-21

Explain the effects of tube fouling and tube scaling on heat exchanger operation.

K1.13 Questions 22-28, 31

Describe the consequences of a heat exchanger tube failure.

K1.14 Questions 29, 30

Recognize performance factors affecting heat exchanger operation.

DEMINERALIZERS AND ION EXCHANGERS
Questions

1. A demineralizer that exhibits a sudden increase in outlet conductivity may have been operated with

   A. low inlet conductivity
   B. low inlet temperature
   C. high effluent pressure
   D. high differential pressure

2. High differential pressure in a demineralizer could be caused by all of the following <u>except</u>

   A. regeneration
   B. coagulation
   C. crud buildup
   D. high flow rates

3. Operation of a demineralizer with high differential pressure could result in

   A. low outlet conductivity
   B. high outlet conductivity
   C. low outlet temperature
   D. high outlet temperature

4. All of the following could cause high demineralizer differential pressure <u>except</u>

   A. high fluid flow rates

   B. oil in the fluid flowstream

   C. ionic impurities in the fluid flowstream

   D. suspended solids in the fluid flowstream

5. The demineralization factor (DF) can be expressed as

   A. (Inlet Conductivity)-(Outlet Conductivity)
   B. (1)-(Outlet Conductivity)
   C. (Inlet Conductivity)/(Outlet Conductivity)
   D. (100) x (Outlet Conductivity)

6. The degree of exhaustion of a demineralizer resin bed is best determined from the

   A. length of time in service and outlet total dissolved solids (TDS)

   B. demineralizer flow rate and total volume treated

   C. demineralizer flow rate and outlet TDS

   D. inlet conductivity and total volume treated

7. The inlet and outlet conductivity of a demineralizer are measured to determine the demineralizer's

   A. flow rate
   B. breakpoint
   C. effectiveness
   D. specific conductance

8. To determine the demineralization factor for a demineralizer, the inlet and outlet ________ must be monitored.

   A. temperatue
   B. conductivity
   C. pressure
   D. flow rate

9. Which one of the following is the first indication of exhausted resin in a demineralizer?

   A. an increase in suspended solids of the effluent

   B. a decrease in the flow rate through the demineralizer

   C. an increase in the conductivity of the effluent

   D. a decrease in the effluent pH

10. The temperature of the water passing through a demineralizer must be controlled because excessively hot water will

    A. increase the ion exchange rate for hydronium ions, therby changing effluent pH

    B. degrade the corrosion inhibitor applied to the inner wall of the demineralizer

    C. result in excessive demineralizer retention element thermal expansion, thereby releasing resin

    D. reduce the affinity of the demineralizer resin for ion exchange

11. The purpose of a demineralizer is to

    A. raise the conductivity of water without affecting pH

    B. reduce the conductivity of water without affecting pH

    C. increase the pH of water by reducing the number of positively charged ions in it

    D. decrease the pH of water by increasing the number of negatively charged ions in it

12. A large pressure drop across a demineralizer indicates that the resin bed

    A. has channeling
    B. is depleted
    C. is clogged
    D. has been regenerated

13. An indication that a demineralizer bed is clogged is

    A. a large pressure drop across the bed
    B. a high flow through the bed
    C. a temperatue rise in the effluent
    D. a large conductivity drop across the bed

14. A lower than expected differential pressure across a demineralizer is one indication of

    A. depletion of the cation resin
    B. channeling through the bed
    C. improper resin regeneration
    D. a decrease in inlet conductivity

15. Which of the following would be indicated by a large pressure drop across a demineralizer?

    A. The bed has developed channeling through it

    B. The resin in the bed is depleted.

    C. The resin bed is clogged.

    D. The bed was recently regenerated.

16. As the operating time of a resin bed increases, the differential pressure across the bed

    A. increases due to depletion of resin sites

    B. increases due to trapping of suspended solids

    C. decreases due to resin breakthrough

    D. decreases due to bead surface erosion

17. How does demineralizer differential pressure indicate the condition of the demineralizer resin bed?

    A. Low differential pressure indicates flow blockage in the demineralizer.

    B. High differential pressure indicates flow blockage in the demineralizer.

    C. Low differential pressure indicates that the demineralizer resin bed is exhausted.

    D. High differential pressure indicates that the demineralizer resin bed is exhausted.

18. A demineralizer is being used in a water purification system. How will accumulation of suspended solids in the demineralizer affect the performance of the demineralizer?

    A. The rate of resin depletion will increase.

    B. The number of ion exchange sites will decrease.

    C. The flow rate of water through the demineralizer will increase.

    D. The rate of unwanted ion removal from the system will decrease.

19. Coolant passing through a deborating demineralizer/ion exchanger suddenly increases to 200°F. As a result, you would expect boron concentration of the coolant leaving the demineralizer to

    A. increase
    B. decrease
    C. stay the same
    D. vary erratically

20. When a mixed-bed demineralizer resin is exhausted, the resin should be replaced or regenerated because

    A. the resin will physically bond together, thereby causing a flow blockage

    B. ions previously removed by the resin will be released to solution

    C. the resin will fracture and possibly escape through the retention screens

    D. particles previously filtered out of solution will be released

21. In addition to exhaustion of the resin, the effectiveness of a demineralizer can be reduced by

    A. high decontaimination factor (DF)
    B. low influent temperature
    C. high influent temperature
    D. low influent pressure

22. A demineralizer that has been exposed to ____________ should be bypassed because the resin beads may release unwanted ions.

    A. high flow
    B. low flow
    C. high temperatue
    D. low temperature

23. What is the reason for bypassing a demineralizer due to high temperature?

    A. Resins expand and restrict flow through the demineralizer.

    B. Resins decompose and restrict flow through the demineralizer.

    C. Resins decompose and create preferential flowpaths through the demineralizer.

    D. Resins decompose and contaminate the system.

24. Prior to a scheduled plant shutdown, the reactor coolant system was chemically shocked to induce a crud burst. What effect will this have on the letdown purification demineralizers?

    A. decreased radiation levels around the demineralizers

    B. increased flow rate through the demineralizers

    C. decreased demineralizer outlet conductivity

    D. increased pressure drop across the demineralizers

25. Which of the following plant evolutions is most likely to induce a crud burst in the reactor coolant system?

    A. starting a charging (makeup) pump

    B. 2 MW/min ramp to full power

    C. a reactor trip from 50% power

    D. a plant heatup from 200°F to 550°F @ 50°F/hr

26. In event of a system crud burst, what adverse effect does the crud burst have on demineralizer operation?

    A. increased pressure drop across demineralizer

    B. increased flow rate through demineralizer

    C. increased demineralizer outlet conductivity

    D. increased demineralizer inlet pH

27. A finely divided material suspended in cooling water that is produced from the corrosion or wear of metals is known as

    A. an ion pair
    B. crud
    C. a cation
    D. resin

28. After either a mechanical or a chemical shock, the breaking free of corrosion products into the reactor coolant system is known as a

    A. release
    B. hideout return
    C. crud burst
    D. breakthrough

29. A demineralizer is boron saturated when the demineralizer

    A. effluent contains a higher boron concentration than the demineralizer influent

    B. absorbs greater than 20 ppm boron per hour

    C. influent and effluent boron concentration are equal

    D. effluent boron concentration rapidly increases

30. Boron concentration in the reactor (primary) coolant system has been decreasing steadily at approximately 10 ppm per hour while using the deborating demineralizer. After several hours, the rate decreases to 2 ppm per hour. What is a possible cause for the change in deboration rate?

    A. Temperature of the coolant passing through the demineralizer has decreased.

    B. pH of the coolant has increased significantly.

    C. Flow through the deborating resins has increased sharply.

    D. Deborating resins have become boron saturated.

31. Which of the following sets of data best indicates a "boron saturated" demineralizer?

    A. $C_b$inlet = 300 ppm, $C_b$outlet = 150 ppm
    B. $C_b$inlet = 700 ppm, $C_b$outlet = 110 ppm
    C. $C_b$inlet = 880 ppm, $C_b$outlet = 530 ppm
    D. $C_b$inlet = 150 ppm, $C_b$outlet = 140 ppm

32. The plant is operating at 70 percent equilibrium power level when the temperature of reactor coolant letdown passing through a saturated mixed bed ion exchanger is decreased by 20 degrees F. As a result, the boron concentration in the effluent of the ion exchanger will ____________ because the affinity of the ion exchanger for boron atoms has ____________.

A. decrease; decreased
B. decrease; increased
C. increase; decreased
D. increase; increased

33. A sudden increase in conductivity of water at the outlet of a demineralizer will result from:

A. increased demineralizer flow rate

B. reduced demineralizer inlet temperature

C. reduced demineralizer inlet conductivity

D. increased demineralizer effluent pressure

34. The ion exchange efficiency of a condensate demineralizer can be determined by:

A. sampling the inlet and outlet of the demineralizer to determine the change in conductivity

B. performing a calculation based on the ratio between the inlet pH divided by the outlet pH

C. sampling the inlet and outlet of the demineralizer to determine the difference in activity

D. performing a calculation based on the change in differential pressure across the demineralizer

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. D

Reference 46.1, page 5-3.

2. A

Reference 46.1, page 5-3.

3. B

Reference 46.1, Page 5-3.

4. C

Reference 46.1, Page 5-3.

5. C

$$DF = \frac{\text{INLET conductivity}}{\text{OUTLET conductivity}}$$

Reference 21, page 1-62.

6. D

Reference 21, page 1-62.

7. C

Ratio of INLET to OUTLET conductivity is a measure of a demineralizer's effectiveness.

Reference 21, page 1-62.

8. B

$$DF = \frac{\text{INLET conductivity}}{\text{OUTLET conductivity}}$$

Reference 21, page 1-62.

9. C

Reference 21, page 1-62.

10. D

High temperatures will damage demineralizer resins, reducing their effectiveness and possibly releasing contaminants into the process flow.

11. B

12. C

Channeling decreases the pressure drop across a demineralizer. Depletion refers to exhaustion of ion exchange site. Regeneration, if done successfully, causes a low differential pressure across a demineralizer. Fouling is the adherence of solid material, usually corrosion products, to the outler layer of resin, causing a higher differential pressure across a demineralizer.

Reference 46.1, page 5-4.

13. A

Fouling causes low flow through a bed.
Fouling has no effect on temperature.
Fouling can only decrease the conductivity drop across a bed.
Fouling does add to the material thickness water must pass through; therefore "A" is the answer.

Reference 46.1, page 5-4

14. B

Channels created in the resin bed provide low resistance flow paths in parallel with the normal flow path, resulting in an overall lower differential pressure across the demineralizer.

Reference 46.1, page 5-4.

15. C

Fouling of a resin bed adds to the material that the water must pass through, increasing the differential pressure across the bed.

Reference 46.1, page 5-4.

16. B

Corrosion products and other suspended solids will eventually build up in the resin bed, increasing the amount of material the water must pass through, and thus increasing differential pressure across the demineralizer.

Reference 46.1, page 5-4.

17. B

Reference 46.1, page 5-4.

18. D

Reference 21, page 1-62.

19. A

Increasing fluid temperature through a deborating demineralizer/ion exchanger reduces absorption rate and at high temperatures causes boron to be released to the coolant.

Reference 60, chapter 7, pages 22 and 23.

20. B

Once resin is exhausted, a reverse exchange can occur.

Reference 21, page 1-61.

21. C

Increasing fluid temperature through a demineralizer reduces the absorption rate.

Reference 21, page 1-64.

22. C

Temperature of resin beds must be kept below 145 °F. Organic compounds used as resins will decompose under high temperatures, introducing impurities into the reactor coolant; thus, bypassing the demineralizer would be required.

Reference 60, chapter 7, page 23.

23. D

Temperature of resin beds must be kept below 145 °F. Organic compounds used as resins will decompose under high temperatures, introducing impurities into the reactor coolant; thus, bypassing the demineralizer would be required.

Reference 60, chapter 7, page 23.

24. D

The pressure differential across the demineralizer increases as it filters impurities from the reactor coolant system.

Reference 59, page 5-8; and Reference 21, page 1-62.

25. C

Plant evolutions characterized by rapid and severe changes in reactor coolant system pressure o. temperature can induce crud bursts.

Reference 59, page 5-8; and Reference 21, page 1-62.

26. A

The pressure differential across the demineralizer increases as it filters impurities from the reactor coolant system.

Reference 59, page 5-8; and Reference 21, page 1-62.

27. B

Crud is material suspended in cooling water that is produced from the corrosion or wear of metals.

Reference 59, page 2-8.

28. C

The breaking free of corrosion products into the reactor coolant system after either a mechanical or chemical shock is known as a crud burst.

Reference 59, Appendix A, page 2.

29. C

Boron saturation occurs when a majority of resin storage sites become occupied by boron atoms. The operators will recognize saturation by a rapid decrease in the rate of absorption.

Reference 59, page 5-8; and reference 21, page 1-62.

30. D

A decrease in boration/dilution rate is indicative of resin saturation.

Reference 49, page 5-8; and reference 21, page 1-62.

31. D

Boron saturation is essentially indicated when the boron concentration entering a demineralizer is equal to the boron concentration exiting the demineralizer. The lower the DF, the closer the demineralizer is to saturation.

Reference 59, page 5-8; and reference 21, page 1-62.

32. B

Reference 60, chapter 7, pages 22 and 23.

33. A

34. A

DEMINERALIZERS AND ION EXCHANGERS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1,3, 33

State the effect of excessive differential pressure on demineralizer performance.

K1.01 Questions 2,4

State possible causes of high demineralizer differential pressure.

K1.03 Question 5

Define the term "demineralization factor (DF)" as it applies to a demineralizer (deionizer).

K1.03 Questions 6-9, 34

State the reason for sampling both the inlet and outlet of a demineralizer.

K1.04 Question 10

Explain why maximum temperature limits are placed on demineralizers.

K1.05 Question 11

State the purpose of a demineralizer.

K1.06 Questions 12-18

State how the differential pressure across a demineralizer is an indicator of resin bed condition.

K1.08 Question 19

Identify changes to plant or system operating conditions that could affect boron concentration.

K1.08 Questions 20, 21

Discuss factors that can affect demineralizer operation.

K1.09 Question 22

Discuss how a change in temperature affects demineralizer operation.

K1.09 Question 23

Discuss the reasons for bypassing demineralizers.

K1.11 Questions 24, 26

Discuss the effects of a crud burst on demineralizer operation.

K1.11 Question 25

Discuss plant evolutions which can cause a crud burst.

K1.11 Question 27

Define the term "crud".

K1.11 Question 28

Define the term "crud burst".

K1.12 Questions 29, 30

Define "boron saturated" as it relates to a demineralizer.

K1.12 Question 31

Determine whether a demineralizer is boron saturated.

K1.14 Question 32

Identify the effect of a change in water temperature on demineralizer operation.

1. An advantage of racking out circuit breakers and removing the associated control power fuses compared to tagging a control switch is that:

   A. indication circuits remain energized for breaker position verification

   B. availability of the control switch and control power remains for testing

   C. the equipment remains operable via the control switch

   D. the equipment and its control and indication circuits are deenergized

2. What should be done to completely deenergize a circuit breaker, including its control and indication power?

   A. Rack out the breaker and pull control power fuses.

   B. Open the breaker and tag it out.

   C. Lift the leads to ensure complete deenergization.

   D. Tag the control switch and post a watch at the breaker.

3. To properly deenergize a component and its associated control and indication circuits, the component circuit breaker should be

   A. open with the control switch in Pull-To-Lock

   B. open with the control switch tagged in the open position

   C. racked out and tagged in racked-out position

   D. racked out with control power fuses removed

4. During maintenance activities, breakers in the open position are tagged and racked out to

   A. deenergize components and associated control and indication circuits

   B. provide administrative control where safety is not of prime importance

   C. maintain remote indication of breaker position (where available) to ensure personnel safety

   D. permit immediate availability of the breaker if required for emergency use

5. While locally investigating the condition of a large circuit breaker, an operator observes the following indications:

   - OPEN/CLOSED mechanical flag indication indicates open
   - OPEN/CLOSED indicating lights indicate open
   - overcurrent trip flags are actuated on all phases
   - loadside voltmeter indicates zero volts
   - loadside ammeter indicates zero amperes

   Based on these indications, the operator should report that the circuit breaker is open, racked ______, with _________ condition indicated.

   A. in; overload
   B. in; no overload
   C. out; overload
   D. out; no overload

6. Which of the following available local circuit breaker indications would be a positive method for identifying whether a circuit breaker is closed or open?

   A. overcurrent trip flags and loadside ammeter

   B. OPEN/CLOSED mechanical flag indication and loadside voltmeter

   C. OPEN/CLOSED indicating lights and overcurrent trip flags

   D. loadside ammeter and OPEN/CLOSED indicating lights

7. Which of the following available local circuit breaker indications will provide reliable and positive indication that a bus feeder breaker is open? (Assume the following indications and mechanisms are operating properly.)

   A. overcurrent trip flags and load-side ammeter

   B. load-side ammeter and load-side voltage

   C. load-side voltage and open/closed mechanical flag indication

   D. open/closed mechanical flag indication and overcurrent trip flags

8. To ensure reliable local circuit breaker indication is being provided, the __________ must be reset after breaker actuation due to a short circuit in its load.

   A. OPEN/CLOSED mechanical flag
   B. OPEN/CLOSED indicating lights
   C. overcurrent trip flag
   D. spring CHARGE/DISCHARGE flag

9. Circuit breaker local overcurrent trip flag indicators

   A. indicate overcurrent conditions only during the actual overcurrent condition

   B. mean that the associated circuit breaker has failed to trip open, if actuated

   C. are normally disconnected; therefore, provide no useful function

   D. should be reported to the control room if found to be actuated

10. Loss of breaker control power will cause

   A. breaker line voltage to indicate zero regardless of actual breaker position

   B. the remote breaker position to indicate open regardless of actual breaker position

   C. inability to operate the breaker locally and remotely

   D. failure of the closing spring to charge following local tripping of the breaker

11. When a typical 4160 volt breaker is racked to the test position control power is __________ the breaker and the breaker is __________ the load.

   A. removed from; isolated from
   B. removed from; connected to
   C. available to; isolated from
   D. available to; connected to

12. Which of the following results from a loss of circuit breaker control power to a circuit breaker supplying a motor?

    A. Motor ammeter indication would be zero regardless of actual breaker position.

    B. Breaker position would remotely indicate closed regardless of actual position.

    C. Breaker would trip open due to the actuation of its protective trip device.

    D. Close spring charging motor would not charge spring following local tripping of the breaker.

13. Which of the following would cause a loss of ability to trip a circuit breaker remotely and a loss of position indication?

    A. failure of breaker control switch
    B. breaker in "test" position
    C. mechanical binding of breaker
    D. loss of breaker control power

14. Which of the following functions or capabilities would remain following a loss of circuit breaker control power?

    A. remote breaker control capability
    B. breaker undervoltage protection trips
    C. ability to close the breaker locally
    D. remote breaker position indication

15. Which one of the following will cause a loss of indication from the remote breaker position indicating lights associated with a typical 480 VAC load supply breaker?

    A. loss of breaker line voltage

    B. locally opening the breaker

    C. burnout of the local breaker position indicating lights

    D. removing the breaker control power fuses

16. How is circuit breaker operation affected when the circuit breaker control power transfer switch is placed in the local position?

    A. Control power will be available to provide protective trips and the circuit breaker can be closed by pushing the close pushbutton on or inside the circuit breaker enclosure.

    B. Control power will be available to provide protective trips and breaker operation is restricted to local manual operation only.

    C. Control power will be removed from both the open and close circuits and the circuit breaker can be closed by pushing the close pushbutton on or inside the circuit breaker enclosure.

    D. Control power will be removed from both the open and close circuits and breaker operation is restricted to local manual operation only.

17. A thermal overload protective device protects a motor by

    A. adding series resistors to limit starting current

    B. adding parallel resistors to limit starting current

    C. shutting off the motor if current becomes excessive

    D. slowing down the motor if current becomes excessive

18. A circuit breaker thermal overload device

    A. compares actual current to a fixed overcurrent setpoint that is equated to temperatue and actuates the overcurrent trip device

    B. when subjected to high current, overheats and actuates a circuit-interrupting device

    C. senses operating equipment temperature and trips protective circuits at preset limits

    D. is a temperature sensitive device that is connected in parallel with the protected load

19. For a motor, which condition would not require a thermal overload protective device to function?

    A. running speed is too high
    B. starting current is too high
    C. ambient temperature is too hot
    D. intermittent or sudden heavy loads

20. Which of the following consequences is not probable if a motor's thermal overload protective device fails to function?

    A. generation of excessive heat in the motor

    B. mechanical damage due to over-speeding the motor

    C. deterioration of winding insulation due to excessive current flow

    D. damaging current flows due to shorting of the windings

21. A temperature-sensitive relay device for a large motor protects the motor from

    A. sustained overcurrent by directly opening motor line contacts at the motor

    B. instantaneous overcurrent by directly opening motor line contacts at the motor

    C. sustained overcurrent by directly

    D. instantaneous overcurrent by directly opening the motor breaker

22. In motors, the thermal overload protective device protects against the degrading effects of abnormally

    A. reduced starting torque
    B. high applied frequency
    C. high line voltage
    D. high winding currents

23. What best describes the arrangement of contacts in Figure 1.8-1?

    A. 1 & 2 in series and in parallel with 3
    B. 1 & 3 in series and in parallel with 2
    C. 1 & 2 in parallel and in series with 3
    D. 1 & 3 in parallel and in series with 2

24. Refer to Figure 1.8-1:

    With the K-3 relay energized, pushing the S-1 pushbutton _______ the K-3 relay when contacts #1 and #2 are ________ .

    A. tests, closed
    B. deenergizes, open
    C. defeats, closed
    D. has no effect on, open

25. Refer to the drawing of a typical valve control circuit (see figure 1.8-1).

    Which one of the following describes the function of the #3 contact?

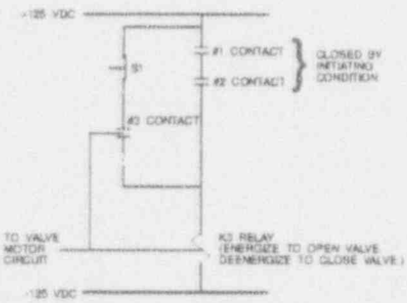
    A. To keep the K-3 relay energized after the initiating condition clears.

    B. To provide a method for manually energizing the K-3 relay.

    C. To increase circuit reliability as any one of three contacts can energize the K-3 relay.

    D. To ensure the K-3 relay deenergizes immediately after the initiating condition clears.

FIGURE 1.8-1



Typical Valve Control Circuit

26. Referring to Figure 1.8-1, select the correct statement regarding the operation of relay K3.

    A. deenergized when the #1 and #2 contacts close

    B. energized when pushbutton S1 is depressed

    C. energized when the #1 <u>or</u> #2 contact closes

    D. energized when the #1 <u>and</u> #2 contacts close

27. Refer to the drawing of a typical valve control circuit (see Figure 1.8-1).

    What is the purpose of depressing the S1 pushbutton?

    A. to reset the K3 relay after the initiating condition has cleared

    B. to prevent pickup of the K3 relay when the initiating condition occurs

    C. to manually energize the K3 relay in the absence of the initiating condition

    D. to maintain the K3 relay energized after the initiating condition has cleared

28. Refer to the drawing of a typical valve control circuit (see Figure 1.8-1).

    The purpose of the K3 relay is to

    A. hold the valve open after one or both of the initiating conditions have cleared, even if the reset pushbutton (S1) is depressed

    B. hold the valve open even if one or both of the initiating conditions have cleared

    C. close the valve as soon as either initiating condition has cleared

    D. close the valve as soon as both initiating conditions have cleared

29. Refer to the drawing of a typical valve control circuit for a 480 VAC motor-operated valve (see Figure 1.8-1).

    The valve is currently open with the contact configuration as shown. If the S1 pushbutton is depressed, the valve will __________ and when the S1 pushbutton is subsequently released, the valve will __________.

    A. remain open; remain open
    B. close; remain closed
    C. remain open; close
    D. close; open

30. In a motor, potential damage due to intermittent or sudden heavy loads can best be prevented by which type of protective device?

    A. thermal overload
    B. reverse power
    C. underfrequency
    D. undervoltage

31. Which of the following describes the best method for deenergizing a breaker control circuit?

    A. breaker in test position
    B. breaker fully racked out
    C. control power fuses removed
    D. control switch in pull-to-lock

32. Paralleling a three-phase A.C. generator with the generator and load currents out of phase will result in

    A. higher than normal current flow through the output breaker during closing

    B. improved circuit breaker life expectancy

    C. lower than normal current flow through the generator windings during closing

    D. no effect since no generator output breaker will close when currents are out of phase

33. While paralleling a three-phase A.C. generator to the grid, closing the generator output breaker with the frequency of the generator higher than grid frequency will result in generator load

    A. decreasing
    B. increasing
    C. remaining constant
    D. fluctuating

34. Closing the output breaker of the main generator with the frequency of the generator <u>higher</u> than grid frequency will result in the generator

    A. behaving as a real load to the grid

    B. behaving as a reactive load to the grid

    C. picking up a portion of the grid real load (MWe)

    D. picking up a portion of the grid reactive load (MVAR)

35. Closing a generator output breaker with the generator frequency much less than grid frequency will cause the generator to trip on

    A. reverse power
    B. overvoltage
    C. overcurrent
    D. overspeed

36. During paralleling operations of the main generator to the grid, closing the generator output breaker with the generator voltage slightly lower than grid voltage and with generator frequency slightly higher than grid frequency will result in

    A. the generator picking up a reactive load from the grid

    B. the generator immediately attaining a leading power factor

    C. the generator shedding real load to the grid

    D. motoring of the generator

37. While paralleling a three-phase A.C. generator to the grid, closing the generator output breaker with the frequency of the generator lower than grid frequency will result in

    A. the generator picking up a portion of the grid real load

    B. generator real load being picked up only if a voltage mismatch exists

    C. generator real load being picked up only if currents are out of phase

    D. possible motoring of the generator

38. The main generator is being paralleled to the grid. Generator voltage has been properly adjusted and the synchroscope is rotating slowly in the clockwise direction. The generator breaker must be closed just prior to the synchroscope pointer reaching the 12 o'clock position to prevent

    A. motoring of the generator due to unequal frequencies

    B. excessive arcing within the generator output breaker due to out-of-phase voltages

    C. excessive MWE load transfer to the generator due to unequal frequencies

    D. excessive MVAR load transfer to the generator due to out-of-phase voltages

39. During paralleling operations of the main generator to the grid, closing the generator output breaker with the frequency of the generator at 60.1 hertz and the grid frequency at 60.0 hertz will

    A. cause the generator to immediately increase load

    B. trip open the generator breaker on reverse power

    C. cause the generator voltage to increase

    D. cause the generator current to decrease

40. Which of the following evolutions will draw the highest current from the main generator during operation of the output breaker?

    A. opening the output breaker under full-load conditions

    B. opening the output breaker under no-load conditions

    C. closing the output breaker with voltages out of phase

    D. closing the output breaker with voltages in phase

41. Closing the output breaker of a three-phase generator onto a deenergized bus can result in

    A. an overvoltage condition on the bus

    B. an overcurrent condition on the generator if the bus was not first unloaded

    C. a reverse power trip of the generator circuit breaker if generator frequency is low

    D. a large reactive current in the generator

42. The primary reason for isolating emergency electrical loads from their power supply bus prior to energizing the bus via the emergency diesel generator is to prevent

    A. an overcurrent condition on the generator

    B. an overcurrent condition on the loads

    C. an underfrequency condition on the generator

    D. an underfrequency condition on the loads

43. Which of the following generator conditions is most likely to cause generator damage because of high current?

    A. tripping the output breaker under full-load conditions

    B. tripping the generator prime mover under full-load conditions

    C. closing the output breaker onto a bus that has an open-circuit fault

    D. closing the output breaker onto a bus that has a short-circuit fault

44. The primary reason for isolating emergency electrical loads from their power supply bus prior to energizing the bus via the emergency diesel generator is to prevent

    A. an overcurrent condition on the generator

    B. an overcurrent condition on the loads

    C. an underfrequency condition on the generator

    D. an underfrequency condition on the loads

45. If a deenergized bus is not unloaded prior to closing the output breaker of a three-phase generator onto the bus, then

    A. an overvoltage condition could occur on the bus

    B. an overcurrent condition could occur on the generator

    C. an overvoltage condition could occur between generator phases

    D. generator undervoltage relay acutation could occur

46. The function of high voltage electrical disconnects is to

    A. isolate equipment electrically during no-load conditions

    B. isolate equipment electrically during overload conditions

    C. protect circuits during overcurrent conditions

    D. protect circuits during undervoltage conditions

47. High voltage electrical disconnects should not be used to

    A. tie buswork sections together
    B. interrupt circuits under load
    C. electrically ground buswork
    D. isolate equipment electrically

48. High voltage electrical disconnects

    A. close automatically requiring no operator action

    B. require a remote means of indication to determine actual position

    C. should <u>not</u> be used to interrupt a circuit under load

    D. should be connected so that they ground the buswork

49. High voltage electrical disconnects

    A. protect circuits during overcurrent conditions

    B. automatically trip open to protect breakers

    C. isolate equipment electrically during no-load conditions

    D. interrupt circuits under load

50. Which of the following statements is correct concerning disconnect switches?

    A. Disconnects should be limited to normal load current interruption.

    B. Disconnects may be used to isolate transformers in an unloaded network.

    C. Disconnects are similar to oil circuit breakers, but are manually operated.

    D. Disconnects must be closed with caution when under load because of possible arcing.

51. High voltage electrical disconnects are primarily used to

    A. isolate electrical equipment for personnel safety

    B. tie electrical buses together for increased capacity

    C. provide electrical equipment protection against a faulted electrical bus

    D. isolate electrical buses to ensure separation of power supplies

52. The function of high voltage electrical disconnects is to provide __________ electrical isolation of equipment during __________ conditions.

    A. manual; no-load
    B. manual; overload
    C. automatic; no-load
    D. automatic; overload

53. Which of the following control room indications alone would identify breaker status?

    A. breaker red indicating light
    B. breaker green indicating light
    C. load amps greater than zero
    D. breaker control switch position

54. The following indications are observed for a motor breaker in the control room

    - red position indicating light "off"
    - green position indicating light "off"
    - load amps indicate normal load current

    Assuming one of the indicating lights is burned out, what is the condition of the breaker,

    A. open and racked in
    B. shut and racked in
    C. open and racked to "test" position
    D. shut and racked "test" position

55. The following remote indications are observed for a 480 VAC load center supply breaker. (The breaker is normally open.)

    - red indicating light is "on."
    - green indicating light is "off."
    - load center voltage indicates 0 volts.
    - breaker incoming voltage indicates 480 volts.

    What is the condition of the breaker?

    A. open and racked in
    B. closed and racked in
    C. open and racked to "test" position
    D. closed and racked to "test" position

56. Refer to the drawing of a typical valve control circuit (see figure 1.8-2).

    The initiating condition occurs and closes the #1 and #2 contacts to energize the K-3 relay and open the valve. Which one of the following will close the valve?

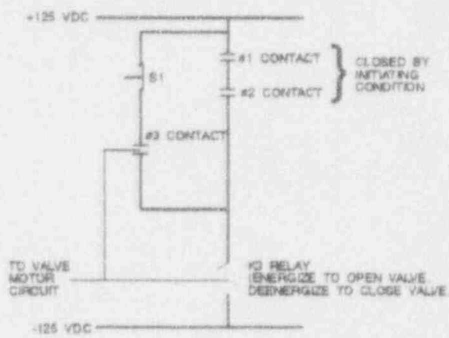
    A. loss of 125 VDC

    B. both #1 and #2 contacts open

    C. either #1 or #2 contact opens

    D. depressing the S1 pushbutton with the initiating condition present

FIGURE 1.8-2



Typical Valve Control Circuit

57. Which of the following describes the normal operation of a local circuit breaker overcurrent trip flag indicator?

    A. actuates to cause a breaker trip when the overcurrent trip setpoint is reached and must be manually reset when the overcurrent condition clears

    B. actuates to satisfy an electrical interlock when no lockout is present which is necessary to remotely close a breaker

    C. actuates when a breaker overcurrent trip has occurred and must be manually reset when the overcurrent condition clears

    D. actuates when the associated breaker has failed to trip on an overcurrent condition and must be manually reset when the overcurrent condition clears

58. A typical 120 VAC manual circuit breaker has tripped due to overload. Which of the following must be performed to close this circuit breaker?

    A. The handle must be moved from the mid-position to the off position to reset the trip latch, and then to the on position.

    B. The handle must be moved from the off position to the mid-position to reset the trip latch, and then to the on position.

    C. The handle must be moved from the mid-position directly to the on position. Trip latch reset is not required.

    D. The handle must be moved from the off position directly to the on position. Trip latch reset is not required.

59. Closing a circuit breaker between two electrical generators that are out of phase will cause:

    A. one generator to become a motor and the other generator to supply the motoring current

    B. a voltage reduction in both generators until normal voltage is manually restored

    C. a sudden large mechanical torque to be exerted on both of the generators

    D. a frequency reduction in both generators until normal frequency is manually restored

60. The following indications are observed in the control room for a normally-open breaker that directly starts/stops a 480 volt AC motor:

    Red position indicating light - ON
    Green position indicating light - OFF
    Load current indicates 50 amps
    Supply voltage indicates 480 volts

    What is the condition of the breaker?

    A. Open and racked in
    B. Closed and racked in
    C. Open and racked to "test" position
    D. Closed and racked to "test" position

61. Which one of the following is an unsafe practice if performed when working on or near energized electrical equipment?

    A. Use two hands for balance and to prevent dropping tools onto energized equipment.

    B. Stand on insulating rubber material to prevent yourself from being grounded.

    C. Have a person standing by to deenergize the equipment in the event of an emergency.

    D. Cover exposed energized circuits with insulating material to prevent inadvertent contact.

62. A three-phase AC generator is being paralleled to the grid with the following conditions:

Generator frequency:	59.5 Hz
Grid frequency:	59.8 Hz
Generator voltage:	115.1 Kv
Grid voltage:	114.8 Kv

When the generator output breaker is closed the generator will:

A. acquire real load and reactive load

B. acquire real load but become a reactive load to the grid

C. become a real load to the grid but acquire reactive load

D. become a real load and a reactive load to the grid

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. D

Circuit breakers are racked out, and control power fuses pulled, to deenergize components and associated control and indication circuits.

Reference 05, chapter 1, page 9.

2. A

Circuit breakers are racked out, and control power fuses pulled, to deenergize components and associated control and indication circuits.

Reference 05, chapter 1, page 9.

3. D

Circuit breakers are racked out, and central power fuses pulled to deenergize components and associated control and indication circuits.

Reference 05, chapter 1, page 9.

4. A

Reference 05, chapter 1, page 9.

5. A

All indications indicate that the breaker is open as supported by load voltage. Breaker is racked in because indicating lights are still available for indication. Breaker overload flags indicated an overload condition existed at some time in the past

*NOTE: Each facility should review this question for applicability to their switchgear.

Reference 05, chapter 14, page 242.

6. B

Mechanical flag indication is a positive means of determining breaker position as supported by load-side voltmeter indication.

*NOTE: Each facility should review this question for applicability to their switchgear.

Reference 05, chapter 14, page 242.

7. C

Mechanical flag indication is a positive means of determining breaker position as supported by load-side voltmeter indication.

*NOTE: Each facility should review this question for applicability to their switchgear.

Reference 05, chapter 14, page 242.

8. C

Overcurrent trip flags must be reset manually by the operator after each overcurrent trip in order to allow the flags to be indicative of future overcurrent events that might occur.

*NOTE: Each facility should review this question for applicability to their switchgear.

Reference 05, chapter 14, page 242.

9. D

Any abnormal condition should be reported to the control room when found.

*NOTE: Each facility should review this question for applicability to their switchgear.

Reference 05, chapter 14, page 242.

10. D

Reference 20.

11. C

Reference 20.

12. D

Reference 20.

13. D

A loss of breaker control power will result in the inability to trip the breaker (remotely or on a fault) concurrent with a loss of indication (local or remote).

Reference 20.

14. C

Reference 20.

15. D

Reference 20.

16. A

Reference 20.

17. C

Reference 36, chapter 7, page 152.

18. B

19. A

Reference 36, chapter 7, page 152.

20. B

Reference 36, chapter 7, page 152.

21. C

Reference 36, chapter 7, page 152.

22. D

Reference 36, chapter 7, page 152.

23. A

Reference 06.

24. B

Closing contacts #1 and #2 completes series circuit, energizing relay coil K3, which closes seal-in contact # 3.

If the condition that closed contacts #1 or #2 clears, relay coil #3 will remain energized until control pushbutton S1 is depressed, breaking the seal-in and resetting the relay.

Reference 06.

25. A

Closing contacts #1 and #2 complete series circuit energizing relay coil K3 which closes seal-in contact #3.

If the condition that closed contacts #1 or #2 clears, relay coil #3 will remain energized until control pushbutton S1 is depressed, breaking the seal-in.

Reference 06.

26. D

Closing contacts #1 and #2 completes series circuit energizing relay coil K3, which closes seal-in contact #3.

Reference 06.

27. A

Reference 06.

28. B

Reference 06.

29. B

Reference 06

30. A

Reference 36, chapter 7, page 152.

31. C

32. A

Phase current or voltages out of phase when closing a generator output breaker during paralleling operations will result in large current flow across the breaker and in both sources of power as currents come back into synchronization.

Reference 05, chapter 16, page 302; and Reference 27, chapter 10, page 182.

33. B

Frequency higher on incoming source will result in load increase of generator.

Reference 05, chapter 16, page 302; and Reference 27, chapter 10, page 182.

34. C

A higher frequency on the incoming source causes it to pick up real load.

35. A

Low frequency on the generator will cause the grid to motorize the generator, thus causing a reverse power condition.

36. B

37. D

Generator output breakers equipped with reverse power trips will open if the grid is sensed to be supplying the generator with power. Otherwise, it may motor the generator.

Reference 05, chapter 16, page 302; and Reference 27, chapter 10, page 182.

38. D

Reference 05, chapter 16, page 302; and reference 27, chapter 10, page 182.

39. A

The higher frequency on incoming source will result in load increase of the generator.

Reference 05, chapter 16, page 302; and reference 27, chapter 10, page 182.

40. C

41. B

Load shed is important for the prevention of excessive starting currents, which could occur through the breaker if load shed does not occur.

Reference 05, chapter 16, page 302; a Reference 27, chapter 10, page 182.

42. A

If the bus is not stripped prior to energizing it excessive generator current could result when several loads simultaneously draw starting current.

43. D

Only answer choice "D" provides a low resistance path, which would result in high currents and possible damage.

44. A

If the bus is not stripped prior to energizing it, excessive generator current could result when several loads simultaneously draw starting current.

45. B

If the bus is not stripped prior to energizing it, excessive generator current could result when several loads simultaneously draw starting current.

46. A

Disconnects are only used to isolate circuits which are not under load.

Reference 11, pages 13 and 66.

47. B

Disconnects are normally used to connect or disconnect sections of buswork. They may also be used to ground isolated buswork to ground. Disconnects must never be opened under load.

Reference 11, pages 13 and 66.

48. C

Disconnects should never be operated to interrupt a circuit which is under load. They never operate automatically, but may be motor-operated. The position of most disconnects may be visibly determined locally. Never ground energized buswork.

Reference 11, pages 13 and 66.

49. C

Disconnects manu-lly may be used to isolate equipment electrically only after the generator is unloaded; disconnects have no protective actuations.

Reference 11, pages 13 and 66.

50. B

Reference 55, chapter 4, page 66; and Reference 11, chapter 1, page 13.

51. A

By opening disconnects, an operator physically isolates unloaded buses, providing assurance that an isolated bus will remain unenergized.

52. A

Opening disconnects manually may be used to isolate equipment electrically only after the equipment is unloaded; disconnects have no protective actuations.

Reference 11, pages 13 and 66.

53. C

Reference 20, and Reference 62.

54. B

Reference 20, and Reference 62.

55. D

Reference 20, and reference 62.

56. A

57. C

58. A

59. C

60. B

61. A

62. C

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01, 1.09 Questions 1-4

State the purposes for and effects of racking out breakers.

K1.02, 1.12 Questions 5-9, 57

Identify the methods by which circuit breaker local indication may be used to determine whether a breaker is open, closed, tripped, or racked out/in.

K1.03, 1.09 Question 10

State the potential consequences of a loss of breaker control power.

K1.03, 1.09 Questions 11-15

Identify potential indications of a loss of circuit breaker control power.

K1.04 Question 16, 58

Describe the operation of circuit breaker controls.

K1.05 Questions 17, 22

State the function of a thermal overload protective device.

K1.05 Question 18

Explain how a thermal overload device functions.

K1.05 Questions 19, 30

Identify situations that can lead to the actuation of a thermal overload protective device.

K1.05 Question 20, 21

Identify the possible consequences to a motor if its thermal overload protective device fails to function.

K1.06 Questions 23-29, 56

Given a typical one-line logic diagram, describe the function of the identified components.

K1.07 Question 31, 61

Describe how to deenergize a breaker control circuit.

K1.08 Questions 32-40, 59, 62

Identify the effects of closing alternating current (A.C.) generator output breakers during paralleling operations under the following conditions:

A. currents out of phase
B. different frequencies
C. high voltage differential
D. with frequency relationship that results in reverse power conditions

K1.08 Questions 41, 44, 45

Identify the effects of closing an A.C. generator output breaker on a deenergized bus.

K1.08 Questions 42, 43

Identify the effects of closing an A.C. generator output breaker onto a faulted bus..

K1.10 Questions 46-52

Identify the function and methods of control of high voltage electrical disconnects.

K1.11 Questions 53-55, 60

Identify control room indications of breaker status.

NEUTRONS
Questions

1. A prompt neutron is

   A. a neutron having kinetic energy greater than 0.1 MeV

   B. emitted by the excited daughter product of a precursor nucleus

   C. born from fission with an average kinetic energy of 2 MeV

   D. released an average of 13 seconds after the fission event

2. Neutrons released by fission fragment daughter products an average of 13 seconds after the fission event are termed ________ neutrons.

   A. slow
   B. delayed
   C. resonance
   D. thermal

3. A delayed neutron is emitted

   A. by the daughter products of neutron precursors

   B. by the excited primary fission fragments

   C. promptly by the delayed neutron precursor nucleus

   D. as a result of photoneutron sources

4. A neutron born within 10^{-14} seconds after the fission event is called a ___________ neutron.

   A. fast
   B. prompt
   C. resonant
   D. thermal

5. A delayed neutron is

   A. in thermal equilibrium with the surrounding atoms

   B. born within about 10^{-14} seconds after the fission event

   C. produced from secondary sources installed in the core

   D. emitted by a highly excited fission product daughter

6. Delayed neutrons are neutrons that

   A. have reached thermal equilibrium with the surrounding medium

   B. are born as thermal neutrons

   C. are born at a lower average kinetic energy than most other fission neutrons

   D. are responsible for the majority of U-235 fissions

7. As compared to a prompt neutron, a delayed neutron is more likely to

   A. cause fast fission in the reactor fuel

   B. be resonantly absorbed in the reactor fuel

   C. cause thermal fission in the reactor fuel

   D. be detected by excore nuclear instrumentation

8. The term "thermal neutron" describes those neutrons

   A. that have energies in excess of 1 MeV

   B. most likely to be absorbed in a resonant energy peak

   C. with approximately the same kinetic energy as surrounding atoms

   D. released simultaneously with the fission event producing them

9. Neutrons with approximately the same kinetic energy as the atoms in their surroundings are called _________ neutrons.

   A. fast
   B. prompt
   C. resonant
   D. thermal

10. Neutrons having approximately the same kinetic energy as atoms in their surroundings are called _________ neutrons.

   A. delayed
   B. intermediate
   C. prompt
   D. thermal

11. In the term "thermal neutron", the word "thermal" refers to the neutron's

   A. kinetic energy
   B. mode of production
   C. potential energy
   D probability of decay

12. A neutron in a PWR is termed "thermal" when

   A. its kinetic energy is in the 1 eV to 1,000 eV energy range

   B. it is in energy equilibrium with the moderating medium

   C. it is released from the fissioning of U^{235} atoms

   D. the cross-section for its absorption in the fuel undergoes a sudden decrease

13. Which of the following is not a desirable property of a neutron moderator?

   A. high scattering cross-section
   B. low absorption cross-section
   C. low energy loss per collision
   D. inexpensive and abundant

14. Water is an excellent neutron moderating medium because

   A. the hydrogen nucleus has approximately the same mass as a neutron

   F. of the water molecule's polarity and unique chemical properties

   C. of its relatively high microscopic absorption cross-section

   D. it is essentially incompressible if kept in a subcooled condition

15. Neutron moderation may be described as

   A. neutrons undergoing scattering reactions in the core and being reduced in energy

   B. neutrons being lost to the fission chain due to resonance absorption

   C. reflecting thermal neutrons that have leaked out of the core back into the core

   D. adjusting Keff so that the neutron population in the core is constant

16. Neutron moderation describes

    A. the loss of fission neutrons from the core by leakage

    B. an increase in the neutron multiplication factor due to a reduction in neutron poisons

    C. the reduction of neutron energy due to scattering reactions

    D. a decrease in the core neutron population from thermal neutron absorption

17. Neutrons born from fission at high energies are reduced to low energies by a process called

    A. ionization
    B. moderation
    C. thermal diffusion
    D. resonance absorption

18. A fast neutron will lose the greatest amount of energy during a scattering reaction in the moderator if it interacts with:

    A. an oxygen nucleus
    B. a hydrogen nucleus
    C. a boron nucleus
    D. an electron surrounding the nuclei

19. Which one of the following is a characteristic of a prompt neutron?

    A. Born with an average kinetic energy below 0.1 MeV.

    B. Emitted by the excited nucleus of a fission product daughter.

    C. Accounts for more than 99% of fission neutrons.

    D. Released an average of 13 seconds after the fission events.

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

Distractor A is the definition of a fast neutron, whereas distractors B and D apply to delayed neutrons. Although choice C is not a "textbook" definition of a prompt neutron, it is the only answer that exclusively applies to the prompt type of fission neutron.

Reference 56, pages 7-5, 7-33.

2. B

This is a concise, textbook definition of a delayed neutron, and only a delayed neutron may be defined in this way.

Reference 56, page 7-27.

3. A

Distractor B applies only to prompt neutrons. Distractor C is incorrect because it disregards the fact that precursors must undergo radioactive decay with some assigned half-life to form the excited daughter products that actually emit the delayed neutrons. Distractor D pertains to the gamma-neutron reaction, known formally as the "nuclear photoeffect."

Reference 56, page 7-23, 7-24

4. B

Reference 56, page 7-93.

5. D

Reference 17, chapter 10, page 390, and Reference 56, page 7-88.

6. C

Distractor A describes a possible definition for thermal neutrons. Distractors B and D are erroneous answers. Delayed neutrons are born in the epithermal (keV) energy range at discrete levels. And, since delayed neutrons represent less than one percent of the neutrons produced, they will not produce the majority of U-235 fissions.

Reference 56, page 7-88.

7. C

Delayed neutrons are born at lower energies (0.5 MeV) than the average energy of prompt neutrons (2.0 MeV). The relative importance of the two types of neutrons to sustaining the chain reaction is considered by looking at the Keff factors. Because of their lower birth energy, delayed neutrons are less likely to leak out of the reactor while slowing down. Thus, they have a greater possibility of causing thermal fission (C). Since delayed neutrons are born below the fission threshold energy for U-238, they are less important than prompt neutrons (A). Both prompt and delayed neutrons must slow down through the resonance region and have an equal likelihood for being absorbed (B). Prompt neutrons, being born at higher energies, have a greater slowing down distance. They are more likely to leak out of the reactor and be detected by excore instrumentation (D).

Reference 56, pages 7-33 to 7-37.

8. C

Reference 17, chapter 11, page 405, and Reference 56, page 4-103.

9. D

Reference 17, chapter 11, page 405, and Reference 56, page 4-103.

10. D

Reference 17, chapter 11, page 405, and Reference 56, page 4-103.

11. A

Reference 17, chapter 11, page 405, and Reference 56, page 4-103.

12. B

Distractor A is the definition of a slow neutron.

Distractor C is not restricted to thermal neutrons.

Distractor D does not relate to thermal neutrons.

Reference 34, chapter 4, page 113.

13. C

All choices except C represent precisely what is needed in a moderating medium. A good scattering medium (A) and low neutron loss via absorption (B) are necessary; however, an equally desirable trait is high energy loss per collision so as to require less collisions to reach thermal equilibrium (less collisions means less chance of neutron leakage since thermalization will be achieved with less distance traveled by the neutron). Answer choice C says just the opposite.

Reference 56, pages 4-77 through 4-79.

14. A

Distractors B and D are incorrect since physical and chemical properties are unrelated to neutron moderating ability. Distractor C represents a negative trait of light water with regard to its moderating ability. This is the reason why fuel enrichment is necessary in a light-water moderated reactor.

Reference 34, chapter 6, pages 168 and 169.

15. A

Reference 56, pages 4-65 and 4-66.

16. C

Reference 56, pages 4-65 and 4-66.

17. B

Reference 56, pages 4-65 and 4-66.

18. B

19. C

Each learning objective listed below is preceded by the associated question number(s) and by the number(s) of its related knowledge statement.

K1.02 Questions 1-7, 19

Define prompt and delayed neutrons and distinguish between the average birth energy, origin, and time of appearance of each with respect to the fission event.

K1.03 Questions 8-12

Define thermal neutrons.

K1.04 Questions 13, 14

Identify the desirable properties of a good neutron moderator.

K1.04 Questions 15, 16, 18

Describe the process of neutron moderation.

K1.04 Question 17

Define neutron moderation.

NEUTRON LIFE CYCLE
Questions

1. A reactor with an effective multiplication factor (K_{eff}) less than one is

   A. critical
   B. prompt critical
   C. subcritical
   D. supercritical

2. A reactor is classified as supercritical when K_{eff} is _____and neutron population is _____.

   A. less than 1, decreasing
   B. less than 1, constant
   C. equal to 1, increasing
   D. greater than 1, increasing

3. A reactor is classified as subcritical when K_{eff} is _____ and the reactor does not have a self-supporting _______.

   A. less than 1, reactor period
   B. less than 1, chain reaction
   C. greater than 1, prompt population
   D. greater than 1, thermal neutron supply

4. Which of the following conditions describes a reactor that is exactly critical?

   A. $K_{eff} = 1$
   B. $K_{eff} = \beta_{eff}$
   C. $K_{eff} > 0$
   D. $K_{eff} = 0$

5. The operator has just pulled control rods and changed the effective multiplication factor (K_{eff}) from 0.998 to 1.002. The reactor is now

   A. prompt critical
   B. supercritical
   C. exactly critical
   D. subcritical

6. If a reactor core with a neutron source is exactly critical at 1000 CPS in the source range, over the next few minutes the count rate should

   A. remain constant
   B. increase linearly
   C. increase geometrically
   D. increase exponentially

7. If the ratio between the number of neutrons from fission in one generation and the number of neutrons in the previous generation is greater than one, then the reactor is

   A. supercritical
   B. critical
   C. delayed critical
   D. subcritical

8. If the ratio between the number of neutrons from fission in one generation and the number of neutrons in the previous generation is equal to one, then the reactor is

   A. critical
   B. subcritical
   C. supercritical
   D. prompt critical

9. If the ratio between the number of neutrons from fission in one generation and the number of neutrons in the previous generation is less than one, then the reactor is

   A. subcritical
   B. critical
   C. supercritical
   D. prompt critical

10. Which of the following conditions describes a reactor that is exactly critical?

    A. $K_{eff} = 1$; $\Delta K/K = 0$
    B. $K_{eff} = 1$; $\Delta K/K = 1$
    C. $K_{eff} = 0$; $\Delta K/K = 0$
    D. $K_{eff} = 0$; $\Delta K/K = 1$

11. Is the following statement true or false? Explain your reasoning:

    "A reactor can have an effective multiplication factor equal to exactly 1 and yet not be critical."

12. The effective multiplication factor (K_{eff}) is defined as

    A. $\frac{\text{no. of neutrons generated by fast fission}}{\text{no. of neutrons generated by thermal fission}}$

    B. $\frac{\text{no. of neutrons generated in the source}}{\text{no. of neutrons in active fuel area}}$

    C. $\frac{\text{no. of neutrons from fission in one generation}}{\text{no. of neutrons in the previous generation}}$

    D. $\frac{\text{no. of neutrons in the previous generation}}{\text{no. of neutrons in the present generation}}$

13. The ratio of the number of neutrons from fission in one generation to the number of neutrons in the previous generation is the

    A. effective multiplication factor
    B. fast fission factor
    C. neutron non-leakage factor
    D. neutron utilization factor

14. Considering the definition of the effective multiplication factor, complete the following example calculation of K_{eff}:

    The number of neutrons produced from fission in the third generation divided by the number of neutrons produced in the ________ generation.

    A. first
    B. second
    C. third
    D. fourth

15. Effective multiplication factor is defined as "the number of neutrons produced from fission in one generation" divided by "the number of neutrons produced in the previous generation" and is represented by

    A. β_{eff}
    B. K_{eff}
    C. K_{ex}
    D. 1/M

16. Select the formula which defines effective multiplication factor (K_{eff}).

    A. $\frac{\text{no. of neutrons produced by thermal fission}}{\text{no. of neutrons produced by fast fission}}$

    B. $\frac{\text{no. of neutrons producing fission in the fuel}}{\text{no. of neutrons absorbed in the fuel}}$

    C. $\frac{\text{no. of delayed neutrons produced from fission}}{\text{no. of prompt neutrons produced from fission}}$

    D. $\frac{\text{no. of neutrons from fission at end of generation}}{\text{no. of neutrons present at start of generation}}$

17. The effective multiplication factor (K_{eff}) is the ratio between the number of

    A. neutrons from fission in one generation and the number of neutrons in the previous generation

    B. fast neutrons produced by all neutron-induced fissions and the number of fast neutrons produced by thermal neutron-induced fissions

    C. thermal neutrons absorbed in the core and the number of thermal neutrons produced in the core

    D. fast neutrons produced from thermal neutron-induced fission and the number of thermal neutrons absorbed in the fuel

18. Select the formula that defines K-excess.

    A. K_{eff} + 1
    B. K_{eff} - 1
    C. K_{eff} (1-SDM)
    D. 1/(1 - K_{eff})

19. K_{excess} is the installed reactivity above the amount necessary to achieve K_{eff} = 1. Which of the following is <u>not</u> a reason for installing K_{excess}?

    A. build-in of Xe-135
    B. fuel burnup
    C. power defect
    D. production of Pu-239

20. Explain why excess reactivity is installed in a core.

21. The formula $K_{eff}-1$ is the mathematical definition of which of the following?

    A. excess multiplication factor
    B. infinite multiplication factor
    C. shutdown margin
    D. subcritical multiplication factor

22. Excess effective multiplication factor (K_{excess}) is the

    A. amount of positive reactivity installed in the core greater than that necessary to achieve criticality

    B. ratio between the number of fissions in one generation and the number of fissions in the previous generation

    C. difference between the shutdown reactivity and reference reactivity

    D. fractional change in neutron population in one generation

23. Nuclear reactors are initially loaded with "excess reactivity," by installing additional fissile material to achieve a value of K_{eff} greater than

    A. 0
    B. 1
    C. β_{eff}
    D. ρ

24. When determining shutdown margin for an operating reactor, how many control rods are assumed to remain <u>fully</u> withdrawn?

    A. a single control rod of the highest reactivity worth

    B. a symmetrical pair of control rods of the highest reactivity

    C. a single control rod of average reactivity worth

    D. a symmetrical pair of control rods of average reactivity worth

25. The amount of reactivity by which the operator must be able to make the reactor subcritical with the most reactive control rod withdrawn is called

    A. shutdown margin
    B. excess reactivity
    C. source reactivity
    D. reactivity margin

26. Shutdown margin is the actual amount of reactivity

    A. inserted by burnable poisons at beginning of life

    B. due to dissolved boron in the RCS

    C. by which the reactor is subcritical

    D. which would be inserted by shutdown bank rods

27. Explain how the term "shutdown margin" can be applied to an <u>operating</u> reactor and how it is used in the technical specifications.

28. Reactivity is defined as the

    A. fractional change in neutron population per generation

    B. number of neutrons by which neutron population changes per generation

    C. rate of change of reactor power in neutrons per second

    D. change in the number of neutrons per second that cause a fission event

29. The formula $(K_{eff}-1)/K_{eff}$ is a mathematical definition of which of the following terms?

    A. reactivity
    B. reactor period
    C. differential rod worth
    D. effective multiplication factor

30. Which term is defined by the following phrases:

    "The fractional change of the effective multiplication factor from criticality," or "a measure of a reactor's departure from criticality."

    A. reproduction factor
    B. reactor period
    C. reaction rate
    D. reactivity

31. With K_{eff} = 0.985, how much reactivity must be added to make the reactor critical?

    A. 1.48% ΔK/K
    B. 1.50% ΔK/K
    C. 1.52% ΔK/K
    D. 1.54% ΔK/K

32. With K_{eff} = 0.987, how much reactivity must be added to make the reactor exactly critical?

    A. 1.30% ΔK/K
    B. 1.32% ΔK/K
    C. 1.34% ΔK/K
    D. 1.36% ΔK/K

33. What is the value of reactivity with a K_{eff} of .95?

    A. - 0.05 % ΔK/K (- 50 pcm)
    B. - 0.27 % ΔK/K (- 270 pcm)
    C. - 5.26 % ΔK/K (- 5,260 pcm)
    D. - 8.64 % ΔK/K (- 8,640 pcm)

34. A reactor at end of life has been shutdown from 100 percent power and cooled down to 140 °F over three days. During the cooldown, boron concentration was increased by 100 ppm.

    Given the following absolute values of reactivities added during the shutdown and cooldown, assign a (+) or (-) as appropriate and choose the current value of shutdown margin.

Xenon -	( ) 2.5% ΔK/K
Temperature -	( ) 0.5% ΔK/K
Power Defect -	( ) 1.5% ΔK/K
Rods -	( ) 7.0% ΔK/K
Boron -	( ) 1.0% ΔK/K

    A. - 8.5% ΔK/K
    B. - 6.5% ΔK/K
    C. - 3.5% ΔK/K
    D. - 1.5% ΔK/K

35. A reactor is operating steady-state at 100% power with all control rods fully withdrawn, Tave is 558 °F, and boron concentration is 1000 ppm. By how much will the reactor be subcritical several minutes following a reactor trip with Tave at its no-load value of 557 °F? Assume no operator actions. Disregard any reactivity effects of xenon.

    Power Defect = -1.5% ΔK/K
    Control/Regulating Rod Worth = -2.788% ΔK/K
    Shutdown/Safety Rod Worth = -4.130% ΔK/K
    MTC = -.0012% ΔK/K/°F

    A. - 5.381% ΔK/K
    B. - 5.418% ΔK/K
    C. - 8.383% ΔK/K
    D. - 8.418% ΔK/K

36. A reactor is operating at steady-state 90 percent power with all control rods fully withdrawn and Tave at 580°F. A reactor trip occurs, after which Tave stabilizes at 550°F and all rods are verified to be fully inserted.

Given the following information, calculate the value of shutdown margin. Assume no operator actions and disregard any reactivity effects of xenon.

Power Coefficient = -0.01% ΔK/K/% power
Control/Regulating Rod Worth = -2.788% ΔK/K
Shutdown/Safety Rod Worth = -4.130% ΔK/K

A. -5.718% ΔK/K
B. -6.018% ΔK/K
C. -7.518% ΔK/K
D. -7.818% ΔK/K

37. At the time of a reactor trip from 100 percent power, shutdown margin was determined to be -5.883% ΔK/K. Over the next 72 hours the reactor coolant system was cooled down and boron concentration was increased. The reactivities affected by the change in plant conditions are as follows:

Reactivity	Change (+ or -)
Xenon	2.675% ΔK/K
Moderator temperature	0.5% ΔK/K
Boron	1.04% ΔK/K

What is the shutdown margin 72 hours after the trip? (Assume end of core life.)

A. - 1.668% ΔK/K
B. - 3.748% ΔK/K
C. - 7.018% ΔK/K
D. - 9.098% ΔK/K

38. Which one of the following plant parameter changes will result in an increase in shutdown margin for a shutdown reactor at end of core life?

A. Reactor coolant system (RCS) boron concentration is increased by 100 ppm.

B. One control rod is fully withdrawn for a test.

C. Xenon has decayed for 72 hours following shutdown.

D. Reactor coolant system (RCS) is cooled down by 300 °F.

39. Which one of the following plant parameter changes will result in an increase in shutdown margin for a shutdown reactor at end of core life?

A. RCS boron concentration is decreased by 100 ppm.

B. One control rod is fully withdrawn for a test.

C. Xenon has decayed for 72 hours following shutdown.

D. The RCS is allowed to heatup 30°F.

40. With the plant operating at 85 percent power and rod control in manual, the operator borates 10 ppm. Assuming reactor power does not change, shutdown margin will

A. increase and stabilize at a higher value

B. increase, then decrease to the original value as coolant temperature changes

C. decrease and stabilize at a lower value

D. decrease, then increase to the original value as coolant temperature changes

41. The plant is operating at 70 percent power with manual rod control. Which one of the following conditions will increase shutdown margin? (Assume that no unspecified operator actions occur and the reactor does not trip.)

    A. The reactor coolant system is diluted by 10 ppm.

    B. A control rod in a shutdown bank (safety group) drops.

    C. Power is decreased to 50 percent using boration.

    D. The plant experiences at 3 percent load rejection.

42. With the plant operating at 75 percent power and rod control in manual, the operator dilutes RCS boron by 5 ppm to adjust RCS temperature. Assuming reactor power does not change, shutdown margin will

    A. increase and stabilize at a higher value

    B. increase, then decrease to the original value as coolant temperature changes

    C. decrease and stabilize at a lower value

    D. decrease, then increase to the original value as coolant temperature changes

43. List five parameters whose change would affect a shutdown reactor's shutdown margin, and explain the effect on shutdown margin of an <u>increase</u> in each.

44. Which one of the following combinations of critical core conditions indicates the <u>most</u> excess reactivity exists in the core?

	Control Rod (CEA) Position	RCS Boron Concentration
A.	25% inserted	500 ppm
B.	50% inserted	500 ppm
C.	25% inserted	1000 ppm
D.	50% inserted	1000 ppm

45. The following are combinations of critical conditions that exist for the same reactor operating at the point of adding heat at different times in core life. Which combination indicates the <u>least</u> amount of excess reactivity is present in the core?

	CONTROL ROD POSITION	RCS BORON CONCENTRATION
A.	25% inserted	500 ppm
B.	50% inserted	500 ppm
C.	25% inserted	1000 ppm
D.	50% inserted	1000 ppm

NEUTRON LIFE CYCLE
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

A reactor is subcritical when K_{eff} is < 1.

Reference 56, page 5-19.

2. D

A reactor is supercritical when K_{eff} is > 1 and neutron population is increasing.

Reference 56, page 5-19.

3. B

Subcriticality is the condition of a reactor when the effective multiplication factor is less than one. A subcritical reactor cannot maintain a self-supporting chain reaction.

Reference 56, page 5-20.

4. A

A reactor is exactly critical when $K_{eff} = 1$.

Reference 56, page 5-19.

5. B

A reactor is supercritical when K_{eff} is > 1.

Reference 56, page 5-19.

6. B

At 1,000 CPS in the source range, the effect of source neutrons is noticeable. In a critical reactor, there is no net gain or loss of neutrons as a result of the fission process. However, the neutron source will generate additional neutrons at a constant (linear) rate, causing a linear increase in the count rate.

Reference 56, page 8-56.

7. A

Reference 56, page 5-20.

8. A

Reference 56, page 5-19

9. A

Reference 56, page 5-20.

10. A

A reactor is exactly critical when $K_{eff}=1$ which means its reactivity $\Delta K/K$ equals zero.

Reference 56, page 5-19, 5-21 and 5.53

11.

The statement is false. By definition, a reactor is critical when its effective multiplication factor equals one. (It is possible, however, for power to be increasing or decreasing when a reactor is critical, due to the effects of source and delayed neutrons.)

Reference 56, page 5-19.

12. C

Reference 56, page 5-16.

NEUTRON LIFE CYCLE
Answers

13. A

K_{eff} is defined as

$$\frac{\text{no. of neutrons produced from fission in one generation}}{\text{no. of neutrons in previous generation}}$$

Reference 56, page 5-16.

14. B

K_{eff} is defined as

$$\frac{\text{no. of neutrons produced from fission in one generation}}{\text{no. of neutrons in previous generation}}$$

Reference 56, page 5-19.

15. B

Reference 56, page 5-16.

16. D

Reference 56, page 5-16.

17. A

Reference 56, page 5-16.

18. B

Reference 38, pages 1.3-2 and 11.1-1.

19. D

K-excess is defined as K_{eff}-1 and is that amount of excess reactivity installed to compensate for fuel burn-up, power defect, fission product poisons, and plant heat-up from cold shutdown to operating temperature.

Reference 61, page 2-7.

20.

Excess reactivity is necessary to allow the reactor to maintain criticality when negative reactivity is inserted by the following:

- fission product poison build-in
- fuel burnup
- power defect
- plant heatup

Without excess reactivity, a reactor would not be able to maintain criticality once achieved.

Reference 61, page 2-7.

21. A

Reference 61, page 2-7; and Reference 38, pages 1.3-2 and 11.1-1.

22. A

Reference 61, page 2-7.

23. B

K-excess is defined as K_{eff}-1.

Reference 61, page 2-7; and Reference 38, pages 1.3-2 and 11.1-1.

24. A

25. A

Reference 61, page 7-13.

26. C

Reference 61, page 7-13.

27.

"Shutdown margin" can be applied to an operating reactor to describe the amount by which the reactor would be subcritical if rods were instantaneously inserted to shut the reactor down. Technical specifications typically set limits on shutdown margin assuming the single most reactive control rod fails to insert.

Reference 61, page 7-13.

28. A

Reference 56, pages 5-21 and 5-53.

29. A

Reference 56, pages 5-21 and 5-53; and Reference 38, page 6.1-1.

30. D

Reference 56, pages 5-21 and 5-53.

31. C

$\Delta\rho = (K_2 - K_1) / K_2K_1$

$= (1.0 - .985) / (1.0)(.985)$

$= .0152$ or 1.52% $\Delta K/K$

32. B

$\Delta\rho = (K_2 - K_1)/K_2K_1$

$= (1.0 - .987)/(1.0)(.987)$

$= .0132$ or 1.32 % $\Delta K/K$

33. C

The definition of reactivity is (K-1)/K

Calculation: (.95 - 1)/(.95) = -.05263
= -5.26 % $\Delta K/K$

Reference 56, page 5-19.

34. C

The following reactivity insertions would have occurred:

xenon: positive, due to decay
temperature: positive, due to cooldown
power defect: positive, due to power reduction
rods: negative, due to insertion
boron: negative, due to increased concentration

The net effect is:

+2.50%
+0.50%
+1.50%
-7.00%
<u>-1.00%</u>
-3.50% $\Delta K/K$

Reference 61, chapter 2, page 39.

35. B

Reactivity changes since critical:

+ 1.5% $\Delta K/K$ due to power decrease
- 2.788% $\Delta K/K$ due to regulating rod insertion
<u>- 4.130% $\Delta K/K$</u> due to shutdown rod insertion
- 5.418% $\Delta K/K$ net reactivity

Note that the moderator temperature effect is included in the power coefficient.

36. B

Reactivity changes since critical:

+0.900% ΔK/K due to 90% power decrease
-2.788% ΔK/K due to control rod insertion
-4.130% ΔK/K due to shutdown rod insertion
-6.018% ΔK/K

Note that the moderate temperature effect is included in the power coefficient

Reference 61, chapter 2, page 39

37. B

Reactivity changes since shutdown margin:

+ 2.675% ΔK/K due to xenon decay
+ 0.500% ΔK/K due to temperature decrease
- 1.040% ΔK/K due to boron increase
+ 2.135% ΔK/K

Therefore, the new shutdown margin is:

- 5.883% ΔK/K
+ 2.135% ΔK/K
- 3.748% ΔK/K

Note that the assumption of end-of-life conditions ensures that the moderator temperature coefficient will be negative.

38. A

Boron concentration increase inserts negative reactivity, increasing the shutdown margin.

39. D

The first three answers add positive reactivity to the shutdown reactor, decreasing shutdown margin. A heatup of 30 °F adds negative reactivity.

Reference 61, page 7-13

40. A

The additional boron inserts negative reactivity which remains in the reactor at shutdown, thereby increasing the shutdown margin at the established shutdown temperature.

Reference 61, page 7-13.

41. C

The boration will insert more negative reactivity at shutdown. Answer A will add positive reactivity decreasing shutdown margin. Answer B has no effect since the shutdown rod is expected to drop into the reactor at shutdown and no operator action has taken place to compensate for its reactivity effect. The load rejection has no effect on shutdown margin since no other operator action is specified.

Reference 61, page 7-13.

42. C

The only physical change to the reactor has been a decrease in boron concentration causing a positive reactivity insertion. When the reactor is now shutdown, at shutdown temperature conditions and rods in, the boron concentration will be less and therefore the shutdown margin is decreased.

43.

Any five of the following parameters and explanations will satisfy this question:

- moderator temperature - An increase would insert negative reactivity (assuming a negative moderator temperature coefficient), increasing the shutdown margin.
- fuel temperature - An increase (caused by a decrease in heat removal rate or an increase in moderator temperature) would insert negative reactivity, increasing the shutdown margin.
- xenon concentration - An increase would add negative reactivity, increasing the shutdown margin.
- boron concentration - An increase would add negative reactivity, increasing the shutdown margin.
- number of fuel assemblies in the core - An increase would add positive reactivity, decreasing the shutdown margin.
- exposure/burnup of fuel assemblies in the core - An increase would add negative reactivity, increasing the shutdown margin.

Reference 61, pages 7-13 through 7-19.

44. D

45. A

NEUTRON LIFE CYCLE
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.07 Questions 1-11

Define critical, subcritical and supercritical with respect to reactor power/neutron population and in terms of the effective multiplication factor.

K1.08 Questions 12-17

Define effective multiplication factor (K_{eff}) and describe its relationship to the state of a reactor.

K1.09 Questions 18, 21-23, 44, 45

Define K-excess (excess reactivity).

K1.09 Questions 19, 20

Explain why excess reactivity is installed in the core.

K1.10 Questions 24-27

Define shutdown margin.

K1.11 Questions 28-30

Define reactivity.

K1.12 Questions 31-33

Given a value of K_{eff}, calculate the associated reactivity.

K1.13 Questions 34-37

Given values for plant parameters, calculate shutdown margins.

K1.14 Questions 38-43

Identify the effects of changes in plant parameters on shutdown margin.

REACTOR KINETICS AND NEUTRON SOURCES
Questions

It is recognized that various symbols are defined differently in different sources. For consistency within this catalog, the following symbols and terms will be used:

β - delayed neutron fraction
- the fraction of neutrons born delayed from fission of a particular nuclide

β_{eff} - effective delayed neutron fraction
- the fraction of neutron-induced fissions caused by delayed neutrons for a particular nuclide

$\bar{\beta}_{eff}$ - average effective delayed neutron fraction
- the weighted average of the β_{eff} for each fissionable nuclide in the core

λ - delayed neutron precursor decay constant
- the decay constant for a particular nuclide whose decay results in production of a delayed neutron

$\bar{\lambda}$ - average delayed neutron precursor decay constant
- the weighted average of the λ for each delayed neutron precursor in the core

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1. Which of the following best describes a subcritical reactor's neutron population response to a small insertion of positive reactivity?

   A. decreases briefly, then increases to the original value

   B. increases briefly, then levels off above the original value

   C. increases briefly, then decreases to the original value

   D. decreases briefly, then increases and levels off below the original value

2. Which of the following statements is true concerning subcritical multiplication?

   A. The time to reach equilibrium count rate increases as K_{eff} approaches one.

   B. Source range count rate is unaffected by changes in K_{eff}.

   C. The source strength increases as K_{eff} approaches one.

   D. Adding additional neutron sources will increase K_{eff}.

3. A subcritical reactor has an initial K_{eff} of 0.8. Positive reactivity is added until the subcritical count rate is doubled. What reactivity addition caused the count rate to double?

   A. 1.39% ΔK/K (1390 pcm)
   B. 3.61% ΔK/K (3610 pcm)
   C. 13.89% ΔK/K (13,890 pcm)
   D. 36.11% ΔK/K (36,110 pcm)

4. A reactor is shutdown by 1.8 percent Δ K/K. If positive reactivity is added until the count rate increases by a factor of 20 and the reactor remains subcritical, what is the new K_{eff}?

   A. .982
   B. .990
   C. .995
   D. .999

5. Following a positive reactivity addition to a shutdown reactor, the neutron count rate will increase even though K_{eff} is less than 1. This is due to the

   A. production of delayed neutrons
   B. isothermal temperature coefficient
   C. neutron moderation in the fuel
   D. subcritical multiplication process

6. Which of the following is a characteristic of subcritical multiplication?

   A. Doubling the indicated count rate by reactivity additions will reduce the margin to criticality by approximately one half.

   B. For equal reactivity additions, it takes less time for the equilibrium subcritical neutron population level to be reached as K_{eff} approaches one.

   C. The increase in count rate achieved by a given reactivity addition will normally double if twice that amount of reactivity is added.

   D. A constant neutron population is achieved when the total number of neutrons produced in one generation is equal to the number of source neutrons in the next generation.

7. Which one of the following lists both items required for subcritical multiplication to occur in a reactor?

   A. neutron source and fissionable nuclides

   B. adequate shutdown margin and positive temperature coefficient

   C. neutron source and positive temperature coefficient

   D. adequate shutdown margin and fissionable nuclides

8. Which one of the following effects is caused by the combination of a neutron source and a subcritical reactor that produces a steady-state neutron population greater than the population of source neutrons alone.

   A. subcritical multiplication
   B. regenerative neutron source production
   C. spontaneous fission
   D. criticality

9. Explain how an insertion of positive reactivity in a reactor that remains <u>subcritical</u> causes the neutron population to increase.

10. Describe and explain the response of neutron population as equal insertions of positive reactivity are made in a subcritical reactor. Assume the reactor remains subcritical.

11. Given two shutdown reactors that are identical except for the strength of their neutron sources: If the source strength in Reactor "A" is twice the source strength in Reactor "B", how will the neutron population differ in the two reactors? Explain.

12. Which one of the following statements is a characteristic of subcritical multiplication?

    A. The subcritical neutron level is directly proportional to the neutron source strength.

    B. Doubling the indicated count rate by reactivity additions will reduce the margin to criticality by approximately one quarter.

    C. For equal reactivity additions, it takes less time for the new equilibrium source range count rate to be reached as Keff approaches unity.

    D. An incremental withdrawal of a given control rod will produce an equivalent equilibrium count rate increase, whether Keff is 0.88 or 0.92.

13. A subcritical reactor has an initial source/startup range count rate of 150 cps with a shutdown reactivity of -2.0% $\Delta K/K$. How much positive reactivity must be added to establish a stable count rate of 300 cps?

    A. 0.5% $\Delta K/K$
    B. 1.0% $\Delta K/K$
    C. 1.5% $\Delta K/K$
    D. 2.0% $\Delta K/K$

14. Which of the following best defines the delayed neutron fraction for a fissionable nuclide?

    A. $\frac{\text{no. of delayed neutrons born in one generation}}{\text{no. of delayed neutrons born in previous generation}}$

    B. $\frac{\text{number of fission neutrons in the core}}{\text{number of delayed neutrons in the core}}$

    C. $\frac{\text{no. of fission neutrons born as delayed neutrons}}{\text{no. of neutrons born from fission}}$

    D. $\frac{\text{no. of fission neutrons born as delayed neutrons}}{\text{no. of fission neutrons born as prompt neutrons}}$

15. For a given fissionable nuclide, the ratio of the number of neutrons born as delayed neutrons to the total number of neutrons born from fission is the

    A. delayed neutron fraction
    B. delayed neutron importance factor
    C. delayed neutron multiplication factor
    D. effective delayed neutron fraction

16. Which of the following is <u>not</u> a contributing factor to the gradual decrease in the average effective delayed neutron fraction over core life?

    A. buildup of Pu-239
    B. depletion of U-235
    C. buildup of Pu-240
    D. depletion of U-238

17. An average prompt neutron is 3 percent more likely to induce a fission event in the core than an average delayed neutron. This fact is expressed by the

    A. core delayed neutron fraction
    B. core delayed neutron yield
    C. delayed neutron fraction
    D. delayed neutron importance factor

18. The value of the average effective delayed neutron fraction will vary, depending on the

    A. thermal non-leakage probability
    B. types of fuel present in the core
    C. thermal fission rate
    D. type of moderator present in the core

19. Define and contrast the delayed neutron fraction (β), the effective delayed neutron fraction (β_{eff}), and the average effective delayed neutron fraction ($\bar{\beta}_{eff}$).

20. Explain the difference between β (delayed neutron fraction) and β_{eff} (effective delayed neutron fraction).

21. The <u>effective</u> delayed neutron fraction takes into consideration the fact that a delayed neutron is

    A. born at energies in the thermal neutron range

    B. less likely than a prompt neutron to cause fast fission

    C. less likely than a prompt neutron to cause thermal fission

    D. more likely to be absorbed in the U-238 resonance

22. The rate of change of reactor power measured in decades per minute is expressed by the

    A. startup rate
    B. shutdown margin
    C. reactor period
    D. heatup rate

23. Which of the following phrases defines startup rate?

    A. The rate of change of source range counts during startup, expressed in counts per minute (CPM).

    B. The rate of change of reactor power expressed in decades per minute (DPM).

    C. The rate of change of reactor power expressed in periods per minute (PPM).

    D. The rate of change of reactor power expressed in decades per second (DPS).

24. If reactor power is changing one decade per minute, it has a _____ of one decade per minute.

    A. doubling time
    B. reactor period
    C. startup rate
    D. generation rate

25. Stating that a reactor has a startup rate of one decade per minute indicates that, over a one-minute time period, _______ will increase by a factor of _________.

    A. K-effective, 10
    B. K-effective, log 10
    C. reactor power, e
    D. reactor power, 10

26. A reactor in which the ________ is changing by a factor of 10 each minute has a startup rate of 1 decade per minute.

    A. power level
    B. reactor period
    C. multiplication factor
    D. doubling time

27. Startup rate is a term used to describe

    A. rates of nuclear power change expressed in decades per minute

    B. rates of nuclear power change expressed as a factor of e

    C. reactivity insertion rates expressed in decades per minute

    D. reactivity insertion rates expressed as a factor of e

28. A given amount of positive reactivity is added to a critical reactor in the source range. The amount added is less than the average effective delayed neutron fraction. Which of the following will have a significant effect on the magnitude of the stable startup rate achieved for this addition?

    A. prompt neutron lifetime
    B. fuel temperature coefficient
    C. average decay constant
    D. moderator temperature coefficient

29. A reactor is critical below the point of adding heat. Control rods are then withdrawn, inserting an amount of reactivity less than the value of the average effective delayed neutron fraction. Which of the following will have the most significant effect on the magnitude of the resultant stable startup rate?

    A. prompt neutron lifetime
    B. average decay constant
    C. control rod height
    D. axial flux imbalance

30. The magnitude of the stable startup rate achieved for a given positive reactivity addition to a critical reactor is dependent on the _________ and _________.

    A. prompt neutron lifetime, axial flux distribution

    B. prompt neutron lifetime, control rod position

    C. average decay constant, average effective delayed neutron fraction

    D. average decay constant, axial flux distribution

31. A reactor is critical below the point of adding heat when a small positive reactivity addition is made. Which of the terms listed below will be a factor in determining the magnitude of the stable startup rate that is achieved?

    A. speed of control rod movement

    B. K excess (excess reactivity)

    C. shutdown margin

    D. average delayed neutron precursor decay constant

32. The addition of a given amount of positive reactivity to a reactor that is at the beginning of life (BOL) produces a stable startup rate of .5 decades per minute (DPM). Which of the following best describes the startup rate that would exist at end of life (EOL) if the same amount of reactivity were added?

    A. no change
    B. slightly lower
    C. slightly higher
    D. greatly lower

33. Which one of the following conditions will initially result in a negative startup rate when the reactor is at power?

    A. dropped control rod
    B. inadvertent dilution
    C. steam line break
    D. feedwater regulator valve fails full open

34. Which one of the following conditions will initially result in a positive startup rate when the reactor is at power?

    A. increase in turbine loading
    B. unintentional boration
    C. turbine runback
    D. accidental closure of a main steam isolation valve

35. Define startup rate (SUR) by writing the equation that relates SUR and reactivity. Describe each term in the equation.

36. Which of the following best explains the effect of delayed neut ons on reactor control?

    A. increases the average generation time of all fission neutrons

    B. decreases the average generation time of all fission neutrons

    C. increases the average generation time of only fast fission neutrons

    D. decreases the average generation time of only fast fission neutrons

37. Over core life, plutonium isotopes are produced with delayed neutron fractions that are __________ than those of uranium delayed neutron fractions, thereby causing reactor power transients that are __________ near the end of core life.

    A. smaller, faster
    B. smaller, slower
    C. larger, faster
    D. larger, slower

38. Which of the following statements best describes the <u>effect</u> of changes in the average effective delayed neutron fraction over core life?

    A. A lower critical boron concentration is required at end of life.

    B. A given reactivity addition at end of life results in a lower startup rate than it would at beginning of life.

    C. A given reactivity addition at end of life results in a higher startup rate than it would at beginning of life.

    D. A larger (more negative) moderator temperature coefficient results at end of life.

39. Delayed neutrons are important for reactor control because

    A. they are produced at lower energy levels than prompt neutrons

    B. a nuclear chain reaction is not possible without delayed neutrons

    C. they are a large fraction of the neutrons available to produce fission

    D. they greatly extend the average neutron generation time

40. The average effective delayed neutron fraction decreases over core life because of the ______. This results in __________ startup rates at end of life than at beginning of life for the same reactivity additions.

    A. increasing fission yield for Pu^{239}, higher
    B. increasing fission yield for Pu^{239}, lower
    C. buildup of Pu^{239} in the core, higher
    D. buildup of Pu^{239} in the core, lower

41. Delayed neutrons contribute more to reactor stability than prompt neutrons because they __________ the average neutron generation time and are born at a __________ kinetic energy.

    A. increase; lower
    B. decrease; higher
    C. increase; higher
    D. decrease; lower

42. Following a reactor trip, the power decrease rate initially stabilizes at negative one-third decade per minute when

    A. the short-lived delayed neutron precursors have decayed away

    B. the long-lived delayed neutron precursors have decayed away

    C. the installed neutron source contribution to the total neutron flux becomes significant

    D. decay gamma heating starts adding negative reactivity

43. Explain why delayed neutrons are important in reactor control.

44. Which one of the following statements describes the effect of changes in the delayed neutron fraction from beginning of core life (BOL) to end of core life (EOL)?

    A. A given set of plant parameters at EOL yields a greater shutdown margin than at BOL.

    B. A given set of plant parameters at EOL yields a smaller shutdown margin than at BOL.

    C. A given reactivity addition at EOL results in a higher startup rate than it would at BOL.

    D. A given reactivity addition at EOL results in a lower startup rate than it would at BOL.

45. When does the power decrease rate initially stabilize at negative one-third decade per minute following a reactor trip?

    A. when decay gamma heating starts adding negative reactivity

    B. when the long-lived delayed neutron precursors have decayed away

    C. when the installed neutron source contribution to the total neutron flux becomes significant

    D. when the short-lived delayed neutron precursors have decayed away

46. A step insertion of positive reactivity into a critical reactor causes a rapid increase in the neutron population known as a prompt jump. This is caused by the

    A. rapid positive reactivity insertion due to the moderator temperature coefficient

    B. rapid increase in the prompt neutron population

    C. magnitude of the reactivity insertion exceeding the value of the average effective delayed neutron fraction

    D. effects of short-lived delayed neutron precursors

47. Following a step insertion of negative reactivity into a critical reactor, the reactor power undergoes a prompt drop that

    A. is caused by the magnitude of reactivity inserted exceeding the value of the average effective delayed neutron fraction

    B. occurs at a rate of -1/3 DPM regardless of the size of the reactivity insertion

    C. is a result of the rapid response of the fuel temperature coefficient

    D. occurs in response to rapid decrease in the prompt neutron population

48. Explain why a "prompt jump" occurs when a step insertion of positive reactivity is made in a critical reactor.

49. Explain why a "prompt drop" occurs when a step insertion of negative reactivity is made in a critical reactor.

50. Which one of the following describes a core condition in which the reactor is prompt critical?

    A. Any increase in reactor power requires a reactivity addition equal to the fraction of prompt neutrons in the core.

    B. A very long reactor period makes reactor control very sluggish and unresponsive.

    C. The net reactivity in the core is greater than or equal to the magnitude of the average effective delayed neutron fraction.

    D. The fission process is occurring so rapidly that the delayed neutron fraction approaches zero.

51. A critical reactor will become prompt critical when reactivity is added equal in magnitude to the

    A. shutdown margin

    B. average effective delayed neutron fraction

    C. average effective decay constant

    D. worth of the most reactive rod

52. When an amount of positive reactivity equal in magnitude to the average effective delayed neutron fraction is inserted into a critical reactor, the reactor is

    A. delayed critical
    B. overmoderated
    C. prompt critical
    D. super saturated

53. A critical reactor will become prompt critical when reactivity is added equal in magnitude to the

A. shutdown margin

B. average effective delayed neutron fraction

C. average decay constant

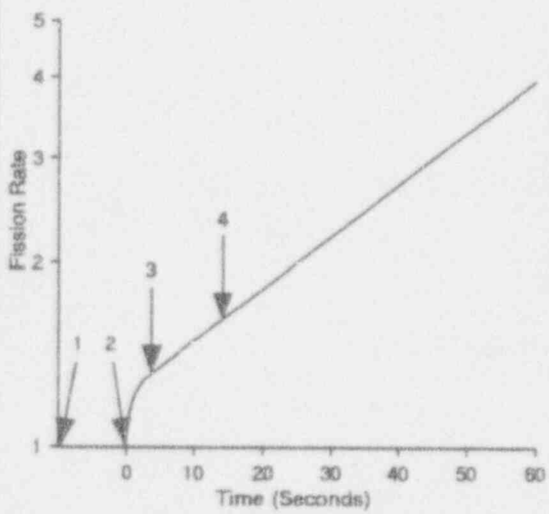
D. worth of the most reactive rod

54. Explain what is meant by the term "prompt critical."

55. On the curve shown in Figure 2.3-1, the prompt jump is represented by the region of the curve between points ______ and

A. 1, 2
B. 1, 3
C. 2, 3
D. 3, 4

FIGURE 2.3-1

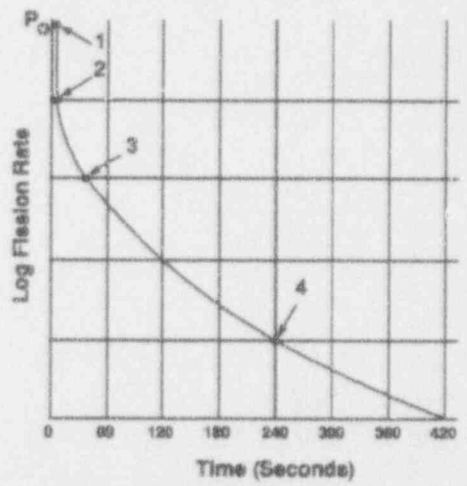


Reactor Response to Positive Reactivity

56. On the curve shown in Figure 2.3-2, the prompt drop is represented by the region of the curve between points ________ and

A. 1, 2
B. 1, 4
C. 2, 3
D. 3, 4

FIGURE 2.3-2



Fission Rate Response to Reactivity Insertion

57. Which of the following describes core conditions when the reactor is prompt critical?

A. Prompt neutrons alone are insufficient to cause an increase in fission rate.

B. Very short reactor periods make the reactor difficult to control.

C. The net reactivity in the core is less than the magnitude of the average effective delayed neutron fraction.

D. The net reactivity in the core is greater than or equal to the average delayed neutron precursor decay constant.

58. A reactor is observed to be on a stable period of 78.18 seconds. Assuming the initial power level is 10 MW, one minute later the operating power level will be

A. 4.6 MW
B. 10.1 MW
C. 21.5 MW
D. 36.8 MW

59. Assuming a stable startup rate (SUR) of 0.75 DPM is established from an initial power level of 30 MW in an operating reactor, which of the following most closely approximates the reactor power level 30 seconds later?

A. 71 MW
B. 78 MW
C. 90 MW
D. 97 MW

60. Reactor power increases from 10^{-8} percent to 5×10^{-7} percent in 2 minutes. What is the average startup rate?

A. 0.95 dpm
B. 0.90 dpm
C. 0.85 dpm
D. 0.82 dpm

61. Reactor power will increase from 20 MW to 95 MW in 93.5 seconds with a stable startup rate of ___________ DPM.

A. 0.007
B. 0.434
C. 0.579
D. 0.657

62. Reactor power was increased from 10^{-9} percent to 10^{-6} percent in 6 minutes. The average startup rate was __________ decades per minute.

A. 0.5
B. 1.3
C. 2.0
D. 5.2

63. Calculate the power level (in percent power) after 2.5 minutes if power level increased from 1×10^{-4} percent power on a constant startup rate of 0.5 DPM.

A. 1.25×10^{-3}
B. 1.8×10^{-3}
C. 3.5×10^{-4}
D. 9.3×10^{-4}

64. Following a reactor trip, an operator notices that the reactor is on a stable startup rate of -1/3 decades per minute. How long will it take power to decrease from 5×10^{-1} to 1×10^{-4} percent power?

A. 1.23 minutes
B. 10.5 minutes
C. 11.1 minutes
D. 25.5 minutes

65. A reactor is operating at a power level of 2,000 watts. Control rods are inserted, which results in a stable negative 80-second period. Which of the following is the best estimate of the reactor power level two minutes after a power level of 120 watts is reached?

A. 27 watts
B. 32 watts
C. 49 watts
D. 54 watts

66. Which of the following is not a purpose of an installed neutron source in a reactor core?

A. Generate a sufficient neutron population to start the fission chain reaction for each startup.

B. Generate a detectable neutron level to allow an orderly and controlled approach to criticality.

C. Generate a sufficient neutron count rate to verify proper operation of nuclear detectors prior to criticality.

D. Generate a detectable neutron source level for monitoring reactivity changes in a shutdown reactor.

67. The purpose of installing a neutron source in the core is to

    A. provide enough neutrons to start a chain reaction in a clean core for initial plant startup

    B. increase core neutron population to a detectable level during startups

    C. compensate for delayed neutrons that will not appear during startup

    D. compensate for those neutrons absorbed in burnable poison in the core

68. The neutron population in a shutdown reactor is maintained at a level detectable on nuclear instrumentation to allow monitoring of core conditions. This is accomplished through the use of

    A. burnable poisons
    B. excess reactivity
    C. installed sources
    D. soluble poison

69. Neutron sources are installed in the core

    A. because subcritical multiplication cannot occur without them

    B. as compensation for those neutrons absorbed in burnable poisons

    C. to increase neutron population sufficiently to allow detection on nuclear instrumentation

    D. to provide enough neutrons to start a chain reaction for startup

70. The purpose of an installed neutron source is to

    A. maintain the production of neutrons high enough to allow the reactor to achieve criticality

    B. provide a means to allow reactivity changes to occur in a subcritical reactor

    C. generate a sufficient neutron population to start the fission process and initiate subcritical multiplication

    D. provide a neutron level that is detectable on the source range nuclear instrumentation

71. A regenerative neutron source is installed

    A. in a reactor during the initial fuel load but is only used after the initial startup

    B. in a reactor during the initial fuel load and can be used if the nonregerative installed neutron source fails during the initial startup

    C. in a reactor during a subsequent fuel load to replace the nonregenerative installed neutron source

    D. external to the reactor to verify proper operation of the excore nuclear detectors

72. A reactor has been shutdown for several days during its second fuel cycle with all artificial neutron sources removed. Which of the following is providing the greatest contribution to the shutdown neutron level in the core?

    A. spontaneous fission
    B. photo-neutron reactions
    C. beta-neutron reactions
    D. alpha-neutron reactions

73. Explain why neutron sources are installed in reactor cores.

74. A subcritical reactor has an initial K_{eff} of 0.8 at a source range count rate of 100 cps. Positive reactivity is added until K_{eff} equals 0.95. What is the final equilibrium source range count rate?

    A. 150 cps
    B. 200 cps
    C. 300 cps
    D. 400 cps

75. A reactor is operating at 75% power with the following conditions:

power defect	= 0.03% Δ K/K
shutdown margin	= 0.06% Δ K/K
effective delayed neutron fraction	= 0.0058
effective prompt neutron fraction	= 0.9942

    How much positive reactivity must be added to take the reactor "prompt critical"?

    A. 0.03% Δ K/K
    B. 0.06% Δ K/K
    C. 0.58% Δ K/K
    D. 0.9942% Δ K/K

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

The insertion of positive reactivity increases K_{eff} and thereby increases the number of neutrons being produced through fission in successive generations of neutron families. The total number of neutrons in the reactor is increased, but since the reactor is still subcritical, the neutron level stabilizes at some higher level.

Reference 56, chapter 8-66.

2. A

Subcritical multiplication is the effect caused by the combination of a neutron source and a subcritical reactor that produces a steady-state neutron population greater than the population of source neutrons alone.

Reference 56, page 8-66.

3. C

Doubling the count rate means the reactor moves halfway to criticality. Therefore, if K_1 is 0.8, K_2 is 0.9.

$\Delta\rho = (K_2 - K_1) / K_1K_2$

$\Delta\rho = (0.9 - 0.8) / (0.9)(0.8) = 0.1389\ \Delta K/K$
$= 13.89\%\ \Delta K/K$

Reference 07, chapter 5, page 11.

4. D

$CR_1 (1-K_1) = CR_2 (1-K_2)$

$1 (1-0.9823) = 20 (1-K_2)$

$K_2 = 0.999$

Reference 07, chapter 5, page 14.

5. D

Reference 56, chapter 8.

6. A

$CR_1 (1-K_1) = CR_2 (1-K_2)$

If CR_2 is twice CR_1, then $(1-K_2)$ is half of $(1-K_1)$.

Reference 56, page 7-28.

7. A

Reference 56, page 8-13.

8. A

Reference 56, page 8-13.

9.

In a subcritical reactor, the fission process is not self-sustaining and would tend to cause the neutron population to decrease. However, source neutrons, which are produced independent of fission, can "make up" for the net loss of neutrons from fission, resulting in a constant neutron population. If positive reactivity is then inserted, the fraction of neutrons lost in the fission process from one generation to the next is reduced. This reduction in neutron "losses" from fission, accompanied by a constant source neutron input, results in an increase in neutron population in the subcritical reactor.

Reference 56, pages 8-83 and 8-4.

10.

When positive reactivity is inserted, the net "loss" of neutrons from the fission process in each generation is reduced. Therefore, neutron population will increase until the net number of neutrons lost per generation from fission equals the number of source neutrons produced.

The same process occurs with the next reactivity insertion. However, the fraction of neutrons "lost" from the fission process is already smaller than before the first insertion, causing the effect of the second equal-size insertion to be greater. Thus, neutron population will increase by a greater amount and therefore take longer to reach steady state.

The larger increases in population and longer time to equilibrium become more pronounced with each subsequent reactivity insertion.

Reference 56, pages 8-48 through 8-55.

11.

The neutron population in a subcritical reactor depends on the source strength and K_{eff}. An equilibrium population will be reached in which the rate of source neutron production equals the net loss rate of neutrons from fission.

With the same value of K_{eff} in the two reactors, the fraction of neutrons from fission "lost" each generation is the same. With twice the source strength, however, Reactor "A" will reach an equilibrium population that is twice that of Reactor "B".

Mathematically:

$$\text{neutron production rate} = S/(1-K_{eff})$$

Doubling the source strength "S" results in twice the neutron production rate.

Reference 18, pages 190 and 191, and reference 56, page 8-48.

12. A

The steady state neutron level achieved in a subcritical reactor is a product of the source strength and the subcritical multiplication factor. The multiplication of neutrons occurs through the fission process. If the neutron source is removed from the subcritical reactor, the neutron level will decrease to zero. Answers B, C and D are all erroneous. B should state approximately one half, C it takes more time and D a greater count rate increase.

Reference 56, page 8-66.

13. B

$$\frac{CR_1}{CR_2} = \frac{1-K_2}{1-K_1} = \frac{\Delta K_2}{\Delta K_1}$$

Assuming $\rho = \frac{\Delta K}{K} \cong \Delta K$,

$$\frac{150}{300} = \frac{-\Delta K_1}{-(-0.02)}$$

$\Delta K_1 = -0.01$

Reactivity to be added:
$\rho = \Delta K_2 - \Delta K_1 = +0.01 = 1\% \Delta K/K$

Reference 07, chapter 5, page 14.

14. C

β is defined as the fraction of all neutrons born from fission that are born as delayed neutrons for a particular fissionable nuclide.

Reference 56, page 7-28.

15. A

β is defined as the fraction of all neutrons born from fission that are born as delayed neutrons for a particular fissionable nuclide.

Reference 56, page 7-28.

16. C

Over core life U-235 is depleted and U-238 is converted into Pu-239. The depletion of U-235 and the production of the plutonium isotope with its smaller delayed neutron fraction decreases the average effective delayed neutron fraction over core life. Pu-240 has no impact on changes in delayed neutron fraction over core life.

Reference 56, page 7-33.

17. D

The delayed neutron importance factor relates the probability (on a one-to-one basis) of a delayed neutron causing a fission in the core in comparison to prompt neutrons.

Reference 56, page 7-36 and 7-37.

18. B

Reference 56, pages 7-33 and 7-37.

19.

The delayed neutron fraction (β) is the fraction of neutrons born delayed from fission of a particular nuclide. The value of β for each fissionable nuclide is a constant.

The effective delayed neutron fraction (β_{eff}) is the fraction of neutron-induced fissions caused by delayed neutrons for a particular nuclide. It differs from β in that it recognizes the lower birth energy of delayed neutrons compared to prompt neutrons. This lower birth energy means delayed neutrons are less likely to cause fast fission or to leak out while slowing down. Depending on core size and fuel loading, β_{eff} might be greater or smaller than β. In a typical large PWR, $\beta_{eff} < \beta$.

The average effective delayed neutron fraction ($\overline{\beta}_{eff}$) is a weighted average of the β_{eff} for each fuel isotope in a given core. Because $\overline{\beta}_{eff}$ considers the effect of delayed neutrons on fission in the entire core, it is the term of most use in discussing and predicting reactor response to reactivity changes.

Reference 56, pages 7-28 through 7-38.

20.

The delayed neutron fraction, β, is a constant for any specific fissionable nuclide. It is the fraction of neutrons from fission of that nuclide that are born delayed.

The effective delayed neutron fraction, β_{eff}, represents the relative contribution of delayed neutrons in producing fission. Because delayed neutron birth energies are less than those of prompt neutrons, delayed neutrons are less likely to cause fast fissions (tending to make $\beta_{eff} < \beta$) but more likely to remain in the core while slowing down (tending to make $\beta_{eff} > \beta$).

Reference 56, pages 7-28 through 7-38.

21. B

Reference 56, pages 7-36 and 7-38.

22. A

Startup rate is defined as the rate of change of reactor power expressed in decades per minute.

Reference 58, page I-3.15.

23. B

Reference 58, page I-3.15.

24. C

Reference 58, page I-3.15.

25. D

Startup rate is defined as the rate of change of reactor power expressed in decades per minute.

Reference 58, page I-3.15.

26. A

Startup rate is defined as the rate of change of reactor power expressed in decades per minute.

Reference 58, page I-3.15.

27. A

Reference 58, pages 1-3.15.

28. C

As long as the reactor remains below prompt criticality, the rate of power changes will be dependent on delayed neutrons. The impact of delayed neutrons is dependent on their relative number and on how "delayed" they are. These two concepts are accounted for by the average effective delayed neutron fraction and the average decay constant, respectively.

Reference 56, chapter 7, page 51.

29. B

As long as the reactor remains below prompt criticality, the rate of power changes will be dependent on delayed neutrons. The impact of delayed neutrons is dependent on their relative number and on how "delayed" they are. These two concepts are accounted for by the average effective delayed neutron fraction and the average decay constant, respectively.

Reference 56, chapter 7, page 51.

30. C

As long as the reactor remains below prompt criticality, the rate of power changes will be dependent on delayed neutrons. The impact of delayed neutrons is dependent on their relative number and on how "delayed" they are. These two concepts are accounted for by the average effective delayed neutron fraction and the average decay constant, respectively.

Reference 56, chapter 7, p[illegible]

31. D

As long as the reactor remains below prompt criticality, the rate of power changes will be dependent on delayed neutrons. The impact of delayed neutrons is dependent on their relative number and on how "delayed" they are. These two concepts are accounted for by the average effective delayed neutron fraction and the average decay constant, respectively.

Reference 56, chapter 7, page 51.

32. C

$SUR = 26\,\bar{\lambda}\rho / (\bar{\beta}_{eff} - \rho)$ for $\rho < \bar{\beta}_{eff}$

As $\bar{\beta}_{eff}$ decreases over core life, the SUR resulting from a given reactivity insertion increases.

Reference 56, chapter 7, page 51.

33. A

Of the four choices, only the dropped rod inserts negative reactivity, causing the reactor to become subcritical and resulting in a negative startup rate.

34. A

Of the four choices, only the increase in turbine loading, causing an increased steam demand, inserts positive reactivity, causing the reactor to become supercritical and resulting in a positive startup rate.

35.

$SUR = 26\,\bar{\lambda}\rho / (\bar{\beta}_{eff} - \rho)$

SUR = the rate of change of power in decades per minute

$\bar{\lambda}$ = the weighted average of delayed neutron precursors' decay constants

ρ = the fractional change of the effective multiplication factor from criticality, a measure of the reactor's departure from criticality

$\bar{\beta}_{eff}$ = the weighted average of the effective delayed neutron fractions of fissionable nuclides in the core

36. A

Delayed neutrons increase average neutron generation time to levels that slow down reactor power changes and make a reactor controllable.

Reference 56, chapter 7, page 51.

37. A

The smaller average effective delayed neutron fraction resulting from plutonium production results in faster response later in core life.

Reference 56, chapter 7, page 33.

38. C

The smaller average effective delayed neutron fraction resulting from plutonium production results in faster response later in core life.

Reference 56, chapter 7, page 29.

39. D

Delayed neutrons increase average neutron generation time to levels that slow down reactor power changes and make a reactor controllable.

Reference 56, chapter 7, page 29.

40. C

The smaller average effective delayed neutron fraction resulting from plutonium production results in faster response later in core life.

Reference 56, chapter 7, page 29.

41. A

42. A

43.

As long as a reactor is maintained prompt subcritical, the fission process is dependent on the appearance of delayed neutrons for neutron flux (and therefore reactor power) to increase. As a result, the delayed neutrons, though only a small fraction of all neutrons, have a large impact on the rate at which power changes. The average generation time for delayed neutrons is much larger than for prompt neutrons, thus making power changes happen much more slowly. Without this effect of delayed neutrons, reactor response would be too fast to control.

Reference 56, pages 7-29 and 7-30.

44. C

The production of plutonium fuel in the reactor causes the effective delayed neutron fraction to decrease with core life. This increases the startup rate at the EOL for a given amount of reactivity since delayed neutrons have less control.

Reference 56, chapter 7.

45. D

A reactor trip renders the reactor highly subcritical. The self sustaining neutron fission chain reaction is turned off. The neutron level drops suddenly due to loss of prompt neutrons but then more slowly as delayed neutron levels are reached. Finally the longest lived delayed neutrons precursor will be the only one remaining, decaying with a mean half life of 80 seconds which corresponds to a negative one third DPM startup rate.

Reference 56, chapter 7, page 68.

46. B

Because of the short prompt neutron lifetime, the prompt neutron population reflects changes in core conditions much more rapidly than delayed neutrons.

Reference 56, chapter 7, pages 62 and 63.

47. D

Reference 56, chapter 7, pages 62 through 68.

48.

When a step insertion of positive reactivity is made in a critical reactor, all neutrons suddenly have a higher probability of causing fission. With their very short neutron generation time, prompt neutrons respond rapidly, causing a rapid increase in neutron population (the "prompt jump"). However, as long as the reactor is kept prompt subcritical, this rapid increase in neutron population cannot be maintained. Therefore, after the initial "jump" in neutron population caused by the effect of prompt neutrons, the startup rate stabilizes at a lower value determined by the slower rate of appearance of delayed neutrons.

Reference 56, pages 7-62 through 7-66.

49.

When a step insertion of negative reactivity is made in a critical reactor, all neutrons suddenly have a lower probability of causing fission. With their very short generation time, prompt neutrons respond rapidly, causing a rapid decrease in neutron population (the "prompt drop"). However, delayed neutrons from precursors formed earlier (and therefore at a higher production rate due to the higher power level) will continue to appear. After the "prompt drop" in neutron population caused by the effect of prompt neutrons, the startup rate stabilizes at a less negative value controlled by the rate of appearance of delayed neutrons from the longest-lived precursors.

Reference 56, page 7-68.

50. C

Prompt critical can be defined as that reactivity condition where delayed neutrons are no longer needed to sustain the chain reaction.

Reference 56, pages 7-57, 7-58.

51. B

Reference 56, pages 7-57, 7-58

52. C

Reference 56, chapter 7, page 57.

53. B

When a reactor's reactivity equals its average effective delayed neutron fraction, the reactor is said to be "prompt critical." In a prompt critical reactor, the fission chain reaction would no longer need to "wait" for the appearance of delayed neutrons to maintain itself. As a result, power transients would occur too quickly to permit operator control.

Reference 56, chapter 7, pages 57 through 62.

54.

A "prompt critical" reactor has a fission chain reaction that would be self-sustaining if there were no delayed neutrons. In fact, it is a highly supercritical reactor in which the effect of delayed neutrons in slowing the rate of power changes is largely lost and power is increasing very rapidly.

Reference 56, pages 248 and 249.

55. C

In a critical reactor, the fission rate is in an equilibrium in which the production of prompt and delayed neutrons equals the removal rate of neutrons. If positive reactivity is suddenly inserted into a critical reactor, the production rate of prompt neutrons will suddenly increase, causing a "prompt jump" in fission rate and reactor power. However, as long as the reactor remains prompt subcritical, this rapid rate of increase cannot be sustained, and the subsequent appearance of delayed neutrons once again controls the rate of increase of reactor power.

Reference 56, chapter 7, page 62.

56. A

In a critical reactor, the fission rate is in an equilibrium in which the production of prompt and delayed neutrons equals the removal rate of neutrons. If negative reactivity is suddenly inserted into a critical reactor, the production rate of prompt neutrons will suddenly decrease, causing a "prompt drop" in fission rate and reactor power. However, this rapid rate of decrease will not be sustained because the subsequent appearance of delayed neutrons will once again control the rate of decrease of reactor power.

Reference 56, chapter 7, page 70.

57. B

Reference 56, chapter 7, pages 57 and 58.

58. C

$P = P_0 e^{t/T}$

$P = 10 \text{ MW } e^{60/78.18}$

$P = 21.5$ MW

Reference 56, chapter 7, pages 19 and 20.

59. A

$P = P_0 \, 10^{(SUR)(t)}$

$P = 30 \text{ MW } 10^{(0.75)(0.5)}$

$P = 71$ MW

Reference 56, chapter 7, pages 19 and 20.

60. C

$P=Po \, 10^{(SUR)(t)}$

$\frac{P}{Po}=10^{(SUR)(t)}$

$\log \frac{P}{Po}=(SUR)(t)$

$SUR=(\log P/Po)/t$

$SUR=(\log 5 \times 10^{-7}/1 \times 10^{-8})/2$

$SUR=(\log 50)/2=0.85$ dpm

Reference 56, pages 7-19, 7-20.

61. B

$P = P_0 \, 10^{(SUR)(t)}$

$\log 10^{(SUR)(t)} = \log (P/Po)$

$SUR = \frac{\log (P/Po)}{t}$

$SUR = \frac{\log (95/20)}{(93.5 \text{ sec}) \frac{(1 \text{ min})}{(60 \text{ sec})}}$

SUR = 0.434 DPM

Reference 56, chapter 7, pages 19 and 20.

62. A

$P = P_o^{(SUR)(t)}$

$$SUR = \frac{\log(P / Po)}{t}$$

$$SUR = \frac{\log(10^{-6} / 10^{-9})}{6\text{min}}$$

$$SUR = \frac{\log 10^3}{6} = \frac{3}{6}$$

SUR=0.5 dpm

Reference 56, chapter 7, pages 19 and 20.

63. B

$P = P_0 10^{(SUR)(t)}$

$P_0 = 1 \times 10^{-4}$

SUR = 0.5 DPM

t = 2.5 min

$P = (1 \times 10^{-4})\ 10^{(0.5)(2.5)}$

$P = (1 \times 10^{-4})\ (17.78)$

$P = 1.8 \times 10^{-3}$

Reference 56, chapter 7, pages 19 and 20.

64. C

$P = P_0 10^{(SUR)(t)}$

$\frac{P}{P_0} = 10^{(SUR)(t)}$

$\log \frac{P}{Po} = (SUR)(t)$

$t = [\log (1 \times 10^{-4}) / (5 \times 10^{-1})] / (-.333)$

t = 11.1 minutes

Reference 56, chapter 7, pages 19 and 20.

65. A

$P = P_0 e^{t/T}$

$= (120 \text{ watts})\ e^{(120 \text{ sec})/(- 80 \text{ sec})}$

= 27 watts

66. A

The purposes of neutron source assemblies are:

1. to provide a means to monitor reactivity changes in a shutdown reactor
2. to provide a base neutron level to ensure an orderly and controlled approach to criticality
3. to verify proper operation of the source range detectors

An installed neutron source is not needed to start the fission chain reaction.

Reference 56, chapter 8, page 11.

67. B

Reference 56, chapter 8, page 11.

68. C

Reference 56, chapter 8, page 11.

69. C

Presence of source neutrons does not affect K_{eff} or the ability to start up the reactor. They are used to increase the neutron population to such a level that they can be detected, allowing the operator to monitor core conditions before and as criticality is reached.

Reference 56, chapter 8, page 11.

70. D

Achieving criticality, ability to change reactivity, and presence of subcritical multiplication in the core are independent of the size of the neutron population, and thus the presence of installed neutron sources.

Reference 56, chapter 8, page 11.

71. A

Reference 38, pages 11.5-3 and 11.5-4.

72. B

73.

An installed source provides a sufficient neutron flux in a shutdown reactor to be observable on nuclear instrumentation. Without an installed source, the neutron population would fall to a subcritical equilibrium level too low for the nuclear instrumentation detectors to measure. The operator would therefore have no indication of neutron level or power changes in the reactor and would be unaware of the criticality condition of the reactor.

Reference 61, page 1-37.

74. D

75. C

REACTOR KINETICS AND NEUTRON SOURCES
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 2, 5, 7, 8, 9, 11, 12

Explain the concept of subcritical multiplication.

K1.01 Questions 1, 6, 10

Explain the response of a subcritical reactor to reactivity insertions.

K1.01 Questions 3, 4, 13, 74

Calculate reactivity changes in a subcritical reactor.

K1.04 Questions 14, 15, 18-20

Define delayed neutron fraction and average effective delayed neutron fraction.

K1.04 Question 16

Describe the variation of the average effective delayed neutron fraction over core life.

K1.04 Questions 17, 21

Explain the significance of the delayed neutron importance factor.

K1.05 Questions 22-27

Define startup rate.

K1.06 Questions 28-34

Recognize the factors that will affect the magnitude of a stable startup rate for a given reactivity addition of less than the average effective delayed neutron fraction.

K1.06 Question 35

Write the startup rate equation and define each term.

K1.07 Questions 36-44

Explain the effect of delayed neutrons on reactor control.

K1.07 Question 45

Describe the neutron level (fission power) change when a reactor trip occurs

K1.08 Questions 46-49, 75

Explain causes for prompt jump, prompt drop, and prompt critical.

K1.08 Questions 50-54

Define prompt critical.

K1.08 Questions 55, 56

Identify prompt jump and prompt drop on a curve showing reactor power response following stepped reactivity addition.

K1.08 Question 57

Describe reactor behavior during the prompt critical condition.

K1.09 Questions 58-65

Given an equation sheet, calculate reactor power level changes, time required for power level changes, startup rate and/or reactor period.

REACTOR KINETICS AND NEUTRON SOURCES
Learning Objectives

K1.11 Questions 66-73

Explain the purpose for installed primary and secondary (regenerative) neutron sources in a reactor core.

REACTIVITY COEFFICIENTS
Questions

1. The moderator temperature coefficient of reactivity indicates the

   A. reactivity effect due to a change in reactor coolant temperature

   B. density change in the moderator due to a change in reactor coolant temperature

   C. reactivity effect due to a change in both the reactor coolant and fuel temperatures

   D. pressure change in the moderator due to a change in the reactor coolant temperature

2. The units of the moderator temperature coefficient of reactivity are

   A. psi per °F change in reactor coolant temperature

   B. % power per °F change in reactor coolant and fuel temperatures

   C. Δk/k per °F change in reactor coolant temperature

   D. Δk/k per °F change in reactor coolant and fuel temperatures

3. The amount of reactivity inserted per °F change in the reactor coolant temperature is referred to as the

   A. Doppler temperature coefficient of reactivity

   B. moderator temperature coefficient of reactivity

   C. heat-up coefficient of reactivity

   D. temperature reactivity defect

4. During low-power physics testing, which of the following indicates a positive moderator temperature coefficient?

   A. A decrease in reactor coolant temperature results in an increase in core reactivity.

   B. An increase in reactor coolant temperature results in a decrease in core reactivity.

   C. An increase in reactor coolant temperature results in an increase in core reactivity.

   D. A decrease or increase in reactor coolant temperature has no effect on core reactivity.

5. Moderator temperature coefficient (MTC) is defined as the change in core reactivity per degree change in

   A. coolant temperature
   B. reactor vessel temperature
   C. cladding temperature
   D. fuel temperature

6. The reactor is critical below the point of adding heat during a normal reactor startup at end of core life. Select the reactivity coefficient that will add the most negative reactivity if reactor coolant temperature increases by 1 degree F.

   A. void coefficient
   B. pressure coefficient
   C. fuel temperature coefficient
   D. moderator temperature coefficient

7. Given that the current value of moderator temperature coefficient is -0.010 % ΔK/K per °F, which one of the following core reactivity changes will be caused by a 50 °F increase in coolant temperature?

   A. -0.50 % ΔK/K
   B. +0.50 % ΔK/K
   C. -0.05 % ΔK/K
   D. +0.05 % ΔK/K

8. Explain why a change in moderator temperature causes a change in core reactivity by describing the effect on each factor in the six-factor formula.

9. The fuel temperature (Doppler) coefficient of reactivity indicates the

   A. the change in K_{eff} due to a change in fuel cladding temperature

   B. reactivity effect due to a change in fuel cladding temperature

   C. change in fuel pellet density due to a change in the fuel pellet temperature

   D. reactivity effect due to a change in the fuel pellet temperature

10. The amount of reactivity added to a reactor for each 1 °F increase in fuel temperature is referred to as the

   A. fuel temperature (Doppler) defect
   B. fuel temperature (Doppler) coefficient
   C. power coefficient
   D. power defect

11. In the definition of fuel temperature (Doppler) coefficient of reactivity, °F refers to

   A. fuel clad temperature
   B. fuel pellet temperature
   C. incore thermocouple temperature
   D. reactor coolant temperature

12. Which of the following phrases defines the fuel temperature (Doppler) coefficient?

   A. the incremental change in reactivity for an incremental change in reactor power

   B. the total change in reactivity for a given change in reactor power

   C. the incremental change in reactivity due to an incremental change in fuel temperature

   D. the total change in reactivity due to a given change in fuel temperature

13. The fuel temperature coefficient is defined as the change in core reactivity per degree change in the temperature of the

   A. uranium dioxide pellets
   B. fuel-to-cladding gap
   C. zircalloy cladding
   D. fission product gases

14. Which one of the following will directly result in a less negative fuel temperature coefficient? (Consider only the effect of the change in the listed parameters.)

   A. increase in fuel burnup
   B. decrease in fuel temperature
   C. increase in void fraction
   D. decrease in moderator temperature

15. If the plant has operated at steady-state 100% power for the past six months, the moderator temperature coefficient most likely

   A. has changed very little
   B. has become less negative
   C. has become more negative
   D. became more negative, then turned, and became less negative

16. The plant is currently at end-of-life in its fuel cycle and will be refueled next month. How will the value of the refueled core' s moderator temperature coefficient (MTC) compare to the present core MTC?

    A. The refueled core's MTC will be less negative.

    B. The refueled core's MTC will be more negative.

    C. The MTC will change very little.

    D. A comparison cannot be made with the available information.

17. Which of the following best describes the change in the moderator temperature coefficient (MTC) during a plant cooldown at end-of-life?

    A. The MTC becomes less negative.

    B. The MTC becomes more negative.

    C. The MTC changes very little during a plant cooldown.

    D. The MTC becomes more negative, then turns and becomes less negative.

18. Which of the following causes the largest <u>increase</u> in the magnitude of the moderator temperature coefficient?

    A. plant heat-up at beginning-of-life
    B. plant heat-up at end-of-life
    C. plant cooldown at beginning-of-life
    D. plant cooldown at end-of-life

19. Under which of the following conditions is a reactor core most likely to have a positive moderator temperature coefficient?

    A. high reactor coolant temperature at end-of-life

    B. high reactor coolant temperature at beginning-of-life

    C. low reactor coolant temperature at end-of-life

    D. low reactor coolant temperature at beginning-of-life

20. Explain how and why the moderator temperature coefficient of reactivity changes over core life.

21. Explain how and why the moderator temperature coefficient of reactivity changes with increasing moderator temperature.

22. At what time in core life is the moderator temperature coefficient most likely to be positive? Why?

23. Select the answer that contains a pair of nuclides that are <u>both</u> significant contributors to the total resonance capture in the core.

    A. U-235 and U-238
    B. Pu-239 and Pu-240
    C. U-235 and Pu-239
    D. U-238 and Pu-240

24. Resonance capture is likely to occur when the kinetic energy of an incident neutron plus the binding energy caused by its absorption

    A. equals the critical energy associated with causing fission

    B. equals the amount of energy required to take the target nucleus to a discrete excitation level

    C. exceeds the energy associated with the lower end of the resonance region

    D. equals the energy necessary to penetrate the electrical field of the electron shells of the target atom

25. The process by which neutrons with specific kinetic energies are lost at discrete peaks in absorption cross section while slowing down is termed

    A. thermal diffusion
    B. thermal absorption
    C. neutron moderation
    D. resonance capture

26. Which one of the following isotopes is the most significant contributor to resonance capture of fission neutrons in the reactor core at the beginning of core life?

    A. U-233
    B. U-238
    C. Pu-239
    D. Pu-240

27. As fuel temperature increases, the shape of a resonance peak as plotted on a graph of microscopic absorption cross section versus neutron energy changes. The best description of this change is that the peak

    A. becomes lower and narrower

    B. becomes higher and narrower

    C. becomes lower and broader

    D. height remains the same as the peak broadens

28. Explain how and why an increase in fuel temperature causes a change in core reactivity.

29. An increase in fuel temperature results in an increase in resonance capture. This occurs mainly because of

    A. thermal expansion of the fuel pellets resulting in increased macroscopic capture cross-section

    B. Doppler broadening and the accompanying reduction in the fuel pellet self-shielding

    C. increased migration of fission product gases into the fuel rod

    D. an associated increase in moderator temperature

30. Which statement best describes the reactivity inserted into the core due to Doppler broadening?

    A. Negative reactivity is inserted due to increased resonance capture in non-fissile fuel.

    B. Negative reactivity is inserted due to increased fast leakage from the core.

    C. Positive reactivity is inserted due to increased thermal absorption of neutrons in fissile fuel.

    D. Positive reactivity is inserted due to a flux distribution shift toward the more reactive regions of the core.

31. Doppler broadening is a term used to describe the

    A. 1/v behavior exhibited by certain light nuclides, e.g., boron-10

    B. change in fast fission that occurs as neutron fast flux increases

    C. increase in width of a resonance peak as fuel temperature increases

    D. shift in flux distribution to the outer edges of the core as center-placed fuel bundles burn up

32. The reactivity inserted into the core due to a fuel temperature increase will be

    A. positive during all core conditions (beginning and end of cycle; all power levels)

    B. positive at beginning of cycle; negative at end of cycle

    C. negative only if the reactor is above the point of adding heat

    D. negative during all core conditions (beginning and end of cycle; all power levels)

33. When fuel temperature is increased, the resonance absorption peaks are shortened and broadened such that more neutron energies are susceptible to absorption, but the average probability of resonance absorption (average microscopic cross-section) remains constant. Which one of the following explains why the Doppler effect adds negative reactivity with increasing fuel temperature despite the constant average microscopic cross-sections of the resonance absorbers?

    A. The self-shielding of epithermal neutrons by the fuel pellets decreases on an overall basis.

    B. The cladding self-shielding decreases as the fuel temperature increases.

    C. Fewer fast neutron fissions occur because the resonance peaks are shortened at higher fuel temperatures.

    D. More epithermal neutrons leak out of the core since the resonance peaks are shortened at higher fuel temperature.

34. Which of the following statements is correct concerning Doppler broadening in a reactor core?

    A. Doppler broadening results in increased resonance capture of off-resonant neutrons.

    B. Doppler broadening results in a substantial increase in neutron absorption by soluble boron.

    C. Doppler broadening occurs mainly because of moderator temperature increases.

    D. Doppler broadening mainly affects neutrons in the fast energy range.

35. During a plant heat-up (with an initial negative moderator temperature coefficient), the moderator temperature coefficient becomes increasingly more negative. This is because

    A. as moderator density decreases, more thermal neutrons are absorbed by the moderator than by the fuel

    B. the change in the thermal utilization factor dominates the change in the resonance escape probability

    C. a greater density change per degree F occurs at higher reactor coolant temperatures

    D. the core transitions from an under-moderated condition to an over-moderated condition

36. During a plant cooldown, a negative moderator temperature coefficient adds positive reactivity to the core. This is primarily due to the

    A. thermal utilization factor decreasing
    B. thermal utilization factor increasing
    C. resonance escape probability decreasing
    D. resonance escape probability increasing

37. As the core ages, the moderator temperature coefficient becomes more negative. This is primarily due to

    A. fission product poisons building up in the fuel

    B. the centerline fuel temperature lowering as the core ages

    C. decreasing control rod worth

    D. reduced reactor coolant system boron concentration

38. Under certain conditions, the moderator temperature coefficient may be positive. Which of the following cases is <u>most likely</u> to result in a positive moderator temperature coefficient?

    A. low reactor coolant system (RCS) temperature, low boron concentration

    B. high RCS temperature, low boron concentration

    C. low RCS temperature, high boron concentration

    D. high RCS temperature, high boron concentration

39. Why does increasing reactor coolant system (RCS) boron concentration cause the moderator temperature coefficient to become less negative?

    A. Reactor coolant temperature increases result in a larger increase in the thermal utilization factor.

    B. Reactor coolant temperature increases result in an increase in the resonance escape probability.

    C. Reactor coolant temperature increases result in an increase in the total non-leakage probability.

    D. The change in resonance escape probability dominates the change in the thermal utilization factor.

40. In which of the following conditions is the moderator temperature coefficient most negative?

    A. BOL, high temperature
    B. BOL, low temperature
    C. EOL, high temperature
    D. EOL, low temperature

41. The moderator temperature coefficient (MTC) becomes less negative (more positive) when which one of the following core parameters is increased?

    A. coolant boron concentration
    B. average coolant temperature
    C. effective core age (or burnup)
    D. effective fuel temperature

42. The moderator temperature coefficient (MTC) becomes least negative (most positive) under which one of the following conditions?

    A. Average temperature is decreased while boron concentration is increased.

    B. Average temperature is decreased while boron concentration is decreased.

    C. Average temperature is increased while boron concentration is increased.

    D. Average temperature is increased while boron concentration is decreased.

43. Moderator temperature coefficient will be least negative at a __________ reactor coolant temperature and a __________ reactor coolant boron concentration.

    A. low; low
    B. high; low
    C. low; high
    D. high; high

44. The reactor is operating at full power following a refueling outage. In comparison to the current moderator temperature coefficient (MTC), the MTC just prior to the refueling was

    A. less negative at all coolant temperatures

    B. more negative at all coolant temperatures

    C. less negative below approximately 350° F coolant temperature and more negative above approximately 350°F coolant temperature

    D. more negative below approximately 350 °F coolant temperature and less negative above approximately 350°F coolant temperature

45. Which of the following best describes how "Doppler broadening" of resonance absorption peaks contributes to making the fuel temperature (Doppler) coefficient of reactivity negative? As fuel temperature increases,

    A. the absorption cross section for the resonance peaks increases, causing more absorption of resonant energy neutrons

    B. absorption of off-resonance neutrons increases while absorption of resonant energy neutrons remains relatively constant

    C. resonance energy absorption cross-sections decrease, resulting in increased resonance escape

    D. the neutron energy spectrum is "hardened," resulting in more resonance absorption

46. Which of the following best describes how "self-shielding" of the fuel contributes to making the fuel temperature (Doppler) coefficient of reactivity negative?

    A. At higher fuel temperatures, resonant energy neutrons travel deeper into the fuel but are absorbed.

    B. The inner fuel is shielded from fast neutrons, reducing the fast fission factor.

    C. The inner fuel is shielded from resonant energy neutrons, increasing resonance escape.

    D. The neutron energy spectrum is "hardened," resulting in more resonance absorption.

47. Why does the fuel temperature (Doppler) coefficient become less negative at higher fuel temperatures?

    A. As reactor power increases, the rate of increase of the fuel temperature diminishes.

    B. Neutrons penetrate deeper into the fuel, resulting in an increase in the fast fission factor.

    C. The amount of self-shielding increases, resulting in less neutron absorption by the inner fuel.

    D. The amount of Doppler broadening per degree change in fuel temperature diminishes.

48. Explain how and why the fuel temperature (Doppler) coefficient of reactivity changes as fuel temperature is increased.

49. Which one of the following will cause the Doppler power coefficient to become more negative?

    A. increased clad creep
    B. increased pellet swell
    C. lower power level
    D. lower coolant boron concentration

50. As fuel temperature increases, the value of the fuel temperature (Doppler) coefficient of reactivity

    A. remains constant
    B. becomes more negative
    C. becomes less negative
    D. becomes positive

51. Which of the following contributes to a negative fuel temperature (Doppler) coefficient?

    A. fission product poison depletion

    B. increased off-resonance neutron absorption

    C. fuel identification and build-up of fission product gases

    D. decrease in fast fission factor

52. List three components of the power defect and explain how each contributes to the change in reactivity resulting from a power increase.

53. Which one of the following groups contains parameters that, if varied, will each have a <u>direct</u> effect on the power defect?

    A. control rod position, reactor power, moderator voids

    B. moderator temperature, RCS pressure, xenon level

    C. fuel temperature, xenon level, control rod position

    D. moderator voids, fuel temperature, moderator temperature

REACTIVITY COEFFICIENTS
Questions

54. The plant is operating at full power with the reactor at end-of-life (EOL) conditions. When compared to the moderator temperature-only power defect, the Doppler-only power defect is approximately

    A. the same
    B. twice as large
    C. five times as large
    D. ten times as large

55. As the core ages, the relative contribution of the void power coefficient to the total power coefficient ________ although its value ______.

    A. decreases; remains about the same
    B. increases; becomes more negative
    C. decreases; becomes less negative
    D. increases; becomes less negative

56. The reactor is operating at full power at the end of core life.

    Which one of the following reactivity coefficients will add the largest amount of positive reactivity following a reactor trip? Assume all parameters stabilize at their no-load values.

    A. moderator temperature coefficient
    B. void coefficient
    C. pressure coefficient
    D. doppler coefficient

57. Which one of the following adds the most positive reactivity following a trip/scram from full power at the beginning of core life? Assume RCS parameters stabilize at their normal post-trip values.

    A. moderator temperature coefficient
    B. void coefficient
    C. pressure coefficient
    D. doppler coefficient

58. Explain how and why differential boron worth varies as boron concentration is increased.

59. The magnitude of differential boron worth increases (becomes more negative) with

    A. decreased boron concentration
    B. increased neutron level
    C. increased moderator temperature
    D. increased fission fragment poison concentration

60. As reactor coolant boron concentration is reduced, differential boron reactivity worth ($\Delta K/K$ per ppm) becomes

    A. less negative due to the increased number of water molecules in the core
    B. more negative due to the increased number of water molecules in the core
    C. less negative due to the decreased number of boron molecules in the core
    D. more negative due to the decreased number of boron molecules in the core

61. Explain how and why differential boron worth varies as moderator temperature increases.

62. The magnitude of differential boron worth increases (becomes more negative) as

    A. boron concentration increases
    B. core age increases
    C. moderator temperature decreases
    D. fission fragment concentration increases

63. The amount of boric acid required to increase the coolant boron concentration by 50 ppm at BOL (1200 ppm) is approximately __________ as the amount of boric acid required to increase boron concentration by 50 ppm at EOL (100 ppm).

    A. twelve times as large
    B. eight times as large
    C. four times as large
    D. the same

REACTIVITY COEFFICIENTS
Questions

64. At EOL, a certain amount of pure water is required for a 20 ppm decrease in boron concentration (from 100 ppm to 80 ppm). The amount of pure water required for a 20 ppm decrease at BOL (from 1000 ppm to 980 ppm) is approximately _________ as the EOL amount.

    A. one-tenth as large
    B. one-fifth as large
    C. one-half as large
    D. the same

65. The amount of boric acid required to increase the reactor coolant boron concentration by 10 ppm at beginning of cycle (BOC) conditions (1200 ppm) is approximately __________ the amount of boric acid required to increase boron concentration by 10 ppm at end of cycle (EOC) conditions (100 ppm).

    A. twelve times
    B. eight times
    C. four times
    D. the same as

66. An operator uses 2,000 gallons of pure water to dilute the boron concentration of the reactor coolant system early in core life. Compare the effect on reactivity of this dilution with a 2,000 gallon dilution late in life. Explain why the effects differ.

67. A reactivity coefficient measures _______ change while a reactivity defect (deficit) measures a _________ change in reactivity due to a change in the measured parameter.

    A. an integrated, total
    B. a rate of, differential
    C. a differential, total
    D. a total, differential

68. Which of the following describes the relationship of reactivity coefficients to reactivity defects (deficits)?

    A. defect = coefficient x Δ parameter
    B. coefficient = defect x Δ parameter
    C. Δ parameter = defect x coefficient
    D. coefficient = Δ parameter + defect

69. Which of the following is best expressed by a reactivity coefficient?

    A. the total reactivity that must be overcome between the point of adding heat and 100% power

    B. the incremental change in reactivity for each degree of fuel temperature change

    C. the reactivity that must be added to take the reactor critical

    D. the amount of reactivity necessary to make power change by a factor of "e" in one minute

70. Given the following initial parameters, select the final coolant boron concentration needed to decrease average coolant temperature by 4 °F (assume no change in rod position or reactor/turbine power)

Initial coolant boron concentration	=	60[illegible] ppm
Moderator temperature coefficient	=	-0.015% ΔK/K per degree F
Differential boron worth	=	-0.010% ΔK/K per ppm
Inverse boron worth	=	-100 ppm/% ΔK/K

    A. 606 ppm
    B. 603 ppm
    C. 597 ppm
    D. 594 ppm

71. Given the following initial parameters, calculate the final RCS boron concentration required to support increasing plant power from 30 percent to 80 percent by boration/dilution only (with no change in controlling rod group position). Assume no change in xenon concentration.

Total power coefficient	=	16 pcm/percent
Boron worth	=	-10 pcm/ppm
Initial coolant boron concentration	=	500 ppm

A. 340 ppm
B. 420 ppm
C. 580 ppm
D. 660 ppm

72. If the average moderator temperature-only power coefficient is -0.005 % ΔK/K per % power, which one of the following is the moderator temperature-only power defect at 100 percent power?

A. -0.005 % ΔK/K
B. -0.050 % ΔK/K
C. -0.500 % ΔK/K
D. -5.000 % ΔK/K

73. Explain the difference between a reactivity coefficient and a reactivity defect.

74. Approximately 3% ΔK/K (3,000 pcm) positive reactivity is required to increase the reactor power from hot-zero power to full power. This is necessary to overcome the

A. integral control rod worth
B. integral boron worth
C. power defect (deficit)
D. samarium reactivity worth

75. During a reactor trip, the power defect (deficit)

A. adds positive reactivity to the core

B. adds negative reactivity to the core

C. has no effect on core reactivity

D. may add either positive or negative reactivity, depending on time in core life

76. Which one of the following statements concerning the power defect is correct?

A. The power defect necessitates the use of a ramped Tave program to maintain an adequate reactor coolant system subcooling margin.

B. The power defect increases the rod height requirements necessary to maintain the desired shutdown margin following a reactor trip.

C. Because of the higher boron concentration, the power defect is more negative at the beginning of core life.

D. The power defect causes control rods to be withdrawn as reactor power is decreased.

77. During a reactor trip, which of the following inserts positive reactivity into the core?

A. control rods
B. boron
C. power defect (deficit)
D. xenon

78. During power operation, while changing power level, core reactivity is affected most quickly by

A. boron concentration adjustments
B. power defect (deficit)
C. xenon transients
D. fuel depletion

79. At high power levels near the end of core life (EOL), the Doppler-only power coefficient plays a much larger role than the moderator temperature-only power coefficient in stopping a rapid power increase due to an ejected rod because:

    A. the fuel temperature increases before the coolant temperature increases.

    B. the Doppler-only power coefficient becomes more negative as the fuel temperature increases.

    C. the moderator temperature-only power coefficient becomes less negative as coolant temperature increases.

    D. the increase in coolant temperature will be smaller than the increase in fuel temperature.

80. The amount of pure water required to decrease the reactor coolant boron concentration by 20 ppm at the end of core life (100 ppm) is approximately __________ the amount of pure water required to decrease reactor coolant boron concentration by 20 ppm at the beginning of core life (1000 ppm).

    A. the same as
    B. 10 times
    C. 20 times
    D. 100 times

81. As core age increases, for the same power level the Doppler power coefficient of reactivity becomes ______________ negative because fuel temperature ______________.

    A. more; decreases
    B. more; increases
    C. less; decreases
    D. less; increases

82. Given the following initial parameters, select the final reactor coolant boron concentration required to increase average coolant temperature by 6°F. (Assume no change in rod position or reactor/turbine power.)

Initial RCS boron concentration	= 500 ppm
Moderator temperature coef.	= -0.012% Δ K/K per degree °F
Differential boron worth	= -0.008% Δ K/K per ppm
Inverse boron worth	= -125 ppm/% Δ K/K

    A. 509 ppm
    B. 504 ppm
    C. 496 ppm
    D. 491 ppm

83. Differential boron reactivity worth will become ________ negative as moderator temperature increases because, at higher moderator temperatures, a 1 ppm increases in RCS boron concentration will add _______ boron atoms to the core.

    A. more; fewer
    B. more; more
    C. less; fewer
    D. less; more

REACTIVITY COEFFICIENTS
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

Reference 38, page 8.3-1.

2. C

Reference 38, page 8.3-1.

3. B

Reference 38, page 8.3-1.

4. C

Positive MTC means reactivity increases as temperature increases or reactivity decreases as temperature decreases.

Reference 38, page 8.4-2.

5. A

6. D

Reference 38, page 8.3-1.

7. A

(-0.010 % ΔK/K/°F) (+50°F) = -.50 % ΔK/K

8.

The effect of an increase in moderator temperature on each term of the six-factor formula is:

fast fission factor - Increases, due to increased slowing down time resulting from the decrease in moderator density. The effect, however, is relatively small.

fast and thermal non-leakage probabilities - Decrease, because the less-dense moderator allows neutrons to travel farther, increasing their chance of leakage. The effect is small because of the large size of a commercial power reactor.

resonance escape probability - Decreases, because the less dense moderator allows neutrons to travel farther at epithermal energies, resulting in a greater chance of resonant absorption. This is a significant effect.

thermal utilization factor - Increases, because fewer neutrons are absorbed by the less-dense moderator. This is a significant effect, which changes as boron is removed from the moderator over core life.

reproduction factor - No change.

Reference 61, pages 3-5 through 3-11.

9. D

The fuel temperature (Doppler) coefficient is based on reactivity change, not k_{eff} or fuel density. The fuel temperature (Doppler) coefficient is based on changing fuel temperature, not cladding temperature.

Reference 38, page 8.2-1.

REACTIVITY COEFFICIENTS
Answers

10. B

The question stem defines the fuel temperature (Doppler) coefficient.

Reference 38, page 8.2-1.

11. B

The fuel temperature (Doppler) coefficient is a function of fuel temperature.

Reference 38, page 8.2-1.

12. C

The fuel temperature (Doppler) coefficient is based on incremental changes, not total changes.

The fuel temperature (Doppler) coefficient is a function of fuel temperature.

Reference 38, page 8.2-1.

13. A

Reference 38, page 8.2-1.

14. D

A decrease in moderator temperature will increase the density of water, thereby improving the slowing down of neutrons in the coolant. This makes fewer epithermal (resonance) neutrons available for absorption in the fuel.

For distracter A, which involves greater fuel burnup, resonance absorbing atom density has on an overall basis been reduced (U-238, Pu-240). The self-shielding factor has decreased accordingly. Now, when fuel temperature rises, the fractional effect on self-shielding will be greater, producing a more negative fuel temperature coefficient.

For distracter B, the coefficient naturally is more negative at lower temperatures because the temperature change has a greater fractional effect.

In distracter C, with more voids being produced in the core, neutrons in the process of slowing down have a greater chance of encountering fuel. This will make the fuel temperature coefficient more negative.

15. C

MTC becomes more negative as the core ages and RCS boron concentration is reduced.

Reference 61, page 3-21.

16. A

Following refueling, RCS boron concentration will be greatly increased, resulting in a less negative MTC.

Reference 61, page 3-21.

17. A

As RCS temperature decreases, the MTC becomes less negative because the moderator density change per °F is less at lower temperatures.

Reference 61, page 3-21.

18. B

RCS temperature increase causes MTC to become more negative. At EOL, the lower boron concentration results in a greater negative contribution from resonance escape probability and a lesser positive contribution from the thermal utilization factor. Therefore, plant heat-up at EOL results in the largest negative change in MTC.

Reference 61, page 3-21.

19. D

MTC is least negative (most positive) under cold conditions with a high RCS boron concentration, due to large changes in the thermal utilization factor.

Reference 61, page 3-21.

20.

The major contributor to the change in moderator temperature coefficient (MTC) over core life is the decrease in required soluble boron concentration. Boron dissolved in the moderator tends to make the MTC positive. With a low boron concentration late in life, MTC is more negative than earlier in life.

Reference 61, page 3-25.

21.

A change in moderator temperature affects reactivity because the density of the moderator changes, affecting its neutron moderating and absorbing ability.

The change in water density per degree change in temperature is small at low temperatures and large at high temperatures. Therefore, the effect on reactivity per degree change in temperature increases as temperature rises. As a result, the magnitude of the moderator temperature coefficient is greater at higher temperatures.

Reference 61, pages 3-20 and 3-21.

22.

Moderator temperature coefficient (MTC) is most likely to be positive early in core life when dissolved boron concentration is greatest.

With a high boron concentration, an increase in moderator temperature, which decreases the moderator density, forces a relatively large amount of boron out of the core. This removal of a neutron poison from the core tends to insert positive reactivity. Thus, a high boron concentration tends to make the MTC positive.

Reference 61, page 3-25.

23. D

Reference 18, pages 544 and 545.

24. B

Reference 18, page 91.

25. D

Reference 18, page 89.

26. B

U-238 and Pu-240 both have high resonance peaks. U-238 is more significant because of its abundance in the core at the beginning of core life or at any other time.

Reference 18, page 254.

27. C

Reference 18, page 94.

28.

The fuel contains certain materials, such as U-238 and Pu-240, that have high cross-sections for capture of neutrons at specific epithermal energies (resonance capture). When the total kinetic energy imparted in a collision between a neutron and the nucleus of one of these target atoms is equal to the energy of a resonant peak in the cross-section, there is a very high probability that the neutron will be captured and thus lost from the fission chain reaction.

However, the target nuclei are themselves in motion, and the higher the fuel temperature, the greater this motion. Thus, for an incoming neutron of a particular energy, the total kinetic energy of the collision will vary due to the nucleus' motion. The higher the temperature, the greater the range of possible collision energies, and thus the greater the number of neutrons that "appear" to have the resonant energy. This phenomenon is known as Doppler broadening, because the resonant peaks on a graph of cross-section versus neutron energy become broader as temperature increases.

At the same time, the Doppler effect lowers the peak cross-section value. The cross-sectional area under the resonant peaks remains the same. Thus, Doppler broadening alone is not expected to increase the capture of resonance neutrons and insert negative reactivity as fuel temperature increases.

However, it can be shown that this broadening effect decreases the self-shielding of the fuel in a heterogeneous reactor (a phenomenon in which the outer portion of the pellet "shields" the inner fuel atoms by absorbing resonance neutrons). The reduction of the peak value of the capture cross-section allows some resonance neutrons to escape capture in the outer portion of a fuel pellet. But these neutrons will then be captured farther inside the pellet. Thus, the lower peak value of the cross-section does not result in less resonance capture while the broadened resonance peak does cause increased resonance capture by "seeing" additional resonance neutrons.

Therefore, as fuel temperature increases, the resonance escape probability decreases, decreasing K_{eff} and inserting negative reactivity.

Reference 61, pages 2-25 through 2-35.

29. B

Reference 18, page 253.

30. A

Reference 18, page 253.

31. C

Reference 18, page 94.

32. D

Reference 18, pages 264 and 545.

33. A

Reference 61, pages 2-29 and 2-30.

34. A

Reference 18, page 94.

35. C

Answer choice "A" is true, but tends to cause MTC to become positive. Answer choices "B" and "D" are false statements. Choice "C" is correct because water density curve shape determines the rate at which MTC changes.

Reference 61, page 3-20.

36. D

The increase in moderator density decreases resonance absorption, causing the resonance escape probability to go up and K_{eff} to increase.

Reference 61, page 3-27

37. D

With a reduced boron concentration, a change in RCS temperature will have a smaller effect on the thermal utilization factor and allows the resonance escape probability to dominate.

Reference 61, page 3-16.

38. C

High boron conditions cause MTC to become less negative. Low RCS temperatures cause MTC to become less negative.

Reference 61, page 3-21.

39. A

With a high boron concentration, a change in RCS temperature will have a larger effect on the thermal utilization factor and allows it to dominate over the resonance escape probability.

Reference 61, page 3-17.

40. C

At EOL, boron concentration is low, causing MTC to be more negative. At higher temperature, the change in water density per degree change in temperature is greater, making MTC more negative.

Reference 61, page 3-21.

41. A

A higher boron concentration causes a more pronounced increase in thermal utilization when coolant temperature increases, tending to make MTC positive.

Reference 61, page 3-18.

42. A

High boron concentrations cause MTC to become less negative. Low RCS temperatures cause MTC to become less negative.

43. C

At a low coolant temperature, density changes are smaller when temperature is increased than at high temperatures. High boron concentrations cause MTC to be less negative due to the more pronounced positive increases in thermal utilization when temperature increases.

Reference 61, page 3-21

44. B

Prior to the refueling, the MTC was strongly negative because the boron concentration was very low. After refueling, the boron concentration is high.

Reference 61, page 3-18

45. B

Due to decreased self-shielding, resonant energy neutron absorption remains relatively constant while off-resonance absorption increases. Thus, the fuel temperature (Doppler) coefficient is negative.

Reference 61, page 2-28.

46. A

Even though resonance energy absorption cross sections are ruduced, neutrons will penetrate deeper into the fuel and will still be absorbed. This combined with "peak broadening" makes Doppler negative.

Reference 61, page 2-29.

47. D

As fuel temperature increases, Doppler broadening diminishes, making the coefficient less negative.

Reference 61, page 2-39.

48.

As fuel temperature is increased, the magnitude of the fuel temperature (Doppler) coefficient decreases (becomes less negative). This is because there is less Doppler broadening per degree increase in fuel temperature at high temperatures than at low temperatures. Less Doppler broadening means less decrease in the resonance escape probability and therefore less negative reactivity inserted per degree of temperature change. Additionally, the rate of change of self-shielding is lower at higher temperatures, contributing to the reduction in the magnitude of the Doppler coefficient as fuel temperature rises.

49. C

At lower power levels the effective fuel temperature will be lower and the Doppler power (fuel temperature) coefficient stronger (more negative).

Distracter A will cause a greater temperature drop across the pellet-cladding gap requiring the fuel temperature to increase. Thus making the Doppler power coefficient less negative.

Distracter B will reduce the gap temperature drop but only slightly since the majority of pellet swell is in the axial direction. The fuel temperature will be reduced and the coefficient will be slightly more negative. Distracter D has no effect on fuel temperature or its coefficient.

Reference 61, page 2-39.

50. C

The fuel temperature (Doppler) coefficient is always negative, and cannot become positive. As temperature increases, it becomes less negative.

Reference 61, page 2-39.

51. B

Doppler broadening results in increased off-resonance neutron capture.

Reference 61, page 2-23.

52.

The components of power defect are:

- o Doppler (fuel temperature) defect
- o moderator temperature defect
- o void defect

As power is increased, fuel temperature increases, causing increased Doppler broadening and inserting negative reactivity. Because average moderator temperature is programmed to increase from zero percent to 100 percent power, negative reactivity is inserted due to the negative moderator temperature coefficient. Finally, a small contribution to the overall insertion of negative reactivity comes from the small increase in steam voids as power is increased.

Reference 61, pages 3-39 through 3-43.

53. D

The power coefficient considers those parameters that necessarily change when power is changed.

54. A

Reference 61, page 3-42.

55. A

Reference 61, page 3-42.

56. A

At the end of life, the boron concentration is highly reduced and the MTC is strongly negative. A decrease in moderator temperature to its no-load value produces a large positive reactivity effect.

Reference 61, page 3-42.

57. D

At the beginning of life, with a high boron concentration, the MTC is only slightly negative and adds a small amount of positive reactivity following a reactor trip. The fuel temperature change is significant and even though the negative fuel temperature coefficient (Doppler) is small, it becomes the dominant factor.

Reference 61, page 3-42

58.

Differential boron worth decreases as boron concentration increases. The addition of boron atoms at higher and higher concentrations has a saturation effect. For each ppm of boric acid added, the resulting changes in the thermal utilization factor will be less. Also, with higher concentrations of boron, the thermal neutron flux distribution is "hardened", i.e., shifted to higher energies. The absorption cross-section for boron is lower at these higher neutron energies, causing the differential boron worth to decrease.

Reference 61, page 5-16.

59. A

Reference 61, pages 5-13 through 5-18.

60. D

The differential worth of boron becomes more negative at lower boron concentration because a one ppm addition has a greater fractional effect on the thermal utilization.

Reference 61, page 5-32 addition.

61.

As moderator temperature increases, the magnitude of differential boron worth decreases (becomes less negative). At higher temperatures, the moderator is less dense; therefore, there is a smaller mass of water in the core. Thus, less boric acid is required for each one ppm of concentration. With less boron for each ppm, there is less poison and therefore less reactivity. Thus, the boron worth is decreased.

Reference 61, pages 5-13 and 5-14.

62. C

Reference 61, page 5-13.

63. D

Because the volume of the reactor coolant system (RCS) and the concentration of the boric acid added have not changed over core life, a given boric acid addition will produce the same ppm change independent of RCS boron concentration.

Reference 61, page 5-32.

64. A

Because every gallon of water removed from the RCS at BOL contains ten times as much boron as at EOL, only one-tenth as much water must be removed through dilution at BOL.

Reference 61, page 5-25.

65. D

For a given boric acid addition, the ppm change is independent of the RCS boron concentration.

Reference 61, page 5-32.

66.

The concentration of boron dissolved in the coolant will be much lower at end-of-life (EOL) compared to beginning-of-life (BOL). Therefore, every gallon of borated water "removed" from the core through dilution will carry with it much less boron at EOL than at BOL. The effect of a 2,000 gallon dilution on boron concentration, and thus on reactivity, will be less at EOL than at BOL.

Reference 61, page 5-29.

67. C

Coefficient measures differential change of reactivity while defect/deficit is the total change.

Reference 38, page 9.3-1.

68. A

Defect = Coefficient x Δ Parameter

Reference 38, page 9.3-1.

69. B

Choices A, C, and D refer to reactivity defects (deficits). Choice B refers to a coefficient.

Reference 38, page 9.3-1.

REACTIVITY COEFFICIENTS
Answers

70. A

A 4 °F decrease in moderator temperature inserts + 0.060 % ΔK/K:

(-4 °F) x (-0.015 % ΔK/K /°F) = 0.060 % ΔK/K

This must be balanced by a boron increase that inserts - 0.060 % ΔK/K:

$$\frac{-0.060\ \%\ \Delta K/K}{-0.010\ \%\ \Delta K/K\ /ppm} = +6\ ppm$$

Thus, the final boron concentration must be 600 ppm plus 6 ppm, or 606 ppm.

71. B

A 50% power increase will insert -800 pcm:

(+50%) x (-16 pcm/%) = -800 pcm

This must be balanced by a boron decrease that inserts + 800 pcm:

$$\frac{+800\ pcm}{-10\ pcm/ppm} = -80\ ppm$$

Thus, the final boron concentration must be 500 ppm -80 ppm, or 420 ppm.

72. C

(-0.005 % ΔK/K /% power) x (100% power)
= -0.5% ΔK/K

73.

A reactivity coefficient expresses a differential change: the change in reactivity for a one-unit change in some parameter.

A reactivity defect expresses a total change in reactivity. For example, the power defect is the total amount of reactivity inserted by a power increase.

Reference 61, page 3-57.

74. C

Power defect (deficit) is the negative reactivity that must be overcome in order to move from HZP to HFP.

Reference 61, page 3-29.

75. A

On power reductions, the power defect (deficit) inserts positive reactivity into the core.

Reference 61, page 3-29.

76. B

Power defect is negative reactivity inserted by increasing power. When a reactor trips, power decreases, inserting positive reactivity. To maintain an acceptable shutdown margin, rods must be initially higher to be able to insert additional negative reactivity to balance the positive reactivity from the power decrease.

77. C

Power defect (deficit) adds positive reactivity on power decreases.

Reference 61, page 3-29.

78. B

Choices A, C, and D affect reactivity over longer periods of time. Power defect (deficit) reactivity effects are very rapid.

Reference 61, page 3-29.

79. A.

80. B

81. C

82. D

83. C

REACTIVITY COEFFICIENTS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1-8

Define the moderator temperature coefficient of reactivity.

K1.02 Questions 9-14

Define the fuel temperature (Doppler) coefficient of reactivity.

K1.03 Questions 15-22

Describe the effect on the moderator temperature coefficient of reactivity from changes in moderator temperature and core age.

K1.04 Question 23

List the isotopes of uranium and plutonium that are the major contributors to resonance capture in the core.

K1.04 Question 24

Describe the major factors that affect the probability of neutron resonance capture.

K1.04 Question 25

Define resonance capture.

K1.04 Question 26

State the fuel isotope that is the most significant contributor to total resonance capture in the core.

K1.05 Question 27

Describe the effect of changes in fuel temperature on the shape of a resonance peak.

K1.05 Question 28

Explain the change in reactivity caused by a change in fuel temperature.

K1.05 Question 29

Explain how changes in fuel pellet self-shielding affect resonance absorption.

K1.05 Questions 30, 32, 33

Explain how and why "Doppler broadening" affects core reactivity.

K1.05 Questions 31,34

Explain "Doppler broadening" as it relates to a nuclear core.

K1.06 Question 35

Describe how water density variation with temperature affects the value of the moderator temperature coefficient.

K1.06 Question 36

Using the 6-factor formula, describe the effects of reactor coolant system temperature on the moderator temperature coefficient.

K1.06 Questions 37, 41

Explain why core age affects the moderator temperature coefficient.

REACTIVITY COEFFICIENTS
Learning Objectives

K1.06 Questions 38, 39, 42-44

Describe the effects of moderator temperature and boron concentration on the moderator temperature coefficient.

K1.06 Question 40

Describe the effects of core age and reactor coolant temperature on the moderator temperature coefficient.

K1.07 Question 45

Describe how "Doppler broadening" of resonance absorption peaks contributes to making the fuel temperature (Doppler) coefficient of reactivity negative.

K1.07 Question 46

Describe how "self-shielding" of the fuel contributes to making the fuel temperature (Doppler) coefficient of reactivity negative.

K1.07 Questions 47-49

Explain the effect of fuel temperature changes on the fuel temperature (Doppler) coefficient.

K1.07 Question 50, 81

Describe the effect of fuel temperature changes on the fuel temperature (Doppler) coefficient.

K1.07 Question 51

Explain why the fuel temperature (Doppler) coefficient is negative.

K1.08 Questions 52, 53

List and explain the parameters that affect the power coefficient and defect.

K1.08 Questions 54-57

Describe the relative contribution of various parameters to the power coefficient.

K1.09 Questions 58-60

Explain how boron concentration affects differential boron worth.

K1.10 Questions 61, 62, 83

Explain how moderator temperature affects differential boron worth.

K1.11 Questions 63-66, 80

Compare actions needed to change boron concentration at beginning and end of life.

K1.12 Questions 67-69, 73

Explain the relationship between reactivity coefficients and reactivity defects (deficits).

K1.12 Questions 70, 71, 82

Perform reactivity balance calculations involving boron concentration.

K1.12 Question 72

Perform calculations relating reactivity coefficients to reactivity defects.

K1.13 Questions 74-79

Explain the effect of power defect (deficit) on reactivity.

CONTROL RODS
Questions

1. The reactor is exactly critical below the point of adding heat. Control rods are withdrawn to establish a 0.5 DPM startup rate. Reactor power will increase

    A. and stabilize at a value above the point of adding heat

    B. temporarily, then stabilize at the original value

    C. and stabilize at a value below the point of adding heat

    D. continuously until control rods are reinserted

2. The reactor is exactly critical below the point of adding heat. Control rods are inserted for five seconds. Reactor power will:

    A. decrease to a shutdown power level low in the source range

    B. decrease temporarily, then return to the original value due to the resultant decrease in moderator temperature

    C. decrease until inherent positive reactivity feedback causes the reactor to become critical at a lower neutron level

    D. decrease temporarily, then return to the original value due to subcritical multiplication

3. The reactor is critical at 50 percent power. Control rods are withdrawn a short distance. Assuming that turbine load remains constant, actual reactor power will

    A. increase to a new higher level

    B. increase temporarily, then return to the original value due primarily to the moderator temperature coefficient

    C. increase continuously until the operator reinserts the rods

    D. increase temporarily, then return to the original value due primarily to the increase in rod worth

4. The reactor is critical at 50 percent power. Control rods are inserted a short distance. Assuming that turbine load remains constant, actual reactor power will

    A. decrease temporarily, then return to the original value due primarily to the reduction in rod worth

    B. decrease continuously until the operator withdraws the rods

    C. decrease to new lower value

    D. decrease temporarily, then return to the original value due primarily to the moderator temperature coefficient

5. The reactor is exactly critical below the point of adding heat (POAH) during a normal reactor startup. If a control rod is manually withdrawn for five seconds, reactor power will:

    A. increase to a stable critical power level below the POAH

    B. increase temporarily, then decrease and stabilize at the original value

    C. increase to a stable critical power level at the POAH

    D. increase temporarily, then decrease and stabilize below the original value

CONTROL RODS
Questions

6. The reactor is subcritical with all rods inserted. One rod is suddenly ejected from the core. Neutron population will

   A. increase to a new higher level due to subcritical multiplication

   B. increase temporarily, then return to the original value due to the moderator temperature coefficient

   C. remain constant

   D. increase to a new higher level due to decreased rod worth

7. When control rods are rapidly and fully inserted to shut down the reactor in response to some abnormal condition, it is referred to as a reactor

   A. runback
   B. fast insertion
   C. scram/trip
   D. cutback

8. Choose the statement below that best defines a reactor scram/ trip.

   A. a rapid full insertion of all controls rods in response to an abnormal condition

   B. a rapid full insertion of specific control rods in response to an abnormal condition

   C. a rapid partial insertion of all control rods until an abnormal signal clears

   D. a rapid partial insertion of specific control rods until an abnormal signal clears

9. A rapid full insertion of control rods is called a reactor

   A. runback/cutback
   B. scram/trip
   C. fast insertion/emergency insertion
   D. shutdown/rampdown

10. Complete the following statement to define a reactor scram/ trip:

    A rapid full _____ of ______ full length control rods.

    A. withdrawal, some
    B. insertion, some
    C. withdrawal, all
    D. insertion, all

11. When a reactor scrams/trips, the control rods are _______to add _________ reactivity.

    A. inserted,negative
    B. inserted, positive
    C. withdrawn, negative
    D. withdrawn, positive

12. Differential control rod worth is defined as the change in ___________ per unit change in rod position.

    A. reactivity
    B. reactor power
    C. neutron flux
    D. fast fissions

13. Differential control rod worth is the change in _______ per _______ change in rod position.

    A. reactor power, total
    B. reactivity, unit
    C. reactor power, unit
    D. reactivity, total

14. A control rod is positioned in the reactor with the following neutron flux parameters:

    Core average thermal neutron flux = 10^{12} neutrons/cm^2-sec

    Control rod tip neutron flux = 5×10^{12} neutrons/cm^2-sec

    If the control rod is slightly withdrawn such that the tip of the control rod is located in a neutron flux of 10^{13} neutrons/cm^2-sec, then the differential control rod worth will increase by a factor of ______. (Assume the average flux is constant.)

    A. 0.5
    B. 1.4
    C. 2.0
    D. 4.0

15. Integral rod worth is the

    A. change in reactivity per unit change in rod position

    B. reactivity inserted by moving a control rod from a Reference point to another point

    C. change in worth of a rod per unit change in reactor power

    D. reactivity inserted by a rod on a power change

16. The change in reactivity per unit change in rod position is called

    A. total rod worth
    B. integral rod worth
    C. differential rod worth
    D. partial rod worth

17. The total amount of reactivity added by a control rod position change from a Reference point to any other rod height is called

    A. differential rod worth
    B. shutdown reactivity
    C. integral rod worth
    D. Reference reactivity

18. Integral control rod worth is the change in ______ per ______ change in rod position.

    A. reactor power; total
    B. reactivity; unit
    C. reactor power; unit
    D. reactivity; total

19. At beginning of life, the differential control rod worth is small at the top and bottom of the core compared to the center due to

    A. boron concentration
    B. neutron flux distribution
    C. xenon concentration
    D. reactor coolant temperature

20. At beginning of life, the differential control rod worth is larger near the center of the core compared to the top and bottom due to

    A. boron concentration
    B. xenon concentration
    C. neutron flux distribution
    D. reactor coolant temperature

21. Draw and label a curve of differential rod worth versus rod position for a single group of control rods. Assume no bank/group overlap.

22. In a simple reactor, a curve of differential rod worth vs. rod position is peaked near the center of the core and is lower near the top and bottom. Why?

23. Which one of the following parameters typically has the greatest effect on the shape of a differential rod worth curve?

    A. core radial flux distribution
    B. core axial flux distribution
    C. core xenon distribution
    D. burnable poi. on distribution

24. The integral control r worth curve for regulating/control rod banks/groups withdrawn sequentially is approximately linear because of

    A. rod speed
    B. boron concentration
    C. reactor coolant temperature
    D. rod overlap

25. Without rod overlap, the slope of the integral control rod worth curve for a group of rods would be steeper in the middle than at the ends due to

    A. neutron flux distribution
    B. boron concentration
    C. core age
    D. reactor coolant temperature

26. The area under the _______ control rod worth curve is represented by the ________ control rod worth curve.

    A. partial, total
    B. integral, differential
    C. total, partial
    D. differential, integral

27. Which one of the following expresses the relationship between differential rod worth (DRW) and integral rod worth (IRW)?

    A. DRW is the area under the IRW curve between two rod positions.

    B. DRW is the slope of the IRW curve at a given rod position.

    C. DRW is the IRW at a given rod position.

    D. DRW is the square root of the IRW at a given rod position.

28. On a curve of integral rod worth vs. inches of withdrawal of a single rod group, the slope of the integral rod worth curve

    A. is greatest at the rod position of the peak on the differential rod worth curve

    B. decreases continuously with increasing rod height

    C. increases continuously with increasing rod height

    D. is greatest at the top of the core

29. Describe the relationship between differential and integral control rod worth.

30. As a control rod is withdrawn from fully inserted to the center of the core, its differential worth will

    A. decrease because moderator density decreases, causing more neutron leakage as the control rod approaches core center

    B. decrease because fuel enrichment decreases at center due to high burnup

    C. increase because poison concentration decreases as the control rod approaches core center

    D. increase because relative neutron flux increases as the control rod approaches core center

31. For a one-inch insertion, a control rod inserts the most reactivity if it is inserted in which one of the following locations?

    A. near the center of the core

    B. near the top of the core

    C. in a region with high poison concentration

    D. in a region with low fuel concentration

32. As moderator temperature increases, the magnitude of differential rod worth increases because

    A. decreased moderator density causes more neutron leakage out of the core

    B. moderator temperature coefficient decreases, causing decreased competition

    C. fuel temperature increases, decreasing neutron absorption in fuel

    D. decreased moderator density increases neutron migration length

33. As moderator temperature decreases, the magnitude of differential rod worth will

    A. decrease due to shorter neutron migration length

    B. increase due to better moderation of neutrons

    C. decrease due to decreased neutron absorption in moderator

    D. increase due to lower fuel temperature, causing less neutron absorption in fuel

34. How and why does control rod worth change as moderator temperature is increased?

35. As reactor coolant system boron concentration changes, differential rod worth will also change. This is due to an effect known as

    A. rod shadowing
    B. overmoderation
    C. poison competition
    D. rod bite

36. How and why does control rod worth change as the concentration of boron in the coolant is increased?

37. Differential rod worth will be the greatest if RCS temperature is ______ and RCS boron concentration is ______.

    A. increased; decreased
    B. decreased, decreased
    C. increased; increased
    D. decreased; increased

38. As xenon concentration changes, differential rod worth will also change. This is due to an effect known as

    A. shadowing
    B. competition
    C. leakage
    D. buckling

39. One reason for designing and operating a reactor with flat neutron flux profiles is to

    A. provide even burnup of control rods

    B. allow a higher average power density

    C. make xenon oscillations easier to control

    D. improve efficiency by reducing neutron leakage

40. Which of the following is not a reason for or benefit of operating with a flat neutron flux profile?

    A. A higher average power density is possible.

    B. More even burnup of fuel results.

    C. Moderator temperature is equalized throughout the core.

    D. Control rod worth is made more uniform.

41. The plant is operating at 80 percent power with manual rod control. It has been determined that power distribution is excessive in the lower half of the core. Which one of the following will shift power distribution toward the upper half of the core? (Assume no additional operator actions.)

    A. reducing power to 40 percent
    B. withdrawing control rods
    C. borating the reactor coolant system
    D. diluting the reactor coolant system

42. Control rod bank overlap

    A. provides more uniform differential rod worth and axial flux distribution

    B. provides a more uniform differential rod worth and allow dampening of xenon-induced flux oscillations

    C. ensures that all rods remain within the allowable tolerance between their individual position indicators and their group counters and to ensure rod insertion limits are not exceeded

    D. ensures that all rods remain within their allowable tolerance between individual position indicators and their group counters and to provide a more uniform axial flux distribution

43. One purpose of using control rod bank/group overlap is to

    A. provide adequate shutdown margin

    B. provide a more uniform differential rod worth

    C. allow dampening of xenon-induced flux oscillation

    D. ensure rod insertion limits are not exceeded

44. Control rod bank/group overlap is used to

    A. ensure the rod insertion limits are not exceeded and to maintain individual and group rod position indicators within allowable tolerances

    B. provide a more uniform axial flux distribution and to maintain individual and group rod position indicators within allowable tolerances

    C. provide a more uniform axial flux distribution and to provide a more uniform differential rod worth

    D. allow dampening of xenon-induced flux oscillations and to ensure rod insertion limits are not exceeded

45. The purposes of using control rod bank overlap are to

    A. ensure the rod insertion limits are not exceeded and to maintain individual and group rod position within allowable tolerances

    B. provide a more uniform differential rod worth and to ensure the rod insertion limits are not exceeded

    C. provide a more uniform axial flux distribution and to provide a more uniform differential rod worth

    D. maintain individual and group rod position indicators within allowable tolerances and to provide a more uniform axial flux distribution

46. Why are control rod groups designed to overlap during withdrawal and insertion?

47. The purpose of sequencing control rod banks/groups with proper bank/group overlap is to

    A. ensure rod insertion limits are not exceeded

    B. limit the rate of reactivity addition

    C. ensure even fuel depletion

    D. provide assurance that core power distribution is within limits

48. Define "axial flux imbalance" (axial flux difference; axial power imbalance) and explain why it is maintained within prescribed limits.

49. Explain how and why the axial flux imbalance (axial flux difference; axial power imbalance) changes over core life.

50. How does axial flux imbalance (axial flux difference; axial power imbalance) change when power is increased? Why?

51. Which one of the following describes why most of the power is produced in the lower half of a core that has been operating at 100 percent power for several weeks at the beginning of core life?

    A. Xenon concentration is lower in the lower half of the core.

    B. The moderator to fuel ratio is lower in the lower half of the core.

    C. The fuel loading in the lower half of the core contains a higher U-235 enrichment.

    D. The moderator temperature coefficient of reactivity is adding less negative reactivity in the lower half of the core.

52. The most likely cause of an excessive quadrant power tilt ratio is

    A. axial xenon oscillations
    B. a misaligned control rod
    C. uneven coolant flow in the core
    D. excessive insertion of a control rod group

53. Define and explain "quadrant power tilt."

54. A comparison of the heat flux in the hottest channel to the average heat flux in the core describes

    A. a core correction calibration factor
    B. a hot channel or peaking factor
    C. a heat flux normalizing factor
    D. an axial/radial flux deviation factor

55. The basis for the maximum power density (kw/ft) power limit is to

    A. provide assurance of fuel integrity
    B. prevent xenon oscillations
    C. allow for fuel pellet manufacturing tolerances
    D. prevent nucleate boiling

56. The hot channel or peaking factor limit that concerns the maximum power density (kw/ft) is designed to

    A. prevent fuel pellet swelling
    B. prevent fuel pellet melt
    C. limit bulk coolant temperature
    D. prevent nucleate boiling

57. Those factors that are controlled to prevent exceeding departure from nucleate boiling ratio limits and linear heat generation (kw/ft) limits are called __________ factors.

    A. thermal utilization
    B. hot channel
    C. importance
    D. infinite multiplication

58. By maintaining the radial and axial core power distribution within prescribed limits, the operator is assured that _______ will remain within acceptable limits.

    A. power density (kw/ft) and departure from nucleate boiling ratio (DNBR)

    B. departure from nucleate boiling ratio (DNBR) and shutdown margin

    C. core ΔT and power density (kw/ft)

    D. shutdown margin and core ΔT

59. If a control rod is fully inserted (from the fully withdrawn position), the effect on the axial flux shape is minimal. This is because

    A. the fully inserted control rod appears to be invisible

    B. the fully inserted control rod is an axially uniform poison

    C. the upper and lower core halves are closely coupled

    D. axial shape is compensated by boron dilution

60. One of the reasons for control rod insertion limits during power operation is that significant insertions

    A. adversely affect core power distribution

    B. generate excessive liquid waste due to dilution

    C. cause reduced control rod lifetime

    D. cause unacceptable fast and thermal neutron leakage

61. The reactor has been taken critical following a refueling outage and is currently below the point of adding heat during a reactor physics startup with all control rods fully withdrawn. Which one of the following describes the axial power distribution in the core?

    A. symmetrically distributed with a peak at the core midplane

    B. symmetrically distributed with peaks above and below the core midplane

    C. asymmetrically distributed with a peak below the core midplane

    D. asymmetrically distributed with a peak above the core midplane

62. If a control rod is fully inserted (from the fully withdrawn position), the normalized axial neutron flux shape in the core will undergo a:

    A. minor distortion, because the fully inserted control rod appears to be invisible

    B. minor distortion, because the fully inserted control rod is an axially uniform poison

    C. major distortion, because the upper and lower core halves are loosely coupled

    D. major distortion, because power production along the length of the rod drastically decreases

63. Choose the statement below that best describes the effect of control rod position on the axial flux distribution.

    A. Differential rod worth is dependent on axial flux distribution, which is normally higher in the lower half of a large pressurized water reactor.

    B. Control rod insertions result in xenon redistribution throughout the active core, producing transient perturbations in axial flux peaks.

    C. Control rod positioning has minimal effect on the axial flux distribution during load maneuvering.

    D. Neutron flux is depressed in the region where the rods are inserted and relatively higher in the region without control rods.

64. The plant is operating at equilibrium 100 percent power level at beginning of life with all control rods fully withdrawn. If the control rods are partially inserted, the axial neutron flux will shift toward ____________ of the reactor.

    A. the top
    B. the middle
    C. the bottom
    D. both the top and the bottom

65. Which of the following is not a consideration in establishing control rod insertion limits?

    A. ensure sufficient control rod movement is available for reactivity control

    B. ensure minimum shutdown margin available

    C. minimize the worth of an ejected control rod

    D. maintain allowable power distribution

66. If the control rod insertion limits are violated during critical operation, one may conclude that

    A. the control rods may have been overstressed

    B. xenon oscillations will begin in four to six hours

    C. shutdown margin may be inadequate

    D. there is excess boron in the reactor coolant

67. If the control rod insertion limits are violated during critical operation, one may conclude that

    A. xenon oscillations will begin in four to six hours

    B. there is excess boron in the reactor coolant

    C. the control rods may have been overstressed

    D. fuel design limits may have been exceeded

68. List and explain three reasons for control rod insertion limits.

69. Control rod insertions are more limited at full power than at low power because at full power

    A. there is nucleate boiling in the upper core region

    B. there is a higher post-accident decay heat load

    C. there is less boron in the reactor coolant

    D. the power defect is the greatest

70. The control rod insertion limits are power-level dependent because the magnitude of

A. control rod worth decreases as power increases

B. power defect increases as power increases

C. Doppler (fuel temperature) coefficient decreases as power increases

D. moderator temperature coefficient increases as power increases

71. Which of the following is considered when establishing control rod insertion limits?

1. Ensuring sufficient control rod movement is available for reactivity control.

2. Ensuring adequate shutdown margin is available after a trip.

3. Minimizing the worth of an ejected control rod.

4. Maintaining allowable power distribution.

A. 1, 2, 3
B. 1, 2, 4
C. 1, 3, 4
D. 2, 3, 4

72. Maintenance of control rods high in the core helps ensure that the resulting axial flux distribution prevents

A. loss of shutdown margin
B. high local power level peaks
C. excessive power defect
D. flux hardening at the core periphery

73. When a control rod becomes misaligned from the rest of its group by a significant amount, which of the following factors may be adversely affected?

A. shutdown margin/power distribution

B. shutdown margin/core ΔT

C. power defect/departure from nucleate boiling ratio

D. departure from nucleate boiling ratio/overall power coefficient

74. Choose the statement below that best describes the effect of a dropped control rod on core power peaking.

A. A control rod drop causes increased xenon burnout, which increases with time due to radial peaks.

B. A control rod drop causes increased axial peaks, which increase with time due to xenon burnout.

C. A control rod drop causes a flux depression, which might lead to adverse radial flux conditions.

D. A control rod drop causes increased xenon burnout, which increases with time due to axial peaks.

75. Of the following, which is <u>not</u> a consequence of long-term power operation with control rods inserted?

A. departure from nucleate boiling ratio (DNBR) decreases

B. critical heat flux (CHF) decreases

C. peak linear heat rate (LHR) decreases

D. axial flux distribution shifts toward the bottom of the core

76. Select the statement that compares the power distribution effects of a dropped control rod to the effects of a partially inserted control rod.

    A. A dropped rod causes a greater change in axial distribution.

    B. A dropped rod causes a radial distribution effect throughout the entire core.

    C. A dropped rod causes partial film boiling if initiated at 100 percent power.

    D. Both cases result in departure from nucleate boiling ratio (DNBR) limit violations if initiated at 100 percent power.

77. The reactor has been operating at 80 percent power for four weeks with the controlling rod group inserted 10 percent from the fully withdrawn position. Which one of the following will be significantly affected by inserting the controlling group an additional five percent? (Assume reactor power does not change.)

    A. total xenon reactivity in the core

    B. quadrant (azimuthal) power distribution in the core

    C. axial power distribution in the core

    D. radial power distribution in the core

78. The reactor is operating at 80 percent power during a load decrease to 60 percent when a control rod becomes stuck during insertion of the rest of its group. If group control rod insertion continues, which of the following will be adversely affected? (Assume the stuck control rod is trippable.)

    A. power distribution and shutdown margin
    B. shutdown margin and power defect
    C. power defect and critical heat flux
    D. critical heat flux and power distribution

79. The reactor is operating at end of core life with a steady state 50% power level when the operator withdraws a group of control rods for 5 seconds. Assume turbine load remains constant and the reactor does not scram/trip.

    Actual reactor power will stabilize ___________ initial power and coolant temperature will stabilize ___________ initial temperature.

    A. at; at
    B. at; above
    C. above; at
    D. above; above

80. If core quadrant power distribution (azimuthal tilt) is maintained within design limits, which one of the following core conditions is indicated?

    A. Axial power distribution is within design limits.

    B. Radial power distribution is within design limits.

    C. Nuclear instrumentation is indicating within design accuracy.

    D. Departure from nucleate boiling ratio is within design limits.

CONTROL RODS
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/ answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

Withdrawing control rods adds positive reactivity. This positive reactivity establishes a positive startup rate and causes reactor power to increase. It will stabilize at or just above POAH.

Reference 61, page 9-17.

2. A

Inserting control rods adds negative reactivity. This negative reactivity will cause reactor power to decrease. It will stabilize at a lower power level (generally in the source range) with the reactor subcritical in these conditions.

Reference 61, page 9-17.

3. B

At power above the point of adding heat, the reactivity feedback of Doppler and moderator temperature are in evidence. Withdrawing control rods will add positive reactivity. This will cause reactor power to initially increase. This in turn will cause fuel and moderator temperature to increase, adding negative reactivity to offset the positive reactivity added by the rods. With turbine load constant, reactor power will return to its original value. Moderator temperature will be elevated above its original value.

Reference 61, page 9-17.

4. D

Above the point of adding heat, reactivity feedback due to Doppler and moderator temperature is in evidence. Inserting rods will add negative reactivity. This will cause an initial drop in reactor power. This in turn will cause a drop in fuel temperature and moderator temperature. These temperature drops will add positive reactivity to counteract the effect of the rod insertion. As long as turbine load remains constant, reactor power will return to its original value. Moderator temperature will remain depressed from its original value.

Reference 61, page 9-17.

5. C

Withdrawal of a control rod adds positive reactivity causing the reactor neutron level and power to increase. The reactor temperature will begin to rise as the power reaches the point of adding heat. Negative reactivity will now be added due to the Doppler and moderator temperature coefficients. The power rise will begin to decrease. With the secondary system in the constant steam pressure mode for steam dump, the power will ultimately level off at or above POAH.

Reference 61, page 9-17.

6. A

Withdrawing a rod from the core will add positive reactivity. This will cause neutron population to increase.

Reference 61, page 6-11.

7. C

A rapid shutdown of a reactor in the event of an emergency is referred to as a scram or trip.

Reference 18, chapter 5, page 302.

8. A

Reference 18, chapter 5, page 302.

9. B

Reference 18, chapter 5, page 302.

10. D

Reference 18, chapter 5, page 302.

11. A

Reference 18, chapter 5, page 302.

12. A

Differential rod worth is defined as the change in reactivity resulting from a unit change in rod position. Answer B is not correct as before power can change a reactivity change must be made. Neutron flux is a synonym for reactor power and is incorrect for the same reason as B. Answer D is incorrect as fast fissions will not change unless a reactivity change is made first.

Reference 61, page 6-14.

13. B

Differential control rod worth is defined as the change in reactivity per unit change in rod position; thus answer B is correct. Answer A is incorrect as reactor power cannot change without a reactivity change first, and the answer also includes a Reference to total change in rod position. Answer C is incorrect as it includes reactor power. Answer D is incorrect as it includes a total change in rod position.

Reference 61, page 6-14.

14. D

The reactivity worth of the tip of the control rod can be assumed to be proportional to the square of the neutron flux that it is in. The increase in neutron flux from 5×10^{12} to 1×10^{13}, a factor of two, produces a reactivity difference of a factor of four.

Reference 18, page 306.

15. B

Integral rod worth is defined as the reactivity inserted by moving a control rod from a Reference point to any other height. Thus, Answer B is the correct answer. Answer A is incorrect as it is the definition of differential rod worth. Answer C is incorrect because it is a ratio of change, not an integral, and it is with respect to power, not rod motion. Choice D is incorrect as it is with respect to power, not rod motion

Reference 61, page 6-16.

16. C

Differential control rod worth is defined as the change in reactivity per unit change in rod position.

Reference 61, page 6-14.

17. C

Integral rod worth is defined as the reactivity inserted by moving a control rod from a Reference point to any other height. Answer A is incorrect as differential rod worth is a rate of change of reactivity, not a total reactivity insertion. Answer B is incorrect as shutdown reactivity and rod worth are unrelated concepts; excess reactivity refers to the amount of reactivity in the core in excess of that needed just to achieve criticality. Answer D is incorrect as Reference reactivity is a term used in the calculation of shutdown margins.

Reference 61, page 6-16.

18. D

Reference 61, page 6-16.

19. B

End of control rod is moving through regions of low flux, so few additional neutrons are absorbed as a result of its motion.

Reference 33, chapter 7, page 270; and Reference 61, page 6-16.

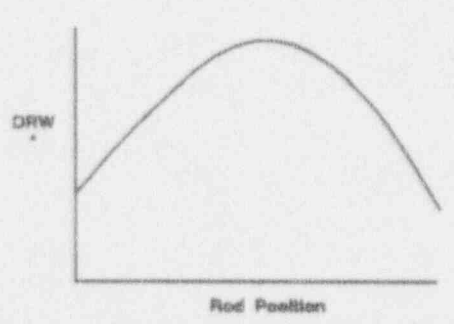
20. C

Tip of rod moving through region of high flux, thus it has a large effect on the neutron flux.

Reference 33, chapter 7, page 270; and Reference 61, page 6-16.

21.

FIGURE 2.5-1



Differential Rod Worth Versus Rod Position

*Units of DRW may be pcm/step, Δk/k/inch, or any measure of reactivity per distance.

Reference 61, page 6-18.

22.

The effect of control rod motion on reactivity depends on the relative thermal neutron flux near the tip of the control rod. The greater the flux near the rod tip, the greater the impact as the rod moves into or out of that flux.

In general, thermal neutron flux tends to be greater near the center of the core and less near the top and bottom (where neutron leakage reduces the flux). Therefore, rod worth tends to be greater near the center and lower at the extremes of rod travel.

Reference 61, page 6-16.

23. B

By definition, the rod worth curve is determined by its direction of motion which is axial in the reactor. The axial motion flux distribution primarily determines the rate at which neutrons are being absorbed in the control rod and the importance of those neutrons to the chain reaction. Xenon and burnable poison distributions are secondary.

24. D

As one bank (or group) of rods is passing <u>out</u> of the high flux region, another bank (group) is moving <u>into</u> the high flux region. This tends to linearize the reactivity addition.

Reference 33, chapter 7, page 271.

25. A

The control rods are moving through areas of high relative flux, near the centerline (mid core), and through areas of low relative flux, at the ends (top and bottom); therefore, more neutrons are absorbed near the centerline than at the ends as a result of rod motion. Therefore, the rod worth is higher in the middle (steeper integral slope).

Reference 33, chapter 7, page 270.

26. D

Reference 33, chapter 7, page 270.

27. B

Differential rod worth is an incremental parameter defined as the reactivity inserted per unit length of rod travel. It can be viewed as the slope of an integral rod worth curve at a given position.

Reference 61, page 6-18.

28. A

Reference 61, page 6-20.

29.

Differential rod worth (DRW) is the reactivity inserted per unit of rod withdrawal. Integral rod worth (IRW) is the total reactivity inserted by withdrawing a rod from a reference height (usually the fully inserted position) to a given height.

Graphically, DRW is the slope of the IRW curve at any point on a graph of rod reactivity vs. position. Conversely, IRW is the area under the DRW curve on a graph of DRW vs. position.

Reference 61, pages 6-14 through 6-22.

30. D

Differential control rod worth is proportional to relative neutron flux squared. This is the ratio of neutron flux at rod tip to core average neutron flux. For a given power level, core average neutron flux is essentially constant, but the flux near the rod tip will increase as the rod is withdrawn from the bottom of the core to the center of the core. Thus Answer D is the correct answer. Answer A is false as a decrease in moderator density increases rod worth, not decreases it. Answer B is false as fuel enrichment has no effect on rod worth. Answer C is false as poison concentration increases as you approach the center of the core.

Reference 61, page 6-16.

31. A

Reference 61, page 6-16.

32. D

As moderator temperature increases, neutrons must travel farther between interactions with water molecules due to the decrease in density of the moderator. This increase in migration length makes it more likely that a neutron will encounter a control rod, thus increasing differential rod worth. Thus, D is the correct answer. Answer A is incorrect as in large PWRs neutron leakage is considered negligible and rod worth and leakage are unrelated. Answer B is incorrect for two reasons. One, moderator temperature coefficient increases (magnitude) as temperature increases, and two, the change in moderator temperature coefficient has no direct effect on competition. Answer C also is false for two reasons. One, as fuel temperature increases, neutron absorption in the fuel increases, not decreases. Two, neutron absorption in the fuel has little or no effect on control rod worth.

Reference 61, pages 6-22 and 6-23.

CONTROL RODS
Answers

33. A

As moderator temperature decreases, moderator density increases. This means that neutrons do not travel as far between moderating collisions. Thus, they will slow to thermal energies faster and diffuse about as thermal neutrons in shorter distances (migration length). They are less likely to encounter a control rod in this process. Thus, A is the correct answer. Answer B is incorrect as better moderation of neutrons would cause rod worth to decrease as described above. Answer C is incorrect as an increase in moderator density will cause increased absorption in the moderator. Answer D is false because fuel temperature effects have little or no effect on rod worth.

Reference 61, pages 6-22 and 6-23.

34.

As moderator temperature increases, density decreases, causing neutrons to travel further while slowing down and diffusing. As a result, neutrons are more likely to enter a control rod and be absorbed. Therefore, control rod worth increases as moderator temperature rises.

Reference 61, pages 6-22 through 6-24.

35. C

Answer A is incorrect as rod shadowing is a term used to define the effect of adjacent control rods on each other's worth. Answer B is incorrect as it is a term used to define a condition in which moderator temperature coefficient is positive. Answer D is incorrect because it is a term used to describe the reactivity worth of a rod at a given point in the core.

Reference 18, chapter 5, page 286.

36.

An increase in boron concentration reduces control rod worth. Boron is a strong thermal neutron absorber, and as its concentration is increased, the thermal diffusion length of neutrons is decreased. Thus, fewer neutrons will reach the control rod, reducing its worth.

Reference 61, page 6-25.

37. A

An increase in moderator temperature will decrease its density and permit thermal neutrons to migrate more easily to the control rod postions. A decrease of boron in the moderator will have the same effect since a thermal neutron absorber is removed.

Reference 61, page 6-25.

38. B

Answer A is incorrect as shadowing refers to the effect of rods on each other's worth. Answer C is incorrect as a change in xenon concentration has little or no effect on leakage, and leakage has little or no effect on rod worth. Answer D is incorrect as buckling refers to the shape of the flux profile and has little or no effect on rod worth.

Reference 18, chapter 5, page 286.

39. B

With a lower peak-to-average power density, the average power density can be raised without causing the peak power density to exceed a thermal limit.

Reference 61, page 341.

CONTROL RODS
Answers

40. C

Even with a perfectly flat flux profile, the temperature of the moderator will increase from inlet to outlet.

41. B

Since the control rods move in an axial direction, removing them will remove neutron-absorbing material in the same direction shifting the power upward. In A, the power reduction may require the control rods to move into the reactor to compensate for the power defect. In C and D, the changes produced are both homogeneous through the reactor; therefore, no power distribution change will occur.

Reference 61, page 8-25.

42. A

Bank/group overlap is used to provide a more uniform differential control rod worth and a more uniform axial neutron flux distribution during control rod maneuvers.

Reference 61, page 6-28.

43. B

Bank/group overlap is used to provide a more uniform differential control rod worth and a more uniform axial neutron flux distribution during control rod maneuvers.

Reference 61, page 6-28.

44. C

Bank/group overlap is used to provide a more uniform differential control rod worth and a more uniform axial neutron flux distribution during control rod maneuvers.

Reference 61, page 6-28.

45. C

Bank/group overlap is used to provide a more uniform differential control rod worth and a more uniform axial neutron flux distribution during control rod maneuvers.

Reference 61, page 6-28.

46.

Control rod groups are designed to overlap to produce a more constant differential rod worth. In general, rod worth tends to be greatest near the center of the core and lowest near the top and bottom. With rod overlap, as one group of rods nears the top during withdrawal, another group begins to move out. The combined differential rod worth approximates that of a single group near the core center.

Reference 61, page 6-28 and 6-29.

47. D

It is the ultimate responsibility of the reactor operator to ensure that the core power distribution is maintained within design limits at all times. Operation within these limits is reasonably assured when

- all control rods in a single group are moved together with no individual rod in the group differing more than ± 12 steps (Westinghouse) from the group position
- control and rod groups are sequenced with proper bank/group overlap
- control rod insertion limits are observed
- axial power distribution is maintained within the limits of the axial flux difference requirements

Reference 61, pages 8-32 and 8-33.

48.

The axial flux imbalance is a measure of the difference between the power produced in the upper and lower halves of the core. By maintaining the axial flux imbalance within prescribed limits, the operator maintains the axial power distribution close to the desired shape, providing a greater margin to thermal limits and promoting even fuel burnup.

Reference 61, page 8-25.

49.

At the beginning of life (BOL), the average power density in the bottom half of the core exceeds that in the top. This is because the moderator enters the core from the bottom; as it flows up the core, it heats up, and the moderator density variation causes a lower neutron flux in the top of the core where the moderator is hotter and less dense.

Power density is proportional to the product of neutron flux and fuel concentration. The higher power density in the bottom of the core causes greater fuel burnup in the bottom. Therefore, over core life, the power produced in the bottom half of the core decreases, so that by end of life (EOL), the axial flux imbalance will be reduced.

Reference 61, page 8-25.

50.

When power (delta T) increases, the axial variation in coolant temperature is more pronounced from the bottom of the core to the top. This causes the coolant (moderator) density to decrease by a greater factor in the top half of the core than in the bottom half. The denser coolant (moderator) in the bottom half of the core increases the neutron flux relative to that in the top half. Since, power density is proportional to the product of neutron flux and fuel concentration, the relative power in the bottom half of the core increases and the axial imbalance becomes greater.

Reference 61, page 8-26.

51. D

This is the most correct answer because it deals with the moderator temperature effects. Since the moderator temperature is lower in the bottom half of the core, the density will be higher and more neutrons will be slowed down and made available to produce fission in the fuel. The thermal neutron flux will be higher in the lower part of the core than in the upper part.

Reference 61, page 8-25.

52. B

Reference 61, page 8-29.

53.

Quadrant power tilt is the effect seen when an imbalance exists in the radial distribution of power in the core. The four ex-core power range nuclear instrumentation detectors measuring the neutron flux each "see" one quadrant of the core. When one quadrant's power exceeds the average quadrant power, a quadrant power tilt exists.

Reference 61, page 8-29.

54. B

The radial nuclear factor is defined as the ratio of average heat flux in the hot channel to core average heat flux.

Reference 08, page 6-14; and Reference 63, page 13-28.

55. A

Reference 63, page 13-9.

56. B

In order to prevent fuel damage, the highest fuel temperature must be kept below the fuel pellet melting temperature. The fuel pellet centerline temperature is directly related to the linear power output of the core. Since fuel centerline temperature is impossible to measure, limiting the kw per foot ensures melting will not occur.

Reference 63, page 13-8.

57. B

Hot channel factors are defined and controlled to control peak fuel centerline temperature and the enthalpy rise through a fuel channel by preventing the exceeding of linear heat generation rate and DNBR limits. Thus, Answer B is the correct answer. Answer A is incorrect as the thermal utilization factor is one of the six factors in the K_{eff} formula and has no effect on DNBR or kw/ft. Answer C is incorrect as the term "importance factor" is used to describe how "important" a neutron is to sustaining the fission chain reaction in the reactor. Answer D is incorrect as the infinite multiplication factor describes the change in neutron population per generation with no leakage (i.e., in an infinite core).

Reference 63, page 13-28.

58. A

Reference 63, pages 13-8, 13-28.

59. B

Rods are not zone loaded. Additionally, poison materials (Ag-In-Cd) are distributed uniformally along the length of the control rods.

Reference 38, pages 7.3-1 through 7.3-3; and Reference 61, pages 1-29, 1-30, and 6-16.

60. A

Rods are strong local absorbers that significantly suppress local flux.

Reference 50, bases section, page B 3/4 1-5; and Reference 61, page 6-30.

61. A

All pertinent parameters, temperature, fuel density, etc., are constant in this axial direction producing a symmetrical axial power (flux) distribution.

62. B

63. D

Answer A describes the effect of axial flux distribution on differential rod worth, not the effect of rod position on axial flux distribution. Answer B describes subsequent, secondary effects of changing control rod position, not direct, primary effects. Answer C is a false statement. Answer D is correct.

Reference 61, page 6-16.

64. C

Reference 61, page 6-17.

65. A

Bases are:

1. guarantee shutdown margin

2. minimize effect of ejected rod

3. ensure appropriate fuel depletion/help prevent high local power peaks--The magnitude of the total power defect increases with power, requiring a higher rod insertion limit.

Reference 61, pages 3-41, 3-43, 6-30, 6-31, 7-13, and 7-14; and Reference 50, bases section, page B 3/4 1-5.

66. C

Bases are:

1. guarantee shutdown margin

2. minimize effect of ejected rod

3. maintain acceptable flux distribution

Reference 61, page 6-30, 6-31, 7-13, and 7-14; and Reference 50, bases section, page B 3/4 1-5.

67. D

Bases are:

1. guarantee shutdown margin

2. minimize effect of ejected rod

3. ensure appropriate fuel depletion/help prevent high local power peaks--Exceeding the rod insertion limits causes more power to be produced in a (lower) smaller region of the core. This higher power density may result in exceeding fuel design limits (kw/ft).

Reference 61, pages 6-30 and 6-31; and Reference 50, bases section, page B 3/4 1-5.

68.

During power operation, control rods must be maintained above the rod insertion limits for three reasons:

1. Minimize the effect of a rod ejection accident. If all rods are maintained relatively high in the core, the amount of positive reactivity inserted by an ejected rod will be minimized.

2. Provide adequate shutdown margin. With rods relatively high in the core, they are able to insert more negative reactivity upon a scram or shutdown than if they were low in the core.

3. Provide more uniform axial flux distribution. Control rods are strong neutron absorbers. If inserted too far into the core, power production would be suppressed in the top of the core. To produce the same total power, the power densities lower in the core would therefore have to increase, perhaps too much for safety.

Reference 61, page 6-30.

69. D

Bases are:

1. guarantee shutdown margin

2. minimize effect of ejected rod

3. ensure appropriate fuel depletion/help prevent high local power peaks--The magnitude of the total power defect increases with power, requiring a higher rod insertion limit.

Reference 61, pages 3-41, 3-43, 6-30, and 6-31; and Reference 50, bases section, page B 3/4 1-5.

CONTROL RODS
Answers

70. B

An adequate amount of negative reactivity must be kept available in the control rods at all power levels to produce the proper shutdown margin. Since the power defect increases with power, the control rod's insertion limit must be established at higher and higher core heights.

Reference 61, page 6-30.

71. D

During power operation, control rods must be maintained above the rod insertion limits for three reasons:

1. Minimize the effect of a rod ejection accident. If all rods are maintained relatively high in the core, the amount of positive reactivity inserted by an ejected rod will be minimized.
2. Provide adequate shutdown margin. With rods relatively high in the core, they are able to insert more negative reactivity upon a scram or shutdown than if they were low in the core.
3. Provide more uniform axial flux distribution. Control rods are strong neutron absorbers. If inserted too far into the core, power production would be suppressed in the top of the core. To produce the same total power, the power densities lower in the core would therefore have to increase, perhaps too much for safety.

Reference 61, page 6-30.

72. B

If the rods are inserted too far into the core, the higher power in the bottom of the core could cause abnormally high fuel temperature and fuel melting.

Reference 61, page 6-30.

73. A

Per the technical specifications bases for movable control assemblies, the alignment of assemblies is important to maintain an acceptable shutdown margin and power distribution. Thus, Answer A is the correct answer. Answer B is incorrect because as long as power remains constant, core ΔT is constant. Answer C is incorrect because power defect is only power, not rod position dependent. Answer D is incorrect because overall power coefficient is dependent on power and temperature, not rod position.

Reference 50, bases section, page B 3/4 1-3.

74. C

Control rod drops have little effect on axial peaking due to uniform reactivity addition axially. The suppression of flux in the area around the dropped rod might cause increased flux peaking in nearby fuel assemblies.

Reference 61, pages 4-28, 4-29, and 6-27; and Reference 8, page 7-21.

75. C

Decreasing the power in one region of the core causes other parts of the core to produce more power. This causes the linear heat generation rate (LHGR) in those regions to increase.

Reference 61, pages 6-28 through 6-31; and Reference 63, page 13-29.

76. B

Rod insertion depresses the flux in the vicinity of the rod. Further insertion causes more power production in non-rodded fuel assemblies, causing large flux peaks in these assemblies.

Reference 61, pages 8-18 and 8-19.

77. C

When the strong neutron-absorbing control rods are inserted further into the core, the axial neutron flux distribution will be suppressed to a greater degree in the upper half of the core.

In A, the total xenon reactivity will be unaffected. In B and D, the radial neutron flux distribution may be affected but only in the upper part of the core.

Reference 61, page 6-30.

78. D

Since the stuck rod is trippable, the shutdown margin will not be adversely affected. The stuck rod will distort the volumetric power distribution and could produce higher hot channel factors and more adverse critical heat flux conditions. The power defect will not be affected by the stuck rod since it primarily involves the moderator temperature coefficient and the Doppler coefficient.

Reference 61, page 6-28 through 6-31.

79. B

Reactor power will rise initially with an accompanying temperature rise. Fuel and moderator temperature coefficients will add negative reactivity due to the increased temperature, returning reactor power to its initial value. Temperature will remain at the elevated value.

80. B

CONTROL RODS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.03 Questions 1-5, 79

Given a set of initial conditions and a rod position change, predict the effect of this position change on reactor power.

K1.03 Question 6

Given a set of initial conditions and a rod position change, predict the effect of this position change on neutron population.

K1.04 Questions 7-11

Define a reactor scram/trip.

K1.05 Questions 12-14, 16

Define differential control rod worth.

K1.05 Questions 15, 17, 18

Define integral rod worth.

K1.06 Questions 19-23

Draw and explain the shape of the differential rod worth curve.

K1.06 Questions 24, 25

Explain the shape of the integral rod worth curve.

K1.06 Questions 26-29

Explain the relation between the differential and integral control rod worth curves.

K1.06 Questions 30, 31

Explain the effects of varying rod position on differential control rod worth.

K1.07 Questions 32-34

Given a change in moderator temperature, explain how and why differential rod worth changes.

K1.07 Questions 35-37

Given a change in boron concentration, explain how and why differential rod worth changes.

K1.07 Question 38

Given a change in fission product poison concentration, explain how and why differential rod worth changes.

K1.08 Questions 39-41

State the reason for the flux flattening.

K1.09 Questions 42-46

Identify the two purposes for using control rod bank/group overlap.

K1.09 Question 47

Identify the purpose of sequencing control rod groups with proper bank/group overlap.

K1.10 Question 48

Define and explain axial flux imbalance/axial flux difference/axial power imbalance.

CONTROL RODS
Learning Objectives

K1.10 Questions 49-51

Explain how and why axial flux imbalance changes with power changes and core age.

K1.11 Question 52

Identify the most likely cause of an excessive quadrant power tilt ratio.

K1.11 Question 53, 80

Define and explain quadrant power tilt ratio.

K1.12 Questions 54-58

Describe power peaking or hot channel factors.

K1.13 No questions

Terms, definitions, and techniques for determining quadrant power tilt ratio were determined to be not generic.

K1.14 Questions 59-60

Explain the effects of control rod insertion/withdrawal on the axial flux distribution.

K1.14 Questions 61-64

Explain how control rod position affects the axial flux distribution.

K1.15 Questions 65-68

State and explain the purposes for control rod insertion limits.

K1.15 Questions 69-71

Explain why control rod insertion limits are power-level dependent.

K1.16 Questions 72-78

Describe the effects of control rod position on power peaking or hot channel factors.

FISSION PRODUCT POISONS
Questions

1. Fission fragments and their daughters that have a substantial neutron absorption cross section and are non-fissionable are called

   A. fissile materials
   B. fission product poisons
   C. fertile nuclides
   D. burnable poisons

2. A fission product poison is defined as a fission product

   A. that is loaded into the core during fabrication

   B. that absorbs a neutron and fissions

   C. that has a substantial neutron absorption cross section and does not fission

   D. that emits a neutron sometime after the initial fission event

3. Which of the following best defines the term "fission product poison?"

   A. fission fragment or its daughter that absorbs a neutron and does not fission

   B. fission fragment or its daughter that absorbs a neutron and fissions

   C. fission fragment or its daughter that emits a neutron and does not fission

   D. fission fragment or its daughter that emits a neutron and fissions

4. Fission products that have substantial neutron capture cross sections are called

   A. delayed neutron precursors
   B. fission product daughters
   C. radioactive fission products
   D. fission product poisons

5. Fission products that have large microscopic cross sections for capture of thermal neutrons are

   A. breeder fuels
   B. burnable poisons
   C. fissionable fuels
   D. reactor poisons

6. A fission product poison is a fission product

   A. with a high fission cross section for neutrons

   B. that has a short half-life, i.e., hours or days versus years

   C. that is produced in large quantities

   D. that competes strongly with fissile material for neutrons

7. What two characteristics of xenon 135 result in it being a major reactor poison/neutron absorber?

   A. relatively low fission yield and large absorption cross section

   B. relatively low fission yield and small absorption cross section

   C. relatively high fission yield and large absorption cross section

   D. relatively high fission yield and small absorption cross section

8. Two characteristics of Xe-135 that result in it being a major reactor poison are its relatively ________ fission yield and relatively ________ absorption cross section.

   A. low; large
   B. low; small
   C. high; large
   D. high; small

9. State and explain two characteristics that make xenon 135 a significant fission product poison.

10. The fission product poison xenon 135 is removed from an operating reactor by

    A. natural decay and ion exchange
    B. neutron capture and filtration
    C. natural decay and neutron capture
    D. ion exchange and filtration

11. The fission product poison xenon 135 is produced in the reactor by

    A. radioactive decay and directly from fission

    B. radiative capture and directly from fission

    C. radioactive decay and radiative capture

    D. neutron activation and directly from fission

12. Which of the following is not a characteristic of the fission product poison xenon 135?

    A. The xenon concentration is related to thermal neutron flux.

    B. Xenon 135 has a large cross section for thermal neutron absorption.

    C. Xenon 135 is a non 1/v absorber.

    D. Xenon 135 is produced from the radioactive decay of barium 135.

13. Two characteristics of Xe-135 that result in it being a major reactor poison are its relatively ________ half-life and relatively ________ absorption cross section.

    A. short; large
    B. short; small
    C. long; large
    D. long; small

14. Xenon 135 is considered a major fission product poison because it has a large

    A. fission cross section
    B. absorption cross section
    C. elastic scatter cross section
    D. inelastic scatter cross section

15. Xenon 135 is produced in the reactor by two methods. One is directly from fission, the other is indirectly from the decay of

    A. xenon 136
    B. promethium 135
    C. cesium 135
    D. iodine 135

16. Xenon is produced in the reactor by two methods. One is directly from fission, the other is from the following decay chain:

    tellurium $\xrightarrow{\beta-}$ ________ $\xrightarrow{\beta-}$ xenon

    What element goes in the blank?

    A. iodine
    B. barium
    C. promethium
    D. gadolinium

17. Which of the decay chains describes the production of xenon 135?

    A. ${}^{135}Ba \xrightarrow{\beta+} {}^{135}Cs \xrightarrow{\beta+} {}^{135}Xe$

    B. ${}^{136}Xe \xrightarrow{n} {}^{135}Xe$

    C. ${}^{135}Te \xrightarrow{\beta-} {}^{135}I \xrightarrow{\beta-} {}^{135}Xe$

    D. ${}^{139}Ba \xrightarrow{\alpha} {}^{135}Xe$

18. Following a reactor trip from sustained high power operation, xenon 135 concentration in the reactor will

    A. decrease because xenon is produced directly from fission

    B. increase due to the decay of iodine already in the core

    C. remain the same because the decay of iodine and xenon balance each other out

    D. decrease immediately, then slowly increase due to the differences in the half-lives of iodine and xenon

19. A reactor has been operating at 50 percent power for two weeks when power is quickly ramped to 100%. How would the xenon 135 production terms below change?

    Xenon direct from fission + Xenon from radioactive decay of iodine

    A. fission term decreases, and iodine decay term decreases until iodine builds in

    B. fission term increases, and iodine decay term is constant

    C. fission term decreases, and iodine decay term is constant

    D. fission term increases, and iodine decay term increases as iodine builds in

20. Describe the xenon 135 production mechanisms in an operating reactor.

21. Xenon 135 is removed from an operating reactor by neutron capture and radioactive decay to

    A. iodine 135
    B. cesium 135
    C. tellurium 135
    D. lanthanium 135

22. Xenon is removed from the reactor by neutron capture and the following β- decay:

    $$\text{iodine} \xrightarrow{\beta-} \text{xenon} \xrightarrow{\beta-} \_\_\_ \xrightarrow{\beta-} \text{barium}$$

    Select the correct isotope in the decay chain.

    A. tellurium
    B. promethium
    C. cesium
    D. gadolinium

23. In a shutdown reactor, which decay chain describes the primary means of removing xenon 135?

    A. $^{135}Xe \xrightarrow{\beta-} {}^{135}Cs$

    B. $^{135}Xe \xrightarrow{n} {}^{134}Xe$

    C. $^{135}Xe \xrightarrow{\alpha} {}^{131}Te$

    D. $^{135}Xe \xrightarrow{\beta+} {}^{135}I$

24. Following a reactor trip from sustained high power operation, the major xenon 135 removal process is

    A. ion exchange
    B. beta decay
    C. neutron capture
    D. alpha decay

25. One method of xenon 135 removal in an operating reactor is beta decay to cesium 135. What is the other method?

    A. gamma decay
    B. alpha decay
    C. ion exchange
    D. neutron capture

26. Following a reactor trip from sustained power operation, the xenon-135 removal process consists primarily of

    A. beta decay
    B. gamma decay
    C. electron capture
    D. gamma capture

27. Reactor power is increased from 50 percent to 60 percent in one hour. The most significant contributor to the initial change in xenon reactivity is the increase in

    A. xenon production from fission
    B. xenon decay to cesium
    C. xenon absorption of neutrons
    D. xenon production from iodine decay

28. Describe the xenon 135 removal mechanisms in an operating reactor.

29. Equilibrium xenon concentration depends on the reactor

    A. boron concentration
    B. power level
    C. coolant temperature
    D. coolant pressure

30. Which of the following is <u>not</u> a condition of equilibrium xenon?

    A. The reactor power level must be constant.

    B. The reactor must have been operating at a steady-state power level for 40 to 50 hours.

    C. The concentration of iodine 135 must have reached equilibrium

    D. The reactor must be at 100 percent power.

31. For the reactor to be at an equilibrium xenon condition, the xenon production rate must be

    A. equal to the removal rate
    B. greater than the removal rate
    C. less than the removal rate
    D. inversely proportional to the removal rate

32. A reactor has been operating at 100 percent power for one week when power is ramped in 4 hours to 50 percent. Which statement describes the new equilibrium xenon concentration?

    A. one-half the 100 percent value

    B. less than one-half the 100 percent value

    C. more than one-half the 100 percent value

    D. equal to the 100 percent value

33. A reactor has been operating at 50 percent power for one week when power is ramped in four hours to 100 percent power. Which statement best describes the new equilibrium xenon concentration?

    A. The new equilibrium xenon will be twice the 50 percent value.

    B. The new equilibrium xenon value will be less than twice the 50 percent value.

    C. The new equilibrium xenon value will be more than twice the 50 percent value.

    D. The new equilibrium xenon value will remain the same since it is independent of power.

34. A reactor has been operating at a steady-state condition for 50 hours. Which of the following best describes the xenon behavior?

    A. xenon peaking
    B. xenon oscillation
    C. transient xenon
    D. equilibrium xenon

35. A reactor has been operating at 50 percent power for a week when power is quickly ramped (over four hours) to 100 percent power. How would the xenon concentration in the core respond?

    A. decreases initially, then builds to a new equilibrium concentration in 8 to 10 hours

    B. increases steadily to a new equilibrium concentration in 20 to 30 hours

    C. decreases initially, then builds to a new equilibrium concentration in 40 to 50 hours

    D. increases steadily to a new equilibrium concentration in 60 to 70 hours

36. A reactor has been operating at 100 percent power for a week when power is ramped down in four hours to 50 percent power. How would the xenon concentration in the core respond?

    A. The xenon level would decrease directly with the reactor power level.

    B. The xenon level would decrease to a new equilibrium value in 8 to 10 hours.

    C. The xenon level would increase initially, then drop off to a new lower equilibrium value in about 40 to 50 hours.

    D. The xenon level would remain the same.

37. A reactor has been operating at a steady-state power level for 15 hours following a rapid power reduction from 100 to 50 percent using boration for reactivity control. Which one of the following describes the current core xenon concentration?

    A. increasing
    B. decreasing
    C. at equilibrium
    D. oscillating

38. A reactor has been operating at 100 percent power for a week when the power is ramped down in four hours to 25 percent power. The new equilibrium xenon value will be

    A. less than 25 percent of the 100 percent value

    B. about 50 percent of the 100 percent power value

    C. about 80 percent of 100 percent power value

    D. the same as the 100 percent power value

39. A reactor has been operating at 100 percent for two weeks when power decreases to 50 percent in one hour. Over the next 50 hours, the xenon concentration will

    A. increase initially, then decrease to a new equilibrium value

    B. decrease initially, then increase to a new equilibrium value

    C. increase to a new equilibrium value

    D. decrease to a new equilibrium value

40. A reactor has just started power operation and is ramped to full power in six hours. How long after the reactor reaches full power will it take to achieve an equilibrium xenon condition?

    A. 8 to 10 hours
    B. 20 to 30 hours
    C. 40 to 50 hours
    D. 70 to 80 hours

41. Explain how, why, and over what time frames xenon 135 concentration changes when reactor power is quickly increased from 50 percent to 100 percent. Assume equilibrium initial conditions.

42. Explain how, why, and over what time frame xenon 135 concentration changes when reactor power is quickly decreased from 100 percent to 50 percent. Assume equilibrium initial conditions.

43. Following a reactor startup from a six-day shutdown, the plant is taken to 100 percent power. How long must the operator compensate for xenon as it built in?

A. 8 to 10 hours
B. 15 to 25 hours
C. 40 to 50 hours
D. 70 to 80 hours

44. A reactor that has been operating at 100 percent power for two weeks experiences a trip. How long would it take for the xenon concentration to peak following the trip?

A. 4 to 6 hours
B. 8 to 12 hours
C. 40 to 50 hours
D. 70 to 80 hours

45. A reactor that has been operating at 100 percent power for two weeks experiences a trip. Over the next 8 to 10 hours xenon concentration will

A. increase to peak value
B. decrease to equilibrium
C. increase to equilibrium
D. remain the same

46. Two identical reactors are operating at power. Reactor "A" is at 50 percent power and reactor "B" is at 100 percent power. Both reactors trip/scram at the same time.

Which statement describes post-trip/scram xenon behavior?

A. Xenon will peak first in reactor "A" with a lower peak value.

B. Xenon will peak first in reactor "B" with a higher peak value.

C. Xenon will peak first in reactor "A" with an equal peak value.

D. Xenon will peak first in reactor "B" with an equal peak value.

47. Two identical reactors are operating at power. Reactor "A" is at 50 percent power and Reactor "B" is at 100 percent power. Both reactors trip/scram at the same time. Which statement best describes the post-trip/scram xenon reactivity worth?

A. Reactors "A" and "B" will have identical peaks.
B. Reactor "A" will have the larger peak.
C. Reactor "B" will have the larger peak.
D. The xenon peaks will be identical but will occur at different times.

48. Two identical reactors have been operating at a constant power level for one week. Reactor A is at 50 percent power and Reactor B is at 100 percent power. If both reactors trip/scram at the same time, xenon-135 will peak first in reactor __________ and the highest xenon-135 reactivity peak will occur in reactor __________ .

A. A; A
B. A; B
C. B; A
D. B; B

49. A reactor that has been operating at 100 percent power for two weeks trips/scrams. How long will it take until the core is considered to be "xenon-free"?

    A. 4 to 6 hours
    B. 8 to 10 hours
    C. 40 to 50 hours
    D. 70 to 80 hours

50. Explain how, why, and over what time frame xenon 135 concentration changes following a scram from equilibrium conditions.

51. Slow changes in axial power distribution in a reactor that has operated at a steady-state power for a long time can be caused by:

    A. xenon peaking
    B. xenon override
    C. xenon burnup
    D. xenon oscillation

52. Which of the following occurrences can cause reactor power to fluctuate between the top and bottom of the core when steam demand is constant?

    A. steam generator level oscillations
    B. iodine spiking
    C. xenon oscillations
    D. inadvertent boron dilution

53. Describe and explain what occurs during xenon oscillations.

54. Xenon oscillations that tend to dampen themselves toward equilibrium over time are said to be ___________ oscillations.

    A. converging
    B. diverging
    C. diffusing
    D. equalizing

55. What condition is developing when there is a steady-state steam demand and power in the core is fluctuating from top to bottom?

    A. xenon burnup
    B. iodine spiking
    C. xenon oscillation
    D. samarium buildup

56. When a reactor experiences xenon oscillations, the most significant shifts in power generation occur between the ________________ of the core.

    A. top and bottom
    B. adjacent quadrants
    C. center and periphery
    D. opposite quadrants

57. Xenon oscillations take about ____ hours to get from maximum bottom peak to maximum top peak.

    A. 6 to 7
    B. 12 to 14
    C. 24 to 28
    D. 40 to 50

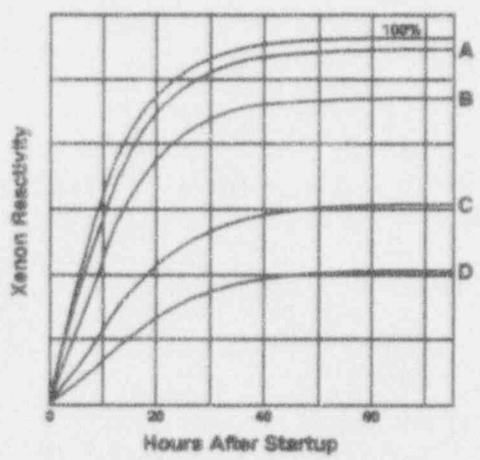
58. Following a reactor startup from a long-term shutdown, the plant is taken to 100 percent power. After reaching 100 percent power, what kind of reactivity, if any, will the operator need to add to compensate for xenon buildup (first 10 to 20 hours)?

    A. positive
    B. negative
    C. positive initially, then negative as burnout occurs
    D. none, power is already at maximum

59. Using the graph in Figure 2.6-1, select the curve that describes the following condition: "Following a long shutdown, a reactor is brought to 50 percent power and held there for 50 hours."

    A. Curve A
    B. Curve B
    C. Curve C
    D. Curve D

FIGURE 2.6-1



Xenon Reactivity Versus Hours After Startup

60. The equilibrium value for xenon 135 increases as reactor power is increased because

    A. the production of tellurium 135 and neodymium 149 is proportional to reactor power

    B. the half-life for xenon 135 is greater than the half-life for iodine 135

    C. neutron absorption by iodine 135 is proportional to reactor power

    D. the production of iodine 135 is proportional to reactor power

61. The reactor is being started up and taken to rated power at a constant ramp rate following an extended outage. To compensate for the effect of xenon 135 while increasing reactor power, it will be necessary to

    A. increase turbine load
    B. withdraw rods or dilute
    C. decrease turbine load
    D. insert rods or borate

62. Following a 7 day shutdown, a reactor startup is performed and the plant is taken to 40 percent power over a 6 hour period. After stabilizing at 40 percent power, what type of reactivity will the operator need to add to compensate for xenon changes over the next 24 hours?

    A. negative only
    B. negative, then positive
    C. positive, then negative
    D. positive only

63. The plant is being returned to operation following a refueling outage. Fuel preconditioning requires reactor power being increased from 10 percent to full power gradually over a one week period.

    During this slow power increase, most of the positive reactivity added by the operator is required to overcome the negative reactivity from

    A. fuel burnup
    B. xenon buildup
    C. fuel temperature increase
    D. moderator temperature increase

64. Four hours after a reactor trip from a long-term, steady-state full power run, the reactor is taken critical and is immediately stabilized at low power for critical data. To maintain a constant reactor power, the operator must add ______ reactivity because xenon concentration is ________.

   A. positive; increasing
   B. positive; decreasing
   C. negative; increasing
   D. negative; decreasing

65. Twelve hours after a reactor trip from a long-term, steady-state rated-power run, the reactor is taken critical and power is raised quickly to 100 percent power. As the power is raised, what is happening to the xenon concentration?

   A. Xenon is building in toward a nev/ equilibrium.

   B. Xenon is burning out faster than it is being produced.

   C. Xenon is not changing since it is independent of flux.

   D. Xenon is decaying away faster than it is being produced.

66. Following a reactor trip from a long-term, steady-state, rated-power run, the reactor is to be taken critical. The operator calculates the estimated critical position for a xenon-free core. How long after the initial trip would this condition exist?

   A. 8 to 10 hours
   B. 24 to 30 hours
   C. 40 to 50 hours
   D. 70 to 80 hours

67. A reactor startup (S/U) to full power is begun five hours after a trip from full power equilibrium conditions. If a 2.0%/min ramp was used rather than a 0.5%/min ramp, the xenon peak would occur _______ and the magnitude of the peak would be _________.

   A. sooner larger
   B. sooner smaller
   C. later larger
   D. later smaller

68. What is meant by the expression "a xenon-precluded startup"? Under what conditions would such a situation be most likely to occur?

69. The plant has been operating at 100 percent power for two months when a reactor trip occurs. Six hours after the trip, the reactor is taken critical and power is raised to 2 percent. In order to maintain power stable at 2 percent, the operator must

   A. add positive reactivity because xenon is building in

   B. add negative reactivity because xenon is building in

   C. add positive reactivity because xenon is decaying away

   D. add negative reactivity because xenon is decaying away

70. A reactor that has been operating at rated power for about two weeks is rapidly reduced in power to 50 percent. What happens to the xenon 135 concentration in the core?

    A. There will be no change because iodine concentration is constant.

    B. Xenon will initially build up, then decrease to a new equilibrium value.

    C. Xenon will initially decrease, then build up to a new equilibrium value.

    D. Xenon will steadily decrease to a new equilibrium value.

71. A reactor that has been operating at rated power for about two weeks undergoes a rapid reduction in power to 50 percent. To compensate for the change in xenon 135 over the next 4 to 6 hours, the operator must

    A. add positive reactivity because xenon is rapidly burning out

    B. add negative reactivity because xenon is rapidly decaying away

    C. add positive reactivity to compensate for xenon building in

    D. add negative reactivity because xenon is rapidly building in

72. A reactor that has been operating at rated power for about two weeks is rapidly reduced in power to 50 percent. Xenon 135 will reach a new equilibrium condition in _____hours.

    A. 8 to 10 hours
    B. 20 to 25 hours
    C. 30 to 35 hours
    D. 40 to 50 hours

73. A reactor has been operating at 50 percent power for about two weeks. Power is then raised over a four-hour period to 100 percent. What must the operator do during the first 2 to 3 hours after reaching 100 percent power to compensate for a change in xenon 135?

    A. add negative reactivity because xenon is burning out

    B. add positive reactivity because xenon is building in

    C. no action is needed since iodine concentration is constant

    D. add positive reactivity because xenon production exceeds xenon decay

74. A reactor has been operating at 25 percent for two weeks. Power is then ramped to 100 percent in four hours. What happens to xenon 135 in the core?

    A. Xenon will ramp up with power.

    B. There will be no change since xenon is not flux-dependent.

    C. Xenon will decrease initially, then build in to a new higher equilibrium.

    D. Xenon will increase initially, then drop off to a new lower equilibrium.

75. A reactor has been operating at full power for several days when a trip occurs. Over the next few hours, xenon concentration is expected to

    A. decrease because xenon concentration is flux dependent

    B. increase rapidly because the burnout term has decreased significantly

    C. remain constant because xenon concentration is not flux-dependent

    D. decrease slowly because xenon is now being removed only by decay

76. A reactor has been operating at 100% power for several days when a reactor trip occurs. If the reactor had been operating at 50 percent power, xenon reactivity would peak ______ and the peak xenon reactivity would be ______.

    A. earlier; the same
    B. earlier; less negative
    C. at the same time; the same
    D. at the same time; less negative

77. Referring to the graph in Figure 2.6-2, why is the xenon concentration increasing initially in a reactor that is shut down?

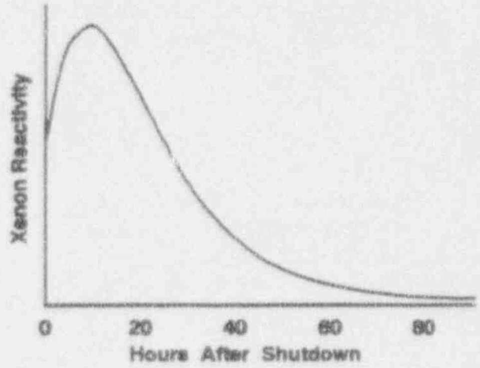
    A. Xenon is being produced from the decay of iodine 135.

    B. Xenon is being produced from the spontaneous fission of uranium.

    C. Xenon decay has dropped off significantly with flux.

    D. Xenon is no longer being removed by ion exchange.

FIGURE 2.6-2



Xenon Reactivity Versus Hours After Shutdown

78. Following a reactor trip, negative reactivity from xenon initially increases due to

    A. xenon production from the decay of iodine-135

    B. xenon production from the spontaneous fission of uranium

    C. the reduction of xenon removal by decay

    D. the reduction of xenon removal by recombination

79. A reactor has been operating at full power for several days when it must be shut down rapidly for maintenance. How will the xenon concentration change over the next three days?

    A. Xenon will steadily decay away to almost zero in three days.

    B. Xenon will build up to a new equilibrium in three days.

    C. Xenon will peak in about 10 hours, then decay to almost zero in three days.

    D. Xenon will ramp down with reactor power in direct proportion.

80. Four hours after a reactor trip from a long-term, steady-state, rated-power run, xenon concentration will be

A. diminishing
B. building up
C. constant
D. no concern

81. Twenty-four hours after a reactor trip from a long-term, steady-state, rated-power run, the xenon concentration will be

A. considerably higher than at the time of the trip

B. considerably lower than at the time of the trip

C. slightly higher than at the time of the trip and increasing rapidly

D. approximately the same as at the time of the trip and decreasing slowly

82. After a reactor shutdown from equilibrium xenon conditions, the maximum xenon reactivity (height of the xenon peak) is _______________ pre-shutdown power level.

A. directly proportional to
B. directly proportional to the inverse of
C. dependent on but not directly proportional to
D. independent of

83. The reactor has been operating at 100% power for 8 weeks when a reactor trip occurs. The reactor is critical 6 hours later and power is increased to 100% over the next 6 hours.

How is core xenon concentration behaving when power reaches 100%?

A. Xenon is building in toward a new equilibrium.

B. Xenon is burning out faster than it is being produced.

C. Xenon is building in toward a peak value.

D. Xenon is at equilibrium.

84. The reactor has been operating at 100% power for 3 weeks when a reactor trip occurs. The core xenon concentration 24 hours after the trip will be:

A. at least 2 times the concentration at the time of the trip and decreasing

B. less than 1/2 the concentration at the time of the trip and decreasing

C. at or approaching a peak value

D. approximately the same as at the time of the trip

85. The reactor has been operating at steady-state 25% power for 24 hours following a power reduction from full power. Which one of the following describes the current status of core xenon?

A. increasing toward a peak
B. decreasing toward equilibrium
C. decreasing toward a valley
D. at equilibrium

FISSION PRODUCT POISONS
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

A fission product poison is a fission fragment or its progeny, which has a substantial neutron absorption cross section and does not fission.

Reference 34, chapter 13, page 467.

2. C

A fission product poison is a fission fragment or its progeny, which has a substantial neutron absorption cross section and does not fission.

Reference 34, chapter 13, page 467.

3. A

A fission product poison is a fission product that has a substantial neutron absorption cross section and does not fission.

Reference 34, chapter 13, page 467.

4. D

Definition of a fission product poison is a fission product with an appreciable neutron absorption cross section.

Reference 01, page 50.

5. D

The term "poisons" is used to denote their negative effect on the neutron chain reacting system by capturing thermal neutrons which could cause fission.

Reference 61, page 6-15

6. D

A fission product poison is a fission fragment or its progeny which has a substantial neutron absorption cross section and does not fission.

Reference 13, chapter 6, page 188; and Reference 32, chapter 6, page 161.

7. C

Xenon 135 has an extremely large microscopic cross section for absorption for thermal neutrons.

Xenon 135 also has a relatively high fission yield (indirect and direct).

Reference 18, chapter 5, pages 250 and 251.

8. C

9.

Xenon 135 is a significant fission product poison because of its large microscopic capture cross-section, its large overall fission product yield, and its variable abundance.

Because of its large capture cross-section, an increase in xenon 135 concentration removes additional neutrons from the fission chain reaction, inserting negative reactivity, which the reactor designer and operator must content with.

Because of its abundance, its macroscopic capture cross-section can be large. Furthermore, the xenon concentration is power (neutron flux) dependent, so that every change in reactor power produces a time transient in which xenon concentration, and therefore reactivity, is changed.

Reference 61, pages 4-11 and 4-24.

FISSION PRODUCT POISONS
Answers

10. C

Xenon is removed both by beta decay and by neutron capture.

Reference 18, chapter 5, page 251.

11. A

Xenon is produced directly from fission and indirectly from the decay of iodine 135.

Reference 18, chapter 5, page 251.

12. D

Xenon is produced from the decay of iodine 135, not barium 135.

Reference 18, chapter 5, page 251.

13. C

The long half-life of Xe-135, 9.2 hours, permits it to buildup in the core and the high absorption cross section causes it to parasitically absorb thermal neutrons readily.

Reference 18, chapter 5, pages 250, 251.

14. B

Xenon 135 has a very large microscopic absorption cross section for thermal neutrons.

Reference 18, chapter 5, page 251.

15. D

Xenon is produced directly from fission and indirectly from the β- decay of iodine 135.

Reference 18, chapter 5, pages 250 and 251.

16. A

$$^{135}Te \xrightarrow{\beta-} {}^{135}I \xrightarrow{\beta-} {}^{135}Xe \xrightarrow{\beta-} {}^{135}Cs$$

Reference 18, chapter 5, pages 250 through 252.

17. C

Reference 18, chapter 5, pages 250 through 253.

18. B

Xenon concentration will increase following a trip because of the iodine concentration already in the core. The half-life for iodine is shorter than for xenon. The flux-related production and removal terms are essentially nonexistent following a trip.

Reference 18, chapter 5, pages 251 and 252.

19. D

As reactor power increases, the direct production of xenon will increase since the direct production from fission is directly related to flux level.

The iodine term must account for the buildup of iodine from fission and the time for it to then undergo a radioactive decay.

Key point is that I-135 has a high fission yield and its concentration in the core is directly flux-dependent.

Reference 34, chapter 13, pages 468 and 469.

20.

Xenon 135 is produced in an operating reactor by two mechanisms. Approximately 0.2 percent of all fissions produce xenon 135 directly as a fission fragment.

A larger, although somewhat delayed, production mechanism is from the decay of other fission fragments. Approximately six percent of fissions produce antimony 135 as a fission fragment. Through a series of β- emissions, the antimony decays to tellurium 135, which decays to iodine 135, which decays to xenon 135.

Reference 61, page 4-11.

21. B

Xenon 135 beta minus decays to cesium 135.

Reference 34, chapter 13, page 468.

22. C

Xenon production and removal β– decay chain

$$^{135}Te \xrightarrow{\beta-} {}^{135}I \xrightarrow{\beta-} {}^{135}Xe \xrightarrow{\beta-} {}^{135}Cs$$

Reference 18, chapter 5, pages 250 through 253.

23. A

Reference 18, chapter 5, pages 250 through 253.

24. B

Following a reactor trip, neutron flux level essentially goes to zero; therefore, the neutron capture portion of the xenon removal term goes to zero. Xenon 135 removal following a reactor trip is from beta minus decay.

Reference 18, chapter 5, pages 256 and 257.

25. D

Xenon 135 is removed from an operating reactor by beta minus decay and neutron capture.

Reference 18, chapter 5, pages 256 and 257.

26. A

The neutron flux reaches a very low level due to the neutron chain reaction being turned off. The removal of Xe-135 atoms by thermal neutron absorption is negligible. The primary way the xenon concentration is decreased is through radioactive decay, beta-gamma emission.

Reference 61, page 4-12

27. C

This occurs because the neutron flux was increased causing the rate of neutrons being absorbed in Xe-135 to increase accordingly. Xe-135 production increases from fission but this is a smaller effect since the majority of Xe-135 is produced from iodine decay. Iodine decay increases but this occurs much more slowly as iodine builds in to its new, higher equilibrium value.

Reference 61, pages 4-24 to 4-28.

28.

Xenon 135 is removed by two mechanisms in an operating reactor. With its half-life of 9.1 hours, xenon decays by β- emission to cesium 135. In addition, because of its large macroscopic capture cross-section, xenon 135 is "burned out" by the neutron flux in an operating reactor. Through neutron capture, xenon 135 is transformed to xenon 136, whose capture cross-section is negligible.

Reference 61, page 4-12.

29. B

Xenon equilibrium value is dependent on the flux level of the reactor. This is not a linear function.

Reference 61, page 4-15.

30. D

To reach a xenon equilibrium condition, the reactor must be at a steady-state power (flux) level for 40 to 50 hours. Iodine 135 concentration has reached equilibrium. The reactor does not have to be at 100 percent to achieve an equilibrium condition; this can occur at any power level.

Reference 34, chapter 13, pages 469 through 473; and Reference 18, chapter 5, pages 253-255.

31. A

The equilibrium values are determined as follows. When the xenon concentration has reached equilibrium, the rate of change of xenon equals zero, and the production rate equals the loss rate.

Reference 61, page 4-15.

32. C

Reference 61, page 4-16

33. B

Reference 61, page 4-16

34. D

Xenon equilibrium is the condition in which the production of xenon equals the removal by neutron capture and radioactive decay. After a startup, xenon will reach its equilibrium value at approximately 40 to 50 hours.

Reference 18, chapter 5, pages 253 through 255.

35. C

The increase in flux increases the rate of neutron capture reactions in xenon, causing an initial drop in xenon concentration. Then xenon slowly builds up to a new equilibrium value in 40 to 50 hours.

Reference 61, page 4-25.

36. C

Following a reduction in power, xenon concentration will increase quickly because the rate of neutron capture by xenon has been reduced. Then xenon concentration slowly decreases to a new equilibrium value in about 40 to 50 hours.

Reference 61, pages 4-26 and 4-27.

37. B

When the power change occurred the xenon concentration initially began building up. Its loss rate had been reduced due to the decrease in neutron flux. The concentration peaks at about six hours and then drops down to its 50 percent power equilibrium level. At the 15 hour point, the concentration is still decreasing since it takes about 30 hours to reach equilibrium.

Reference 61, page 4-26.

38. B

The 25 percent power xenon equilibrium value will be approximately 57 percent (50 to 60%) of the 100 percent power-level value.

Reference 61, pages 4-26 and 4-27.

.39. A

Xenon concentration would increase for 4 to 6 hours following the transient, peak, and then decrease to its 50 percent equilibrium value over the next 40 to 50 hours

Reference 61, pages 4-26 and 4-27.

40. C

Xenon equilibrium occurs after 40 to 50 hours of steady-state power operation.

Reference 61, page 4-15.

41.

When power is increased, an immediate increase in xenon burnout takes place, causing xenon concentration to decrease. The power increase also causes a rapid increase in the iodine production rate. After approximately four-to-six hours, the production rate of xenon from iodine decay, combined with production directly from fission, overcomes the increased burnout, causing xenon concentration to begin to increase. After 40 to 50 hours, xenon concentration will have reached a new equilibrium level above its initial level.

Reference 61, pages 4-24 and 4-25.

42.

When power is decreased, the burnout rate of xenon is also decreased, resulting in an increase in xenon concentration. However, the production rate of iodine is reduced when power is decreased. After four to six hours, the "store" of iodine has largely decayed, and the xenon concentration begins to decrease. After 40 to 50 hours, xenon concentration reaches a new, lower equilibrium level.

Reference 61, pages 4-26 and 4-27.

43. C

Xenon equilibrium is reached approximately 40 to 50 hours after a startup. The operator must dilute or pull rods to maintain power at 100 percent.

Reference 61, page 4-16.

44. B

Xenon peaks 8 to 10 hours following a reactor trip from 100% power. The time from reactor trip to xenon peak is roughly the square root of the power change. Westinghouse plants use 0.8 times the square root of the power change for determining the time it takes xenon to peak (or dip) during any down-power (or up-power) maneuver.

Reference 61, pages 4-20 and 4-22.

45. A

Following a reactor trip, xenon builds up rapidly for about 8 to 10 hours.

Reference 61, pages 4-20 and 4-22.

46. A

Reactor "A" would peak first with a smaller magnitude. Reactor "B" would peak some time later with a larger magnitude.

Reference 61, pages 4-20 and 4-22.

47. C

Reactor "B" will have the larger peak following a trip.

The magnitude of peak xenon following a trip is a function of the I-135 concentration at the time of the trip. Since Iodine concentration is directly proportional to flux, a higher peak will be seen after a trip from a higher power level.

Reference 61, pages 4-20 and 4-22.

48. B

Reference 61, pages 4-20 and 4-22.

49. D

A xenon-free condition would occur about 72 hours following the trip.

Reference 61, pages 4-20 and 4-22.

50.

When the reactor scrams, production of xenon directly from fission and production of iodine effectively cease. However, xenon burnout also immediately ceases. The decay of the existing iodine causes xenon concentration to rise because I-135 has a shorter half-life than Xe-135. After approximately eight to ten hours, production of xenon from iodine decay is overcome by decay of xenon, and the xenon concentration begins to decrease. After approximately 80 hours, effectively all xenon will have decayed.

Reference 61, pages 4-21 and 4-22.

51. D

Xenon oscillation: Oscillations in the space-dependent xenon 135 concentration in a nuclear reactor cause oscillations in the space-dependent neutron flux.

Reference 01, page 124.

52. C

53.

When some perturbation causes a small change (say a decrease) in neutron flux in a localized area of the core, the xenon concentration in that area will change (increase due to reduced burnout). The changing xenon concentration will affect (insert negative) reactivity in that area further affecting (reducing) local power density. For total core output to remain constant, power density in another area of the core will change (increase), initiating a localized xenon transient (decrease due to increased burnout) in that area.

After a few hours, xenon concentration in the higher-powered area will be increasing from its "dip", and that in the lower-owered area will be falling from its "peak". These changes in xenon concentration will likewise affect local reactivity in the opposite direction of the initial shift. Thus, xenon concentration and power density will oscillate from one area of the core to another.

Reference 61, pages 4-28 and 4-29.

54. A

Convergent oscillations dampen themselves to equilibrium. Each half-cycle of oscillation is less in magnitude then the preceding half-cycle.

Reference 34, chapter 13, page 478.

55. C

Even with constant steam demand, xenon oscillations are occurring when power fluctuates between one portion of the core and another. The higher power portion builds in more iodine/xenon, eventually adding negative reactivity and causing power to decrease slightly in this portion and move to the other portion.

Reference 34, chapter 13, page 478.

56. A

Due to the physical dimensions and nonuniformity of temperature conditions in the axial directions, xenon oscillations are most likely axially. (top to bottom).

Reference 34, chapter 13, page 478

57. B

A full-cycle xenon oscillation takes 24 to 28 hours; therefore, a half-cycle (from maximum bottom xenon to maximum top) takes half as long: 12-14 hours.

Reference 18, chapter 5, pages 259 and 260.

58. A

Xenon will be building in for about 40 to 50 hours, so the operator will have to add positive reactivity.

Reference 61, pages 4-14 through 4-22.

59. B

Reference 61, pages 4-16.

60. D

By virtue of the very short half-lives of Sb-135 and Te-135, these isotopes will saturate at a decay rate equal to the production rate in a matter of seconds. This simplification allows us to not treat Sb-135 and Te-135 separately, but to allow for their existence by adding their yield values to the yield value for iodine. Because I-135 is produced by fission, the production of I-135 is proportional to power.

Reference 13, chapter 6, page 188; and Reference 18, chapter 5, page 253.

61. B

Xenon 135 adds negative reactivity; therefore, if reactor power is to be maintained constant, positive reactivity must be added by some mechanism -- the most common method being pulling rods or boron dilution. More dilution or rod withdrawal will be required to raise power than would be the case if xenon 135 did not build in as the power increase was occurring.

Reference 18, chapter 5, page 262; and Reference 32, chapter 6, page 167.

62. D

After a seven day shutdown, the reactor is xenon free. The six hour startup to 40 percent power will require the operator to add positive reactivity since xenon is building in to its 40 percent power equilibrium value.

Reference 61, page 4-16.

63. B

The time taken to increase the power gradually will permit xenon essentially to build into its equilibrium values. A large amount of positive reactivity will have to be added to compensate for this poisoning. The power defect caused by the fuel and moderator temperature coefficients will be of smaller magnitude since the core is at BOL.

Reference 61 pages 3-40 to 3-42 and 4-16.

64. A

Xenon is building in rapidly, which is adding negative reactivity. The operator must add positive reactivity to maintain power.

Reference 61, pages 4-14 through 4-28.

65. B

At this time, xenon will have peaked and started to decay away faster than it is building in from the decay of iodine. As the power increases, xenon will be removed at an increasing rate (xenon burnout).

Reference 61, pages 4-14 through 4-28.

66. D

The core is essentially xenon-free about 72 hours following a reactor trip.

Reference 61, pages 4-14 through 4-28.

67. B

68.

Late in core life, when a core's excess reactivity is low, there might be insufficient excess reactivity to overcome the negative reactivity associated with a post-shutdown xenon peak. When this occurs, the operator's ability to startup the reactor is precluded for the period of time that xenon reactivity exceeds excess reactivity. This situation is called a xenon-precluded startup.

69. A

Following the reactor trip, the xenon concentration will increase because the neutron flux was essentially decreased to zero. The xenon is expected to reach a peak at about 10 hours following the full power trip. Six hours after the trip, positive reactivity must be added to keep the reactor critical at 2 percent.

Reference 61, page 4-22.

70. B

Xenon concentration will increase for a few hours, then drop off slowly to a new lower xenon equilibrium value.

Reference 61, pages 4-14 through 4-28.

71. C

Xenon concentration will be increasing for 4 to 6 hours. During this time the operator will have to be adding positive reactivity.

Reference 61, pages 4-14 through 4-28.

72. D

Xenon will reach a new equilibrium condition in 40 to 50 hours.

Reference 61, pages 4-14 through 4-28.

73. A

On a rapid power increase from a previous steady-state condition, the xenon concentration will drop off because of burnout. This decrease in xenon concentration will require the operator to add negative reactivity.

Reference 61, pages 4-14 through 4-28.

FISSION PRODUCT POISONS
Answers

74. C

Xenon will drop off quickly because of burnout, then build in to a new higher equilibrium value.

Reference 61, pages 4-14 through 4-28.

75. B

Xenon concentration will build in significantly because the burnout term has essentially gone away. Iodine 135 is at its 100 percent value initially and is decaying to xenon 135, yielding a net increase in xenon concentration.

Reference 61, pages 4-14 through 4-28.

76. B

A lower power level will have an earlier and smaller peak.

Reference 61, pages 4-20 through 4-28.

77. A

Xenon will build in from the decay of iodine 135. As the xenon builds in, the xenon decay will increase. Xenon concentration peaks in 8 to 10 hours as the iodine concentration starts to drop off. Xenon decay will then be the primary factor shaping the curve.

Reference 61, pages 4-20 through 4-28.

78. A

Reference 61, pages 4-20 through 4-22.

79. C

Xenon will peak in 8 to 12 hours and then decay away to essentially a xenon-free condition in about 72 hours.

Reference 61, pages 4-20 through 4-28.

80. B

Xenon will be building in very quickly four hours after a trip. Decay of iodine 135 is faster than the decay of xenon 135.

Reference 61, pages 4-14 through 4-28.

81. D

Following a reactor trip from 100 percent power, the xenon will peak and be back to about where it started from 24 hours after the trip. The concentration will be decreasing at this time.

Reference 61, pages 4-14 through 4-28.

82. C

Reference 61, page 4-22.

83. B

84. D

85. B

FISSION PRODUCT POISONS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1-6

Define fission product poison.

K1.02 Questions 7-14

State the characteristics of xenon 135 as a fission product poison.

K1.03 Questions 15-20

Describe the production of xenon 135.

K1.04 Questions 21-28

Describe how xenon 135 is removed from a reactor.

K1.05 Questions 29-34, 85

Describe the following process and state its effect on reactor operations: equilibrium xenon.

K1.06 Questions 35-43

Describe the following process and state its effect on reactor operations: transient xenon.

K1.07 Questions 44-50

Describe the following process and state its effect on reactor operations: Xenon following a scram.

K1.08 Questions 51-57

Describe the characteristics and effects of xenon oscillations on reactor operations.

K1.09 Questions 58-63

Plot the curve and/or explain the reasoning for the reactivity insertion by xenon 135 versus time for the following: initial reactor startup and ascension to rated power.

K1.10 Questions 64-69, 83

Explain the reasoning for the reactivity insertion by xenon 135 versus time for the following: reactor startup with xenon 135 already present in the core.

K1.11 Questions 70-74

Explain the reasoning for the reactivity insertion by xenon 135 versus time for the following: power changes from one steady-state power to another.

K1.12, 1.13 Questions 75-82, 84

Plot the curve and explain the reasoning for the reactivity insertion by xenon 135 versus time for the following: reactor scram or shutdown.

K1.14 No Questions

Methods for dealing with xenon oscillations are dependent upon plant-specific procedures and were determined to be not generic.

FUEL DEPLETION AND BURNABLE POISONS
Questions

1. Burnable poisons are installed in a new reactor core instead of using a larger soluble boron concentration in order to

   A. prevent boron precipitation during normal operation

   B. limit the magnitude of a positive moderator temperature coefficient

   C. increase differential boron worth

   D. increase integrated control rod worth

2. A burnable poison can be described as a neutron absorber

   A. whose strength is normally varied by operator action

   B. whose strength remains relatively constant over core life

   C. that is rapidly depleted during the first 100 hours of exposure to compensate for the initial buildup of xenon

   D. that is gradually depleted with exposure to neutron flux over a few months

3. Burnable poisons are loaded into a core to

   A. compensate for control rod depletion that occurs over core life

   B. compensate for the installed excess reactivity

   C. ensure that the fuel temperature coefficient remains negative throughout the operating cycle

   D. control xenon oscillations

4. Which of the following are reasons for using burnable poisons in an operating reactor?

   1. Provide more uniform power density.

   2. Counteract the effects of control rod burnout.

   3. Allow higher fuel enrichment of initial core load.

   4. Provide neutron flux shaping.

   A. 1, 2, 3
   B. 1, 2, 4
   C. 1, 3, 4
   D. 2, 3, 4

5. In some initial core loads, burnable poisons are installed to ensure that the moderator temperature coefficient (MTC) is negative. Explain the link between burnable poisons and the MTC.

6. List and explain three reasons for installing burnable poisons in a new core.

7. Which of the following is <u>not</u> a characteristic or purpose of burnable poisons?

   A. They allow for improved control during xenon oscillations.

   B. They gradually deplete with neutron exposure.

   C. They compensate for excess reactivity added to the core.

   D. Their use minimizes the magnitude of a positive moderator temperature coefficient.

8. Select the statement which most accurately describes how the amount of burnable poison in the core changes from beginning to end of cycle.

   A. increases continually
   B. increases briefly, then levels off
   C. decreases continually until fully depleted
   D. decreases briefly, then levels off

9. During a six-month period of continuous full power reactor operation, the reactor coolant boron concentration must be decreased steadily to compensate for

   A. buildup of fission product poisons and decreasing control rod worth

   B. fuel depletion and buildup of fission product poisons

   C. decreasing control rod worth and burnable poison burnout

   D. burnable poison burnout and fuel depletion

10. The plant is operating at end-of-life with a full-power boron concentration of 15 ppm. Following the upcoming refueling, the full-power concentration will be increased to 1,200 ppm. Which of the following is the major reason for the necessary increase in boron concentration?

    A. The refueled core will be xenon free.

    B. The excess reactivity at beginning-of-life is much greater than at end-of-life.

    C. Differential boron worth is significantly less at beginning-of-life.

    D. The integral control rod worth is less at beginning-of-life.

11. As the core ages, the excess reactivity decreases due to fuel depletion. Over the long term, how is the reactor maintained critical as the fuel is depleted? Disregard coastdown conditions.

    A. withdrawing control rods
    B. reducing coolant temperature
    C. reducing reactor power
    D. reducing boron concentration

12. The reactor is near the end of its operating cycle. In order to stay critical, power and temperature have been allowed to "coastdown." Why is boron dilution no longer used to compensate for fuel depletion?

    A. Boron concentration has become so low that very large amounts of water must be added to produce a small change in boron concentration.

    B. The reactivity worth of the boron has decreased to such a low value that very large amounts of water must be added to produce a small change in reactivity.

    C. Boron concentration has become so high that very large amounts of boron must be added to produce a small change in boron concentration.

    D. The reactivity worth of the boron has increased so much that reactivity changes via boron dilution cannot be safely controlled by the operator.

13. The reactor is operating at steady-state, full-power at the middle-of-cycle. How often will the reactor operator need to make adjustments in reactor coolant system boron concentration?

    A. every 3 months
    B. monthly
    C. weekly
    D. daily

14. The plant is operating at EOL with a full-power boron concentration of 15 ppm. After refueling, the full-power boron concentration is approximately 1,000 ppm. Which one of the following is the primary reason for the large increase in full-power boron concentration after the refueling?

    A. Reactivity from power defect at BOL is much greater than at EOL.

    B. Differential boron worth at BOL is much less than at EOL. [IBW at BOL is much greater than at EOL.]

    C. Reactivity from fissionable fuel in the core at BOL is much greater than at EOL.

    D. The integral rod worth at BOL is much less than at EOL.

15. The reactor is near the end of its operating cycle. In order to stay critical, power and temperature have been allowed to "coastdown." Why is boron no longer used to compensate for fuel depletion?

    A. The differential boron worth has decreased below its usable point.

    B. The boron in the coolant has been depleted due to neutron absorption.

    C. "Coastdown" is preferred due to fuel conditioning limitations.

    D. Boron concentration approaches zero and requires excessive amounts of water to dilute.

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

Without using burnable poisons, the amount of soluble boron needed to compensate for the excess reactivity in a new core would result in a positive moderator temperature coefficient (MTC). A positive MTC causes difficulty in controlling reactor power.

Reference 18, page 745.

2. D

Reference 34, page 300.

3. B

Reference 34, page 300.

4. C

5.

The link between burnable poisons and moderator temperature coefficient (MTC) is an indirect one. In an initial core load, in which none of the fuel assemblies have had any neutron exposure, the excess reactivity of the core tends to be high. This high excess reactivity could be offset by using a larger concentration of soluble boron in the coolant. However, a high concentration of soluble poison could cause MTC to be positive.

By installing some negative reactivity in the core through use of installed burnable poisons, excess reactivity is reduced. This allows lower concentration of soluble boron to be used, thereby avoiding a positive MTC.

Reference 61, pages 8-10 and 8-11..

6.

Avoid a positive moderator temperature coefficient. Without burnable poisons, a very high soluble boron concentration would be needed to compensate for the high excess reactivity. Such a high concentration could cause MTC to be positive. This problem is avoided by using burnable poisons to help counteract the high excess reactivity.

Provide neutron flux shaping to make power density more uniform. Burnable poison pins are installed in locations that would tend to have a high local flux, thus reducing the local flux and power density.

Allow loading of higher enrichment fuel, which provides for longer core life. Increasing the amount or enrichment of fuel causes excess reactivity to increase. Burnable poison can be used to counteract this additional excess reactivity early in life and then burnout as the fuel is consumed.

Reference 61, page 1-32.

7. A

Burnable poisons do not provide for control.

Reference 34, page 300.

8. C

Reference 34, page 300.

9. B

A. The buidup of fission product poisons adds negative reactivity requiring the reduction of boron concentration. However, control rod worth does not decrease, it increases due to the increased diffusion length of thermal neutrons.

B. Fission product buildup and U-235 depletion add negative reactivity. The boron concentration must be reduced steadily to compensate for the negative reactivity and hold the reactor critical.

C. Burnable poison burnout adds positive reactivity and would require an increase in boron concentration.

D. Same as above.

Reference 61, page 5-3.

10. B

A. True, but not significant as compared to B.

B. Core excess reactivity over core life greatly affects boron concentration.

C. False statement, only slightly less.

D. True, but due to increase in boron concentration, not the other way around.

Reference 61, page 5-3.

11. D

A. Short-term adjustment.

B. and C These are maintained constant over core life (except end-of-cycle coastdown).

D. Reducing boron concentration is the primary means to compensate for fuel depletion.

Reference 61, page 5-3.

12. A

A. As boron concentration approaches zero, boron is no longer effective to compensate for fuel depletion.

B. Differential boron worth increases over core life.

C. Boron concentration has become very low.

D. The boron worth has become greater but not so much as to cause a safety concern.

Reference 61, page 5-30.

13. D

Boron concentration adjustments are needed very regularly (shiftly) to keep coolant temperature, reactor power, and control rod position at nominal values.

Reference 61, page 5-6.

14. C

A. The power defect is greater at the end of life when the moderator temperature coefficient has become more negative.

B. This is a true statement but has no bearing on the question asked.

C. Extra fuel is added to the reactor at BOL to makeup for future fuel depletion. This amounts to excess positive reactivity which is compensated for by a higher boron concentration.

D. True statement. The integral rod worth (IRW) is required to be high enough at all times to meet the reactor shutdown requirements. The limiting condition occurs at BOL, thereby restricting how high the boron concentration can be. The statement only limits the increase in boron concentration.

15. D

FUEL DEPLETION AND BURNABLE POISONS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1, 3, 4, 6

State why burnable poisons are installed in a reactor core.

K1.01 Questions 2, 7, 8

Describe the characteristics of burnable poison that relate to its use in a reactor core.

K1.01 Question 5

Explain how burnable poisons can be used to avoid a positive moderator temperature coefficient.

K1.04 Questions 9-15

Describe how and why boron concentration changes over core life.

K1.05 No questions

The effects of boration/dilution on reactivity are addressed under "Reactivity Coefficients," and it was determined that the effects are the same whether circulation is forced-flow or natural-flow.

1. Which of the following parameters should be specifically monitored and controlled during the approach to criticality?

   A. source range count rate, startup rate, and rod position

   B. source range count rate, coolant temperature, and turbine first stage pressure

   C. axial flux difference, startup rate, and source range count rate

   D. axial flux difference, steam demand, and primary temperature

2. Which of the following parameters is <u>most</u> important to closely monitor and control specifically during the approach to criticality?

   A. turbine first stage pressure
   B. startup rate
   C. primary temperature
   D. axial flux difference

3. Which of the following parameters is <u>most</u> important to closely monitor and control specifically during the approach to criticality?

   A. moderator temperature
   B. core exit thermocouple indications
   C. source range count rate
   D. axial flux difference

4. Which of the following parameters is <u>most</u> important to closely monitor and control during the approach to criticality?

   A. steam dump demand
   B. core ΔT
   C. core flow
   D. rod position

5. Which of the following parameters should be closely monitored and controlled during the approach to criticality?

   1. axial flux difference
   2. startup rate
   3. source range (neutron) count rate
   4. rod position

   A. 1, 2, 3
   B. 1, 2, 4
   C. 1, 3, 4
   D. 2, 3, 4

6. During a reactor startup, the first reactivity addition caused the count rate to increase from 20 to 40 cps. The second reactivity addition caused the count rate to increase from 40 to 160 cps.

   Which one of the following statements describes the reactivity additions?

   A. The first reactivity addition was larger.

   B. The second reactivity addition was larger.

   C. The first and second reactivity additions were equal.

   D. There is not enough data given to determine the relationship of reactivity values.

7. List three parameters that should be monitored and controlled during an approach to criticality. Explain why each is monitored.

8. Which one of the following will be controlled by an operator to add positive reactivity during a reactor startup?

   A. RCS boron and/or control rods

   B. control rods and/or moderator temperature

   C. moderator temperature and/or RCS flow

   D. RCS flow and/or RCS boron

9. Which of the following may an operator use as a means of reactivity control during an approach to criticality?

   A. doppler feedback
   B. rod movement
   C. moderator temperature adjustment
   D. moderator pressure adjustment

10. Which of the following reactivity control means is used to bring the reactor to criticality?

    A. boron addition
    B. coolant temperature reduction
    C. rod movement
    D. steaming rate adjustment

11. _________ is an acceptable reactivity control mechanism used by the operator as the reactor approaches criticality.

    A. doppler feedback control
    B. primary system temperature control
    C. soluble boron addition
    D. control rod positioning

12. Which one of the following will affect the control rod position at which criticality occurs during a reactor startup?

    A. steam dump valve controller setpoint

    B. hotwell level controller setpoint

    C. steam generator level controller setpoint

    D. the number of condensate pumps in operation

13. Which one of the following conditions will result in criticality occurring at a lower than estimated control rod position?

    A. Adjusting RCS boron concentration to 50 ppm lower than assumed for startup calculations.

    B. A malfunction resulting in control rod speed being lower than normal speed.

    C. Delaying the time of startup from 10 days to 14 days following a trip from 100% power equilibrium conditions.

    D. Misadjusting the steam dump (turbine bypass) controller such that steam pressure is maintained 50 psig higher than the required no-load setting.

14. List four parameters or mechanisms that can affect reactivity during an approach to criticality and explain the effect of each. Indicate two mechanisms that can be used by operators to control reactivity during a startup.

15. The reactor is subcritical with a reactor startup in progress. Assuming the reactor remains subcritical, a short control rod withdrawal will cause the reactor startup rate indication to increase rapidly in the positive direction, and then

    A. gradually decrease and stabilize at zero

    B. rapidly decrease and stabilize at a negative 1/3 dpm

    C. stabilize until the point of adding heat is reached; then decrease to zero

    D. continue a rapid increase until the point of adding heat is reached; then decrease to zero

16. As a subcritical reactor approaches criticality, for equal positive reactivity additions

    A. the neutron population increase is greater when k_{eff} is closer to 1.0

    B. the neutron population increase is smaller when k_{eff} is closer to 1.0

    C. the same increase in neutron population will result as k_{eff} approaches 1.0

    D. the neutron population decreases until k_{eff} exceeds 1.0

17. For equal positive reactivity additions, as k_{eff} approaches 1.0, steady-state neutron population will

    A. take longer to reach
    B. take less time to reach
    C. be reached in the same amount of time
    D. be reached instantaneously

18. While withdrawing control rods during an approach to criticality, the count rate doubles. If the same amount of reactivity that caused the first doubling is added again, the

    A. count rate will increase slightly
    B. count rate will double
    C. reactor will remain subcritical
    D. reactor will be critical

19. While withdrawing control rods during an approach to criticality, the stable count rate doubles. If the same amount of reactivity that caused the first doubling is added again, stable count rate will ___________ and the reactor will be _____________.

    A. double; subcritical
    B. more than double; supercritical
    C. double; critical
    D. more than double; critical

20. During a reactor startup, equal increments of reactivity are added and the count rate is allowed to reach equilibrium each time. Choose the statement that best describes what is observed.

    A. The time required to reach equilibrium is longer each time.

    B. The time required to reach equilibrium is shorter each time.

    C. The change in equilibrium count rate is the same each time.

    D. The change in equilibrium count rate is smaller each time.

21. During a reactor startup, equal increments of positive reactivity are sequentially added and the count rate is allowed to reach equilibrium after each addition. Which one of the following describes the equilibrium count rate after each reactivity addition?

    A. The time required to reach equilibrium count rate is the same each time.

    B. The time required to reach equilibrium count rate is shorter each time.

    C. The increase in equilibrium count rate is greater each time.

    D. The increase in equilibrium count rate is the same each time.

22. Which one of the following is the expected count rate response resulting from a short control rod withdrawal during the approach to criticality?

    A. an immediate rapid rise followed by a gradual increase to a higher steady-state value

    B. an immediate rapid rise continuing to criticality, with a higher steady-state value

    C. a gradual rise continuing to criticality, with a higher steady-state value

    D. a gradual increase followed by a rapid decrease when control rod withdrawal is stopped

23. Which one of the following statements best describes the change in count rate resulting from a short control rod withdrawal with K_{eff} at 0.99 as compared to an identical control rod withdrawal with K_{eff} at 0.95. Assume reactivity additions are equal, and the reactor remain subcritical.

    A. The prompt jump in count rate will be greater, and the increase in court rate will be greater with K_{eff} at 0.99.

    B. The prompt jump in count rate and the increase in count rate will be the same.

    C. The prompt jump in count rate will be the same, but the increase in count rate will be greater with K_{eff} at 0.99.

    D. The prompt jump in count rate will be greater with K_{eff} at 0.99, but the increase in count rate will be the same.

24. A series of rod withdrawals is made during an approach to criticality. Assuming each withdrawal inserts the same amount of reactivity, describe the effect on reactor power (neutron count rate) after each successive rod withdrawal.

25. Select the equation used to determine the subcritical multiplication factor (M) of a reactor.

    A. $M = (k_{eff} - 1)/k_{eff}$

    B. $M = \frac{\text{total neutrons}}{\text{source neutrons}}$

    C. $M = \frac{\text{source neutrons}}{\text{total neutrons}}$

    D. $M = \frac{\text{total neutrons - source neutrons}}{\text{total neutrons}}$

26. Prior to withdrawing control rods, the source range count is 220 cps. If the reactivity addition causes the subcritical multiplication factor to double, what is the final steady-state count rate following this evolution?

    A. 110 cps
    B. 320 cps
    C. 440 cps
    D. 520 cps

27. Prior to withdrawing control rods, the source range count rate is 210 cps. Following the withdrawal, the final steady-state count rate is 420 cps. What is the ratio of the subcritical multiplication factor after rod withdrawal to the subcritical multiplication factor prior to rod withdrawal?

    A. 0.5
    B. 1.0
    C. 1.5
    D. 2.0

28. If k_{eff} = 1.0, what is the subcritical multiplication factor?

    A. zero
    B. 0.5
    C. 1.0
    D. undefined

29. During an initial fuel load, the subcritical multiplication factor increases from 1.0 to 2.0 as the first 100 fuel assemblies are loaded. What is the corresponding final k_{eff}?

    A. 0.2
    B. 0.5
    C. 1.0
    D. 2.0

30. During a reactor startup, the operator adds 1,000 pcm (1.0% Δk/κ) of positive reactivity by withdrawing control rods, thereby increasing equilibrium source range neutron level from 220 cps to 440 cps. In order to raise equilibrium source range neutron level to 880 cps, an additional ______________ of positive reactivity must be added.

    A. 500 pcm (0.5% Δk/k)
    B. 1000 pcm (1.0% Δk/k)
    C. 2000 pcm (2.0% Δk/k)
    D. 4000 pcm (4.0% Δk/k)

31. During a reactor startup, control rods are withdrawn such that 1.05% Δk/k (1,050 pcm) of reactivity is added. Before the withdrawal k_{eff} was 0.97 and count rate was 500 cps. Which one of the following is the final steady-state count rate following rod withdrawal?

    A. 750 cps
    B. 1000 cps
    C. 2000 cps
    D. 2250 cps

32. During a startup, control rods are withdrawn such that the new steady-state count rate is 800 cps. If the count rate before rod withdrawal was 400 cps and K_{eff} was 0.96, what is K_{eff} following rod withdrawal?

    A. 0.970
    B. 0.975
    C. 0.980
    D. 0.985

33. During a reactor startup, control rods are withdrawn such the K_{eff} increases from 0.98 to 0.99. If the count rate before the rod withdrawal was 500 cps, which one of the following will be the final count rate?

    A. 707 cps
    B. 1000 cps
    C. 1500 cps
    D. 2000 cps

34. Explain the effect of subcritical multiplication on reactor power (neutron count rate) for a control rod withdrawal in a subcritical reactor.

35. During a reactor startup, as K_{eff} approaches 1.0, the number of source neutrons present in the reactor

    A. increases

    B. decreases

    C. remains constant

    D. increases during rod withdrawal, then returns to initial value

36. During a startup of a reactor with a source, a non-changing neutron flux over a few minutes is indicative of criticality or

    A. prompt criticality
    B. supercriticality
    C. equilibrium xenon conditions
    D. equilibrium subcritical count rate

37. As criticality is approached during a reactor startup, equal insertions of positive reactivity result in a _________ change in equilibrium count rate and a ________ time to reach each new equilibrium.

    A. smaller; shorter
    B. smaller; longer
    C. greater; shorter
    D. greater; longer

38. In a reactor with a source, a non-changing neutron flux over a few minutes is indicative of criticality or:

    A. the point of adding heat
    B. supercriticality
    C. subcriticality
    D. equilibrium subcritical count rate

39. Which one of the following statements describes count rate characteristics after a 5 second control rod withdrawal with the reactor very close to criticality? Assume the reactor remains subcritical.

    A. The count rate will rapidly increase (prompt jump) then gradually increase and stabilize at a higher value.

    B. The count rate will rapidly increase (prompt jump) then gradually decrease and stabilize at the previous value.

    C. The count rate will rapidly increase (prompt jump) and stabilize at a higher value.

    D. There will be no change in count rate until criticality is achieved.

40. The following data were obtained during a reactor startup:

Rod Position (units withdrawn)	Count Rate (CPS)
0	20
10	25
15	29
20	33
25	40
30	50

Assuming uniform differential rod worth, at what approximate rod height would you predict criticality?

    A. 25 to 35 units withdrawn
    B. 35 to 45 units withdrawn
    C. 45 to 55 units withdrawn
    D. 55 to 65 units withdrawn

41. During fuel loading, which of the following will have no effect on the shape of a 1/M plot?

    A. the location of the neutron sources in the core

    B. the location of the neutron detectors around the core

    C. the strength of the neutron sources in the core

    D. the order of placement of the fuel assemblies during loading

42. During fuel loading, which three of the following will affect the shape of a 1/M plot?

    1. the location of the neutron sources in the core

    2. the location of the neutron detectors around the core

    3. the strength of the neutron sources in the core

    4. the order of placement of the fuel assemblies during loading

    A. 1, 2, 3
    B. 1, 2, 4
    C. 1, 3, 4
    D. 2, 3, 4

43. The equation used to predict criticality by the 1/M method is

    A. $1/M = \frac{1}{1-k_{eff}}$

    B. $1/M = k_{eff} - 1$

    C. $1/M = \frac{\text{total neurons}}{\text{source neutrons}}$

    D. $1/M = \frac{\text{source neutrons}}{\text{total neutrons}}$

44. During a reactor startup, as k_{eff} increases toward criticality, the value of 1/M

    A. decreases toward zero
    B. decreases toward one
    C. increases toward infinity
    D. increases toward one

45. Using a 1/M plot, estimate the critical rod position given the following data:

Rod position (units withdrawn)	Count Rate (CPS)
0	75
10	95
20	115
30	180
40	290

46. In order to predict criticality, the excess reactivity of the core must be balanced with the reactivity associated with boron concentration, moderator temperature, xenon concentration, samarium concentration, and

A. rod position
B. iodine concentration
C. moderator void fraction
D. RCS pressure

47. In order to predict criticality, the operator must predict the amount of positive reactivity that must be added to overcome the effects of

A. boron, moderator voids, and burnable poisons

B. control rods, xenon, and moderator temperature

C. power defect, burnable poisons, and control rods

D. moderator temperature, moderator voids, and xenon

48. An estimated critical rod position (ECP) has been calculated for a reactor startup that is to be performed 6 hours after a trip from a 60 day full power run. Which one of the following events or conditions will result in the actual critical rod position being lower than the ECP?

A. The startup is delayed for approximately 2 hours.

B. The main steam header pressures are decreased by 100 psi just prior to criticality.

C. A new boron sample shows a current boron concentration 20 ppm higher than that used in the ECP calculation.

D. Steam generator feedwater addition rate is reduced by 5 percent just prior to criticality.

49. At EOL, critical rod position has been calculated for a reactor startup four hours after a trip from 100 percent power equilibrium conditions. The actual critical rod position will be <u>lower</u> than the predicted critical rod position if

A. the startup is delayed until eight hours after the trip

B. the steam dump pressure setpoint is lowered by 100 psi prior to reactor startup

C. actual boron concentration is 10 ppm more than the assumed boron concentration

D. one control rod remains fully inserted when its group is withdrawn

50. Which of the following is <u>not</u> needed to determine estimated critical boron concentration?

A. rod height

B. xenon worth at projected time of startup

C. shutdown boron concentration

D. samarium worth at projected time of startup

51. A reactor startup is being performed 15 hours after a trip from 100 percent power equilibrium conditions. Which of the following conditions would cause the actual critical rod position to be higher than the predicted critical rod position?

    A. The startup is delayed approximately two hours.

    B. A reactor coolant pump is stopped.

    C. The steam dump pressure setpoint is lowered by 100 psi.

    D. The boron concentration is increased by 10 ppm.

52. Identify the four parameters from the list below that must be considered when predicting criticality.

    I. boron concentration
    II. source strength
    III. xenon concentration
    IV. samarium concentration
    V. U-238 concentration
    VI. moderator temperature
    VII. pressurizer level

    A. I, III, IV, VI
    B. I, IV, V, VI
    C. II, IV, VI, VII
    D. III, IV, V, VII

53. Which one of the following conditions will result in criticality occurring at a lower than estimated control rod position?

    A. inadvertent dilution of reactor coolant system boron concentration

    B. a malfunction resulting in control rod speed being slower than normal speed

    C. delaying the time of startup from three hours to five hours following a trip from 100% power equilibrium conditions

    D. misadjusting the steam dump (turbine bypass) controller such that steam pressure is maintained 50 psig higher than the required no-load setting

54. Which one of the following is not required to determine the estimated critical boron concentration for a reactor startup to be performed 48 hours following an inadvertent reactor trip?

    A. reactor power level just prior to the trip

    B. steam generator levels just prior to the trip

    C. xenon reactivity in the core just prior to the trip

    D. samarium reactivity in the core just prior to the trip

55. Which one of the following conditions will result in criticality occurring at a higher than estimated control rod position?

    A. misadjusting the steam dump (turbine bypass) controller such that steam pressure is maintained 50 psig higher than the required no-load setting

    B. inadvertent dilution of RCS boron concentration during control rod withdrawal

    C. delaying the time of startup from 16 hours to 20 hours following a trip from 100% power equilibrium conditions

    D. a malfunction resulting in control rod speed being faster than normal speed

56. Listed below are several deviations between assumptions used in calculating an estimated critical rod position (ECP) and actual core conditions at the time of startup. Considering each deviation independently, state and explain its effect on the actual critical rod position relative to the ECP.

    A. boron concentration
       assumed: 400 ppm
       actual: 325 ppm

    B. time since scram from 100% equilibrium conditions
       assumed: 10 hours
       actual: 14 hours

    C. coolant temperature
       assumed: 559°F
       actual: 557°F

57. Which of the following, if changed, have the most significant effect on reactivity while the reactor is critical below the point of adding heat?

    A. coolant temperature and rod position

    B. coolant temperature and coolant pressure

    C. rod position and reactor power

    D. coolant pressure and reactor power

58. Which of the following parameter changes in a critical reactor below the point of adding heat (POAH) would cause a change in reactor power? (Assume a reactor trip does not occur.)

    A. increase pressurizer level by 5 percent

    B. decrease the number of operating reactor coolant pumps by one

    C. decrease RCS temperature 5°F

    D. increase volume control (makeup) tank level

59. A reactor that is just critical is operating at 10^{-8} amps (10^{-4} %). Which of the following methods could be used to raise reactor power to the point of adding heat (POAH)?

    A. lowering RCS pressure

    B. withdrawing control rods

    C. raising the steam dump pressure setpoint by 100 psi

    D. increasing RCS boron concentration

60. During a reactor startup, the reactor has reached criticality and power has been leveled off to record critical data. In monitoring RCS temperature, the control operator should expect temperature to

    A. increase because power is above the point of adding heat

    B. decrease because power is below the point of adding heat

    C. remain constant because power is above the point of adding heat and steam demand is constant

    D. remain constant because power is below the point of adding heat and steam demand is constant

61. The reactor is critical at 10,000 cps when a steam generator atmospheric relief valve fails open. Assume end of core life conditions, no reactor trip, and no operator actions are taken.

    When the reactor stabilizes, Tave will be __________ than the initial Tave and reactor power will be __________ the point of adding heat.

    A. greater; at
    B. greater; above
    C. less; at
    D. less; above

62. Given a reactor that is critical below the point of adding heat, how will each of the following parameter changes affect reactor power? Explain.

    a. Moderator temperatures decreases 3°F.

    b. Pressurizer level increases 5 inches.

    c. Soluble boron concentration increases 10 ppm.

    d. A single control rod drops in one step.

63. When the reactor is exactly critical, core reactivity is

    A. less than zero
    B. equal to zero
    C. equal to 1
    D. greater than 1

64. Given an initial k_{eff} = 0.99, the control operator dilutes the RCS by 30 ppm boron. Assuming boron worth is 0.01% Δk/k /ppm (10 pcm/ppm) and with no other reactivity effects, determine the final condition of the reactor. The reactor is

    A. subcritical
    B. critical
    C. supercritical
    D. prompt critical

65. A reactor is subcritical by 1.0% Δk/k. The operator dilutes the RCS by 30 ppm boron. Assuming boron worth is 0.025% Δk/k per ppm and that no other reactivity changes occur, the reactor is

    A. subcritical
    B. critical
    C. supercritical
    D. prompt critical

66. For a reactor that is exactly critical, complete the following statement to best describe the change in neutron population. The neutron population is _______ the neutron population in the previous generation. (Neglect any source neutron effect.)

    A. approximately equal to
    B. less than
    C. greater than
    D. exactly equal to

67. In a reactor that is exactly critical, k_{eff} is

    A. equal to one

    B. greater than one

    C. less than one

    D. a value that fluctuates above and below one

68. A reactor startup is in progress. The initial source range count rate prior to control rod withdrawal was 10 cps on each source range instrument. Rods were pulled. The counts have now stabilized at 20 cps. Complete the following statement to describe the size of the reactivity addition. The reactivity addition was __________ of the reactivity needed to reach criticality.

    A. less than one quarter

    B. approximately one quarter

    C. greater than one quarter, but less than one half

    D. approximately one half

69. With k_{eff} = 0.985, how much reactivity must be added to make the reactor critical?

    A. 1,480 pcm (1.48% Δk/k)
    B. 1,500 pcm (1.50% Δk/k)
    C. 1,520 pcm (1.52% Δk/k)
    D. 1,540 pcm (1.54% Δk/k)

70. During a reactor startup, a __________ with no further reactivity addition is an indication that a reactor has achieved criticality.

    A. constant positive startup rate
    B. primary temperature increase
    C. constant steaming rate
    D. pressurizer level increase

71. If, during a reactor startup, the startup rate is constant and positive without any further reactivity addition, then the reactor is

    A. exactly critical
    B. slightly supercritical
    C. slightly subcritical
    D. prompt critical

72. If a reactor is exactly critical and K_{eff} is constant, and neglecting source neutrons, the fission rate

    A. increases exponentially
    B. increases linearly
    C. is constant
    D. decreases linearly

73. An operator's first positive observable indication that criticality has been achieved occurs when the reactor is

    A. subcritical
    B. prompt critical
    C. critical
    D. supercritical

74. The reactor is critical at 10,000 cps when a S/G PORV (atmospheric relief valve) fails open. Assuming BOL conditions, no rod motion, and no reactor trip, choose the one answer below that best describes the values of Tave and nuclear power for the resulting new steady state. (POAH = point of adding heat.)

    A. final Tave greater than initial Tave, final power at POAH

    B. final Tave greater than initial Tave, final power above POAH

    C. final Tave less than initial Tave, final power at POAH

    D. final Tave less than initial Tave, final power above POAH

75. A reactor startup is being performed following a one-month shutdown period. If the reactor is taken critical and then stabilized at 10,000 cps in the source/startup range, over the next 10 minutes the count rate will

    A. remain constant
    B. decrease lineraly
    C. decrease geometrically
    D. decrease exponentially

76. If a reactor is exactly critical, and source neutrons are negligible, the startup rate is

    A. zero
    B. -1/3 DPM
    C. +1/3 DPM
    D. +1 DPM

77. Describe indications used by the operator to determine that a reactor has reached criticality.

78. During a reactor startup, the operator must make the reactor slightly supercritical to be able to determine that criticality has been attained. Why?

79. In a critical reactor below the point of adding heat, control rods are withdrawn a very short distance. Then, a minute later, rods are inserted to their original position. Reactor power would initially increase, then

    A. level off at a higher power
    B. return to initial power
    C. ramp up continuously
    D. decrease at a steady rate

80. If a reactor is exactly critical, and source neutrons are negligible, the neutron flux is

A. increasing
B. constant
C. decreasing
D. fluctuating

81. A reactor that has been shut down for one week is being started up. Control rods have been withdrawn to make keff equal to exactly one. If no further reactivity insertions are made over the next several minutes, describe how reactor power will change.

82. The reactor is critical at 10^{-8} amps (10^{-4}%). To increase power to the point of adding heat, the control operator should perform which of the following actions?

A. increase steam demand
B. withdraw control rods
C. increase boron concentration
D. decrease coolant temperature

83. During a reactor startup from a xenon-free condition, after recording critical data, the operator establishes a positive startup rate to continue increasing power. Soon power begins leveling off and the startup rate decreases toward zero, well below the expected power level for the point of adding heat. Which of the following changes might have caused this?

A. xenon buildup in the core

B. inadvertent boration

C. gradual cooling of the reactor coolant system

D. fission-induced heating of the fuel pellets

84. The reactor has just achieved criticality at 10^{-8} percent reactor power during a reactor startup from xenon-free conditions. The operator establishes a 0.5 decade per minute startup rate to increase power. After 10 minutes, startup rate decreases to zero and then becomes increasingly negative. A possible cause for these indication is

A. inadvertent boration
B. reaching the point of adding heat
C. fuel depletion
D. burnable poison burnout

85. The "point of adding heat" (POAH) is defined as that power level where the reactor is producing enough heat

A. for Doppler coefficient to produce a positive reactivity feedback

B. for void coefficient to produce a negative reactivity feedback

C. to cause a measurable temperature increase in fuel and coolant

D. to support main turbine operations

86. After recording critical data during a reactor startup, the reactor operator withdraws the control rods to continue the startup. Along with the reactor coolant system (RCS) temperature, which of the following two parameters are monitored to indicate when the reactor reaches the "point of adding heat" (POAH)?

A. RCS flow, pressurizer level
B. reactor power, reactor startup rate
C. steam pressure, turbine load
D. RCS flow, pressurizer level

87. During a reactor startup, reactor startup rate initial response to reaching the "point of adding heat" is best described as

A. increase due to increasing turbine load

B. increase due to decreasing reactor coolant system (RCS) flow

C. decrease due to decreasing RCS pressure

D. decrease due to increasing fuel temperature

88. After taking critical data during a reactor startup, the control operator begins increasing power. At the "point of adding heat," the doppler coefficient is one of the reactivity effects that will cause power initially to

A. level off
B. decrease
C. increase more rapidly
D. fluctuate

89. Explain the significance of the point of adding heat on reactor stability.

90. The point of adding heat is that power level where

A. fuel temperature equals coolant temperature

B. fission heat is observable to the operator

C. decay heat is observable to the operator

D. pump heat input surpasses ambient heat loss

91. Define the point of adding heat.

92. Which of the following parameters most significantly affects reactivity in a critical reactor below the point of adding heat?

A. coolant flow rate
B. control rod position
C. RCS pressure
D. neutron flux level

93. The reactor is critical well below the point of adding heat. Assuming a negative moderator temperature coefficient, a 5°F decrease in coolant temperature would initially cause reactor power to

A. increase
B. decrease
C. remain constant
D. fluctuate

94. If positive reactivity is added to a critical reactor well below the point of adding heat, power will increase

A. only during the reactivity addition
B. linearly
C. asymptomatically
D. exponentially

95. During a xenon-free reactor startup, critical data were inadvertently taken two decades below the required intermediate range (IR) level. The critical data were taken again at the proper IR level with the same reactor coolant temperatures and boron concentration.

The critical rod position taken at the proper IR level __________ the critical rod position taken two decades below the proper IR level.

A. is less than
B. is the same as
C. is greater than
D. cannot be compared to

96. A reactor has just achieved criticality. A subsequent 5 second rod withdrawal is performed. After the initial prompt jump, the neutron population

   A. increases linearly

   B. increases exponentially

   C. decreases to the original value

   D. levels off at the value reached during the prompt jump

97. During a xenon-free reactor startup, critical data were inadvertently taken one decade above the required intermediate range (IR) level. The critical data were taken again at the proper IR level with the same reactor coolant temperatures and boron concentration.

   The critical rod position taken at the proper IR level is __________ the critical rod position taken one decade above the proper IR level.

   A. less than
   B. the same as
   C. greater than
   D. unrelated to

98. A reactor is critical well below the point of adding heat when a small amount of positive reactivity is added to the core. If the same amount of negative reactivity is then added to the core, reactor power will level off

   A. somewhat higher than the initial power level

   B. somewhat lower than the initial power level

   C. at the initial power level

   D. at the subcritical multiplication equilibrium level

99. During a reactor startup, after reaching criticality, the operator has established a positive startup rate. Upon reaching the point of adding heat, the startup rate should

   A. double
   B. increase slowly
   C. not change until rods are inserted
   D. decrease

100. During a reactor startup, after recording critical data, the operator inserts enough positive reactivity into the core to cause power to increase. After a few minutes, power begins to level off without operator action. This is an indication of reaching the

   A. rated thermal power level

   B. DNBR safety limits

   C. design limits for fuel centerline temperature

   D. point of adding heat

101. What are the operator's indications that reactor power has reached the point of adding heat during a startup? Explain.

102. Which of the following parameters is an indication of reactor power reaching the point of adding heat?

   A. boron concentration increase
   B. startup rate increase
   C. pressurizer level increase
   D. power level increase

103. The reactor is critical below the point of adding heat with a startup rate of 0.5 decades per minute. Which one of the following will decrease first when the reactor reaches the point of adding heat?

   A. pressurizer level
   B. RCS temperature
   C. reactor power
   D. startup rate

104. After taking critical data during a reactor startup, the operator establishes a stable 1 dpm startup rate to increase power to the point of adding heat (POAH). How much negative reactivity feedback must be added at the POAH to stop the power increase?

Assume: $\bar{\beta}_{eff}$ = 0.00579

l^* = 1.0×10^{-5} sec

$\bar{\lambda}$ = 0.1 sec^{-1}

A. 0.16% Δk/k
B. 0.19% Δk/k
C. 0.23% Δk/k
D. 0.29% Δk/k

105. During a reactor startup, the first coefficient to begin inserting negative reactivity into the core at the point of adding heat is

A. doppler coefficient
B. void coefficient
C. moderator temperature coefficient
D. pressure coefficient

106. [Babcock & Wilcox reactors only] The reactor is at the point of adding heat with Tave = 532° F. The reactor operator withdraws control rods as necessary to establish and maintain a 10° F/hr heatup rate. What will reactor power be two hours after establishing the heatup rate? (Assume Tave setpoint of 582° F is reached at 15 percent power.)

A. 2 percent
B. 4 percent
C. 6 percent
D. 8 percent

107. [Babcock & Wilcox reactors only] As reactor power is increased from 0 percent to 15 percent,

A. Tave remains constant by the action of the turbine controls or turbine bypass valves

B. Tave increases due to OTSG level and secondary saturation temperature being held constant

C. Tave decreases due to increased steam flow through the turbine or turbine bypass valves

D. Tave remains constant due to increasing OTSG water levels

108. [Babcock & Wilcox reactors only] As reactor power is increased from 0 percent to 15 percent,

A. T_{hot}, T_{cold}, and T_{ave} all increase

B. T_{hot} and T_{ave} increase while T_{cold} is held constant

C. T_{hot} increases, T_{ave} is held constant, and T_{cold} decreases

D. T_{hot} increases while T_{ave} and T_{cold} both decrease

109. [Babcock & Wilcox reactors only] Which of the following statements is not true concerning power increase from 0 percent to 15 percent?

A. The heat transfer area in the OTSG is held constant by maintaining low level limits.

B. The saturation temperature on the secondary side of the OTSG is held constant.

C. OTSG steam pressure is increased to allow T_{ave} to reach setpoint.

D. T_{ave} will increase as power is increased.

110. [Babcock & Wilcox reactors only] As reactor power is increased from 0 percent to 15 percent, T_{ave} increases because

    A. OTSG level and saturation temperature both increase

    B. OTSG level and saturation temperature both decrease

    C. OTSG level is held constant and OTSG saturation temperature increases

    D. OTSG level and saturation temperature are both held constant

111. During a reactor startup after a refueling outage, which of the following coefficients is the most predominant in [illegible] power when above the point of ad[illegible]eat (POAH)?

    A. moderator temperature
    B. fuel temperature
    C. isothermal temperature
    D. void fraction

112. After taking critical data, the reactor operator pulls rods and establishes a positive .25 DPM startup rate. Which of the following best describes the final power level of the reactor, assuming no operator action and a constant xenon concentration?

    A. above the point of adding heat and stable

    B. below the point of adding heat and stable

    C. above the point of adding heat and increasing

    D. below the point of adding heat and decreasing

113. A reactor is operating just above the point of adding heat. In order to raise reactor power to a higher stable power level, the operator must increase

    A. steam generator levels

    B. steam demand

    C. Tave

    D. reactor coolant system boron concentration

114. Given a critical reactor operating below the point of adding heat, what reactivity effects are associated with reaching the point of adding heat?

    A. There are no reactivity effects since the reactor is critical.

    B. The increase in fuel temperature will begin to create a positive reactivity effect.

    C. The decrease in fuel temperature will begin to create a negative reactivity effect.

    D. The increase in fuel temperature will begin to create a negative reactivity effect.

115. A reactor nearing end-of-life is at 5×10^{-6} amps (5×10^{-2}%) with a 0.3 DPM startup rate. With no operator action, if these conditions were allowed to continue, what would final plant conditions be 10 minutes later?

    A. reactor power above the point of adding heat and stable

    B. reactor power above the point of adding heat and increasing at the same rate

    C. reactor power below the point of adding heat and stable

    D. reactor power below the point of adding heat and increasing at the same rate

116. Given a reactor with the following parameters:

    boron concentration = 200 ppm
    reactor power = 10^{-6} amps (10^{-2}%)
    startup rate = 0.25 DPM and stable
    coolant temperature = 555°F and stable

    If the operator took no further action, how will these parameters change before stabilizing?

117. [Not applicable to Babcock & Wilcox reactors.] During power operation, pulling control rods (while maintaining constant steam demand) will result in a new steady-state condition in which

    A. Tave is higher

    B. reactor coolant system pressure is lower

    C. reactor power is higher

    D. pressurizer level is lower

118. The reactor is operating at 100 percent reactor power at the end of core life with all control systems in manual. The reactor operator inadvertently adds 10 gallons of boric acid to the Reactor Coolant System (RCS).

    Which of the following will occur as a result of the boric acid addition? (Assume megawatt output remains constant.)

    A. RCS pressure will increase and stabilize at a higher value

    B. reactor power will decrease and stabilize at a lower value

    C. T_{ave} will increase and stabilize at a higher value.

    D. pressurizer level will decrease and stabilize at a lower value.

119. The reactor is operating at 80 percent power. Over the next seven hours, power is ramped up to 100 percent at a rate of 3 percent per hour. The initial boron concentration was reduced by 30 ppm during the power increase. Given the following data, determine the net reactivity in the core with power stable at 100 percent.

    Power defect = -1.5% Δk/k = -1,500 pcm
    Moderator temperature coefficient = -5 x 10^{-3}% Δk/k/°F = -5 pcm/°F
    Differential boron worth = -1 x 10^{-2}% Δk/k/ppm = -10 pcm/ppm

    A. -1.5% Δk/k = -1,500 pcm
    B. -0.3% Δk/k = -300 pcm
    C. 0% Δk/k = 0 pcm
    D. +0.03% Δk/k = +30 pcm

120. From the items listed below, select the one that best describes the effect of boron dilution on a reactor that is operating at 60 percent reactor power. Assume turbine load and rod position remain constant. Reactor power will initially

    A. increase, causing reactor coolant system (RCS) average temperature to increase, which, in turn, will cause reactor power to decrease to a new power level below 60 percent

    B. increase, causing RCS average temperature to increase, which, in turn, will cause reactor power to decrease to approximately 60 percent power

    C. decrease, causing RCS average temperature to decrease, which, in turn, will cause reactor power to increase to approximately 60 percent power

    D. decrease, causing RCS average temperature to increase, which, in turn, will cause reactor power to increase to a new power level above 60 percent power

121. During 100 percent power operations, the reactor operator added 100 gallons of dilution water. The rod control system, in automatic, inserted the control rods to match Tave with its initial value. Which of the following best describes the reactivity changes associated with this transient?

    A. The positive reactivity added due to the boron dilution was greater than the negative reactivity added due to the rod insertion.

    B. The negative reactivity added due to the boron dilution is equal to the positive reactivity added due to the rod insertion.

    C. The positive reactivity added due to the boron dilution was less than the negative reactivity added due to rod insertion.

    D. The positive reactivity added due to the boron dilution was equal to the negative reactivity added due to the rod insertion.

122. The plant is operating at equilibrium 50 percent power level. Control rods are manually withdrawn for 5 seconds. When plant parameters have stabilized

    A. coolant temperature will be higher

    B. reactor (primary) coolant system pressure will be lower

    C. reactor power will be higher

    D. pressurizer level will be lower

123. [Not applicable to Babcock & Wilcox reactors.] During power ascension to 100 percent power, reactor power is increased by increasing turbine load. Which of the following best describes the reactor operator's role in the power increase?

    A. Use reactor coolant system (RCS) dilution and rod motion to maintain desired Tave.

    B Use RCS boration and rod motion to maintain desired Tave.

    C. Prevent rod motion by slowly increasing load.

    D. Use rod motion alone to maintain desired Tave.

124. [Not applicable to Babcock & Wilcox reactors.] A reactor is operating at steady-state 50 percent power when steam flow is increased by 5 percent. Assuming all control systems function normally on automatic, no protective systems actuate, and no operator action, which of the below listed parameters will typically have <u>increased</u> when steady-state conditions are again established?

    A. reactor coolant system boron concentration

    B. reactor coolant system flow

    C. steam generator steam temperature

    D. hot leg coolant temperature

125. Which of the following statements best describes the actions required to return the unit to full power from 70 percent?

A. Increase steam flow to the main turbine, pull control rods to establish a positive startup rate, then reinsert control rods to their initial position to ensure the reactor is just critical.

B. Increase steam flow to the main turbine, then pull control rods and/or dilute the reactor coolant system (RCS) to add enough positive reactivity to offset the remainder of the power defect.

C. Increase steam flow to the main turbine, then borate the RCS as necessary to maintain T_{ave} on program.

D. Increase steam flow to the main turbine, insert rods to offset the positive reactivity added due to the power increase.

126. A typical PWR inherently displays automatic load-following behavior. Changes in which of the following parameters is most responsible for initiating this behavior?

A. steam generator feed flow
B. steam generator steam flow
C. reactor coolant system loop flow
D. core bypass flow

127. A reactor is operating at 90 percent power steady-state. Steam flow is then decreased with all systems in automatic. Reactor power will

A. increase to a new, higher value

B. increase temporarily, then return to its initial value

C. decrease to a new, lower value

D. decrease temporarily, then return to its initial value

128. How do the following parameters change during a normal ramp of reactor power from 15 percent to 75 percent?

	Turbine First-Stage Pressure	RCS Boron Concentration
A.	Increase	Decrease
B.	Decrease	Decrease
C.	Increase	Increase
D.	Decrease	Increase

129. The reactor is critical at 2×10^{-7} percent power. The operator withdraws rods to establish a constant 0.10 DPM startup rate. How long will it take for the reactor power to reach 7×10^{-7} percent power?

A. 2.5 minutes
B. 5.5 minutes
C. 7.4 minutes
D. 10.5 minutes

130. If reactor power changes one decade in 5 minutes due to rod motion, the reactor period would be ______ seconds. (Assume the reactor is below the point of adding heat.)

A. 30 seconds
B. 80 seconds
C. 130 seconds
D. 300 seconds

131. The reactor is critical below the point of adding heat. A group of control rods falls into the core, inserting 5% Δk/k negative reactivity (-5,000 pcm). The resultant stable startup rate will be approximately

A. -0.1 DPM
B. -0.2 DPM
C. -0.3 DPM
D. -0.4 DPM

132. A reactor is at 50 percent power, steady-state, and the rods are withdrawn 1 percent of full rod travel. Assuming no further operator or automatic actions, what will the condition of the reactor be after the power transient has terminated?

A. Power will not be changed significantly. Tave will increase.

B. Power will not be changed significantly. Tave will decrease.

C. Power will increase significantly. Tave will increase.

D. Power will decrease significantly. Tave will decrease.

133. A reactor is operating in steady-state at 80% power. The operator then dilutes boron concentration from 450 ppm to 430 ppm. What effect will this have on the reactor with control rods in manual? In automatic? Explain.

134. A reactor has been operating at 100 percent power for several weeks with power production symmetrically distributed axially above and below the core midplane. Reactor power is reduced to 50 percent using boration to control Tave while maintaining control rods fully withdrawn.

The axial power distribution will

A. shift toward the top of the core

B. shift toward the bottom of the core

C. remain evenly distributed above and below the core midplane

D. peak at the top and the bottom of the core

135. The reactor is operating at 100 percent power, BOL, with equilibrium xenon conditions. Reactor power is reduced, within a one day period, to 50 percent by boration only. Control rods are maintained fully withdrawn. The following parameter values are given

	Prior to Power Change	After Power Change
Reactor power:	100%	50%
Average coolant temperature:	580°F	565°F
RCS boron concentration:	740 ppm	820 ppm
Control rod position:	fully withdrawn	fully withdrawn

What is the effect on power distribution in the core during the first 8 hours following the power reduction?

A. There is no relative change in power distribution in the core.

B. Power production in the top of the core increases relative to the bottom.

C. Power production in the top of the core decreases relative to the bottom.

D. It is impossible to determine without additional information

136. The reactor is at 90 perc power, steady-state, when an inadvertent boron dilution of 10 ppm occurs. Assuming no automatic or operator action, which statement below best describes the reactor response from steady- state to steady-state?

A. Power increases. Tave increases.

B. Power decreases. Tave decreases.

C. Power remains constant. Tave increases.

D. Power remains constant. Tave decreases.

137. A reactor startup is in progress and criticality has just been achieved. After recording critical rod height, the operator withdraws control rods for 20 seconds to establish a 1 dpm startup rate (SUR). One minute later (prior to the point of adding heat) the operator inserts the same control rods for 30 seconds.

During the insertion, the SUR will become

A. zero during the entire period of control rod insertion

B. negative after the control rods pass through the critical rod height

C. negative just as the control rods pass through the critical rod height

D. negative prior to control rods passing through the critical rod height

138. A reactor has been operating at 80 percent power for several weeks with power production symmetrically distributed axially above and below the core midplane. Reactor power is increased to 100 percent using dilution to control T_{ave} while maintaining control rods fully withdrawn.

During the power increase, axial power distribution will

A. shift toward the top of the core

B. shift toward the bottom of the core

C. remain evenly distributed above and below the core midplane

D. peak at the top and the bottom of the core

139. The reactor is operating at 75 percent power, steady-state, when a partial steam line break occurs and 3 percent total steam flow is escaping. Assuming no operator or automatic action, which statement best describes the reactc response?

A. Power will decrease to a value less than 75 percent. T_{ave} will decrease to a new lower value.

B. Power will increase to a value greater than 75 percent. T_{ave} will decrease to a new lower value.

C. Power will not change. T_{ave} will increase to a new higher value.

D. Power will increase to a value greater than 75 percent. T_{ave} will increase to a new higher value.

140. The reactor has been operating at 75 percent power for several weeks. A partial steam line break occurs and 3 percent total steam flow is escaping. Assuming no operator or automatic actions, stable reactor power will __________ and stable reactor coolant temperature will __________.

A. increase; increase
B. not change; increase
C. increase; decrease
D. not change; decrease

141. The reactor is critical at a stable power level below the point of adding heat. An unisolable steam line break occurs and 3 percent of rated steam flow is escaping. Assuming no reactor trip, which one of the following describes the response of the reactor? (Assume a negative moderator temperature coefficient.)

A. The reactor will go subcritical. T_{ave} will decrease

B. The reactor will go to 3 percent power. T_{ave} will increase.

C. The reactor will go to 3 percent power. T_{ave} will decrease.

D. Power will not change because the reactor was below the point of adding heat. T_{ave} will increase.

142. The reactor is at normal operating temperature and subcritical with a K_{eff} of .999 when a steam dump fails open. Assuming no operator or automatic action, which statement below best describes the reactor response? (Assume a negative moderator temperature coefficient.)

   A. K_{eff} will drop below .999.

   B. Reactor power will increase to the point of adding heat and level out.

   C. Source range instruments will decrease and level out.

   D. Power will increase to match steam flow.

143. The reactor is operating at 75 percent power, steady-state.

   A 10 percent step load decrease on the turbine occurs. Assuming no automatic or operator action, which statement best describes the plant response.

   T_{ave} will ________. Power will ________.

   A. increase, decrease
   B. increase, increase
   C. decrease, decrease
   D. decrease, increase

144. Explain the statement, "Power follows steam demand."

145. A reactor is operating at 50 percent power with a negative moderator temperature coefficient and rods in manual. Steam flow is then increased by 5 percent. Which of the following statements best describes how reactor power will respond to this change? Reactor power will

   A. increase to a new higher value

   B. increase temporarily, then return to its initial value

   C. decrease to a new lower value

   D. decrease temporarily, then return to its initial value

146. Which one of the following conditions will initially result in a positive startup rate when the reactor is at power?

   A. increase in turbine loading

   B. unintentional boration

   C. turbine runback

   D. accidental closure of a main steam isolation valve

147. A high boron concentration is necessary at the beginning of core life to:

   A. compensate for excess reactivity in the fuel

   B. ensure a negative moderator temperature coefficient exists

   C. flatten the axial and radial neutron flux distributions

   D. maximize control rod worth until fission product poisons accumulate

148. Increasing the reactor coolant system boron concentration will allow

   A. more fresh fuel to be loaded during refueling

   B. a longer core life using less fuel

   C. the reactor to operate with rods inserted further

   D. the reactor to operate with a lower dissolved lithium concentration

149. An increase in soluble boron concentration allows core life to be extended by an increase in

A. thermal utilization factor
B. amount of fuel loaded
C. reactor coolant system flow
D. heat transfer of the steam generator

150. The use of boron as a burnable poison in a reactor core

A. increases the amount of fuel required to produce the same amount of heat

B. allows the plant to operate longer on a smaller amount of fuel

C. allows more fuel to be loaded and prolongs core life

D. absorbs neutrons that would otherwise be lost from the core

151. The major reason boron is used in a reactor is to permit

A. a reduction in the shutdown margin

B. an increse in the amount of control rods installed

C. an increase in core life

D. a reduction in the effect of resonance capture

152. A reactor that has been operating at 100 percent power, steady-state, trips, dropping rods worth 10 percent Δk/k (10,000 pcm) into the core. This will cause an immediate prompt drop in reactor power to approximately _______ percent, followed by a slower decrease.

A. 18
B. 12
C. 6
D. 1.8

153. Shortly after a reactor trip, reactor power indicates 10^{-8} amps. How long will it take power to be reduced to 10^{-9} amps?

A. 3 seconds
B. 80 seconds
C. 180 seconds
D. 220 seconds

154. Shortly after a reactor trip, reactor power indicates 0.5 percent where a stable negative SUR is attained. Reactor power will be reduced to 0.05 percent in approximately ______ seconds.

A. 90
B. 180
C. 270
D. 360

155. The reactor has been operating at 100 percent power for several weeks when a reactor trip occurs. How much time will be required for core heat production to decrease to 1.0 percent following the trip?

A. 4 to 8 seconds
B. 4 to 8 minutes
C. 4 to 8 hours
D. 4 to 8 days

156. Which of the following is responsible for the negative 80-second stable reactor period experienced shortly after a reactor scram/trip?

A. the longest-lived fission product poisons

B. the shortest-lived fission product poisons

C. the longest-lived delayed neutron precursors

D. the shortest-lived delayed neutron precursors

157. When does the power decrease rate initially stabilize at negative one-third decade per minute following a reactor trip?

A. when decay gamma heating starts adding negative reactivity

B. when the long-lived delayed neutron precursors have decayed away

C. when the installed neutron source contribution to the total neutron flux becomes significant

D. when the short-lived delayed neutron precursors have decayed away

158. Which equation below best describes the decrease in reactor power (neutron flux) from Point A to Point B in Figure 2.8-1?

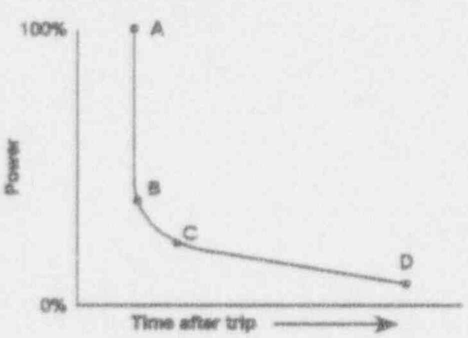
A. $T = (\overline{\beta}_{eff} - \rho) / \overline{\lambda}\rho$

B. $P = P_o e^{t/T}$

C. $P = P_o 10^{SUR(t)}$

D. $P = P_o \overline{\beta}_{eff} / (\overline{\beta}_{eff} - \rho)$

FIGURE 2.8-1



Reactor Power Versus Time After Trip

159. Figure 2.8-1 shows the response of reactor power to a scram from 100 percent power. Explain the shape of the curve between points A and B, B and C, and C and D.

160. Which equation below best describes the decrease in neutron power in the core from Point C to Point D in Figure 2.8-1?

A. $T = (\overline{\beta}_{eff} - \rho) / \overline{\lambda}\rho$

B. $P = P_o e^{t/T}$

C. $P = P_o \overline{\beta}_{eff} / (\overline{\beta}_{eff} - \rho)$

D. $T = l^*/\rho$

161. Beta effective decreases over core life. Which of the following statements best describes the results of this change on the power response after a reactor trip late in life compared to early in life? Later in core life, the prompt drop causes power to fall immediately to

A. a larger value; power then decreases at a slower rate than early in life

B. the same value; power then decreases at a faster rate than early in life

C. the same value; power then decreases on the same stable period (startup rate) as early in life

D. a smaller value; power then decreases on the same stable period (startup rate) as early in life

162. The reactor is exactly critical below the point of adding heat, with the operator taking critical data. A single rod is accidentally inserted into the core. Assume no operator or automatic action. Which statement best describes the response of the plant?

   A. Power will increase. T_{ave} will increase.

   B. Power will decrease. T_{ave} will increase.

   C. Power will not change. T_{ave} will not change.

   D. Power will decrease. T_{ave} will not change.

163. The reactor is at 100 percent power, steady-state, when the operator inserts the control rods slightly. The reactivity insertion is countered by dilution of boron. Which of the statements below best describes the response of the reactor power.

   A. Power will shift toward the upper region of the core.

   B. Power will shift toward the lower region of the core.

   C. The axial power profile will not change. T_{ave} will decrease.

   D. The radial power profile will not change. T_{ave} will increase.

164. The reactor is exactly critical below the point of adding heat when a single control rod is fully inserted into the core. Assuming no operator or automatic action, reactor power will slowly decrease to

   A. zero

   B. an equilibrium value less than the source neutron strength

   C. an equilibrium value greater than the source neutron strength

   D. a slightly lower value, then slowly increase to the initial value

165. A reactor is operating at 10 percent power during a reactor startup when a control rod is inserted, which results in a stable negative 80-second reactor period. Assuming a constant period since rod insertion, which of the following is the reactor power level two minutes after rod insertion?

   A. 2.2 percent
   B. 3.2 percent
   C. 4.9 percent
   D. 5.4 percent

166. A reactor is operating at 50% power when the operator inserts control rods a short distance. How will reactor power respond, and how will the new steady-state power level compare to the initial power?

167. What is the reason for inserting control rods in a predetermined sequence during a normal reactor shutdown?

   A. to prevent uneven fuel burnup

   B. to prevent an excessive RCS cooldown rate

   C. to prevent abnormally high local power peaks

   D. to prevent divergent xenon oscillations

168. The primary source of decay heat production is the

   A. fission reaction
   B. fuel cladding
   C. activation products
   D. fission products

169. The most significant amount of heat generated by the core after shutdown is produced by

A. prompt neutrons
B. delayed neutrons
C. gamma and beta decay
D. alpha and neutron emission

170. After one month of operation at 100 percent reactor power, the fraction of thermal power being produced from the decay of fission products in the operating reactor is

A. greater than 10 percent

B. greater than five percent but less than 10 percent

C. greater than 1 percent but less than five percent

D. less than one percent

171. The heat generated by the core after shutdown is referred to as _________ heat.

A. latent
B. pump
C. delayed
D. decay

172. Reactor coolant temperature is being maintained at 500°F one week following an normal shutdown from several months of operation at 100 percent power. All reactor coolant pumps are operating. The primary source of heat input to the reactor coolant is from

A. reactor coolant pumps
B. fission of activated U-235 and Pu-239
C. spontaneous fission
D. fission product decay

173. The largest source of heat generated by the core after shutdown after an extended run at full power is

A. delayed neutrons
B. fission product decay
C. spontaneous fission from plutonium
D. fissions from source neutrons

174. The major reason for the increase in decay heat over core life is increased

A. fission product activity
B. spontaneous fissions
C. production of plutonium
D. neutron flux

175. The reactor trips after an extended run at full power. Ten minutes after the trip, decay heat will produce approximately ________ percent of full power.

A. 10^{-5}
B. 2
C. 7
D. 15

176. Reactor "A" is operating at 50 percent power and Reactor "B" is operating at 100 percent power. They are otherwise identical. Following a trip/ scram, decay heat in the two reactors will be

A. the same in both initially, but decay at different rates

B. higher in "A" than in "B", and decay at different rates

C. higher in "B" than in "A", and decay at the same rate

D. the same in both initially, and decay at the same rate

177. Following a reactor trip or shutdown from continuous full-power operation, post-trip heat removal is required for

A. hours
B. days
C. months
D. years

178. The magnitude of decay heat generation is determined primarily by

A. core age
B. power history
C. final power at shutdown
D. emergency core cooling capability

179. A reactor is operating at 100% equilibrium conditions when a scram occurs. Contrast the response of neutron-generated power to the total thermal output of the core during and after the scram.

180. The reactor is critical at a stable power level below the point of adding heat (POAH) when a small amount of positive reactivity is added. Which of the following reactivity coefficient(s) will stabilize reactor power at the POAH?

A. moderator temperature only

B. fuel temperature only

C. moderator temperature and fuel temperature

D. fuel temperature and voids

181. The reactor is operating with the following initial conditions:

Power level	=	100%
Coolant boron	=	620 ppm
Coolant temperature	=	587°F

After a load decrease reactor conditions are as follows:

Power level	=	80%
Coolant boron	=	650 ppm
Coolant temperature	=	577°F

Given the following values, how much reactivity was added by control rod movement during the load decrease? (Assume fission product poison reactivity does not change.)

Total power coefficient
$= -1.5 \times 10^{-2}\%\ \Delta K/K/\%$
Moderator temperature coefficient
$= -2.0 \times 10^{-2}\%\ \Delta K/K/°F$
Differential boron worth
$= -1.0 \times 10^{-2}\%\ \Delta K/K/ppm$

A. -0.0% ΔK/K
B. -0.2% ΔK/K
C. -0.6% ΔK/K
D. -0.8% ΔK/K

182. Which of the following indicates that the reactor has achieved criticality during a normal reactor startup?

A. constant positive startup rate during rod withdrawal

B. increasing positive startup rate during rod withdrawal

C. constant positive startup rate with no rod motion

D. Increasing positive startup rate with no rod motion

183. A reactor near the end of core life is at $5 \times 10^{-2}\%$ power with a 0.3 dpm startup rate. With no operator action, what will be the approximate reactor power 10 minutes later? (Assume no protective system actuation.)

A. 1% (point of adding heat)
B. 10%
C. 50%
D. 100%

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

These are the specific parameters that must be monitored and controlled during the approach to criticality.

Reference 61, page 9-15.

2. B

Startup rate indication monitors the rate of change of power.

Reference 61, page 9-15.

3. C

Source range count rate is a direct indication of core neutron flux.

Reference 61, page 9-15.

4. D

Rod position must be monitored to ensure group insertion limits and rod alignment limits are not exceeded.

Reference 61, page 9-15.

5. D

Axial flux difference is not on-scale (power range) at this plant condition.

Reference 61, page 9-15.

6. A

In a subcritical reactor, when the reactivity added is the same as that in the previous step which had made the count rate double, the reactor will go critical. The subsequent count rate will continue to rise linearly. Since this did not happen, the second reactivity addition must be less than the first.

Reference 61, page 9-10.

7.

Three parameters monitored and controlled during an approach to criticality are:

1. control rod position - Rods provide the most direct means of reactivity control available to the operator. Rod position must be observed to ensure criticality is attained within the limits determined in the estimated critical position (condition) calculation. Also, proper rod motion and overlap must be verified.
2. source range neutron count rate - This measure of reactor power reflects the effects of reactivity insertions, provides a means of predicting criticality (through count rate doubling and 1/M plots), and serves as an indicator of having reached criticality.
3. startup rate - This is a measure of the rate of change of the neutron level. A constant positive SUR with no rod motion indicates that criticality has been reached and the reactor is supercritical.

Reference 61, page 9-15.

8. A

Boration/dilution can be used in this plant condition as a reactivity control mechanism.

Reference 18, pages 293 and 301.

9. B

Control rod movement is directly used as a reactivity control mechanism for reactor startup.

Reference 18, page 325.

10. C

Rod movement is used for startup.

Reference 18, page 325.

11. D

Control rod movement is a direct reactivity control mechanism for this plant condition.

Reference 18, page 325.

12. A

During a startup, the steam dump valve controller controls reactor coolant temperature, and changes in moderator temperature will insert reactivity, altering the critical rod height.

13. A

In A, the boron concentration reduction, which adds positive reactivity, lowers the shutdown margin permitting criticality to be achieved at a lower control rod position. In B, the speed of the control rod movement only affects the rate at which reactivity is being added not the final amount. In C, the effects of xenon will have decayed to negligible amounts at 10 or 14 days. The buildup difference of samarium will be small and since negative reactivity is being added the critical control rod position must be higher. In D, a higher steam pressure control setpoint increases the average coolant temperature in the core adding negative reactivity. This requires that the critical control rod position be higher.

Reference 61, chapter 9.

14.

Factors affecting reactivity are:

1. control rod position - Rod withdrawal reduces neutron absorption in poisons, inserting positive reactivity. Rods are most often used as the operators' reactivity control mechanism during startups.

2. soluble boron concentration - Dilution of RCS boron removes poisons from the core, inserting positive reactivity. Boron dilution is a mechanism of reactivity control available to operators.

3. moderator temperature - Assuming a negative moderator temperature coefficient, a reduction in moderator temperature inserts positive reactivity by improving neutron moderation.

4. fuel temperature - An increase in the temperature of the fuel pellets inserts negative reactivity due to the doppler effect.

5. xenon concentration - xenon-135 is a fission product poison that increases shortly after shutdown, then decreases, inserting negative, then positive, reactivity. If a reactor is started up soon after a shutdown, these reactivity effects may take place.

15. A

The rod withdrawal reduces the fraction of neutrons lost each generation, allowing neutron population (and power) to increase to a new subcritical equilibrium level. Startup rate will become positive, then decline to zero when power reaches this new equilibrium level.

16. A

More significant generations are produced as K_{eff} approaches 1.0.

Reference 56, page 8-54.

17. A

More time is required for an increased number of generations and increased effect of longer-lived precursor production of delayed neutrons.

Reference 56, page 8-54.

18. D

Doubling counts means halving the distance to criticality. Adding the same amount of reactivity again will make the reactor critical $C_2/C_1 = (1-K_{eff_1}) / (1-K_{eff_2})$

Reference 07, page 5-9.

19. B

Reference 56, page 8-56.

20. A

With each added increment, more neutron generations are produced. Therefore, it takes longer to reach equilibrium.

Reference 56, page 8-54.

21. C

Each equal increment increases core reactivity, resulting in more neutron generations. The inverse relationship between the subcritical reactivity condition of the reactor and the neutron population (source multiplication) requires longer and longer times to reach equilibrium. Therefore, for each increment, the increase in equilibrium level is greater.

Reference 56, page 8-54.

22. A

Prompt neutrons react immediately to the insertion of positive reactivity, but, because the reactor remains subcritical, the count rate soon levels off to a new subcritical equilibrium value.

Reference 56, page 8-54.

23. A

Reference 56, page 8-54.

24.

When rods are withdrawn, count rate increases sharply (the "prompt jump") as prompt neutrons respond to the insertion of positive reactivity. Count rate then gradually levels off at a value determined by Keff and the source strength. Each subsequent withdrawal causes a larger increase in count rate and requires a longer time to reach the new equilibrium value.

Reference 56, page 8-54.

25. B

Reference 56, page 8-27.

26. C

$M = C_i / C_o$

$M_2 / M_1 = C_2 / C_1$

$2 = C_2 / 220$ cps

$C_2 = 440$ cps

Reference 56, page 8-16.

27. D

Mathematical Relationship

$M = C_i / C_o$

Reference 56, page 8-27.

28. D

Reference 56, page 8-20.

29. B

$2 = 1/(1-K_{eff})$

$2 - 2\,K_{eff} = 1$

$-2\,K_{eff} = -1$

$K_{eff} = 1/2 = 0.5$

Reference 56, page 8-27.

30. A

The initial insertion of 1,000 pcm caused count rate to double. Therefore, this reactivity insertion halved the distance to criticality. (Net reactivity increased from -2,000 pcm to -1,000 pcm).

To double the count rate again (from 440 cps to 880 cps), the distance to criticality must be halved again. This requires insertion of +500 pcm. (Net reactivity increases from -1,000 pcm to -500 pcm.)

31. A

$CR_1\,(1-k_1) = CR_2\,(1-k_2)$

$CR_2 = CR_1\,(1-k_1)/(1-k_2)$

$CR_1 = 500$ cps
$k_1 = 0.97$

Determination of k_2:

$\rho = (k-1)/k$

$\rho_1 = (0.97-1)/0.97$
$= -3.093\%\ \Delta k/k$

$\rho_2 = \rho_1 + \Delta\rho$
$= -3.093\% + 1.050\%$
$= -2.043\%\ \Delta K/K$

$k_2 = 1/(1-\rho_2)$
$= 1/(1-(-.02043))$
$= 0.98$

Therefore,

$CR_2 = (500\ \text{cps})\,(1-0.97)/(1-0.98)$
$= 750$ cps

32. C

$CR_1 (1-k_1) = CR_2 (1-k_2)$

$k_2 = 1 - (CR1/CR2)(1-k_1)$
$= 1 - (400/800)(1-0.96)$
$= 0.980$

Or, the answer can be found simply by using the relationship that doubling the count rate halves the margin to criticality (1-keff).

33. B

$$\frac{CR_2}{CR_1} = \frac{1-k_1}{1-k_2}$$

$$CR_2 = CR_1 \frac{(1-k_1)}{(1-k_2)}$$

$$= 500cps \frac{(1-0.98)}{(1-0.99)}$$

$$= 1000 \text{ cps}$$

Reference 61, page 9-10

34.

Assuming equilibrium initial conditions, count rate will be constant at a level determined by keff and the strength of the neutron source(s). At this equilibrium level the loss of neutrons from each generation in the subcritical fission process is balanced by the appearance of source neutrons, resulting in a constant neutron population. When rods are withdrawn, the insertion of positive reactivity results in fewer neutrons being lost in each generation. Because the source strength is unchanged, there will be a net increase in neutron population each generation, causing count rate to increase. Eventually, the neutron population will grow to a level at which losses from fission in each generation are again balanced by the source input. A new equilibrium will then exist at this higher count rate.

Reference 56, pages 8-12 to 8-20.

35. C

Source strength is independent of K_{eff} or current power levels.

Reference 56, page 8-4.

36. D

A non-changing flux can be caused by either subcritical multiplication (resulting in an equilibrium subcritical count rate) or criticality.

Reference 56, pages 8-12 through 8-16.

37. D

Each subsequent insertion of reactivity increases k_{eff} toward a value of one and produces more neutrons per generation. This increases the equilibrium count rate and also requires a longer time to reach equilibrium because later generations now make a significant contribution.

Reference 56, page 8-51.

38. D

At low neutron levels, a non-changing neutron flux or count rate can occur only with the reactor subcritical. At high neutron levels, a non-changing neutron flux can occur only when the reactor is critical. The source effects on the neutron flux are negligible.

Reference 56, pages 8-12 through 8-16.

39. A

The rod withdrawal reduces the fraction of neutrons lost each generation, allowing neutron population and count rate to increase, quickly at first (as prompt neutrons appear), then more gradually (as delayed neutrons appear). Eventually, a new subcritical equilibrium is reached.

Reference 56, page 8-54.

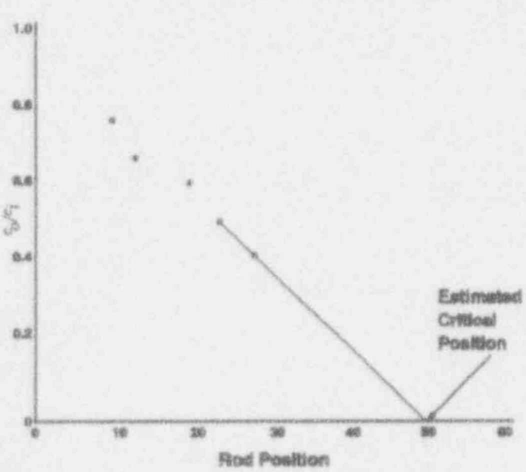
40. C

To construct a 1/M plot, find the ratio of the initial count rate to each count rate:

i	c_i	c_o/c_i
0	20	1.00
1	25	0.80
2	29	0.69
3	33	0.61
4	40	0.50
5	50	0.40

Next, plot these ratios against the related rod position. Finally, extrapolate from the final two data points to the "x" axis to estimate critical rod position, as shown in Figure 2.8-2.

FIGURE 2.8-2



1/M Plot

Reference 56, pages 8-20 through 8-47.

41. C

Source strength is a constant for the duration of the 1/M plot and, therefore, doesn't change the shape of the plot.

Reference 56, pages 8-28 through 8-33.

42. B

Source to detector to fuel geometry directly affects data obtained due to what is "seen" by the detector. The detector's count rate should be representative of the total number of neutrons in the core (fuel). Strength of sources is a constant from commencing loading to completion and, therefore, doesn't affect the shape of the 1/M plot.

Reference 56, pages 8-28 through 8-33.

43. D

Reference 56, page 8-27.

44. A

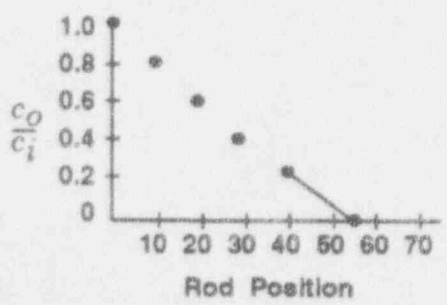
Since $1/M = 1 - K_{eff}$, then $1/M = 0$ when $K_{eff} = 1$ by this equation.

Reference 56, pages 8-28 through 8-33.

45.

i	c_i	c_o/c_i
0	75	1.0
10	95	0.79
20	115	0.65
30	180	0.42
40	290	0.26

FIGURE 2.8-3



1/M Plot

Extrapolating a straight line onto the x-axis results in an estimated critical rod position of 55 units.

Reference 56, pages 8-20 through 8-47.

46. A

Rod position is the only selection that represents a significant reactivity contribution in the approach to criticality.

Reference 61, pages 7-4 and 7-5.

47. B

Neither samarium burnout, moderator voids, nor negative reactivity associated with power defect come into play until after power reaches the point of adding heat.

48. B

The reduced steam header pressure and saturation temperature causes a lower reactor coolant temperature to exist. This positive reactivity effect reduces shutdown margin and permits the reactor to go critical below the ECP.

Reference 61, page 7-24.

49. B

Lowering the steam dump pressure setpoint lowers primary system temperature, which, in turn, results in positive reactivity via MTC. To compensate, actual critical rod height must be lower.

Reference 61, pages 7-4 and 7-5.

50. C

Shutdown boron concentration does not contribute to the calculation of estimated critical concentration.

Reference 61, pages 7-4 and 7-5.

51. D

Increasing the boron concentration adds negative reactivity, which was not originally accounted for. Therefore, rods must be higher to counter this negative reactivity.

Reference 61, pages 7-4 and 7-5.

52. A

Boron concentration, xenon concentration, samarium concentration, and moderator temperature affect the reactivity balance of the core.

Reference 61, pages 7-4 and 7-5.

53. A

Dilution inserts positive reactivity, so the rods will not need to be pulled as far to attain criticality.

Reference 61, page 7-4.

54. B

The steam generator levels do not produce a reactivity effect in the core. The parameters in A, C, and D all do.

55. A

Raising the steam dump pressure setpoint raises reactor coolant temperature, inserting negative reactivity. To compensate, actual rod height to attain criticality will be higher.

Reference 61, page 7-4.

56.

a. Actual boron is less than assumed, so there is less negative reactivity that rods must overcome. Therefore, actual critical position will be <u>lower</u> than ECP.

b. ECP assumed xenon would be near its peak, when it is actually lower. With less negative xenon reactivity to overcome, actual critical position will be <u>lower</u> than ECP.

c. Actual temperature is lower than assumed. With the negative MTC that no doubt exists at this temperature, the lower temperature means there is less negative reactivity to be overcome. Therefore, actual critical position will be <u>lower</u> than ECP.

Reference 61, pages 7-4 and 7-5.

57. A

PWRs have minimum temperature requirements for criticality, due to effects of temperature on reactivity. Below point of adding heat, rod position has the most significant effect on core reactivity in a critical reactor

58. C

Reference 56, page 6-42.

59. B

Reference 56, page 8-47, figure FND-RF-184-7.

60. D

Below POAH, RCS temperature is controlled by steam demand and feedwater temperature.

Reference 38, page 13.5-2.

61. D

The relief valve failure places a continuous heat load on the reactor coolant system lowering its temperature. Positive reactivity is inserted due to the moderator's strong negative temperature coefficient. The reactor is supercritical, power increases to above the point of adding heat until an energy rate balance is achieved between the primary and secondary systems. Reactor power will trend toward leveling off at this balanced condition. Also, the reactor coolant temperature will have increased toward its initial value, ultimately leveling off less than this value. A static reactivity balance between the fuel reactivity effect (negative) and the coolant reactivity effect (positive) will occur rendering the reactor critical.

62.

With the reactor critical below the point of adding heat (POAH), any positive reactivity insertion will result in a power increase to the POAH. Any negative reactivity insertion will reduce power to a subcritical equilibrium level.

a. A decrease in moderator temperature inserts positive reactivity (assuming a negative MTC). Power will increase.

b. Pressurizer level has no effect on core reactivity. Power will remain constant.

c. An increase in boron concentration inserts negative reactivity. Power will decrease.

d. A rod insertion inserts negative reactivity. Power will decrease.

Reference 56, chapters 6 and 7.

63. B

$\rho = (k_{eff} - 1) / k_{eff}$

The reactor is critical when $k_{eff} = 1$.

Therefore, $\rho = (1-1) / 1 = 0 / 1 = 0$

Reference 56, page 5-21.

64. A

$K_1 = 0.99$

$\rho_1 = (K_1-1)/K_1 = (.99-1)/.99 = -.01/.99 = -0.01$

$\Delta\rho = .003$

$-0.01 + 0.003 = -.007 = \rho_2$

$K_2 = 1/(1-\rho_2) = 1/[1-(-.007)] = 1/1.007 = 0.993$

K_2 less than 1.0 means that the reactor is subcritical.

Reference 56, pages 8-57 through 8-60.

65. A

Reactivity effect caused by boron dilution
$\Delta\rho = -30$ ppm $(-0.00025\ \Delta K/K/\text{ppm})$
$\Delta\rho = +0.0075\ \Delta K/K$

Since the reactor is subcritical by $-0.01\ \Delta K/K$, it will still be subcritical by $-0.0025\ \Delta K/K$ after the dilution.

66. D

Reference 56, page 5-21.

67. A

Reference 56, page 5-21.

68. D

$CR_1\ (1-K_1) = CR_2\ (1-K_2)$

$(1-K_2) / (1-K_1) = CR_1 / CR_2 = 10 / 20 = 0.5$

Thus, the rod withdrawal reduced the margin to critical by half, and the reactivity insertion was about half that needed for criticality.

Reference 56, page 8-29, figure FND-RF-217.

69. C

$\rho = (K-1) / K$

$= (0.985 - 1) / 0.985$
$= 0.0152$
$= 1.52\%\ \Delta K/K$
$= 1520$ pcm

Reference 56, page 5-22.

70. A

Even though a constant positive SUR is related to supercritical conditions, it is the operator's indication that criticality has been achieved.

Reference 56, pages 8-57 through 8-60.

71. B

A constant, positive SUR without reactivity being added is indicative of supercritical conditions.

Reference 56, pages 8-57 through 8-60.

72. C

In a critical reactor, the chain reaction is exactly self-sustaining; hence, the fission rate is constant.

Reference 56, pages 8-57 through 8-60.

73. D

Supercritical conditions must be observed due to critical neutron population and subcritical neutron population increase being so similar in response.

Reference 56, pages 8-57 through 8-60.

74. D

The relief valve failure places a continuous heat load on the reactor coolant system lowering its temperature. Positive reactivity is inserted due to the moderator's strong negative temperature coefficient. The reactor is supercritical, power increases to above the point of adding heat until an energy rate balance is achieved between the primary and secondary systems. Reactor power will trend toward leveling off at this balanced condition. Also, the reactor coolant temperature will have increased toward its initial value, ultimately leveling off less than this value. A static reactivity balance between the fuel reactivity effect (negative) and the coolant reactivity effect (positive) will occur rendering the reactor critical.

75. A

The reactor will remain slightly subcritical (almost critical) and the neutron flux (count rate) will remain constant.

76. A

Reference 56, pages 8-57 through 8-60.

77.

The response of neutron count rate and SUR instruments for an exactly critical reactor is very similar to the response for a slightly subcritical reactor. As a result, the operator can only determine that criticality has been attained when the reactor becomes slightly supercritical.

The indications used to make this determination are a constant, positive SUR and exponentially increasing count rate with no control rod motion in progress. This occurs only after reaching a neutron level where source neutron effects can be neglected.

Reference 56, pages 8-57 through 8-60.

78.

When a reactor is very slightly subcritical, power (count rate) will eventually level off at a subcritical equilibrium value. However, many minutes must elapse before power has completely leveled off.

In an exactly critical reactor, an almost identical response is observed. In this case, power actually increases linearly; but on the logarithmic count rate indication, power appears to slowly level off.

Because the behavior of count rate is so similar in a critical and a slightly subcritical reactor, the operator must make the reactor slightly supercritical (exponential count rate increase; positive SUR) to know that criticality has been attained.

Reference 56, pages 8-57 through 8-59.

79. A

Reference 56, pages 8-57 through 8-60.

80. B

The correct answer is constant and assumes that the source does not impact power (neutron level) indication.

Reference 56, pages 8-57 through 8-60.

81.

During a reactor startup, criticality will typically be attained with power in the source range, i.e., at a level where source neutron effects are observable. The fission process in a critical reactor is exactly self-sustaining, but the continual addition of source neutrons will cause neutron population, and therefore power, to increase linearly.

Note that this linear increase will appear as a "tapering-off" on the logarithmic source range instrument.

Reference 56, page 8-54.

82. B

Reference 38, pages 13.5-2 through 13.5-4.

83. B

Reference 38, pages 13.5-2 through 13.5-4.

84. A

Since the startup rate is becoming increasingly negative, negative reactivity is being continuously added. In B, a power balance and reactivity balance will occur not a continuous decrease in neutron flux. In C and D, the effects are long-term and therefore negligible. Fuel depletion is a negative reactivity effect and burnable poison burnout is a positive effect.

85. C

Once a reactor is generating a significant amount of heat, the heat changes reactivity in the core through moderator, void and doppler coefficients. Typically, the power level at which heat generated is sufficient to cause a temperature increase in the coolant is termed "point of adding heat." Doppler and moderator temperature coefficients provide negative reactivity feedback.

Reference 38, pages 13.5-2 through 13.5-4.

86. B

Upon reaching POAH, negative reactivity from fuel and moderator temperature increases will turn power and reduce the SUR.

Reference 38, page 13.5-4.

87. D

Upon reaching POAH, negative reactivity from fuel and moderator temperature increases will turn power and reduce the SUR.

Reference 38, page 13.5-4.

88. A

Upon reaching POAH, negative reactivity from fuel and moderator temperature increases will turn power and reduce the SUR.

Reference 38, page 13.5-4.

89.

When reactor power is below the POAH, the fission rate is too low to produce a noticeable change in temperature. Above the POAH, fission heat is observable. With a negative fuel temperature (Doppler) coefficient and moderator temperature coefficient, a temperature increase inserts negative reactivity.

Therefore, with power above the POAH, any increase in power will tend to increase fuel and moderator temperatures, inserting negative reactivity and limiting the power increase. Conversely, a power decrease will tend to lower temperatures, inserting positive reactivity and limiting the decrease. This "inherent stability" of the reactor is lacking with power below the POAH.

Reference 81, pages 9-17 and 8-18.

90. B

POAH is where nuclear heat is observable above and beyond the heat input provided by the reactor coolant pumps.

Reference 38, pages 13.5-2 through 13.5-4.

91.

The point of adding heat (POAH) is the reactor power level at which the generation of heat by fission becomes noticeable. As reactor power reaches and exceeds the POAH, negative reactivity feedback from increasing fuel and moderator temperature tends to halt the power increase.

Reference 61, page 9-17.

92. B

Reference 38, page 13.5-4.

93. A

A negative moderator temperature coefficient provides a positive reactivity addition as temperature decreases; positive reactivity causes power to increase. This increase will continue until power level exceeds the point of adding heat. The question asks for <u>initial</u> power response.

Reference 63, pages 12-32 and 12-33.

94. D

Power is an exponential function below the point of adding heat.

Reference 30, page 107.

95. B

If no reactivity changes occur in the reactor over the two decades of neutron flux, the critical data will be identical.

96. B

Reference 56, page 8-54.

97. B

No reactivity changes will have taken place so the critical rod positions must be the same.

98. A

The reactor will be critical somewhat above initial power level.

Reference 63, pages 12-32 and 12-33.

99. D

Reference 38, pages 13.5-2 through 13.5-4.

100. D

Reference 38, pages 13.5-2 through 13.5-4.

101.

The operator can determine that reactor power has reached (and passed) the POAH by any of the following indications:

a. increase in coolant temperature - When nuclear heating becomes noticeable, coolant temperature will increase.

b. increase in pressurizer level - Expansion of coolant will cause pressurizer level to increase.

c. leveling off of power/startup rate falling to zero - Negative reactivity inserted by increasing fuel and moderator temperature will cause power to level off.

d. increase in steam generator temperature and pressure - Heat from the hot coolant increases steam generator temperature and pressure.

Reference 61, page 9-17.

102. C

Pressurizer level increases due to expansion of coolant as temperature increases.

Reference 38, pages 13.5-2 through 13.5-4.

103. D

As the reactor temperature increases, negative reactivity will be added lowering the supercritical conditions of the reactor and decreasing the startup rate.

104. A

$$SUR(dpm) = \frac{26}{T(sec)}$$

$$\rho = \bar{\beta}_{eff} / (1 + \bar{\lambda} T)$$

$$T = \frac{26}{1} = 26\,sec$$

ρ = 0.00579/(1+0.1x26)

= 0.00579/3.6

= 0.0016 $\Delta K/K$

= 0.16% $\Delta K/K$

105. A

Due to heat transfer time through fuel/clad to RCS, doppler will affect reactivity before RCS temperature.

Reference 38, pages 8.2-1, 8.3-1; and 13.5-2 through 13.5-4.

106. C

10°F/hr x 2 hrs = 20°F

582°F - 532°F = 50°F   50°F / 15% = 3.3°F/%

20°F / 3.3°F/% = 6%

Reference 03, page V-4.

107. B

$\dot{Q} = UA\,(T_{ave} - T_{sat})$

$\dot{Q}$ = heat produced in the primary system

U = heat transfer coefficient

A = heat transfer area of OTSG

$T_{ave} - T_{sat}$ = reactor coolant average temperature minus the saturation temperature of the secondary side of the OTSG

As reactor power is increased from 0% to 15%, $\dot{Q}$ increases. Since the steam generators are on low-level limits, the level in the OTSG is constant; thus, A is constant. T_{sat} is constant by the action of the turbine controls on the turbine bypass valves. T_{ave} must rise as the primary side heat is increased by raising reactor power for the equation to remain constant.

Reference 03, page V-3.

108. A

T_{hot} increases due to reactor power increasing. T_{cold} increases due to maintaining a constant heat transfer area in the OTSG, while primary side heat is increased. T_{ave} increases because both T_{hot} and T_{cold} are increasing.

Reference 03, page V-2.

109. C

OTSG steam pressure is held constant by the action of the turbine controls or the turbine bypass valves.

Reference 03, page V-3.

110. D

$\dot{Q} = UA\,(T_{ave} - T_{sat})$

$\dot{Q}$ = heat produced in the primary system

U = heat transfer coefficient

A = heat transfer area of OTSG

$T_{ave} - T_{sat}$ = reactor coolant average temperature minus the saturation temperature of the secondary side of the OTSG

As reactor power is increased from 0 percent to 15 percent, $\dot{Q}$ increases. Since the steam generators are on low-level limits, the level in the OTSG is constant; thus, A is constant. T_{sat} is constant by the action of the turbine controls or the turbine bypass valves. T_{ave} must rise as the primary side heat is increased by raising reactor power for the equation to remain constant.

Reference 03, page V-3.

111. B

Reference 61, page 3-41.

112. A

Reference 61, page 9-17.

113. B

Reference 18, page 301.

114. D

Reference 61, page 3-41.

115. A

Reference 61, page 9-17.

116.

Power will continue to increase until negative reactivity is inserted. This will occur once power reaches the point of adding heat. As power reaches and exceeds the POAH, fuel and moderator temperature will rise. Both will insert negative reactivity. (The low boron concentration and hot conditions ensure a negative moderator temperature coefficient.) Temperatures will continue to rise until the reactor is critical, and power will stabilize at or just above the POAH. Startup rate will be zero, and boron concentration will remain 200 ppm.

Reference 61, page 9-17.

117. A

Unless steam demand changes, steady-state reactor power will not change.

Reference 61, page 6-11.

118. D

The negative reactivity inserted by the boron decreases reactor power below steam demand, causing reactor temperature to decrease.

Reference 61, page 5-31.

119. C

A reactor stabilizes at a critical condition where reactivity = 0.

Reference 56, page 5-21.

120. B

If steam demand is constant, then reactivity inserted causes a temperature change.

Reference 61, page 5-24.

121. D

Reactivity balance

Reference 61, page 5-41.

122. A

With steam demand constant, a reactivity insertion causes a moderator temperature change.

123. A

Increasing power imparts negative reactivity due to the doppler effect from increasing fuel temperature. T-ave is either constant (in which case there is no moderator temperature coefficient feedback) or increasing (in which case the MTC feedback usually imparts negative reactivity). The negative reactivity must be offset by adding positive reactivity (e.g., control rod withdrawal or boron dilution).

Reference 61, page 9-17.

124. D

Increasing steam flow causes T_{ave} to decrease, adding positive reactivity. Control rods would withdraw adding positive reactivity while trying to adjust T_{ave}. The increase in power adds negative reactivity, counteracting the above effects until net reactivity is zero.

Reference 61, page 9-17.

125. B

Increasing power imparts negative reactivity due to the doppler effect from increasing fuel temperature. T-ave is either constant (in which case there is no moderator temperature coefficient feedback) or increasing (in which case the MTC feedback usually imparts negative reactivity). The negative reactivity must be offset by adding positive reactivity (e.g., control rod withdrawal or boron dilution).

Reference 61, page 9-17.

126. B

Changing steam flow results in changing reactor power. Increasing steam flow causes primary system temperature to decrease, resulting in core power increase. Decreasing steam flow causes primary system temperature to increase, resulting in core power decrease. Both effects are due to moderator temperature coefficient effects.

Reference 61, page 9-17.

127. C

Changing steam flow results in changing reactor power. Decreasing steam flow causes primary system temperature to increase, resulting in core power decrease.

Reference 61, page 9-17.

128. A

First-stage pressure increases due to greater and greater steam flow requirements as electrical load increases. The reactor temperatures, both in the fuel and moderator increase adding negative reactivity. This reactivity can be balanced by control rod motion or boron dilution.

Reference 61, pages 9-17 and 9-18; reference 63, pages 12-6 and 12-7.

129. B

Power increase with respect to time is calculated by

$P = P_0\ 10^{SUR(t)}$

$7 \times 10^{-7} = (2 \times 10^{-7})\ 10^{SUR(t)}$

$\text{Log}\ 7 \times 10^{-7} / 2 \times 10^{-7} = (0.1)\ t$

$.5441 = 0.1t$

$t = 5.4$ min.

Reference 18, page 245.

130. C

$P = P_0\ e^{t/T}$

$10 = 1\ e^{300 / T}$

$\ln 10 = 300 / T$

$2.30 = 300 / T$

$T = 130$ sec

Reference 18, page 245.

131. C

After the transients have died out, power will decrease on approximately a negative 1/3 DPM SUR.

Reference 18, page 245.

132. A

Power will stay approximately the same. T_{ave} will increase to balance the reactivity applied by the rods.

Reference 18, page 301.

133.

The boron dilution gradually inserts positive reactivity. In response, reactor power increases slightly, causing moderator temperature to increase, due to the imbalance between reactor power and steam demand. If control rods are in manual, the net effect will be power essentially unchanged at 80%, but coolant temperature will be higher. With rods in automatic, they will step in to maintain T_{ave} at its initial value, so that in the new steady-state condition, rods will be lower with power and T_{ave} virtually unchanged.

Reference 61, page 1-18.

134. A

The core outlet temperature decreases and the inlet temperature increases. This increases the moderator density in the top of the core relative to the bottom. This changes the moderation of neutrons relatively (top to bottom) and shifts the thermal neutron axial flux distribution upward.

135. B

The core outlet temperature decreases and the inlet temperature increases. This increases the moderator density in the top of the core relative to the bottom. This changes the moderation of neutrons relatively (top to bottom) and shifts the thermal neutron axial flux distribution upward.

136. C

Boron dilution adds positive reactivity to the reactor. Since the steam demand does not change, the reactor power does not change. The positive reactivity will cause T_{ave} to increase until MTC cancels out the positive reactivity added by the boron dilution.

Reference 18, page 301.

137. D

The imbalance of delayed neutrons during the neutron flux increase and the subsequent insertion of the control rods will produce a transient which will become negative well before the critical rod height is reached.

138. B

The relative moderator density change in the top and bottom of the core causes a axial power shift toward the bottom.

139. B

The moderator temperature will decrease, providing the necessary reactivity for the reactor to follow steam demand. Power increases and T_{ave} decreases.

Reference 18, page 301.

140. C

The moderator temperature will decrease providing the necessary reactivity to increase the reactor power to meet the steam demand. Power will increase and T_{ave} will decrease.

Reference 18, page 301.

141. C

The moderator temperature will decrease providing the necessary reactivity to increase the reactor power to meet the steam demand. Power will increase and T_{ave} will decrease.

Reference 18, page 301.

142. D

Although the reactor is subcritical, power will still follow steam demand. The moderator temperature will decrease the required amount to provide the reactivity necessary to increase power to match the steam demand.

Reference 18, page 301.

143. A

When the turbine load decreases, power will decrease to meet steam demand. Negative reactivity to reduce power is inserted because the moderator temperature will increase due to reduced steam flow.

144.

For a reactor operating at power, a change in steam demand will result in a comparable steady-state change in reactor power. If steam demand is increased, more heat is removed from the reactor coolant, lowering Tave and inserting positive reactivity. The reactor thus becomes supercritical, and power increases. Eventually power exceeds the new steam demand, causing Tave to begin to increase and stopping the power increase. The final steady state will find reactor power equal to steam demand, with Tave lower and fuel temperature higher than initially. (Or, with rod control in automatic, rods will have moved out to maintain Tave in its reference band.)

Reference 61, pages 9-21 and 9-22.

145. A

Thermodynamically, heat generated must equal heat removed or stable conditions cannot exist.

Reference 33, page 281.

146. A

Increased turbine load requires increased steam demand. This results in cooling the reactor coolant in the steam generator more, causing a positive reactivity insertion and a positive SUR.

Reference 61, pages 9-21 and 9-22.

147. A

A high boron concentration is necessary to offset the excess reactivity of a new core.

Reference 18, page 301.

148. A

The higher the boron concentration, the more fuel that can be loaded.

Reference 18, page 301.

149. B

The more fuel that can be loaded, the longer the core can produce power.

Reference 18, page 301.

150. C

More fuel can be loaded into the reactor at the beginning of life increasing K-excess. This additional reactivity is held down, balanced, by loading burnable poisons as well. The poisons burn out slowly as the reactor operates, essentially increasing core life.

Reference 61, page 2-12.

151. C

152. C

Using the formula for prompt drop,

$P = Po\ \bar{\beta}_{eff} / (\bar{\beta}_{eff} - \rho)$, and given 10% negative rho and $\bar{\beta}_{eff} = .0065$

P = (100%) .0065 / [.0065 - (-.1)]

P = (100%) .0065 / (.0065 + .1)

P = (100%) .0065 / .1065

P = 6.1%

Reference 18, page 240.

153. C

Since the neutron power is decreasing on a negative 80-second period, then the time for power to go from 10^{-8} amps to 10^{-9} amps is given by the equation $P = P_o e^{t/T}$

$10^{-9} = (10^{-8}) e^{t/T}$

$\ln 10^{-9} / 10^{-8} = t / T$

-2.3 = t / (-80)

t = 184 sec

154. B

The neutron flux is decreasing on a negative 80-second period or negative 1/3 dpm SUR.

$P = Po\ e^{t/T}$	$P = Po\ 10^{SURxt}$
$0.05 = 0.5\ e^{t/T}$	$0.05 = 0.5\ (10^{SURxt})$
ln 0.05/0.5 = t/T	log 0.05/0.5 - SURxt
-2.3 = t/-(80)	-1.0 = -1/3 dpm (t)
t = 184 sec	t = 3 min = 180 sec

155. C

Reference 18, pages 122-125.

156. C

The delayed neutrons coming from the decay of the longest-lived fission product (precursor) are responsible for establishing the stable period. This isotope is bromine-87 which has a radioactive half life of 55 seconds.

Reference 18, pages 111 and 245.

157. D

The negative 1/3 DPM SUR results from the relatively slow decay of the longest lived precursors and predominates after the shorter lived precursors have decayed.

158. D

The decrease in neutron power due to a prompt drop is dependent on the magnitude of the negative reactivity inserted.

Reference 18, page 240.

159.

A-B: The rapid insertion of a large amount of negative reactivity causes the prompt neutron population to decrease rapidly. Segment A-B of the curve depicts this prompt drop.

B-C: During this period, the neutron population is dominated by the appearance of delayed neutrons from shorter- and intermediate-lived delayed neutron precursors. These precursors which were formed when the reactor was at 100 percent power, decay over a period of a few minutes.

C-D: Once the shorter-lived precursors have effectively all decayed, neutron population is controlled by the appearance of delayed neutrons from the longest-lived precursors. From this point, power falls at a constant exponential rate of -1/3 DPM until neutron population is low enough for the effect of source neutrons to be seen and a subcritical equilibrium is reached.

Reference 56, page 7-70.

160. B

The delayed neutrons are decaying on a negative 80-second period. The formula for a change in neutron power when the period is given is:

$P = P_o e^{t/T}$

Reference 18, page 234.

161. D

The prompt drop is determined by the equation $P = P_o \bar{\beta}_{eff} / (\bar{\beta}_{eff} - \rho)$. As $\bar{\beta}_{eff}$ becomes smaller, the power following the prompt drop becomes smaller. About three minutes after the trip, power will be decreasing on a stable - 80 second period. The stable 80-second period is determined by the longest lived group of delayed neutrons, and their decay constant does not change over core life.

Reference 18, page 246.

162. D

When the reactor is exactly critical below POAH, the insertion of negative reactivity will make the reactor go subcritical. Power will decrease. However, since the moderator temperature is being maintained by pump heat, it will not change.

Reference 18, pages 229 through 250.

163. B

When the control rods are inserted, power is shifted downward. The rods are absorbing more neutrons in the top part of the core, so in order for power to remain constant, more power must be produced in the bottom regions.

Reference 18, page 342.

164. C

The reactor is made subcritical. The neutron flux (reactor power) will decrease then stabilize at a specific level determined by the source multiplication.

165. A

$P = P_o e^{t/T}$

$\ln P/Po = t/T$

$\ln P/10 = 120/-80$

$\ln P/10 = -1.5$

$P/10 = 0.22$

$P = 2.2\%$

166.

The rods insert negative reactivity, causing a decrease in reactor power. With steam demand unchanged, the mismatch between power and steam demand causes T_{ave} to decrease. The temperature decrease inserts positive reactivity, bringing reactor power back up to meet steam demand. (Steam demand will have decreased slightly due to the temperature decrease reducing steam pressure, but this effect is small.) The final steady-state power will match steam demand at (or slightly less than) 50 percent, and T_{ave} will be lower than its initial value.

Reference 38, page 13.5-4.

167. C

Local power peaks are possible at all power levels. In A, uneven fuel burnup is a long term affect and will not occur during a reactor shutdown. In B, the statement is not a factor because of fission product decay heat and the fact that the cooldown rate is controlled by the secondary system. In D, the reactor is being shutdown so xenon oscillations are not of concern.

168. D

The greatest amount of decay heat results from the decay of fission products.

Reference 18, page 122.

169. C

While other types of decay produce decay heat, they are insignificant compared to the heat produced by gamma and beta decay.

Reference 18, page 122.

170. B

Reference 18, page 123.

171. D

The generic term for heat generation after shutdown is decay heat.

Reference 18, page 122.

172. A

One week following a normal reactor shutdown the fission product decay heat will have decreased below 0.003 of full power. Each reactor pump will be providing a heating rate of about 3 to 4 MW.

Reference 18, page 123.

173. B

Although some decay heat results from fission, the fission rate is very low in a shutdown reactor. However, the fission products are decaying, providing the most significant amount of the decay heat.

Reference 13, page 122.

174. A

Over core life, fission products (especially the longest-lived nuclei) that produce decay heat are increasing as the fuel is depleted. Activation products are also increasing; thus, the decay heat load increases.

Reference 18, page 124.

175. B

From figure 2.33 of the reference.

Reference 18, page 123.

176. C

Decay heat level is proportional to power. The fission product mixture will decay at the same rate, regardless of the initial quantity present, in the same way that radioactive decay of a single isotope is independent of the amount present.

Reference 18, page 122.

177. D

Although heat production by fission drops off rapidly, heat production by decay of fission products continues for years.

Reference 56, page 3-42.

178. B

Decay heat is caused by decay of fission products. The fission product inventory depends on power history.

Reference 56, page 3-42.

179.

When the scram occurs, neutron power level will fall quickly to below the point of adding heat. After a few minutes neutron power will decrease at a steady -1/3 DPM startup rate until source neutrons level power at a subcritical equilibrium power level.

Thermal power behaves quite differently. There is an initial rapid decrease as the fission process diminishes. However, while the contribution of the fission process to thermal power quickly becomes negligible, the decay of fission products continues to produce a significant amount of thermal power. This decay heat produces approximately 7% of reactor power at the time of the scram, decreasing to about 1% after an hour and about 0.5% after a day and diminishing gradually over weeks and years.

Reference 56, page 7-70, and reference 18, Figure 2.33.

180. C

Sensible temperature increases in the fuel and the moderator at the POAH will cause the attendant reactivity coefficients to insert negative reactivity resulting in power turning and stabilizing at the POAH.

181. B

182. C

183. A

Each learning objective listed below is preceded by the associated question number (s) and by the number of its related knowledge statement.

K1.01 Questions 1-7

List the parameters that should be monitored and controlled specifically during the approach to criticality.

K1.02 Questions 8-13

List reactivity control mechanisms that exist for plant conditions during the approach to criticality.

K1.02 Question 14

List and explain the effect of parameters and mechanisms that affect reactivity during an approach to criticality.

K1.03 Questions 15-24

Describe count rate and startup rate response that should be observed for rod withdrawal during the approach to criticality.

K1.04 Questions 25-34

Relate the concept of subcritical multiplication to predicted count rate and the period response for control rod withdrawal during the approach to criticality.

K1.05 Question 35

Explain the role of source neutrons in subcritical multiplication.

K1.05 Questions 36-39

Explain characteristics to be observed when the reactor is very close to criticality.

K1.06 Questions 40-45

Explain and use a 1/M plot to predict criticality.

K1.07 Questions 46-56

Identify and describe the reactivity parameters that affect the prediction of criticality.

K1.08 Questions 57-59

Specify reactor plant parameters that should be monitored and controlled upon reaching criticality to maintain the reactor in a critical condition.

K1.08 Questions 60, 61

Predict reactor coolant temperature response in a critical reactor below the point of adding heat.

K1.08 Question 62

Explain the effect on reactor power of various parameter changes in a critical reactor below the point of adding heat.

K1.09 Question 63

Define criticality in terms of reactivity.

K1.09 Questions 64, 65

Given initial conditions and the ability to calculate reactivity, determine final conditions in a reactor core.

K1.09 Question 66

Define criticality in terms of the change in neutron population between one neutron generation and the previous generation.

K1.09 Question 67

Define criticality in terms of the effective multiplication factor (K_{eff}).

K1.09 Question 68

Given that neutron counts double from the initial count rate during a reactor startup, state the relationship between the amount of reactivity added and the total amount of reactivity required to reach criticality.

K1.09 Question 69

Given initial conditions and the ability to calculate reactivity, determine the change in reactivity required to make the reactor critical.

K1.10, 1.11 Questions 70-78, 182

Describe how to determine if a reactor is critical.

K1.10, 1.11 Questions 79-81

Describe reactor power response when critical below the point of adding heat.

K1.12 Questions 82-84

List parameters that affect reactivity that should be monitored and controlled during startup from criticality to the point of adding heat.

K1.13 Questions 85, 90, 91

Define "point of adding heat" (POAH).

K1.13 Questions 86-89

Describe the impact on reactor power of reaching the point of adding heat.

K1.14 Questions 92-97

Describe reactor power response to changing plant parameters after reaching criticality and below the point of adding heat.

K1.14 Question 98

Describe reactor power response below the point of adding heat when equal amounts of positive and negative reactivity are added sequentially.

K1.15 Questions 99-103

Explain characteristics to look for when POAH is reached.

K1.15 Question 104

Determine the amount of negative reactivity required to level power at the point of adding heat.

K1.15 Question 105

Explain the cause for characteristics exhibited when the point of adding heat is reached.

K1.16 Questions 106-110

Describe monitoring and control of reactor power and primary temperature during 0 percent to 15 percent power operation. (B&W)

K1.17 Questions 111-116, 180, 183

Describe reactor power response after reaching the point of adding heat (POAH).

K1.18 Questions 117, 118, 121, 122

Describe the monitoring and control of T_{ave} during power operation.

K1.18 Questions 119-120, 181

Describe the monitoring and control of reactor power during power operation.

K1.19 Questions 123-128

Describe means by which reactor power will be increased to rated power.

K1.20 Questions 129-133

Explain the effect of control rod motion or boration/dilution on reactor power.

K1.20 Questions 134-138

Explain the effect of a change in boron concentration on an operating reactor.

K1.21 Questions 139-140

Explain the effect of a steam line break on reactor response.

K1.21 Question 141

Explain the effect of a steam release on reactor power.

K1.21 Question 142

Explain the effect of a steam release on a subcritical reactor.

K1.21 Questions 143-144

Explain the effect of steam flow on reactor power.

K1.21 Questions 145, 146

Explain the relationship between steam flow and reactor power, given specific conditions.

K1.22 Questions 147-151

Explain how the use of soluble boron allows increased core life.

K1.23 Questions 152-155

Perform calculations involving reactor power responses to reactor trips.

K1.23 Questions 156-161

Explain the shape of a curve of reactor power versus time after a trip.

K1.24 Questions 162-167

Explain reactor response to control rod insertion.

K1.25 No questions

Questions dealing with control rod sequencing and overlap are found in the Control Rods section.

K1.26 Questions 168-169

Describe how decay heat is produced.

K1.26 Questions 170-172

Define decay heat.

K1.27 Questions 173-179

Explain the relationship between decay heat generation and

A. power-level history
B. power production
C. time after a reactor shutdown

THERMODYNAMIC UNITS AND PROPERTIES
Questions

1. If a main steam line pressure gauge reads 900 psig, what is the absolute pressure? (Assume an atmospheric pressure of 15 psia.)

   A. 880 psia
   B. 885 psia
   C. 915 psia
   D. 920 psia

2. A pressure gauge on a condenser reads 27 inches of mercury (Hg) vacuum. What is the absolute pressure corresponding to this vacuum? (Assume an atmospheric pressure of 15 psia.)

   A. 1.0 psia
   B. 1.5 psia
   C. 13.5 psia
   D. 14.0 psia

3. Assuming an atmospheric pressure of 15 psia, 5 inches of mercury (Hg) vacuum is the same pressure as

   A. 2.5 psia
   B. 5.0 psia
   C. 10.0 psia
   D. 12.5 psia

4. Assuming an atmospheric pressure of 15 psia, 5 psia is equal to which of the following?

   A. 20 psig
   B. 10 psig
   C. 10 inches Mercury (Hg) vacuum
   D. 20 inches Mercury (Hg) vacuum

5. The relationship between absolute pressure and gauge pressure can be expressed as

   A. gauge + atmospheric pressure = absolute
   B. atmospheric pressure = gauge
   C. atmospheric pressure - gauge = absolute
   D. absolute + atmospheric pressure = gauge

6. An atmospheric pressure of 15 psia equals

   A. 30 psig
   B. 15 psig
   C. 5 psig
   D. 0 psig

7. A water storage tank is enclosed to prevent vapors from escaping to the environment. The tank is also pressurized to prevent boiling. A differential pressure detector with a dry reference leg is used to measure the tank level.

   To achieve the greatest accuracy of measurement, the low pressure side of the detector should sense which one of the following?

   A. the pressure at the bottom of the tank

   B the pressure of the atmosphere surrounding the tank

   C. the pressure of a column of water external to the tank

   D. the pressure of the vapor space at the top of the tank

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

psig + 15 = psia

900 psig + 15 = 915 psia

Reference 10; and Reference 16, chapter 2.

2. B

30 inches Hg vaccum = 0 psia

2 inches Hg/psia

27 inches Hg

2 inches Hg/psia = 13.5 psia

15 psia - 13.5 psia = 1.5 psia

Reference 10; and Reference 16, chapter 2.

3. D

30 inches Hg vacuum = 0 psia

2 inches Hg/psia

5 inches Hg

2 inches Hg/psia = 2.5 psia

15 psia - 2.5 psia = 12.5 psia

Reference 10; and Reference 16, chapter 2.

4. D

1 psia = 2 inches Hg

(5 psia) (2 inches Hg/psia) = 10 inches Hg

30 inches Hg vacuum = 0 psia

30 inches Hg - 10 inches Hg = 20 inches Hg vacuum

Reference 10; and Reference 16, chapter 2.

5. A

Absolute pressure is equal to the gauge pressure plus the atmospheric pressure.

Reference 10, and Reference 16, chapter 2.

6. D

psig = psia - 15

= 15 - 15

= 0 psig

Reference 10; and reference 16, chapter 2.

7. D

Reference 53, chapter 2, pag 87.

THERMODYNAMIC UNITS AND PROPERTIES
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1-6

Convert between absolute and gauge pressure and vacuum scales.

K1.03 Question 7

Describe how pressure and level sensing instruments function.

STEAM
Questions

1. Liquid that exists at the boiling point is said to be

   A. subcooled
   B. saturated
   C. compressed
   D. superheated

2. Which of the following best defines the temperature of a saturated liquid as related to boiling point?

   A. below the boiling point
   B. at the boiling point
   C. above the boiling point
   D. unrelated to the boiling point

3. If a liquid is saturated and pressure remains constant, the addition of heat will

   A. raise the liquid to the boiling point
   B. result in a subcooled liquid
   C. result in vaporization of the liquid
   D. cause the liquid to become superheated

4. Which of the following is not a characteristic of a saturated liquid?

   A. The addition of heat will cause the liquid to boil with no temperature change.

   B. The liquid's temperature depends on its pressure.

   C. The liquid's temperature will increase as heat is added.

   D. The liquid is at the temperature at which boiling will occur.

5. A liquid is considered to be saturated when

   A. it is at the boiling temperature and the addition of heat would cause vaporization

   B. its temperature increases with an addition of heat

   C. it is converted to 100% vapor

   D. its pressure is held constant with its temperature below the boiling point

6. A liquid is saturated with zero percent quality. Assuming pressure remains constant, the addition of a small amount of heat will

   A. raise the liquid temperature above the boiling point
   B. result in a subcooled liquid
   C. result in vaporiaation of the liquid
   D. result in a superheated liquid

7. The pressurizer is operating in a saturated condition at 636°F. If a sudden pressurizer level decrease of 10 percent occurs, pressurizer pressure will ____________ and pressurizer temperature will ____________ .

   A. remain the same; decrease
   B. remain the same; remain the same
   C. decrease; decrease
   D. decrease; remain the same

8. A two-phase mixture is composed of 30,000 lbm of steam vapor and 5, 000 lbm of liquid water. The moisture content of the mixture is

   A. 14.3%
   B. 16.7%
   C. 20.0%
   D. 85.7%

9. A two-phase mixture is composed of 30,000 lbm of steam vapor and 5, 000 lbm of liquid water. The quality of the mixture is

   A. 14.3%
   B. 80.0%
   C. 83.3%
   D. 85.7%

STEAM
Questions

10. What is the moisture content of steam at 1,000 psia and 1,145 BTU/lbm?

    A. 3%
    B. 5%
    C. 7%
    D. 9%

11. What is the quality of steam at 900 psia and 1,100 BTU/lbm?

    A. 71%
    B. 86%
    C. 89%
    D. 92%

12. What is the quality of steam at 800 psia and 1,155 BTU/lbm?

    A. 6%
    B. 10%
    C. 90%
    D. 94%

13. Which of the following alone can be used to determine steam quality?

    A. enthalpy
    B. moisture content
    C. water pressure
    D. specific volume

14. Steam quality is defined as the

    A. fraction of the total mass that is saturated vapor

    B. fraction of the total mass that is saturated liquid

    C. mass of the water vapor divided by the mass of air in the mixture

    D. mass of the saturated liquid divided by the mass of the saturated vapor

15. Which of the following alone can be used to determine the moisture content of steam?

    A. enthalpy
    B. water pressure
    C. steam quality
    D. specific volume

16. The fraction of the total mass of a vapor/liquid mixture that is saturated vapor defines

    A. dew point
    B. moisture content
    C. relative humidity
    D. steam quality

17. Determine the quality of steam at 1.0 psia with specific enthalpy of 990 BTU/lbm.

    A. 89%
    B. 85%
    C. 15%
    D. 11%

18. Any vapor having a temperature above saturation temperature is a

    A. saturated vapor
    B. superheated vapor
    C. dry saturated vapor
    D. wet saturated vapor

19. Water vapor whose pressure is less than the saturation pressure for its temperature is said to be

    A. condensing
    B. vaporizing
    C. subcooled
    D. superheated

20. A superheated vapor is a vapor

    A. whose pressure is greater than the pressure corresponding to its saturation temperature

    B. whose temperature is greater than the saturation temperature corresponding to its pressure

    C. with a specific enthalpy less than its specific entropy

    D. containing entrained droplets of liquid

21. The temperature of a subcooled liquid

    A. is below the saturation temperature for a given pressure

    B. is at the saturation temperature for a given pressure

    C. will remain constant during heat addition or removal

    D. is dependent upon the system pressure

22. A condition where the temperature of the liquid is below the boiling temperature for a given pressure is the definition of a

    A. saturated liquid
    B. superheated liquid
    C. subcooled liquid
    D. boiling liquid

23. A liquid is considered to be subcooled when

    A. the temperature of the liquid is above the temperature at which the liquid will boil

    B. heat addition results in an increase in the liquid temperature

    C. heat addition results in no change in the liquid temperature

    D. the liquid starts to vaporize as heat is added

24. A liquid is considered to be a subcooled liquid when the liquid's temperature

    A. remains constant as heat is added
    B. remains constant as heat is removed
    C. is above the saturation temperature
    D. is below the saturation temperature

25. Which statement best describes the relationship between a subcooled liquid and a compressed liquid?

    A. A compressed liquid has a higher pressure for a given temperature than does a subcooled liquid.

    B. There is no difference between a compressed liquid and a subcooled liquid.

    C. A subcooled liquid is cooler than a compressed liquid.

    D. A compressed liquid has the same pressure but a lower temperature than a subcooled liquid.

26. Which one of the following steam generator (S/G) pressures will come closest to producing a 50°F reactor coolant system (RCS) subcooling margin with RCS pressure at 1000 psia? (Assume a negligible ΔT across the S/G tubes.)

    A. 550 psia
    B. 600 psia
    C. 650 psia
    D. 700 psia

27. The reactor is shutdown with RCS pressure at 1500 psig with decay heat being removed by the steam generators. What pressure must be maintained in the steam generators to obtain a 110°F subcooling margin in the RCS loops? (Assume a negligible ΔT exists between the RCS and the steam generators.)

    A. 577 psig
    B. 592 psig
    C. 607 psig
    D. 622 psig

28. Condensate depression is defined as

    A. cooling the condensate below its saturation temperature

    B. maintaining the condensate at a constant temperature throughout the system

    C. the difference between the height of the condensate and the hotwell pumps

    D. cooling the condensate to the point of saturation

29. Subcooling of the water in the condenser to below the saturation temperature is

    A. heat capacity
    B. condensate depression
    C. subcooled monitoring
    D. fluid compression

30. Which of the following changes will result in increased subcooling of the condensate water in the condenser hotwell?

    A. isolate one bay of the condenser circulating water system

    B. increase circulating water temperature

    C. decrease circulating water flow

    D. decrease the main turbine steam flow rate

31. Which of the following best defines condensate depression?

    A. decreasing the circulating water temperature to limit discharge temperature

    B. maintaining reactor coolant temperature below saturation temperature to prevent boiling

    C. subcooling feedwater prior to discharge into the steam generator to prevent boiling

    D. decreasing the temperature of the water in the condenser below saturation temperature

32. Which of the following terms refers to the subcooling of condenser hotwell water prior to its entry into suction of the condensate/hotwell pumps?

    A. temperature gradient
    B. net positive suction head
    C. condensate depression
    D. departure from nucleate boiling

33. The temperature of the water in the main condenser hotwell is below saturation temperature. Which of the following terms applies to this process of subcooling?

    A. condensate depression
    B. fluid compression
    C. evaporative cooling
    D. subcooled margin

34. Condensate depression is defined as cooling the condensate below its

    A. saturation temperature
    B. absolute pressure
    C. specific volume
    D. saturation pressure

35. Determine the reactor coolant system subcooling for Tave = 400°F and pressurizer pressure = 1,000 psig.

    A. 146°F
    B. 188°F
    C. 247°F
    D. 545°F

36. A saturated liquid at 1,100 psia has a specific enthalpy of

    A. 557.5 BTU/lbm
    B. 631.5 BTU/lbm
    C. 1,189.1 BTU/lbm
    D. 1,192.9 BTU/lbm

37. If condensate temperature in the hotwell is 4°F subcooled with a temperature of 112°F, what is the condenser pressure?

    A. 1.0 psia
    B. 1.2 psia
    C. 1.5 psia
    D. 1.8 psia

38. If a wet vapor is at 130°F and has a quality of 90%, its specific enthalpy is

    A. 1,015.78 BTU/lbm
    B. 1,019.80 BTU/lbm
    C. 1,117.80 BTU/lbm
    D. 1,215.76 BTU/lbm

39. If steam pressure is 230 psia at a temperature of 900°F, the degree of superheat is

    A. 368.28°F
    B. 393.70°F
    C. 506.30°F
    D. 510.12°F

40. The saturation pressure for water at 328°F is

    A. 85 psig
    B. 100 psig
    C. 115 psig
    D. 130 psig

41. Given the following plant conditions:

    Power = 100 percent
    Tave = 573.5°F
    Tstm = 513.5°F

    Select the new steam pressure if 5 percent of the total steam generator tubes are plugged and the plant is returned to 100 percent power. Assume RCS mass flow rate and reactor coolant temperature are unchanged.

    A. 710.6 psia
    B. 733.8 psia
    C. 748.5 psia
    D. 763.2 psia

42. What is the reactor coolant system subcooling margin when reactor coolant temperature is 280°F and pressurizer pressure is 400 psig?

    A. 165°F
    B. 168°F
    C. 265°F
    D. 268°F

43. Given the following RCS parameters, determine the RCS subcooling margin.

    RCS pressure = 2233.5 psig
    RCS hot leg temperature = 610°F

    A. 25°F, 302 psi
    B. 31°F, 433 psi
    C. 38°F, 505 psi
    D. 43°F, 588 psi

44. The plant is shutdown with the pressuzier conditions as follows:

Pressurizer liquid temperature	=	588°F
Pressurizer vapor temperature	=	607°F
Pressurizer pressure	=	1410 psia

If the pressurizer is vented until pressure equals 1200 psia, pressurizer liquid temperature will:

A. increase due to condensation of vapor
B. increase due to evaporation of liquid
C. decrease due to condensation of vapor
D. decrease due to evaporation of liquid

45. Consider a water/steam mixture with a current quality of 99 percent. If pressure remains constant and heat is removed from the mixture, the temperature of the mixture will __________ and the quality of the mixture will __________. (Assume the mixture remains saturated.)

A. decrease; remain the same
B. decrease; decrease
C. remain the same; remain the same
D. remain the same; decrease

46. The plant is shutdown with the pressurizer in a saturated condition with liquid and vapor temperatures at 650°F. After an RCS cooldown, pressurizer conditions are as follows:

Pressurizer liquid temperature	=	587°F
Pressurizer vapor temperature	=	607°F
Pressurizer pressure	=	1400 psia

Given these conditions, the pressurizer liquid is _________ and the pressurizer vapor is __________.

A. saturated; saturated
B. saturated; superheated
C. subcooled; saturated
D. subcooled; superheated

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

Reference 51, pages 113 through 115; and Reference 63, page 2-47.

2. B

Reference 51, pages 113 through 115; and Reference 63, page 2-47.

3. C

Reference 51, pages 113 through 115; and Reference 63, page 2-47.

4. C

Reference 63, page 2-47.

5. A

Reference 63, page 2-47.

6. C
Reference 63, page 2-46

7. C
Reference 63, page 2-50

8. A

$$\text{Moisture Content} = \frac{\text{mass of water}}{\text{mass of steam + mass of water}} \times 100$$

$$\text{Moisture Content} = \frac{5{,}000 \text{ lbm}}{30{,}000 \text{ lbm} + 5{,}000 \text{ lbm}} \times 100 = 14.3\%$$

Reference 43, page 1.4-4.

9. D

$$\text{Quality} = \frac{\text{mass of steam}}{\text{mass of steam + mass of water}} \times 100$$

$$\text{Quality} = \frac{30{,}000 \text{ lbm}}{30{,}000 \text{ lbm} + 5{,}000 \text{ lbm}} \times 100 = 85.7\%$$

Reference 43, page 1.4-5.

10. C

The point where 1,000 psia and 1,145 BTU/lbm intersect defines the moisture content on the Mollier Diagram.

Reference 43, page 3.5-6.

11. B

The point where 900 psia and 1,100 BTU/lbm intersect defines the moisture content on the Mollier Diagram. For these conditions, the moisture content equals 14%. Therefore, the quality is equal to 100% - 14% = 86%.

Reference 43, pages 1.4-5 and 3.5-6.

12. D

The point where 800 psia and 1,155 BTU/lbm intersect defines the moisture content on the Mollier Diagram. For these conditions, the moisture content equals 6%. Therefore, the quality is equal to 100% - 6% = 94%.

Reference 43, pages 1.4-5 and 3.5-6.

13. B

Reference 53, page 2-47.

14. A

Quality is defined as the fraction of the total mass that is saturated vapor.

Reference 45, page 87; and Reference 63, page 2-47.

15. C

Reference 63, page 2-47.

16. D

Reference 45, page 87.

17. A

Reference 10, Mollier diagram.

18. B

Reference 24, page 97.

19. D

Reference 24, page 97.

20. B

Reference 24, page 97.

21. A

Reference 63, pages 2-47 through 2-49.

22. C

Reference 63, pages 2-47 through 2-49.

23. B

Reference 63, pages 2-47 through 2-49.

24. D

Reference 63, pages 2-47 through 2-49.

25. B

Reference 63, pages 2-47 through 2-49.

26. C

From the Steam Tables:
Saturation temperature at 1000 psia is 544°F. The reactor temperature with 50°F of subcooling is 494°F. The saturated steam generator pressure will be 650 psia corresponding to this temperature.

Reference 63, pages 2-47 through 2-49.

27. B

Reference 63, pages 2-47 through 2-49 and reference 10

28. A

Condensate depression is defined as cooling the condensate below the saturation temperature.

Reference 39, page 5.3-2; and Reference 63, page 9-22.

29. B

Condensate depression is defined as cooling the condensate to below the saturation temperature.

Reference 63, page 9-22.

30. D

Reference 10.

31. D

Condensate depression is defined as cooling the condensate to below the saturation temperature.

Reference 63, page 9-22; and Reference 39, page 5.3-2.

32. C

Condensate depression is defined as cooling the condensate to below the saturation temperature.

Reference 63, page 9-22; and Reference 39, page 5.3-2.

33. A

Condensate depression is defined as cooling the condensate to below the saturation temperature.

Reference 63, page 9-22; and Reference 39, page 5.3-2.

34. A

Reference 63, page 9-22.

35. A

From Steam Tables:

1000 psig = 1015 psia
Tsat for 1015 psia:
1015 is 30% of the distance from 1000 to 1050, therefore:
Tsat = 544.58 + 0.30 (550.53 - 544.58)
= 546°F
Subcooling = Tsat - T
= 546°F - 400°F
= 146°F

Reference 10.

36. A

From Steam Tables:

Saturated Liquid (hf) at 1,100 psia is 557.5 BTU/lbm.

Reference 10.

37. C

From Steam Tables:

112°F + 6°F = 118°F
Saturation pressure at 118°F = 1.6 psia

Reference 10.

38. A

From Steam Tables:

$h_x = h_f + (X)\, h_{fg}$

$h_v = 97.96 + (.9)\,(1019.8)$

$h_v = 1{,}015.78$ BTU/1bm

Reference 10.

39. C

From Steam Tables:

Saturation temperature for 230 psia = 393.70°F
900° - 393.70° = 506.30°F

Reference 10.

40. A

From Steam Tables, 328°F water has a saturation pressure of 100.245 psia, which equates to approximately 85 psig.

41. C

The temperature difference across the steam generator tubes is normally:

$\Delta T = 573.5 - 513.5 = 60°F$

When 5% of the tubes are plugged the new ΔT must be:

$1.05 \times 60 = 63°F$,

to achieve 100% percent power. The new Tstm will equal

$573.5 - 63.0 = 510.5°F$

From the Steam Tables:
Saturated steam pressure at 510.5°F is 748.5 psia

42. B

From the Steam Tables:
The saturated temperature at 400 psig (415 psia) is 448°F. The reactor coolant system is subcooled by:

$448 - 280 = 168°F$

43. D

From the Steam Tables:
2233.5 psig = 2248.5 psia
Tsat for 2248.5 psia is 653°F
Subcooling = Tsat - T
= 653 - 610
= 43°F

Saturation pressure at 610°F is 1660.5 psia
Pressure margin = Psat - P
= 2248.5 - 1660.5
= 588 psi

44. D

45. D

46. B

STEAM
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.02 No questions

The topics of effects of pressure and temperature on liquid density are adequately addressed as supporting topics within such sections of this catalog as Sensors/Detectors under Components and Reactivity Coefficients under Reactor Theory.

K1.08 Questions 1-7, 45

Define saturated liquid.

K1.12 Question 8

Determine moisture content.

K1.12 Questions 9, 11, 12

Determine quality.

K1.12 Question 10

Determine moisture content using a Mollier Diagram.

K1.13 Questions 13, 15

Explain the relationship of steam quality and moisture content.

K1.13 Questions 14, 16

Define quality.

K1.13 Question 17

Given a Mollier Diagram, determine the quality of a wet vapor.

K1.14 Questions 18-20, 44, 46

Define superheated vapor.

K1.16 Questions 21-27

Define subcooled and compressed liquids.

K1.17 Questions 28-34

Define condensate depression.

K1.24 No questions

The topic of steam table usefulness is subordinate to their use as covered under K1.25.

K1.25 Questions 35-43

Explain and use saturated and superheated steam tables.

THERMODYNAMIC PROCESSES
Questions

1. Air entrainment in the nozzle of an air ejector is caused by the

   A. air volume available to the nozzle
   B. steam pressure entering the nozzle
   C. pressure reduction at the nozzle throat
   D. size of the nozzle

2. To accelerate steam until its pressure is reduced to below the condenser pressure is the function of

   A. an air ejector nozzle
   B. a moisture separator
   C. a vapor extractor
   D. a steam trap

3. Which of the following forms of energy is most affected in a fluid passing through the throat of an air ejector nozzle?

   A. heat
   B. internal
   C. kinetic
   D. potential

4. Condensate depression is a term that describes the

   A. amount of net positive suction head available at the suction of the condensate pump

   B. amount of condensate subcooling in the condenser hotwell

   C. compressibility of water at the suction of the condensate pump

   D. pressure of the water at the suction of the condensate pump

5. Condenser pressure is 1.0 psia. During the cooling process in the condenser the LP turbine exhaust temperature decreases to 100.0°F, at which time it is a

   A. saturated liquid
   B. saturated vapor
   C. subcooled liquid
   D. superheated vapor

6. Condensate depression is the process of

   A. removing condensate from turbine exhaust steam

   B. spraying condensate into turbine exhaust steam

   C. heating turbine exhaust steam above its saturation temperature

   D. cooling turbine exhaust steam below its saturation temperature

7. Excessive heat removal from the low pressure turbine exhaust steam in the main condenser will result in excessive

   A. thermal stress
   B. reduction in condenser vacuum
   C. condensate depression
   D. fluid compression

8. Raising the hotwell condensate temperature will

   A. decrease the vapor pressure in the condenser

   B. decrease the amount of condensate depression

   C. increase the amount of subcooling at the suction of the condensate pump

   D. increase the net positive suction head at the suction of the condensate pump

9. If the condensate depression increases from 5°F to 10°F, plant efficiency will

   A. fluctuate
   B. remain the same
   C. increase
   D. decrease

10. Condensate depression is directly affected by the

    A. amount of feedwater preheating

    B. temperature of the reactor coolant system

    C. temperature of the circulating water system

    D. moisture content of the steam entering the condenser

11. The amount of condensate subcooling below saturation temperature in the condenser hotwell is

    A. condensate depression
    B. fluid compression
    C. evaporative cooling
    D. condensation

12. Calculate the condensate depression in a condenser operating at 1 psia with a condensate temperature of 100°F.

    A. 1.74°F
    B. 3.74°F
    C. 5.74°F
    D. 7.74°F

13. Which one of the following explains why condensate subcooling is necessary in the steam turbine/condenser phase of a plant cycle?

    A. to maximize overall secondary efficiency

    B. to provide a better condenser vacuum

    C. to minimize turbine blade and condenser tube erosion by entrained moisture

    D. to provide net positive suction head (NPSH) for the condensate pumps

14. Explain how condensate depression affects plant operation. Describe one benefit and one harmful effect.

15. Given that condensate depression lowers Rankine cycle efficiency, why do plants operate with some condensate depression?

16. Vacuum is established in the condenser to

    A. increase condensate depression

    B. decrease the condensation process

    C. increase the amount of available energy in a Rankine cycle

    D. decrease the moisture content of steam entering the condenser

17. If the steam exiting the low pressure turbine is at 130°F, what is the pressure in the condenser?

    A. 2.1068 psia
    B. 2.2230 psia
    C. 2.3445 psia
    D. 2.4717 psia

18. The pressure in the condenser is dependent on the vapor pressure of the

    A. condensate
    B. circulating water
    C. feedwater
    D. steam entering the high pressure turbine

19. Non-condensible gases mixed in the vapor of the condenser will

    A. increase the efficiency of the plant

    B. decrease the effficiency of the plant

    C. increase the heat transfer rate from the condenser

    D. increase the flow rate through the turbine

20. Assuming the temperature of the circulating water system is at 60°F at the inlet of the condenser, theoretically what is the lowest pressure that can be established in the condenser?

    A. 0.25611 psia
    B. 0.27494 psia
    C. 0.50683 psia
    D. 0.94924 psia

21. The saturation pressure at which condensing occurs is directly affected by the

    A. amount of subcooling of the condensate

    B. level of the condensate in the hotwell

    C. temperature of the circulating water

    D. quality of the steam entering the high pressure turbine

22. Which statement best describes the condensing process?

    A. phase change and rejection of latent heat of vaporization

    B. conversion of latent heat of vaporization to latent heat of condensation

    C. sublimation of the steam in the condenser

    D. isentropic expansion through the condenser

23. Using water as a cooling medium, what is the lowest pressure that theoretically could be achieved in the condenser?

    A. 0.08859 psia
    B. 0.50683 psia
    C. 0.69813 psia
    D. 0.94294 psia

24. Which of the following statements best describes the ideal condensing process with no subcooling?

    A. isobaric
    B. isenthalpic
    C. adiabatic
    D. isentropic

25. As steam goes through a throttling process in a main steam header to atmospheric leak, in which of the following parameters will there be an increase?

    A. enthalpy
    B. pressure
    C. specific volume
    D. temperature

26. The reactor coolant system is being maintained at 985 psig. A pressurizer safety/relief valve is slowly discharging to a collection tank, which is being maintained at 5 psig. What is the enthalpy of the fluid entering the tank?

    A. 1,156 BTU/lbm
    B. 1,178 BTU/lbm
    C. 1,193 BTU/lbm
    D. 1,210 BTU/lbm

27. The plant is maintained at 2,000 psia with a pressurizer temperature of 636°F. A pressurizer safety/relief valve is leaking to the a collection tank which is being held at 10 psig. What is the temperature of the fluid downstream of the relief valve?

    A. 280°F
    B. 240°F
    C. 190°F
    D. 170°F

28. The pressurizer power-operated relief valve has stuck in a partially opened position with the fluid being discharged into the pressurizer relief tank. The pressurizer pressure is 2200 psia and the relief tank pressure is 5 psig. What is the condition of the fluid downstream of the relief valve?

    A. superheated steam
    B. subcooled liquid
    C. dry saturated steam
    D. wet vapor

29. If steam at 500 psia and 900°F were throttled to 40 psia, what would be the resulting entropy of the fluid?

    A. 1.97
    B. 1.90
    C. 1.70
    D. 1.65

30. What is the temperature and phase of the fluid downstream of the pressurizer relief valve if it sticks open at 2,200 psia in the pressurizer with a 50 psia back pressure?

    A. 281°F, saturated
    B. 281°F, superheated
    C. 332°F, saturated
    D. 332°F, superheated

31. You are involved in a routine plant shutdow with a steam bubble in the pressurizer. Pressurizer pressure is 415 psig and pressurizer pressure and level are slowly decreasing. You suspect a pressurizer power operated relief valve (PORV) is partially open but the position indicating lights are not working.

    Which one of the following is the expected PORV tailpipe temperature if the PORV is partially open? (Assume downstream pressure is atmospheric.)

    A. 652°F
    B. 450°F
    C. 330°F
    D. 212°F

32. If a pressurizer safety/relief valve is leaking past its seat with the plant at power, and the fluid discharged is being collected by a vented collection tank, would the temperature in the tank necessarily be at least 212°F (neglecting ambient losses)? Explain.

33. Which one of the following is an advantage of condensate depression in the main condenser?

    A. increased secondary cycle efficiency

    B. increased feedwater temperature entering the steam generators

    C. increased NPSH available to condensate pumps

    D. increased inventory in the main condenser hotwell

34. What is the condensate depression in a condenser operating at 26 inches Hg vacuum with a condensate temperature of 100°F?

    A. 2°F
    B. 15°F
    C. 26°F
    D. 53°F

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. C

Reference 45, page 299.

2. A

Reference 45, page 299.

3. C

Reference 45, page 299.

4. B

By definition, condensate depression is the amount of subcooling of the condensate in the condenser.

Reference 63, page 9-22.

5. C

Reference 63, page 9-22.

6. D

Reference 63, page 9-22.

7. C

Condensate depression is subcooling of the condensate in the condenser. Excessive removal of heat will cause excessive subcooling.

8. B

Reference 63, page 9-22.

9. D

Reference 63, page 9-22.

10. C

Reference 63, page 9-22.

11. A

Reference 63, page 9-22.

12. A

From steam tables, 1 psia corresponds to a saturation temperature of 101.74°F; therefore, condensate depression is

101.74°F - 100°F = 1.74°F

Reference 63, page 9-22.

13. D

Reference 63, page 9-22.

14.

Condensate depression is cooling the condensate in the condenser hotwell below its saturation temperature. A benefit derived from operating with some condensate depression is that the colder water provides an increased net positive suction head at the suction of the condensate booster pumps and condensate pumps. A disadvantage is that condensate depression reduces plant efficiency, since it represents additional heat rejected to the circulating water.

Reference 63, page 9-22.

15.

By subcooling the water in the condenser hotwell, the likelihood of cavitation in the condensate booster pumps or condensate pumps is reduced. The lower suction temperature increases pump net positive suction head.

Reference 63 page 9-22.

16. C

Reference 63, page 9-14.

17. B

Reference 10.

18. A

Reference 08, chapter 8, page 117.

19. B

The increased turbine exhaust pressure decreases efficiency.

Reference 08, chapter 8, page 116.

20. A

Reference 10.

21. C

Reference 08, chapter 8, page 116.

22. A

Reference 63, page 9-19.

23. A

Reference 10, and Reference 63, page 9-4.

24. A

Reference 63, page 9-19.

25 C

As the steam expands, its specific volume (volume per pound mass) increases.

26. C

Steam Tables or Mollier Chart. Throttling process is a constant enthalpy process. Enthalpy for 1,000 psia (985 psig + 15 = 1,000 psia) is 1,192.9 BTU/1bm.

Reference 10.

27. B

Mollier Chart: Throttling is a constant enthalpy process. Go to 2,000 psia line. Follow constant enthalpy line over to 25 psia (10 psig + 15 = 25 psia) pressure line. Follow 25 psia line back up to saturation curve and read constant temperature line at that point.

Reference 10.

28. D

Throttling is a constant enthalpy process. Any pressure line brought across a constant enthalpy line to 20 psia line (5 psig + 15 = 20 psia) will place the fluid in the wet vapor region of the Mollier chart.

Reference 10.

29. A

On Mollier Chart:

Find the point where 500 psia and 900°F line cross. Since this is a throttling process, follow the constant enthalpy line across to the 40 psia line. Then follow the entropy line up to read 1.97.

Reference 10.

30. A

Mollier Chart: Throttling is constant enthalpy process. Go to the 2,200 psia point on the saturation line. Cross the constant enthalpy line to the 50 psia pressure line. Follow that line up to the saturation curve and read the constant temperature line that ends at that point. Where the constant enthalpy line intersects the 50 psia line establishes the phase, which is below the saturation curve, thereby indicating a wet vapor.

Reference 10.

31. C

On the Mollier Chart:
Find the point on the saturation line for a pressure of:

415 + 15 = 430 psia

The saturation temperature at this point reads about 450°F. Since this is a throttling process, follow the constant enthalpy line across to the 15 psia line (atmospheric pressure). The temperature reads about 330°F.

32.

Leakage past a valve seat as described is a constant enthalpy throttling process. Referring to a Mollier diagram, the process would begin at the intersection of the pressurizer pressure line with the saturation line. The throttling process follows the constant enthalpy line to the downstream pressure line. Downstream temperature is found at the intersection of the downstream pressure line and the saturation line.

As shown by the Mollier diagram, for any pressure at or above standard atmosphere (as would exist in the vented tank), the resulting temperature would be at or above 212°F.

Reference 10.

33. C

34. C

$P_{abs.}$ = [(29.92 - 26) in. Hg] x 1 psia/ 2 in. Hg = 1.96 psia.

From the steam tables, $T_{sat.}$ for 1.96 psia is 126 °F, and condensate depression is (126 - 100) °F = 26 °F.

THERMODYNAMIC PROCESSES
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.04 Questions 1-3

Describe the function and operation of air ejector nozzles.

K1.11 Questions 4-6, 11

Define condensate depression.

K1.11 Questions 7, 8, 10

Describe the factors that affect condensate depression.

K1.11 Question 9

Describe the effect on plant efficiency due to changes in condensate depression.

K1.11 Question 12, 34

Calculate condensate depression.

K1.11 Questions 13-15, 33

Relate condensate depression to plant operation considerations.

K1.12 Question 16

Explain the purpose of establishing a vacuum in the condenser.

K1.12 Questions 17, 20

Determine condenser pressure based on plant conditions.

K1.12 Questions 18, 19

Describe the factors that affect condenser pressure.

K1.13 Questions 21-24

Explain the condensing process.

K1.15 Questions 25-32

Determine the exit conditions of a fluid for a throttling process.

THERMODYNAMIC CYCLES
Questions

1. Which of the following will cause plant efficiency to increase?

   A. increasing total steam generator blowdown from 30 gpm to 40 gpm

   B. changing steam quality from 99.7% to 99.9%

   C. bypassing a feedwater heater during normal plant operations

   D. increasing condenser pressure from 1 psia to 2 psia

2. Which of the following actions will result in a decrease in plant efficiency?

   A. increasing the steam quality by adding additional heat to the steam prior to entering the turbine

   B. increasing the temperature of the feedwater entering the steam generator

   C. decreasing the amount of condensate depression in the main condenser

   D. decreasing the temperature of the steam at the turbine inlet

3. Which of the following actions will decrease plant efficiency?

   A. reducing steam moisture content

   B. reducing condensate depression

   C. increasing turbine exhaust pressure

   D. increasing temperature of feedwater entering the steam generators

4. Overall secondary plant efficiency will decrease if

   A. additional moisture is removed from the steam entering the turbine

   B. the temperature of the feedwater entering the steam generator is increased

   C. the amount of condensate depression (subcooling) in the main condenser is decreased

   D. the temperature of the steam at the turbine exhaust is increased

5. Saturated steam at 250 psia enters turbine "X". Superheated steam at 250 psia, 500°F enters turbine "Y". Both turbines are 100 percent efficient and exhaust to a 1 psia condenser. Which one of the following lists the percentage of moisture at the exhaust of turbines X and Y?

   A. turbine "X" = 24.5 percent; tubine "Y" = 20.2 percent

   B. turbine "X" = 26.3 percent; turbine "Y" = 13.0 percent

   C. turbine "X" = 24.5 percent; turbine "Y" = 13.0 percent

   D turbine "X" = 26.3 percent; turbine "Y" = 20.2 percent

6. To achieve maximum secondary plant efficiency, feedwater should enter the steam generator (S/G) ____________ and the pressure difference between the S/G and the condenser should be as __________ ___ as possible.

   A. close to saturation; small
   B. close to saturation; great
   C. as subcooled as practical; small
   D. as subcooled as practical; great

7. The addition of feedwater heaters increases plant efficiency because

   A. the average temperature at which heat is transferred in the steam generator is increased

   B. less steam flow passes through the turbine thereby increasing turbine efficiency

   C. increased feedwater temperature will lower the temperature at which heat is rejected

   D. a gradual increase in feedwater temperature allows for a lower heat transfer rate

8. Which of the following plant changes will cause an increase in plant efficiency?

   A. decreasing the enthalpy of the water entering the steam generator

   B. increasing the enthalpy of the steam exhausting the turbine

   C. decreasing the circulating water flow rate to the condenser

   D. increasing the circulating water flow rate to the condenser

9. Explain how the following secondary system parameter changes would affect plant efficiency.

   a. increasing condenser vacuum

   b. increasing feedwater heating

   c. reducing condensate depression

   d. increasing steam temperature at the turbine entrance

10. Explain how the following actions would affect plant thermodynamic efficiency.

    a. isolating a feedwater heater
    b. increasing circulating water temperature
    c. plugging condenser tubes
    d. failure of condenser air ejectors

11. High steam quality is desired at the inlet of the low pressure turbine because a high quality

    A. increases the plant's heat rate

    B. lowers the heat transfer rate from the main condenser to the circulating water

    C. provides improved lubrication to the turbine blades, thus reducing friction losses

    D. reduces erosion of the turbine blades

12. A low percent moisture is desirable at the inlet of the low pressure turbine because it

    A. reduces erosion of the turbine blades

    B. reduces the required size of the low pressure turbine

    C. lowers the heat transfer rate from the main condenser to the circulating water

    D. increases the plant's heat rate

13. The critical location for blade erosion in the turbine is at the ______ of the ______ pressure turbine.

    A. last stages, high
    B. last stages, low
    C. first stages, high
    D. first stages, low

14. Which of the following turbines exhausting to a 1 psia condenser will have the least erosion of its turbine blades per pound mass of steam flow? A Mollier Diagram may be used.

 A. a 90% efficient turbine with 900 psig saturated vapor at its entrance

 B. a 100% efficient turbine with 900 psig saturated vapor at its entrance

 C. a 90% efficient turbine with 250 psia, 500°F steam at its entrance

 D. a 100% efficient turbine with 250 psia, 500°F steam at its entrance

15. Assume that reactor and turbine control systems are in manual and that the moderator temperature coefficient is negative. If feedwater heaters are removed from service, reactor power initially _____; plant efficiency _____.

 A. remains constant, increases
 B. increases, decreases
 C. increases, remains constant
 D. decreases, decreases

16. The plant is operating at full power with 0°F of condensate subcooling. If main condenser cooling water inlet temperature increases by 3°F, secondary steam cycle efficiency will:

 A. decrease due to reduced main condenser heat rejection

 B. increase due to increased main condenser heat rejection

 C. decrease due to a reduced main condenser vacuum

 D. increase due to an improved main condenser vacuum

17. Which one of the following plant changes will cause an <u>increase</u> in plant efficiency?

 A. decreasing the temperature of the water entering the steam generators

 B. reducing the superheat of the steam entering the low pressure turbine

 C. decreasing the circulating water flow rate to the main condenser

 D. removing accumulated non-condensable gases from the main condenser

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

Increasing steam quality provides a higher available inlet enthalpy to the turbine allowing for a greater Dh across the turbine and increasing work output. Overall plant efficiency increases.

Reference 63, pages 7-66 through 7-106; and Reference 45, chapter 9, pages 305 through 315.

2. D

Decreasing turbine inlet steam temperature will decrease the available work extracted by the turbine. Less turbine work will decrease overall plant efficiency.

Reference 63, page 7-104; and Reference 45, chapter 9, pages 305 through 315.

3. C

Increasing condenser pressure results in rejecting heat at a higher temperature. This will increase the heat rejected, which will decrease plant efficiency.

Reference 63, pages 7-66 through 7-105; and Reference 45, chapter 9, pages 305 through 315.

4. D

Increasing the temperature of the steam leaving turbine increases the amount of unavailable energy in the cycle. All the other answers will increase efficiency.

Reference 63, pages 7-66 through 7-105

5. A

On the Mollier Chart:
Find the 250 psia point on the saturation line and extrapolate line to the 1 psia pressure line. The moisture percentage reads 24.5. Find the 250 psia, 500°F supercheated point on the chart. Extrapolate vertically (constant enthropy) to the 1 psia pressure line. The moisture percentage reads 20.2.

Reference 63, pages 7-8 through 7-53.

6. B

Reference 63, pages 7-67 and 7-68

7. A

An increase in average temperature at which heat is added increases thermal efficiency.

Reference 63, page 7-104; and Reference 45, chapter 9, pages 305 through 315.

8. D

Increasing circulating water flow rate will reduce the condenser temperature, thus lowering the enthalpy of the turbine exhaust. This allows for a greater Δh output from the turbine, thereby increasing plant efficiency.

Reference 63, page 7-104; and Reference 45, chapter 9, pages 305 through 315.

9.

Secondary system parameter changes affecting plant thermodynamic efficiency include:

a. increasing condenser vacuum - The lower the pressure in the main condenser, the greater the work done by the turbine and hence the greater the overall plant efficiency.

b. increasing feedwater heating - For greatest efficiency, heat transfer should occur at a constant temperature. By raising feedwater temperature to near Tsat for steam generator pressure, efficiency is increased.

c. reducing condensate depression - The less heat energy lost to the circulating water by excessively subcooling condensate, the more efficient the plant.

d. increasing steam temperature at the turbine entrance - Moisture separator-reheaters are included in typical steam systems to serve this function for the low pressure turbine. Some plants have steam superheaters to serve a similar function for the high pressure turbine.

Reference 63, pages 7-66 through 7-82.

10.

a. Isolating a feedwater heater would decrease plant thermodynamic efficiency by decreasing the temperature of the feedwater. Efficiency is maximized when the heat input into the secondary system occurs at a constant high temperature.

b. Increasing circulating water temperature reduces the heat transfer rate in the condenser, causing condenser temperature and pressure to rise. This higher pressure at the turbine outlet reduces cycle efficiency.

c. As in "b" above, plugging condenser tubes reduces heat transfer in the condenser, causing condenser pressure and temperature to increase and efficiency to decrease.

d. With an air ejector not operating to remove non-condensible gases from the condenser, pressure will gradually increase, reducing cycle efficiency.

Reference 63, pages 7-68, 7-80, 9-25, and 9-34.

11. D

A high steam quality means a low percent moisture, which reduces the water droplet bombardment of the turbine blades, which creates erosion.

Reference 24, chapter 12, page 528.

12. A

Low percent moisture reduces the water droplet bombardment of the turbine blades, which creates erosion.

Reference 24, chapter 12, page 528.

13. B

Mechanical separation of steam from water is sufficient to protect the blades in the front of the low pressure turbine from erosion, but to protect the turbine blades in the back of the low pressure turbine from excessive erosion requires superheating the steam entering the low pressure turbine.

Reference 24, chapter 12, page 528.

14. C

Superheating the steam and lowering turbine efficiency both cause the quality of the turbine exhaust to increase, thereby reducing blade erosion. A quick check on the Mollier diagram will confirm the higher quality of the exhaust of the superheated, lower efficiency turbine.

Reference 24, chapter 12, pages 528, 537, and 538.

15. B

Removing the feedwater heating reduces plant efficiency. Reactor power increases because the cooler feedwater entering the steam generators lowers reactor coolant system average temperature slightly, which increases reactor power slightly.

Reference 24, chapter 12, pages 531 through 537.

16. C

17. D

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.03 Questions 1-10, 16, 17

Describe how changes in secondary system parameters affect thermodynamic efficiency.

K1.04 Questions 11, 12

State the reason for maintaining high-quality, low-moisture steam for the turbines.

K1.04 Question 13

Identify the critical location for blade erosion in the turbine.

K1.04 Question 14

Determine the effect of steam conditions and turbine efficiency on turbine blade erosion. A Mollier Diagram may be used.

K1.05 Question 15

Explain the effects of feedwater heating on steam cycle efficiency.

FLUID STATICS AND DYNAMICS
Questions

NOTE: Some of the following questions are similar to those found in the "Pumps" section of this catalog. Therefore, caution must be exercised to avoid duplication when selecting questions for an examination.

1. The possibility of a water hammer is minimized by

   A. maintaining system temperature above the saturation temperature

   B. starting centrifugal pumps with the casing vent valve fully open

   C. starting positive displacement pumps with the discharge valve closed

   D. venting systems prior to starting centrifugal pumps

2. Which one of the following methods would <u>increase</u> the possibility and/or severity of water hammer?

   A. venting fluid systems prior to starting a pump

   B. starting a centrifugal pump with the discharge valve fully closed

   C. starting a centrifugal pump with the discharge valve fully open

   D. opening and closing system valves slowly

3. The possibility of a water hammer would be <u>increased</u> by

   A. maintaining the discharge line filled with liquid on an automatically starting pump

   B. water collecting in a steam line due to condensation

   C. warming system steam lines prior to initiating flow

   D. slowly closing the discharge valve on an operating pump

4. The main reason for keeping condensate out of the steam lines is to

   A. prevent corrosion buildup
   B. reduce heat losses
   C. eliminate steam traps
   D. prevent water/steam hammers

5. The major concern with starting a feedwater pump with downstream fluid in a saturated condition is

   A. cavitation
   B. water hammer
   C. thermal shock
   D. positive reactivity addition

6. The proper method to initiate flow into a system to <u>minimize</u> the possibility of a water hammer is to

   A. vent the system prior to initiating flow

   B. vent the system after flow has been initiated

   C. fully open pump discharge valves prior to starting the pump

   D. rapidly open the discharge valve after a pump is running

7. A sudden stop of fluid flow in a piping system, due to rapid closure of an isolation valve, will most likely result in

   A. check valve slamming
   B. pump runout
   C. water hammer
   D. pressurized thermal shock

8. Mass flow rate is expressed by which of the following formulas?

   A. (fluid velocity) / (specific volume)
   B. (density) x (area) x (fluid velocity)
   C. (density) x (area) x (volumetric flow rate)
   D. (volumetric flow rate) / (density)

9. Write the equation that relates fluid velocity to mass flow rate. Identify symbols used.

10. An 85 gpm leak has developed in a cooling water system that is operating at 100 psig. Which one of the following is the expected leak rate when system pressure has decreased to 50 psig?

    A. 33.3 gpm
    B. 42.5 gpm
    C. 51.7 gpm
    D. 60.1 gpm

11. A 55 gpm leak has developed in a cooling water system that is operating at 100 psig. Which one of the following is the expected leak rate when system pressure has decreased to 50 psig?

    A. 27.5 gpm
    B. 31.8 gpm
    C. 38.9 gpm
    D. 43.4 gpm

12. Mass flow rate equals volumetric flow rate

    (V) times

    A. specific volume
    B. density
    C. specific gravity
    D. velocity

13. Explain the difference between mass flow rate and volumetric flow rate.

14. Explain what is meant by the term "two-phase" flow."

15. Reactor coolant system hot leg temperature is 568 °F and reactor coolant system pressure is decreasing due to a small leak. Which one of the following pressure ranges includes the pressure at which two-phase flow will first occur in the hot leg?

    A. 1250 to 1201 psig
    B. 1200 to 1151 psig
    C. 1150 to 1101 psig
    D. 1100 to 1051 psig

16. The plant is recovering from a loss of off-site power. Prior to starting a reactor coolant pump, the steam generator temperatures must be equal to or less than RCS temperature to avoid the possibility of

    A. a large pressure spike throughout the RCS

    B. pressurized thermal shock to the steam generators

    C. inadvertently lifting a steam generator atmospheric relief vlave

    D. localized water hammer in the RCS

17. A centrifugal pump is being returned to service after maintenance. The operator fails to vent the pump properly. When the pump is started the operator should see _______ capacity and _______ discharge head.

    A. lower; lower
    B. lower; higher
    C. higher; lower
    D. higher; higher

18. The piping system pressure change caused by suddenly stopping fluid flow is referred to as

    A. cavitation
    B. shutoff head
    C. water hammer
    D. flow head

19. The formation of vapor bubbles in the eye of a pump impeller and the subsequent collapse of these bubbles in the higher pressure areas of the pump is called

    A. cavitation
    B. condensation
    C. convection
    D. convergence

20. Cavitation is best defined as

    A. the process of subcooling the condensate below saturation conditions in the condenser

    B. the formation of vapor bubbles, usually in the low pressure side of a pump, followed by the collapse of these bubbles in the high pressure side of the pump

    C. the formation of vapor bubbles along the heat transfer surface of the fuel rods due to high rates of heat transfer

    D. an unstable condition caused by a fluid being brought from a superheated state to the saturated region more rapidly than the vapor can condense

21. The condition that would most likely cause cavitation of an operating centrifugal pump is

    A. lowering the suction temperature
    B. throttling the pump suction valve
    C. throttling the pump discharge valve
    D. decreasing the pump speed

22. Cavitation in an operating pump may be caused by

    A. lowering the suction temperature
    B. throttling the pump suction valve
    C. increasing the pump backpressure
    D. increasing the pump suction pressure

23. Which one of the following is not an indication of cavitation?

    A. fluctuating discharge pressure
    B. pump vibration
    C. pump overheating
    D. high discharge pressure

24. Which of the following are indications of cavitation?

    A. low discharge pressure and low flow
    B. high discharge pressure and high flow
    C. low discharge pressure and high flow
    D. high discharge pressure and low flow

25. While on surveillance rounds, an operator notices that a low pressure centrifugal pump is making a great deal of noise and the discharge pressure is fluctuating. This set of conditions indicates

    A. excessive shutoff head
    B. excessive net positive suction head
    C. pump cavitation
    D. pump head

26. Cavitation of a centrifugal pump in an open system is indicated by ____________ discharge pressure and ____________ flow rate.

    A. low; low
    B. high; high
    C. low; high
    D. high; low

27. While on surveillance rounds, an operator notices that a centrifugal pump is making a great deal of noise (like marbles rattling inside the pump casing) and the discharge pressure is fluctuating. This set of conditions indicates

    A. pump bearing deterioration
    B. pump runout
    C. pump cavitation
    D. pump packing deterioration

28. The temperature of a fluid in a system is increased. How does this affect indicated volumetric flow rate if the flow instrument is not density compensated and a constant mass flow rate is maintained? Indicated flow rate will

    A. increase due to the velocity increase of the fluid to maintain the same mass flow rate

    B. decrease due to the velocity decrease of the fluid to maintain the same mass flow rate

    C. not change since the density of a fluid has no effect on indicated mass flow rate

    D. not change since the velocity of the fluid must change to compensate for the density change to maintain a constant mass flow rate

29. In an operating cooling water system with a constant water velocity, if water temperature decreases, indicated volumetric flow rate (gpm) will

    A. remain the same, because the density of the water has not changed

    B. increase, because the density of the water has increased

    C. remain the same, because the water velocity has not changed

    D. increase, because the viscosity of the water has increased

30. The temperature of a fluid in a system is decreased. How does this affect indicated volumetric flow rate if the flow instrument is not density compensated and a constant mass flow rate is maintained? Indicated flow rate will

    A. increase due to the velocity increase of the fluid to maintain the same mass flow rate

    B. decrease due to the velocity decrease of the fluid to maintain the same mass flow rate

    C. not change since the density of a fluid has no effect on indicated mass flow rate

    D. not change since the velocity of the fluid must change to compensate for the density change to maintain a constant mass flow rate

31. Flow instruments used to measure the mass flow rate of saturated steam are density compensated because, for a steam pressure increase at a constant volumetric flow rate, steam density will ______ and the actual mass flow rate will ______.

    A. decrease; increase
    B. increase; decrease
    C. increase; increase
    D. decrease; decrease

32. Why does fluid temperature affect flow measurements in a dynamic system? Assume that the fluid velocity does not change.

    A. The volumetric flow rate is directly proportional to density.

    B. The volumetric flow rate is directly proportional to the change in the absolute temperature.

    C. The mass flow rate is directly proportional to density.

    D. The mass flow rate is directly proportional to the change in absolute temperature.

33. Given a constant volumetric flow rate, the actual mass flow rate will

    A. decrease with an increase in density of the fluid

    B. increase with a decrease in density of the fluid

    C. increase with an increase in temperature of the fluid

    D. decrease with an increase in temperature of the fluid

34. If a flow measuring instrument is not density compensated, then indicated mass flow rate will be

    A. the same as actual mass flow rate with a change in temperature of the fluid

    B. greater than actual mass flow rate with a decrease in temperature of the fluid

    C. less than actual mass flow rate with a decrease in temperature of the fluid

    D. less than actual mass flow rate with an increase in temperature of the fluid

35. Flow measurements are normally corrected for density changes. Which one of the following relationships is true for a flow measuring instrument that is not density compensated? With a constant fluid velocity, indicated mass flow rate will be ________ actual mass flow rate with _______ in temperature of the fluid.

    A. the same as, a change
    B. greater than, a decrease
    C. less than, a decrease
    D. less than, an increase

36. System total volumetric flow rate is normally controlled by

    A. adjusting system throttle valves

    B. installing or removing flow orifices

    C. altering the system pipe diameter

    D. varying the suction pressure on operating pumps

37. To significantly increase total system volumetric flow rate,

    A. place several pumps in series alignment

    B. place several pumps in parallel alignment

    C. ensure the system exhibits laminar flow conditions

    D. ensure the system exhibits turbulent flow conditions

38. One common method of increasing feedwater flow to the steam generators is

    A. increasing condenser hotwell level

    B. throttling open the feedwater regulating valves

    C. decreasing backpressure by reducing steam generator pressure

    D. throttling open the feedwater pump isolation valves

39. Operating two pumps in parallel instead of operating a single pump will result in

    A. a large increase in system head and a small increase in flow rate

    B. a small increase in system head and a small increase in flow rate

    C. a small increase in system head and a large increase in flow rate

    D. a large increase in system head and a large increase in flow rate

40. During operation of a positive displacement pump, the most desirable method of decreasing system volumetric flow rate is to

    A. throttle the pump discharge valve
    B. throttle the pump suction valve
    C. decrease the pump NPSH
    D. decrease the pump speed

41. To decrease the flow rate through an operating positive displacement pump, an operator should

    A. throttle the pump discharge valve
    B. throttle the pump suction valve
    C. decrease the pump NPSH
    D. decrease the pump speed

42. Placing two pumps in parrellel alignment versus a single pump will result in

    A. a large increase in system head and the same flow rate

    B. a small increase in system head and a large increase in flow rate

    C. the same system head and a small increase in flow rate

    D. a decrease in system head and a large increase in flow rate

43. The major effect of starting a second centrifugal pump in parallel with an operating centrifugal pump in an open system is

    A. increased system pressure
    B. increased system flow rate
    C. increased pump discharge pressure
    D. increased pump flow rate

44. A steam generator transient causes main steam pressure to decrease although mass flow rate to the main turbine remains constant. If the main steam flow instrument is not density compensated, indicated volumetric flow rate will:

    A. increase due to the velocity increase of the steam

    B. decrease due to the velocity decrease of the steam

    C. increase due to the increased density of the steam

    D. decrease due to the decreased density of the steam

45. Mass flow rate equals volumetric flow rate

    ($\dot{V}$) times:

    A. specific volume
    B. density
    C. specific gravity
    D. velocity

46. Which one of the following will decrease the head loss experienced in an operating cooling water system?

    A. starting a second pump in series with the operating pump

    B. starting a second pump in parallel with the operating pump

    C. replacing a 20' section of 10" pipe with a 20' section of 12" pipe

    D. replacing a 10' section of 10" pipe with a 20' section of 10" pipe

47. A density compensated flow instrument is being used to measure mass flow rate in a steam system. If the pressure of the steam decreases, indicated mass flow rate will: (Assume volumetric flow rate is constant.)

    A. increase due to effect of density compensation

    B. decrease due to the effect of density compensation

    C. not change since the velocity of the steam has not changed

    D. not change since the volumetric flow rate of the steam has not changed

48. A cooling water system is supplying 10^6 lbm/hr of flow at a temperature of 100°F. Assuming volumetric flow rate does not change, what mass flow rate will be supplied by the system if cooling water temperature increases to 140°F?

    A. 7.5 X 10^5 lbm/hr
    B. 8.3 x 10^5 lbm/hr
    C. 9.0 x 10^5 lbm/hr
    D. 9.9 x 10^5 lbm/hr

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. D

System venting ensures air removal, thereby minimizing the possibility of water hammer.

Reference 14, chapter 3, pages 185 through 193.

2. C

The surge of flow when a pump is started with its discharge valve fully open will tend to increase the possibility of a system pressure surge and a resulting water hammer.

Reference 14, chapter 3, pages 185 through 193.

3. B

Admitting steam to a pipe with water in it will result in water/steam hammer.

Reference 14, chapter 3, pages 185 through 193.

4. D

Condensate in steam lines will result in water/steam hammer when flow is initiated.

Reference 14, chapter 3, pages 185 through 193.

5. B

With saturated fluid in the pipe, a mixture of steam and liquid could exist. If the pump is started, the liquid could then be propelled into a section of piping formerly filled with steam, resulting in water hammer.

Reference 29, page 9-80.

6. A

Slow initiation of flow by slowly opening valves after the system has been properly vented will greatly reduce the possibility of water hammer.

Reference 14, chapter 3, pages 185 through 193.

7. C

The sudden decrease of the fluids' velocity within the pipe transfers its flow energy into compressing the fluid, expending the pipe or through frictional loss in pressure wave propagation. The pressure wave that is established produces a water hammer effect.

Reference 14, chapter 3 page 185.

8. B

m = (density) x (area) x (fluid velocity)

$= (lbm/ft^3) \times (ft^2) \times (ft/hr)$

= lbm/hr

Reference 63, page 8-12.

9. $\dot{m} = \rho \dot{V} = \rho A v$

where $\dot{m}$ is mass flow rate

$\dot{V}$ is volumetric flow rate

ρ is density

A is cross sectional area

v is fluid velocity

Reference 63, page 8-12.

10. D

The leak rat'e is proportioned to the velocity of the water leaking out. The velocity in turn is proportional to the square root of the system pressure.

$$\frac{\dot{Q}_2}{\dot{Q}_1} = \frac{v_2}{v_1} \frac{\sqrt{P_2}}{\sqrt{P_2}}$$

$$\dot{Q}_2 = 85 x \frac{\sqrt{50}}{\sqrt{100}}$$

$$\dot{Q}_2 = 60.1 gpm$$

Reference 63, pages 8-12 through 8-15.

11. C

$$\frac{\dot{Q}_2}{\dot{Q}_1} = \frac{\sqrt{P_2}}{\sqrt{P_1}}$$

$$\dot{Q}_2 = 55 x \frac{\sqrt{50}}{\sqrt{100}}$$

$$\dot{Q}_2 = 38.9 gpm$$

Reference 63, pages 8-12 through 8-15.

12. B

$\dot{m} = \rho \dot{V} = \rho A v$

where $\dot{m}$ is mass flow rate

$\dot{V}$ is volumetric flow rate

ρ is density

A is cross sectional area

v is fluid velocity

Reference 63, page 8-12.

13.

In a fixed system, the difference between mass and volumetric flow rates depends on the density of the fluid. The mass flow rate is proportional to the product of the density and volumetric flow rate.

Reference 63, page 8-12.

14.

Two-phase flow takes place when a flowing liquid undergoes a partial phase change, resulting in a mixture of liquid and vapor in the fluid.

Reference 15, pages 325 and 326; reference 63, pages 6-14 through 6-17.

15. B

From the Steam Tables:
Saturation pressure corresponding to 568°F is 1208 psia or 1193 psig.

16. A

17. A

18. C

19. A

Cavitation is defined as formation and subsequent collapse of vapor bubbles in a pump.

Reference 63, page 10-53.

20. B

Cavitation is defined as formation and subsequent collapse of vapor bubbles in a fluid system.

Reference 63, page 10-53.

21. B

Reference 63, page 10-55.

22. B

Throttling the suction valve will increase the pressure drop between the pump suction and the eye of the impeller. This may drop pressure to the vapor pressure at the eye of the impeller.

Reference 63, pages 10-53 through 10-77.

23. D

High discharge pressure is not an indication of cavitation. High discharge pressure is an indication of low flow conditions.

Reference 63, pages 10-53 through 10-77.

24. A

25. C

Fluctuating discharge pressure and excessive pump noise are indications of cavitation.

Reference 63, page 10-53.

26. A

Reference 63, page 10-77.

27. C

Reference 63, pages 10-53 and 10-54.

28. A

If mass flow rate is held constant, a decrease in density (caused by the temperature increase) must be accompanied by an increase in velocity. The increase in velocity results in an increase in differential pressure, which causes indicated flow to increase.

Reference 22, part A, chapter 2, page 316; and Reference 63, pages 11-17 through 11-24.

29. C

Since the volumetric flow rate (gpm) is:

$V = Av$
A is cross sectional area
v is the water velocity
The rate remains the same.

Reference 63, page 11-18.

30. B

If mass flow rate is held constant, an increase in density (caused by the temperature decrease) must be accompanied by a decrease in velocity. The decrease in velocity results in a decrease in differential pressure, which causes indicated flow to decrease.

Reference 22, part A, chapter 2, page 316; and Reference 63, pages 11-17 through 11-24.

31. C

Higher pressure causes increased steam density or more mass per unit volume. With a constant volumetric flow rate, mass flow rate will therefore increase.

32. C

Mass flow rate equals the product of density, velocity, and cross-sectional area.

Reference 22, part A, chapter 2, page 316; and Reference 63, pages 11-17 through 11-24.

33. D

Mass flow rate is proportional to fluid density. An increase in temperature causes a decrease in density and thus a decrease in mass flow rate.

Reference 22, part A, chapter 2, page 316; and Reference 63, pages 11-17 through 11-24.

34. C

Reference 63, page 11-19.

35. C

An uncompensated flow detector measures fluid velocity. A temperature decrease causes density to increase, resulting in an increase in mass flow rate without a change in velocity. Therefore, indicated flow will be less than actual mass flow.

Reference 22, part A, chapter 2, page 316; and Reference 63, pages 11-17 through 11-24.

36. A

Opening system throttle valves will increase flow rates, while closing system throttle valves will decrease flow rate.

Reference 63, pages 10-1 through 10-79.

37. B

Two pumps in parallel will increase system flow rate.

Reference 63, pages 10-45 and 10-46.

38. B

Opening or closing feedwater regulating valves is the most common method of varying feed flow.

Reference 63, pages 10-1 through 10-79.

39. C

Placing two pumps in parallel is used to primarily increase system flow rate but also will result in a small increase in pump head due to increase in flow rate causing higher head loss in system.

Reference 63, pages 10-45 and 10-46..

40. D

Increasing the speed of a positive displacement pump will increase flow rate out of the pump, thus increasing total flow.

Reference 63, pages 10-1 through 10-79.

41. D

Reference 63, pages 10-49 through 10-53.

42. B

Reference 63, pages 10-45 and 10-46.

43. B

Reference 63, pages 10-45 and 10-46

44. A

In order to maintain the same mass flow rate at the reduced pressure, steam velocity must increase. An increase in steam velocity will cause an increase in steam flow instrument pressure differential resulting in a higher indicated steam flow rate.

45. B

46. C

47. A

With a constant volumetric flow rate, the differential pressure across the flow instrument will remain constant. The density decrease which accompanies the pressure decrease will result in a decreased mass flow rate. The density compensation will cause a decrease in indicated flow to account for the decreased mass flow rate.

48. D

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.04 Questions 1-7

Explain the operational implications of water hammer.

K1.05 Questions 8-13, 45

Define mass flow rate and contrast it to volumetric flow rate.

K1.06 Questions 14, 15

Define two-phase flow and describe existing conditions.

K1.07 Question 16

Describe the concept of pressure spiking in fluid systems.

K1.08 Question 17

Identify the symptoms of centrifugal pump gas binding.

K1.08 Other questions

Other questions dealing with gas binding are found in the Pumps section of Components.

K1.10 Question 18

Define water hammer.

K1.11 Questions 19, 20

Define cavitation.

K1.11 Questions 21-27

Explain cavitation.

K1.12 Questions 28-35, 44, 47, 48

Explain why flow measurements must be corrected for density changes.

K1.15 Questions 36-43, 46

Describe methods of controlling system flow rates.

HEAT TRANSFER
Questions

1. The basic mode of heat transfer that involves the transfer of heat by interaction between adjacent molecules of a material is called ________ heat transfer.

   A. conduction
   B. convection
   C. radiation
   D. molecular

2. The basic mode of heat transfer that involves the transfer of heat by motion and mixing of macroscopic portions of a fluid is called _______ heat transfer.

   A. conduction
   B. convection
   C. radiation
   D. molecular

3. The basic mode of heat transfer that involves the transfer of heat due to the differential temperature of two separated bodies in a vacuum is called _________ heat transfer.

   A. conduction
   B. convection
   C. radiation
   D. molecular

4. The transfer of heat through a solid piece of material would be considered ______ heat transfer.

   A. conduction
   B. convection
   C. radiant
   D. molecular

5. List and describe three mechanisms of heat transfer.

6. During a loss-of-coolant accident, which of the following heat transfer mechanisms provides the most core cooling when fuel elements are not in contact with the coolant?

   A. radiation
   B. emission
   C. convection
   D. conduction

7. If an accident causes a portion of the reactor core to become steam-blanketed, which form of heat transfer will predominate? Why will this form predominate?

8. Convection heat transfer can be described as the transfer of heat by

   A. interaction and mixing of molecules of a solid material

   B. electromagnetic radiation that arises due to the temperature of a body

   C. interaction between adjacent molecules without macroscopic interaction of the material through which the heat is being transferred

   D. motion and mixing of macroscopic portions of a fluid

9. The transfer of heat from the reactor fuel to the fuel cladding during normal operations is an example of __________ heat transfer.

   A. conduction
   B. convection
   C. radiant
   D. two-phase

10. Refer to the drawing of a fuel rod and coolant flow channel at beginning of core life (see Figure 3.7-1).

    Given the following initial core parameters:

    Reactor power = 100%

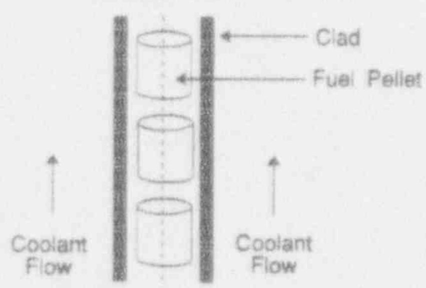
    $T_{coolant}$ = 500°F

    $T_{fuel\ centerline}$ = 3000°F

    What would the fuel centerline temperature be if, over core life, the total fuel-to-coolant thermal conductivity were doubled? (Assume reactor power is constant.)

    A. 1000°F
    B. 1250°F
    C. 1500°F
    D. 1750°F

FIGURE 3.7-1



Fuel Rod and Coolant Flow Channel

11. Refer to the drawing of a fuel rod and coolant flow channel at beginning of core life (see Figure 3.7-1).

    What is the primary method of heat transfer through the gap between the reactor fuel and the fuel clad?

    A. conduction
    B. convection
    C. radiation
    D. natural circulation

12. As fluid flow rate increases through the tubes of a shell-and-tube heat exchanger, the laminar film thickness __________, which causes heat transfer rate to __________.

    A. increases; increase
    B. increases; decrease
    C. decreases; increase
    D. decreases; decrease

13. Why is bulk boiling undesirable in a single-phase heat exchanger?

    A. The bubble formation will break up the laminar layer in the heat exchanger.

    B. Flow blockage can occur in the heat exchanger.

    C. The ΔT across the tubes will decrease across the heat exchanger.

    D. The heat transfer coefficient will increase in the heat exchanger.

14. Excessive amounts of gases passing through a single-phase (liquid) heat exchanger are undesirable because

    A. flow blockage can occur in the heat exchanger

    B. the laminar layer will increase in the heat exchanger

    C. the heat transfer coefficient will increase in the heat exchanger

    D. the ΔT across the tubes will decrease in the heat exchanger

15. Which of the following best explains the effects of steam formation on heat transfer in single-phase (liquid) heat exchangers?

    A. Th~ ΔT across the tubes will decrease in the heat exchanger.

    B. Steam voids will increase the heat transfer coefficient of the heat exchanger.

    C. A small amount of steam will reduce the amount of heat transfer.

    D. Steam voids can accumulate and cause blockage.

16. Which of the following would <u>not</u> affect the mass flow ~ate of a fluid through a heat exchanger?

    A. gases present in the fluid
    B. steam voids in the fluid
    C. soluble chemicals in the fluid
    D. temperature of the fluid

17. A feedwater heat exchanger tube has a restriction in it which reduces the flow rate of the feedwater so that feedwater flashes to steam halfway along the tube. This restriction causes the heat transfer rate of the tube to ________ and the overall heat transfer rate of the heat exchanger to ________.

    A. decrease, decrease
    B. decrease, remain the same
    C. increase, increase
    D. increase, remain the same

18. An air leak into the main condenser causes non-condensable gasses to build up in the shell side of the condenser. This causes the heat transfer rate in the condenser to

    A. decrease, because the gasses accumulate on the surfaces of the condenser tubes where they significantly restrict conductive heat transfer

    B. decrease, because the gas modecules create windage losses in the thermodynamic process of condensation

    C. increase, because the gasses improve the mixing of the steam and prevent the accumulation of condensation on the tubes

    D. increase, because the gasses increase the pressure in the condenser which reduces the amount of condensate depression

19. How and why does the presence of air affect heat transfer in a condenser?

20. State and explain two effects that the presence of gas would have on the performance of a single-phase (liquid) heat exchanger.

21. Core thermal power is defined as the

    A. average power density multiplied by the volume of the core

    B. net work out divided by the energy added

    C. power produced by the electrical generator

    D. thermal energy output per cubic centimeter of the reactor core per unit time

22. Core thermal power can be determined by multiplying

    A. the change in enthalpy across the core times the heat addition rate

    B. mass flow rate of the reactor coolant system times the specific heat times the change in temperature across the core

    C. mass flow rate of the reactor coolant system times the specific heat times the change in temperature across the steam generator (secondary side)

    D. mass flow rate of the reactor coolant system times the change in temperature across the core

23. At steady state, core thermal power can be estimated by

    A. mass flow rate of the feedwater times the change in temperature across the core

    B. mass flow rate of the reactor coolant system times the change in temperature across the steam generator

    C. mass flow rate of the total feedwater flow rate times the change in enthalpy across the steam generator

    D. the average power density in the core times the critical heat flux

24. The amount of heat input per unit time from the core to the reactor coolant system defines

    A. specific heat
    B. power density
    C. percent reactor power
    D. core thermal power

25. When the reactor is at power, one of the limits placed on the operator is core thermal power. In what units is core thermal power normally expressed?

    A. MW_e
    B. MW_t
    C. BTU/hr - °F
    D. BTU/lbm - °F

26. The reactor is producing 200 MW core thermal power. Reactor coolant pumps are adding 10 MW of additional thermal power into the coolant system based on heat balance calculations. The core is rated at 1330 MW thermal power. What is core thermal power in percent?

    A. 14.0 percent
    B. 14.3 percent
    C. 15.0 percent
    D. 15.8 percent

27. During steady state operation, core thermal power can be most accurately determined by multiplying the total mass flow rate of the

    A. reactor coolant by the change in temperature across the core

    B. reactor coolant by the change in enthalpy in the steam generator.

    C. feedwater by the change in enthalpy in the steam generators

    D. feedwater by the change in temperature across the core

28. The change in temperature across the core times the mass flow rate and the specific heat of the reactor coolant system can be used to determine which of the following?

    A. percent reactor power
    B. heat capacity
    C. heat flux
    D. core thermal power

29. Which of the following equations cannot be used to calculate core thermal power ($\dot{Q}$)? Symbols used are for primary-side parameters and are defined as follows:

$\dot{m}$ = mass flow rate
ΔT = change in temperature
Δh = change in specific enthalpy
c_p = specific heat
Δs = change in entropy
P.D. = average power density
V = core volume

A. $\dot{Q}$ = P.D.V

B. $\dot{Q} = \dot{m}\Delta s$

C. $\dot{Q} = \dot{m}c_p\Delta T$

D. $\dot{Q} = \dot{m}\Delta h$

30. The change in enthalpy on the secondary side of a steam generator multiplied by the total mass flow rate of the feedwater can be used to determine which of the following?

A. core thermal power
B. maximum power density
C. thermal neutron flux
D. power distribution

31. The power range nuclear instruments have been adjusted to 100 percent based on a calculated calorimetric (secondary heat balance). Which one of the following will result in actual reactor power being less than indicated reactor power?

A. The feedwater temperature used in the calorimetric calculation was higher than actual feedwater temperature.

B. The reactor coolant pump heat input term was omitted from the calorimetric calculation.

C. The feed flow used in the calorimetric calculation was lower than actual feed flow.

D. The steam pressure used in the calorimetric calculation is lower than actual steam pressure

32. The reactor is operating at 80 percent power with a core ΔT of 48°F when a station blackout occurs. Natural circulation is established and core ΔT stabilizes at 40°F. If mass flow rate is 3.0 percent, what is the current decay heat level?

A. 1.0 percent
B. 2.0 percent
C. 3.0 percent
D. 4.0 percent

33. Which one of the statements below is correct if the power range instruments have been adjusted to 100 percent based on a calculated calorimetric?

A. If the feedwater temperature used in the calorimetric calculation was higher than actual feedwater temperature, actual power will be less then indicated power.

B. If the reactor coolant pump heat input used in the calorimetric calculation is omitted, actual power will be less than indicated power.

C. If the steam flow used in the calorimetric calculation was lower than actual steam flow, actual power will be less than indicated power.

D. If the steam pressure used in the calorimetric calculation is lower than atual steam pressure, actual power will be less than indicated power.

34. Which one of the terms in the formula,

$Q = UA(T_1 - T_2)$, is (affected the most, and therefore) most responsible for the initial increase in heat transfer rate from the reactor fuel during a minor (3 percent) steamline break? Assume no change in reactor power.

A. U
B. A
C. T1
D. T2

35. Which of the following formulas should be used in calculating core thermal power? Symbols used are defined as follows:

$\dot{M}_{rcs}$ = mass flow rate of the reactor coolant system

$\dot{M}_{fwtr}$ = total mass flow rate of the steam generator feedwater

T_h = temperature of coolant exiting core
T_c = temperature of coolant entering core
T_{fwtr} = temperature of steam generator feedwater

h_{fwtr} = specific enthalpy of steam generator feedwater

h_{stm} = specific enthalpy of steam leaving steam generator

c_p = specific heat

A. $\dot{M}_{rcs} (h_{stm} - h_{fwtr})$

B. $\dot{M}_{rcs} c_p (T_h - T_{fwtr})$

C. $\dot{M}_{fwtr} (h_{stm} - h_{fwtr})$

D. $\dot{M}_{rcs} (T_c - T_h)$

36. Which of the following formulas should be used in calculating core thermal power? Symbols used are as follows:

$\dot{M}_{rcs}$ = mass flow rate of the reactor coolant system

$\dot{M}_{fwtr}$ = total mass flow rate of the steam generator feedwater

T_h = temperature of coolant exiting core

T_c = temperature of coolant entering core
T_{fwtr} = temperature of steam generator feedwater

h_{fwtr} = specific enthalpy of steam generator feedwater

h_{stm} = specific enthalpy of steam exiting steam generator

c_p = specific heat

A. $\dot{M}_{rcs} (T_c - T_h)$

B. $\dot{M}_{rcs} c_p (T_h - T_c)$

C. $\dot{M}_{rcs} (h_{stm} - h_{fwtr})$

D. $\dot{M}_{fwtr} (h_{fwtr} - h_{stm})$

37. Explain how and why each of the following would affect the value of reactor power <u>calculated</u> using a <u>secondary</u> heat balance. Consider each item separately.

a. Heat input from reactor coolant pumps is omitted.

b. Steam generator pressure indication is reading lower than actual.

38. Percent reactor power is defined as the measure of reactor power in percent of

A. rated core thermal power
B. rated electrical output
C. rated neutron flux level
D. total megawatts electric of the system

39. In the definition of percent reactor power, percent power refers to percent

    A. thermal neutron flux
    B. neutron count level
    C. rated thermal power
    D. rated electric power

40. The term "percent rated thermal power" refers to percent

    A. electrical power
    B. reactor power
    C. thermal neutron flux
    D. generator power

41. Nuclear power plants are limited by the amount of reactor power they may generate. When referring to percent reactor power this means percent

    A. thermal neutron flux
    B. megawatt output
    C. rated electrical output
    D. rated thermal output

42. The statement percent reactor power refers to percent

    A. electrical power output
    B. rated thermal power
    C. thermal neutron flux
    D. BTUs per pound mass

43. The reactor coolant enters the core at 545 °F and leaves at 595 °F with a flow rate of 6.6×10^7 lbm/hr. The specific heat capacity of the coolant is 1.3 BTU/lbm-°F. Letdown cooling removes 1.2×10^7 BTU/hr from the reactor coolant system, and pump heat adds 4.8×10^7 BTU/hr to the RCS. What is the core thermal power? (1 watt = 3.4127 BTU/hr)

    A. 1,243 MW_t

    B. 1,247 MW_t

    C. 1,[illegible]57 MW_t

    D. 1,268 MW_t

44. The reactor coolant enters the core at 553 °F and leaves at 611 °F. The reactor coolant flow rate is 1.48×10^8 lbm/hr and the specific heat capacity of the coolant is 1.35 BTU/lbm-°F. Feedwater flow totals 7.5×10^6 lbm/hr, steam generator is 850 psia, and condenser vacuum is 28 inches of mercury. What is the core thermal power?

    A. 2,714 MW_t

    B. 3,050 MW_t

    C. 3,396 MW_t

    D. 3,590 MW_t

45. Consider a two-loop pressurized water reactor. Reactor coolant temperature increases 54 °F across the core. Feedwater flow to each steam generator is 3.3×10^6 lbm/hr at an enthalpy of 419 BTU/lbm. The steam exiting each steam generator is at 800 psia with 100% steam quality. Ignoring blowdown, ambient losses, and pump heat, what is the core thermal power?

    A. 1,509 MW_t

    B. 1,406 MW_t

    C. 754 MW_t

    D. 703 MW_t

46. For a three-loop pressurized water reactor, the reactor coolant system flow rate is 9.6×10^9 lbm/hr. Feedwater flow to <u>each</u> steam generator is 3.2×10^6 lbm/hr at a specific enthalpy of 414 BTU/lbm. The steam exiting each steam generator is at 800 psia with 100% steam quality. Ignoring blowdown, ambient losses, and pump heat, what is the core thermal power?

    A. 2,945 MW_t

    B. 2,209 MW_t

    C. 1,472 MW_t

    D. 736 MW_t

47. For a two-loop pressurized water reactor operating at 100% power, the ΔT across the core is 56 °F. The mass flow rate of the reactor coolant system is 6.7×10^7 lbm/hr. Specific heat at the temperature of the reactor coolant system is 1.3 BTU/lbm °F. Ignoring blowdown and reactor coolant pump heat input, what is the core thermal power?

    A. 1,099 MW_t

    B. 1,276 MW_t

    C. 1,429 MW_t

    D. 1,530 MW_t

48. Given the following plant conditions:

    Power = 100 percent
    Tave = 573.5 degrees F
    Tstm = 513.5 degrees F

    Calculate the new steam pressure if 5 percent of the total steam generator tubes are plugged and the plant is returned to 100 percent power. Assume RCS mass flow rate and reactor coolant temperature are unchanged.

    A. 710 psia
    B. 733 psia
    C. 748 psia
    D. 763 psia

49. The reactor is operating with the following parameters:

    Reactor power - 100%
    Core ΔT - 42°F
    RCS flow rate - 100%
    Average coolant temperature - 587°F

    A station blackout occurs and natural circulation is established with the following stable parameters:

    Decay heat - 2%
    Core ΔT - 28°F
    Average coolant temperature - 572°F

    What is the core mass flow rate in percent?

    A. 2.0 percent
    B. 2.5 percent
    C. 3.0 percent
    D. 4.0 percent

50. The reactor coolant enters the core at 545°F and leaves at 595°F. If the reactor coolant flow rate is 6.6×10^7 lbm/hr and the specific heat capacity of the coolant is 1.3 BTU/lbm-°F, what is the core thermal power? (1 watt = 3.4127 BTU/hr)

    A. 100.6 MWt
    B. 125.7 MWt
    C. 1005.7 MWt
    D. 1257.1 MWt

51. In a two-loop pressurized water reactor, feedwater flow to each steam generator is 3.3×10^6 lbm/hr at an enthalpy of 419 BTU/lbm. The steam exiting each steam generator is at 800 psia with 100 percent steam quality. Ignoring blowdown and pump heat, what is the core thermal power?

    A. 3,411 MWt
    B. 2,915 MWt
    C. 2,212 MWt
    D. 1,509 MWt

52. Which one of the statements below is correct if the power range instruments have been adjusted to 100% based on a calculated calorimetric?

    A. If the feedwater temperature used in the calorimetric calculation was higher than actual feedwater temperature, actual power will be less than indicated power.

    B. If the reactor coolant pump heat input used in the calorimetric calculation is omitted, actual power will be less than indicated power.

    C. If the steam flow used in the calorimetric calculation was lower than actual steam flow, actual power will be less than indicated power.

    D. If the steam pressure used in the calorimetric calculation is lower than actual steam pressure, actual power will be less than indicated power.

53. Helium gas is used to fill the gap between the fuel pellet and the cladding to improve the heat transferred by ____________ from the pellet to the cladding.

    A. conduction
    B. convection
    C. radiation
    D. natural ci culation

HEAT TRANSFER
Answers

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

Definition of conduction: The transfer of heat by interaction between adjacent molecules of the material through which the heat is being transferred.

Reference 22, part A, chapter 3, page 99; and Reference 39, page 3.1-1.

2. B

Definition of convection: The transfer of heat by motion and mixing of macroscopic portions of a fluid.

Reference 22, part A, chapter 3, page 99; and Reference 39, page 3.1-1.

3. C

Definition of radiation or radiant heat transfer: The transfer of heat by electromagnetic radiation that arises due to the temperature of a body.

Reference 22, part A, chapter 3, page 99; and Reference 39, page 3.1-2.

4. A

Reference 22, part A, chapter 3, page 99; and Reference 39, page 3.1-1.

5.

Three mechanisms of heat transfer are:

conduction - transfer of heat by interaction between adjacent modecules of a material

convection - transfer of heat by combined action of heat conduction, energy storage, and mixing motion of a fluid flowing between regions of high and low temperature

radiation - transfer of heat by emission of electromagnetic radiation

Reference 63, pages 3-10, 3-66, and 3-82.

6. A

Without any coolant present in the core the primary method of transfering heat comes from the emission of electromagnetic radiation.

Reference 63, page 3-92.

7.

Once the fuel becomes steam-blanketed, decay heat will increase fuel temperature to a level that will cause radiation to become the principal heat transfer mechanism. Conduction in the steam-blanketed region will cease, and convective heat transfer to the steam will be less than radiative heat transfer.

Reference 63, page 3-92.

8. D

Reference 22, part A, chapter 3, page 99.

9. A

Reference 63, page 3-57.

10. D

With constant reactor power, the heat conduction rate remains constant. With cylindrical fuel rods the heat conduction rate is proportional to the fuel-to-coolant thermal conductivity and the ΔT from the fuel rod centerline to the coolant boundary. Since the conductivity has been doubled, the ΔT required is only one half:

Original ΔT	= 3000 - 500 = 2500°F
New ΔT	= 1250°F
New centerline temperature	= 1250 + 500 = 1750°F

Reference 63, pages 3-56 through 3-65.

11. A

Reference 63, page 3-57.

12. C

The higher flow rate increases turbulence, decreasing the thickness of the laminar layer and thereby improving heat transfer.

13. B

Excessive steam voids (gases) in a heat exchanger can block the flow of the water.

Reference 39, page 1.1-6.

14. A

Excessive steam void (gases) in a heat exchanger can block the flow of the water.

Reference 39, page 1.1-6.

15. D

Excessive steam voids (gases) in a heat exchanger can block the flow of the water.

Reference 39, page 1.1-6.

16. C

Gases, steam voids, and fluid temperature all affect fluid density and therefore mass flow rate.

Reference 39, pages 1.1-6, 3.1-1, and 3.1-3.

17. A

Heat transfer to the steam is less efficient than to water, reducing the heat transfer rate.

18. A

19.

Air is a mixture of noncondensible gases, and the condenser cannot change air into a liquid state. Therefore, the gases will accumulate along the condenser tubes, significantly reducing the heat transfer coefficient. As a result, the rate of heat transfer will decrease, causing an increase in condenser temperature and pressure and a decrease in plant efficiency.

Reference 63, pages 9-24 and 9-25.

20.

Gases in a liquid heat exchanger can exert two detrimental effects:

(1) Gases can accumulate on the heat transfer surfaces, lowering the heat transfer coefficient and thereby decreasing the heat transfer rate.

(2) A large volume of gas can form a pocket inside the heat exchanger, blocking a portion of the liquid flow. This would then decrease the heat transfer rate.

Reference 63, pages 9-24 and 9-25; and reference 39, page 1.1-6.

21. A

Reference 37, page 15.5-3.

22. B

Reference 22, part A, chapter 3, page 101.

23. C

Reference 22, part A, chapter 3, page 101.

24. D

Reference 22, part A, chapter 3, page 101.

25. B

Reference 39.

26. C

The core thermal power is defined as the power produced in the reactor core.

$$\text{Percent Power} = \frac{200}{1330} = 15.0\%$$

Reference 63, page 13-41

27. C

Reference 63, pages 12-7 through 12-15.

28. D

$\dot{Q} = \dot{m} c_p \Delta T$

$\dot{Q}$ = thermal power

$\dot{m}$ = mass flow rate

c_p = specific heat

ΔT = change in temperature

Reference 22, part A, chapter 3, page 101.

29. B

Reference 22, part A, chapter 3, page 101; and Reference 37, page 15.5.3.

30. A

Reference 22, part A, chapter 3, page 101.

31. B

Reference 63, pages 13-41 through 13-43

32. B

The reactor thermal power is

$$\dot{Q} = \dot{m} C_p \Delta T$$

$\dot{m}$ is mass flow rate

C_p is coolant specific heat capacity

ΔT is the temperature across the core

$\Delta T = T_H - T_C$

At 80% power:

$\dot{Q}$ = 80%, $\dot{m}$ = 100% and ΔT = 48°F

At shutdown with natural circulation:

$\dot{Q}$ = ?, $\dot{m}$ = 3% and ΔT = 40°F

$$\frac{\dot{Q}}{80} = \frac{3 \times 40}{100 \times 48} = \frac{120}{4800} = \frac{1}{40}$$

$\dot{Q}$ = 2.0%

Reference 63, page 12-14.

33. B

Reference 63, pages 13-41 through 13-43.

34. D

T_2 represents the steam temperature and will be reduced due to the steamline leak. T_1 represents the average reactor temperature which will ultimately be adjusted.

Reference 63, page 12-8.

35. C

Reference 22, part A, chapter 3, page 101.

36. B

Reference 22, part A, chapter 3, page 101.

37.

The general equation for a secondary heat balance is:

Power = (feed flow) (h_{stm} - h_{feed}) - (pump power) + (heat losses)

a. If pump heat is omitted, calculated power will be incorrectly high. In effect, the reactor will erroneously be given "credit" for the heat input from the reactor coolant pumps.

b. If steam generator pressure indicates low, the enthalpy of the steam will be assigned too high a value. The reactor will be credited with power it is not producing and calculated power will be incorrectly high.

Reference 63, pages 13-41 through 13-43.

38. A

Reference 50, page 1-1, and Reference 46, chapter 2, page 13.

39. C

Reference 50, page 1-1; and Reference 46, chapter 2, page 13.

40. B

Reference 50, page 1-1; and Reference 46, chapter 2, page 13.

41. D

Reference 50, page 1-1; and Reference 46, chapter 2, page 13.

42. B

Reference 50, page 1-1; and Reference 46, chapter 2, page 13.

43. C

$\dot{Q} = \dot{m} c_p \Delta T$

$\dot{Q}$ = heat rate (core thermal power)

$\dot{m}$ = mass flow rate

c_p = specific heat

ΔT = change in temperature

$\dot{Q} = (6.6 \times 10^7 \text{ lbm/hr})(1.3 \frac{\text{BTU}}{\text{lbm-°F}})(595°F-545°F)$

$\dot{Q} = 4.29 \times 10^9 \text{ BTU/hr} \left(\frac{1 \text{ Watt}}{3.4127 \text{ BTU/hr}}\right) =$

1257 MW_t

Reference 22, part A, chapter 3, page 101.

44. C

$\dot{Q} = \dot{m} c_p \Delta T$

$\dot{Q}$ = heat rate (core thermal power)

$\dot{m}$ = mass flow rate

c_p = specific heat

ΔT = change in temperature

$\dot{Q} = (1.48 \times 10^8 \text{ lbm/hr})(1.35 \text{ BTU/lbm°F})$

(611°F-553°F)

$\dot{Q} = 1.15884 \times 10^{10}$ BTU/hr

$(1.15884 \times 10^{10} \text{ BTU/hr})\left(\frac{1 \text{ Watt}}{3.4127 \text{ BTU/hr}}\right) =$

3,396 MW_t

Reference 22, part A, chapter 3, page 101.

45. A

$\dot{Q} = \dot{m} \Delta h$

$\dot{Q}$ = heat rate (core thermal power)

$\dot{m}$ = mass flow rate

Δh = change in enthalpy

$\dot{Q} = (6.6 \times 10^6 \text{ lbm/hr})(1,199.4 - 419)$

$\dot{Q} = 5.1506 \times 10^9$ BTU/hr

$5.1506 \times 10^9 \text{ BTU/hr} \left(\frac{1 \text{ Watt}}{3.4127 \text{ BTU/hr}}\right) =$

1,509.3 MWt

Reference 22, part A, chapter 3, page 101.

46. B

$\dot{Q} = \dot{m}\,\Delta h$ Total Flow = 3 x (3.2 x 10^6)

$\dot{Q}$ = 9.6 x 10^6 (1,199.4 - 414)

$\dot{Q}$ = 7.5398 x 10^9 BTU/hr

7.5398 x 10^9 BTU/hr $\left(\frac{1 \text{ Watt}}{3.4127 \text{ BTU/hr}}\right)$

$\dot{Q}$ = 2,209 MW_t

Reference 22, part A, chapter 3, page 101.

47. C

$\dot{Q} = \dot{m}\,c_p\,\Delta T$

$\dot{Q}$ = 6.7 x 10^7 lbm/hr (1.3 BTU/bm-°F) (56°F)

$\dot{Q}$ = 4.8776 x 10^9 BTU/hr

4.8776 x 10^9 BTU/hr $\left(\frac{1 \text{ Watt}}{3.4127 \text{ BTU/hr}}\right)$

$\dot{Q}$ = 1,429.2 MW_t

Reference 22, part A, chapter 3, page 101.

48. C

Power = UA (T_{ave} - T_{stm})

IF "A" decreases 5% due to tube plugging, and "Power" and "U" remain constant, then "T_{ave} - T_{stm}" must increase 5%:

new ΔT = (1.05) x (old ΔT)

= (1.05) x (573.5 - 513.5)

= 63 °F

With "Tave" constant, the new "Tstm" is" 573.5 - 63 = 510.5 °F

From the steam tables, saturation pressure for 510.5 °F is 748 psia.

49. C

$\dot{Q} = \dot{m}\,C_p\,\Delta T$

Where,

$\dot{m}$ is the mass flow rate

C_p is the coolant specific heat capacity

ΔT is the temperature across the core

At power,

$\dot{Q}$ = 100%, $\dot{m}$ = 100% and ΔT = 42°F

At shutdown,

$\dot{Q}$ = 2%, $\dot{m}$ = ? and ΔT = 28°F

$$\frac{\dot{m} \times 28}{100 \times 42} = \frac{2}{100}$$

$$\dot{m} = \frac{8400}{2800} = 3.0\%$$

Reference 63, page 12-14.

50. D

$\dot{Q} = \dot{m}\,C_p\,\Delta T$

$\dot{Q}$ = [(6.6 x 10^7) x 1.3 x (595 - 545)] ÷ 3.4127

$\dot{Q}$ = 1257.1 MWt

Reference 63, page 12-14.

51. D

$\dot{Q} = \dot{m}\,(h_e - h_i)$

$\dot{m}$ is the mass flow rate of the feedwater

h_i is the enthalpy of the feedwater

h_e is the enthalpy of steam at 800 psia with 100% quality

From the Steam Tables:

Steam at 800 psia has an enthalpy of 1200 BTU/lb.

$\dot{Q} = 2 \times 3.3 \times 10^6 \times (1200 - 419)$

$\dot{Q} = 5.15 \times 10^9$ BTU

$\dot{Q}$ = 1,509 MWt

(Using, 1 watt = 3.4127 BTU/hr)

Reference 63, page 12-7.

52. B

If the power input from pump heat is omitted, the calculated reactor power will be greater than actual. This will result in adjustments being made that cause indicated power to match calculated power. Therefore, actual power will be less than indicated.

Reference 63, pages 13-41 through 13-43.

53. A

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1-5, and 8-11, 53

Describe three mechanisms of heat transfer.

K1.01 Questions 6, 7

Describe core heat transfer under accident conditions.

K1.03 Question 12

Explain how the flow rate through a heat exchanger affects the heat transfer rate.

K1.04 Questions 13-20

Describe how the presence of gases or steam can affect heat transfer and fluid flow in heat exchangers.

K1.05 Questions 21-27

Define core thermal power.

K1.06 Questions 28-37

Explain methods of calculating core thermal power.

K1.07 Questions 38-42

Define percent reactor power.

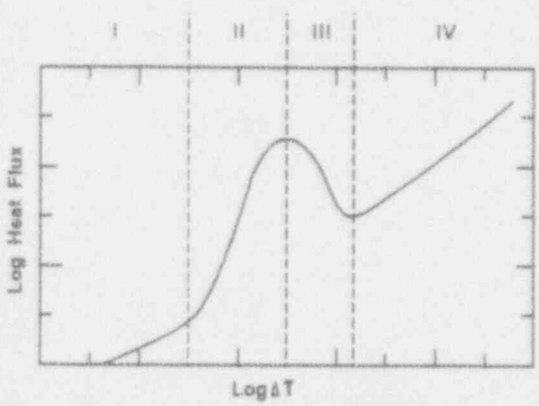
K1.08 Questions 43-52

Calculate core thermal power using a simplified heat balance.

1. Using the diagram in Figure 3.8-1, identify the region of the curve that most closely identifies where the hottest locations of your reactor operate to transfer heat from the cladding to the coolant at 100% power.

   A. Region I - Single-phase Convection
   B. Region II - Nucleate Boiling
   C. Region III - Partial Film Boiling
   D. Region IV - Film Boiling

FIGURE 3.8-1



Pool Boiling Curve

2. Using the diagram in Figure 3.8-1, identify the region of the curve where the most efficient safe form of heat transfer exists.

   A. Region I - Single-phase Convection
   B. Region II - Nucleate Boiling
   C. Region III - Partial Film Boiling
   D. Region IV - Film Boiling

3. Which phrase illustrates radiation heat transfer?

   A. heat transfer from the fuel cladding to the core barrel within a voided reactor vessel

   B. heat transfer from the center to the edge of a fuel pellet

   C. heat transfer from the reactor coolant to the feed water in a steam generator

   D. heat transfer from the fuel cladding to the reactor coolant via subcooled nucleate boiling

4. A reactor is operating at full power with a fuel coolant channel that is experiencing each of the following heat transfer mechanisms somewhere along the length of the coolant channel. Which of the following causes the first reduction in the local cladding heat transfer coefficient as the coolant flows upward through the coolant channel?

   A. partial film boiling
   B. nucleate boiling
   C. single-phase convection
   D. stable film boiling

5. Nucleate boiling occurring at the surface of the fuel rod will

   A. increase the convective heat transfer from the fuel rod to the coolant

   B. decrease the convective heat transfer from the fuel rod to the coolant

   C. have no effect on convective heat transfer because it is boiling heat transfer

   D. cause damage to the fuel rod because it agitates the laminar flow of coolant next to the fuel rod

6. As compared to saturated nucleate boiling (bulk boiling), subcooled nucleate boiling

   A. occurs to a greater extent in the pressurizer and steam generators

   B. requires fewer BTU/lbm to convert reactor coolant to steam at a given temperature

   C. occurs less in the reactor core during normal plant operation

   D. yields a lower convective heat transfer coefficient

7. Nucleate boiling enhances the convective heat transfer coefficient by __________ the thermal conductivity of the coolant and __________ the laminar layer thickness.

   A. increasing; decreasing
   B. increasing; increasing
   C. decreasing; decreasing
   D. decreasing; increasing

8. Explain two mechanisms by which onset of nucleate boiling (ONB) affects convection heat transfer in a reactor core.

9. Nucleate boiling in the core improves heat transfer from a fuel rod to the coolant because the steam bubbles

   A. cause agitation of the coolant layer next to the fuel rod, increasing the convective heat transfer

   B. form a blanket on the fuel cladding, causing an increase in radiative heat transfer

   C. reduce coolant flow rate next to the fuel rod, increasing the convective heat transfer

   D. have a larger specific heat capacity than the liquid of the coolant layer

10. Why does nucleate boiling improve heat transfer in the core?

   A. The formation of steam bubbles at nucleation sites on the fuel clad allows more heat to be transferred by conduction.

   B. Heat is removed from the fuel rod as both sensible heat and latent heat of vaporization, and the motions of the steam bubbles cause rapid mixing of the coolant adjacent to the fuel rods.

   C. Heat is removed from the fuel rod as both sensible heat and latent heat of condensation, and the heat is transferred directly to the coolant by radiative heat transfer.

   D. The formation of steam bubbles at nucleation sites on the fuel clad reduces coolant flow in that area and allows more heat to be transferred by convection.

11. Two means by which nucleate boiling improves heat transfer are

   A. steam blanketing of fuel rods and transfer of latent heat of vaporization

   B. steam blanketing of fuel rods and radiative heat transfer

   C. agitation of the coolant by steam bubbles and transfer of latent heat of vaporization

   D. agitation of the coolant by steam bubbles and radiative heat transfer

12. Convection heat transfer actually improves when nucleate boiling begins on the surface of the fuel rod. This is because heat is removed as both sensible heat and latent heat of vaporization, and

    A. the steam bubbles decrease coolant flow along the fuel rod

    B. the steam bubbles increase coolant flow along the fuel rod

    C. a steam blanket begins to form along the surface of the fuel rod

    D. the motion of the steam bubbles causes rapid mixing of the coolant

13. How does the convective heat transfer coefficient vary as reactor coolant flows up along a fuel rod that has experienced departure from nucleate boiling (DNB) near the top of the fuel rod.

    A. increases, then decreases
    B. increases continuously
    C. decreases, then increases
    D. decreases continuously

14. How does convection heat transfer vary as reactor coolant flows up along a fuel rod experiencing nucleate boiling during full power operations?

    A. increases continuously
    B. increases, then decreases
    C. decreases continuously
    D. decreases, then increases

15. The maximum convective heat transfer coefficient exists when

    A. departure from nucleate boiling begins
    B. partial nucleate boiling begins
    C. subcooled nucleate boiling begins
    D. saturated nucleate boiling begins

16. As heat is transferred to water adjacent to a heating surface, many factors influence steam bubble formation. Select the characteristic below that will enhance steam bubble formation.

    A. chemicals dissolved in the water

    B. the absence of ionizing radiation exposure to the water

    C. a highly polished heat transfer surface with minimal scratches or cavities

    D. the presence of gases dissolved in the water

17. What type of boiling can be described as follows: The liquid is at its saturation temperature, and steam bubbles formed on the heating surface persist within the coolant stream. There is a net output of steam.

    A. stable film boiling
    B. subcooled nucleate boiling
    C. bulk boiling
    D. pool boiling

18. What type of boiling can be described as follows: The bulk temperature of the liquid is below saturation, but the temperature of the heat transfer surface is above saturation. Vapor bubbles form at the heat transfer surface, but condense in the cold liquid so that no net generation of vapor is obtained.

    A. bulk boiling
    B. subcooled nucleate boiling
    C. total film boiling
    D. partial film boiling

19. What type of boiling can be described as follows: Small bubbles of vapor are formed within the liquid at the heat transfer surface and then move away from the surface.

    A. turbulent boiling
    B. partial film boiling
    C. transition film boiling
    D. nucleate boiling

20. Subcooled nucleate boiling is occurring along a heated surface. The heat flux is then increased slightly. What will be the effect on the ΔT between the surface and the fluid?

A. large increase in ΔT because of steam blanketing

B. large increase in ΔT causing radiative heat transfer to become significant

C. small increase in ΔT because of steam blanketing

D. small increase in ΔT as vapor bubbles form and collapse

21. Explain the difference between subcooled and saturated nucleate boiling, and state which exists in a PWR during normal operation.

22. As the heat flux is raised during pool boiling, the proper sequential classifications of boiling regimes would be

A. subcooled nucleate, saturated nucleate, film

B. saturated nucleate, subcooled nucleate, film

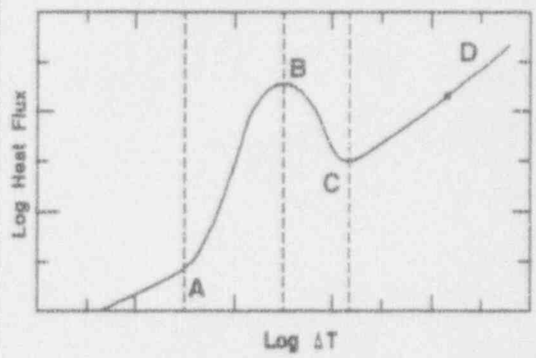
C. film, saturated nucleate, subcooled nucleate

D. saturated nucleate, film, subcooled nucleate

23. In Figure 3.8-2, which point on the curve is the point of departure from nucleate boiling (DNB)?

A. A
B. B
C. C
D. D

FIGURE 3.8-2



Pool Boiling Curve

24. Which of the following best describes departure from nucleate boiling?

A. Steam bubbles begin to blanket the fuel rod causing a rapid increase in the ΔT between the fuel rod and the coolant.

B. Steam bubbles completely blanket the fuel rod causing an increase in the heat flux from the fuel rod.

C. Steam bubbles begin to blanket the fuel rod causing a rapid decrease in the ΔT between the fuel rod and the coolant.

D. Steam bubbles begin to form on the surface of the fuel rod causing an increase in the heat flux from the fuel rod.

25. Reactor power is increased sufficiently to cause steam blanketing of several fuel rods. This condition is being caused by

A. departure from nucleate boiling
B. subcooled nucleate boiling
C. saturated nucleate boiling
D. onset of nucleate boiling

26. Describe the process and effects of departure from nucleate boiling.

27. As heat flux through a fuel rod is increased, a condition is reached in which there is a rapid increase in the ΔT between the fuel clad and the coolant, with a decrease in heat flux. These changes indicate that

A. bulk boiling has begun

B. departure from nucleate boiling (DNB) has been reached

C. critical heat flux (CHF) has begun to increase

D. nucleate boiling has begun

28. Departure from nucleate boiling (DNB) should not be allowed to occur in the core because

A. the steam bubbles begin to blanket the clad and decrease radiative heat transfer

B. the steam bubbles in the coolant may cause flow oscillations

C. the rapid increase in ΔT between the clad and coolant may cause clad damage

D. the associated addition of reactivity from the void coefficient could be uncontrollable

29. If departure from nucleate boiling (DNB) is reached in the core, the surface temperature of the fuel clad will

A. increase rapidly
B. decrease rapidly
C. increase gradually
D. decrease gradually

30. Following a loss-of-coolant accident, incore instrumentation indicates that superheated steam is exiting several fuel assemblies. This condition is caused by

A. departure from nucleate boiling
B. subcooled nucleate boiling
C. saturated nucleate boiling
D. onset of nucleate boiling

31. Which parameter change will reduce the departure from nucleate boiling ratio (DNBR)?

A. decrease reactor power
B. increase pressurizer pressure
C. increase reactor coolant flow
D. increase reactor coolant temperature

32. Which of the following parameter changes would move the plant farther away from departure from nucleate boiling? (Evaluate each parameter change separately.)

A. decrease pressurizer pressure
B. decrease reactor coolant flow
C. decrease reactor power
D. increase reactor coolant temperature

33. Which parameter change will increase the departure from nucleate boiling ratio (DNBR)? (Evaluate each parameter change separately.)

A. decrease reactor power
B. decrease pressurizer pressure
C. decrease reactor coolant flow
D. increase reactor coolant temperature

34. Which parameter change will reduce the departure from nucleate boiling ratio (DNBR)? (Evaluate each parameter change separately.)

    A. decrease pressurizer pressure
    B. increase reactor coolant flow
    C. decrease reactor power
    D. decrease reactor coolant temperature

35. Which one of the following core conditions will increase the margin to departure from nucleate boiling (DNB)? (Evaluate each condition separately.)

    A. coolant temperature decreases
    B. coolant flow decreases
    C. coolant pressure decreases
    D. reactor power increases

36. Which one of the following core conditions will decrease the departure from nucleate boiling ratio (DNBR)? (Evaluate each condition separately.)

    A. coolant flow decreases
    B. coolant temperature decreases
    C. coolant pressure increases
    D. reactor power decreases

37. Which parameter change will increase the departure from nucleate boiling ratio (DNBR)? (Evaluate each parameter change separately.)

    A. increase reactor coolant temperature
    B. increase pressurizer pressure
    C. increase core bypass flow
    D. increase reactor power

38. Which one of the following reactor coolant system (RCS) parameters has the least effect on margin to departure from nucleate boiling (DNB)? Consider each separately.

    A. pressurizer level
    B. local power density
    C. cold leg temperature
    D. coolant flow rate

39. Which one of the following incidents will cause the departure from nucleate boiling ratio (DNBR) to increase? (Assume the reactor does not trip.)

    A. a reactor coolant pump trips at 20 percent reactor power

    B. a rod drops at 100 percent reactor power with manual rod control

    C. one steam dump valve fails open at 50 percent reactor power

    D. all pressurizer heaters energize fully at 40 percent reactor power

40. List three parameters that affect DNBR and explain the effect of each.

41. Critical heat flux (CHF) can best be described as

    A. heat transfer per unit area of fuel rod when the reactor is critical

    B. heat transfer per unit area of fuel rod necessary to cause departure from nucleate boiling

    C. the total heat transferred to the coolant when nucleate boiling begins to occur

    D. the total heat transfer necessary to cause bulk boiling in the coolant

42. The critical heat flux (CHF) is the rate of heat transfer per unit area which, if exceeded, causes a rapid

    A. increase in the convective heat transfer coefficient

    B. decrease in the temperature difference between the fuel clad surface and the reactor coolant

    C. increase in the fuel pellet temperature

    D. decrease in the thermal gradient from the fuel centerline to the cladding

43. The heat transfer rate that causes departure from nucleate boiling (DNB) is the

A. critical heat flux
B. nucleate heat flux
C. transition heat flux
D. departure heat flux

44. How does critical heat flux (CHF) vary with core height?

A. CHF increases from bottom to top of the core.

B. CHF decreases from bottom to core midplane, then increases from midplane to the top of the core.

C. CHF decreases from bottom to the top of the core.

D. CHF increases from bottom to core midplane, then decreases from midplane to the top of the core.

45. How does critical heat flux vary from the bottom to the top of the reactor core during normal full power operation?

A. decreases continuously
B. decreases then increases
C. increases continuously
D. increases then decreases

46. At what core height does the actual heat flux come closest to the critical heat flux (CHF) during full power operations? Assume a normal power distribution centered at the core midplane.

A. at the core midplane

B. at the top of the core

C. between midplane and the top of the core

D. between core midplane and the bottom of the core

47. Which of the following conditions will result in a decrease in critical heat flux?

A. reactor coolant subcooling is increased

B. reactor power is decreased

C. reactor coolant flow is increased

D. reactor coolant pressure is decreased with no change in temperature

48. During full power operation, critical heat flux (CHF) is <u>most likely</u> to occur in a

A. centrally located fuel assembly with flow restrictions

B. centrally located fuel assembly without flow restrictions

C. peripherally located fuel assembly with flow restrictions

D. peripherally located fuel assembly without flow restrictions

49. What parameter change would move the plant farther away from the critical heat flux?

A. decrease pressurizer pressure
B. decrease reactor coolant flow
C. decrease reactor power
D. increase reactor coolant temperature

50. A small increase in ΔT (at the heat transfer and coolant interface) causes increased steam blanketing and a reduction in heat flux. This best describes which type of boiling?

A. subcooled boiling
B. nucleate boiling
C. partial film boiling
D. total film boiling

51. Select the statement that best describes transition (partial film) boiling.

A. A small increase in ΔT (at the heat transfer surface and coolant interface) causes increased steam blanketing and a reduction in heat flux.

B. The temperature of the heat transfer surface is so high that thermal radiation heat transfer becomes significant and heat flux increases.

C. As the ΔT increases, the increasing number of bubbles causes increased agitation and turbulence of the boundary layer, consequently increasing heat flux.

D. As the ΔT increases, a few vapor bubbles, are formed but collapse when they enter into the bulk of the fluid.

52. Select the statement that describes the effect of transition (partial film) boiling at the fuel clad surface-to-coolant interface.

A. A small increase in heat flux causes increased steam blanketing and a large increase in clad temperature.

B. The temperature of the fuel clad surface is so high that thermal radiation heat transfer becomes significant, which causes heat flux to increase.

C. A small increase in heat flux increases the formation of steam bubbles causing increased agitation and turbulence of the boundary layer, consequently decreasing clad temperature.

D. As the heat flux increases, a few vapor bubbles are formed but collapse when they enter into the bulk of the fluid, which decreases clad temperature.

53. When partial film boiling (transition boiling) occurs, the steam layer formation has a __________ thermal conductivity and a __________ convective heat transfer coefficient.

A. good; high
B. poor; low
C. poor; high
D. good; low

54. Film boiling in a reactor core is

A. heat transfer through a vapor blanket that covers the fuel cladding

B. heat transfer accomplished with no phase change

C. the most efficient method of boiling heat transfer

D. heat transfer through an oxide film on the cladding

55. What type of boiling can be described as follows: The ΔT at the heat transfer interface increases significantly. The contribution from thermal radiation becomes significant, and the heat flux increases.

A. nucleate boiling
B. transition boiling
C. subcooled convection
D. film boiling

56. Which of the following best describes the change in ΔT between clad and coolant for a step increase in heat flux while operating in the film boiling regime of heat transfer?

A. increases slightly, then returns to original value

B. decreases slightly, then returns to original value

C. increases;

D. decreases

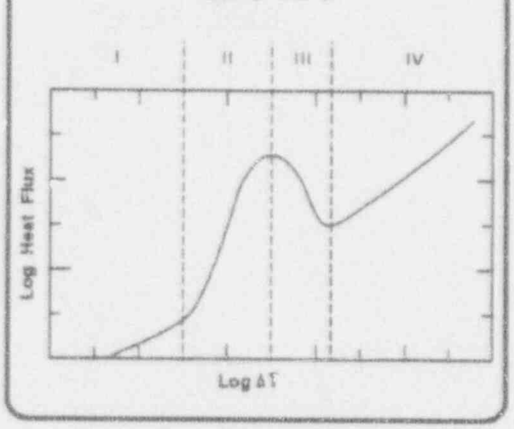
57. If heat flux in a reactor core steadily increases, the boiling heat transfer regime that will be achieved once the critical heat flux is exceeded is:

A. transition boiling
B. subcooled nucleate boiling
C. saturated nucleate boiling
D. stable film boiling

58. Referring to Figure 3.8-3, choose the region of the curve where film boiling occurs.

A. region I
B. region II
C. region III
D. region IV

FIGURE 3.8-3



Pool Boiling Curve

59. The departure from nucleate boiling ratio (DNBR) is defined as

A. the actual heat flux divided by the critical heat flux at any point along a fuel rod

B. the critical heat flux divided by the actual heat flux at any point along a fuel rod

C. the core thermal power divided by the total reactor coolant mass flow rate

D. the number of coolant channels that have reached DNB divided by the number of coolant channels that are subcooled

60. In the definition of th departure from nucleate boiling ratio (DNBR), the term "actual heat flux" refers to the

A. heat transfer rate per unit area at any point along the fuel rod

B. heat transfer rate along the entire fuel rod

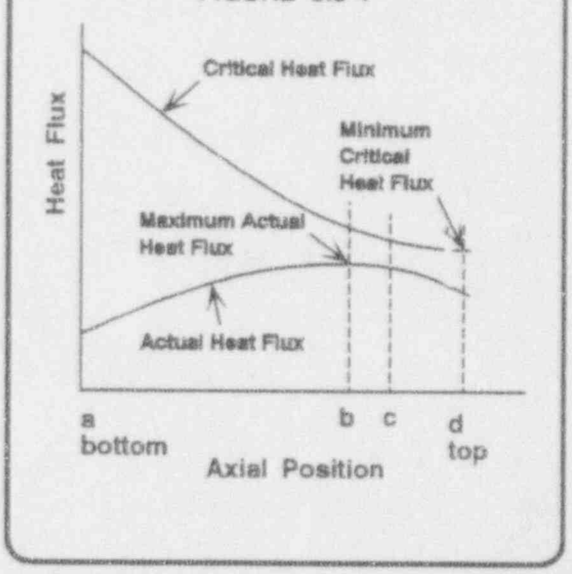
C. average heat transfer rate per unit area across the core

D. total heat transferred along the fuel rod

61. Referring to Figure 3.8-4, choose the point that represents the minimum departure from nucleate boiling ratio (DNBR) for the fuel rod.

A. a
B. b
C. c
D. d

FIGURE 3.8-4



Departure from Nucleate Boiling Ratio

62. Departure from nucleate boiling is assumed to occur in the core when the departure from nucleate boiling ratio (DNBR) reaches

A. 2.0
B. 1.5
C. 1.0
D. 0.5

63. The departure from nucleate boiling ratio (DNBR) is the ratio of critical heat flux (CHF) to the actual ____________ heat flux.

A. local
B. average
C. linear
D. core

64. The relationship between the core heat transfer coefficient and the type of coolant flow is best described by which of the following?

A. The heat transfer coefficient is greater with laminar flow.

B. The heat transfer coefficient is greater with turbulent flow.

C. The heat transfer coefficient does not depend on the type of flow, only flow rate.

D. The heat transfer coefficient begins to fluctuate as flow becomes turbulent.

65. If the reactor coolant flow changes from laminar flow to turbulent flow in the core, the heat transfer coefficient will

A. increase
B. decrease
C. remain the same
D. fluctuate

66. As nucleate boiling begins to occur in the core, the heat transfer coefficient becomes

A. negative
B. significantly smaller
C. constant
D. significantly larger

67. Core heat transfer is maximized by the presence of

A. laminar flow with no nucleate boiling
B. turbulent flow with no nucleate boiling
C. laminar flow with nucleate boiling
D. turbulent flow with nucleate boiling

68. The heat transfer coefficient of the core will be directly increased if (Assume bulk coolant subcooling.)

A. the coolant temperature is decreased

B. the coolant flow rate is decreased

C. nucleate boiling occurs in the coolant

D. the coolant flow is laminar instead of turbulent

69. If the coolant is allowed to undergo nucleate boiling in the core, the heat transfer coefficient will be ___________ than if no nucleate boiling occurs.

A. slightly higher
B. slightly lower
C. significantly higher
D. significantly lower

70. Explain how an increase in reactor coolant flow affects the overall heat transfer coefficient in the core.

71. State two parameters that directly affect the reactor coolant subcooling margin, and explain the effects of each.

72. The difference between the actual temperature and the saturation temperature of a liquid is the definition of

    A. critical heat flux
    B. departure from nucleate boiling ratio
    C. subcooling margin
    D. saturation margin

73. An adequate subcooling margin during a loss-of-coolant accident (LOCA) is the most direct indication the is being maintained.

    A. steam generator water level
    B. containment integrity
    C. core cooling
    D. subcriticality

74. Which parameter change will reduce the reactor coolant subcooling margin? Choose only the change that affects subcooling margin <u>directly</u>. (Evaluate each change separately.)

    A. increase pressurizer level
    B. reduce pressurizer pressure
    C. increase coolant flow
    D. reduce boron concentration

75. Which parameter change will <u>directly</u> increase the reactor coolant subcooling margin? (Evaluate each change separately.)

    A. increase pressurizer pressure
    B. decrease pressurizer level
    C. increase coolant flow
    D. increase T_{inlet}

76. The reactor coolant subcooling margin will be directly reduced by

    A. increased pressurizer pressure
    B. increased pressurizer level
    C. increased reactor coolant flow
    D. increased reactor coolant temperature

77. During a plant cooldown and depressurization with natural circulation, reactor coolant system (RCS) subcooling will be minimum in the

    A. reactor vessel head
    B. RCS loop hot leg
    C. RCS loop cold leg
    D. reactor core

78. Which parameter change will <u>directly</u> increase the reactor coolant subcooling margin? (Evaluate each change separately.)

    A. decrease pressurizer level
    B. decrease pressurizer pressure
    C. decrease coolant flow
    D. decrease coolant temperature

79. Which one of the following must be present to assure adequate core cooling following a small loss-of-coolant accident?

    A. emergency cooling injection flow rate on scale

    B. pressurizer level in the indicating range

    C. subcooling margin greater than zero

    D. pressurizer pressure greater than safety injection actuation setpoint

80. Given the following reactor coolant system (RCS) parameters, determine the RCS subcooling margin.

    RCS pressure = 2,235 psig
    RCS hotleg temperature = 610°F

    A. 25°F, 32 psi
    B. 31°F, 433 psi
    C. 38°F, 505 psi
    D. 43°F, 588 psi

81. Consider the temperature profile from the centerline of a fuel pellet to the centerline of the flow channel under 100 percent power conditions and single-phase cooling. Which of the following portions of the temperature profile will have the GREATEST temperature difference across it at the beginning of a fuel cycle?

    A. pellet-to-clad
    B. zircalloy cladding
    C. cladding corrosion film
    D. flow channel boundary layer

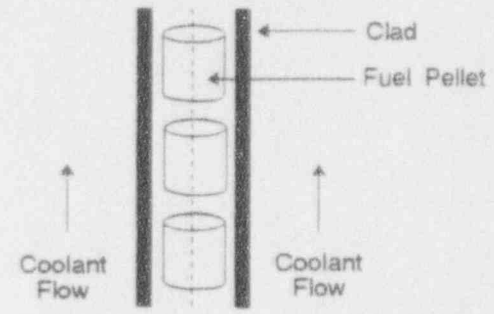
82. Draw and label the temperature profile from the centerline of a fuel pellet to the centerline of the coolant flow channel for a reactor at power.

83. Refer to the drawing of a fuel rod and coolant flow channel (see Figure 3.8-5)

    At 100 percent reactor power, the greatest temperature difference in a fuel channel radial temperature profile will occur across the (Assume the temperature profile begins at fuel centerline.)

    A. fuel
    B. fuel-to-clad gap
    C. zircalloy cladding
    D. flow channel boundary (laminar) layer

FIGURE 3.8-5



Fuel Rod and Coolant Flow Channel

84. The pellet-to-clad gap in fuel rod construction is designed to

    A. decrease fuel pellet slump
    B. attenuate fission gammas
    C. increase heat transfer
    D. reduce internal clad strain

85. If a reduction of reactor coolant flow occurs during power operation, what effect will this have on core ΔT, assuming no change in reactor power level?

    A. increases
    B. decreases
    C. remains unchanged
    D. temporarily decreases, then returns to previous value

86. Assuming that reactor power remains constant at 30 percent, if reactor coolant flow decreases by 10 percent, fuel temperature will

    A. increase, then stabilize at a higher value
    B. decrease, then stabilize at a lower value
    C. increase, then return to the original steady-state value
    D. decrease, then return to the original steady-state value

87. Assuming that reactor power remains constant, steady-state to steady-state, as reactor coolant flow increases, fuel temperature will

A. increase

B. decrease

C. remain the same, steady-state to steady-state

D. increase, then return to the original steady-state value

88. Assuming that reactor power remains constant at 30 percent, if reactor coolant flow decreases by 10 percent, fuel temperature will

A. increase, then stabilize at a higher value

B. decrease, then stabilize at a lower value

C. increase, then return to the original steady-state value

D. decrease, then return to the original steady-state value

89. Which of the following parameters, when changed, would not directly affect the heat transfer rate to the reactor coolant system? (Evaluate each change separately.)

A. overall heat transfer coefficient of the RCS

B. reactor coolant flow rate

C. pressurizer temperature

D. fuel centerline temperature

90. During a plant cooldown and depressurization with forced circulation, reactor coolant system (RCS) loop flow and reactor coolant pump (RCP) current indications become erratic. This is most likely caused by

A. RCP cavitation
B. RCP runout
C. RCS loop water hammer
D. RCS hot leg saturation

91. Reactor coolant system (RCS) loop flow is monitored as an input to the reactor protection system (RPS) to provide protection against

A. departure from nucleate boiling (DNB)
B. RCS overcooling
C. loss of heat sink
D. RCS overpressure

92. Which of the following factors directly affect resistance to single-phase flow in a system?

A. fluid velocity, pipe diameter, pipe roughness

B. fluid pressure, pipe diameter, pipe length

C. pipe roughness, fluid density, fluid velocity

D. specific volume, fluid temperature, fluid pressure

93. List three factors that affect head loss in a system, and explain the effect of each.

94. Assuming a constant mass flow rate in a system, which of the below statements best compares the flow resistance of single-phase flow to that of two-phase flow?

A. Flow resistance is greater with single-phase flow.

B. Flow resistance is greater with two-phase flow.

C. Flow resistance depends on the mass flow rate and is therefore the same for single- and two-phase flow.

D. Two-phase flow resistance is less except when bulk boiling occurs in which case it is greater than single-phase resistance.

95. Reactors have a small percentage of reactor coolant flow that is called core bypass flow. Core bypass flow is coolant that bypasses the core

A. and does not provide core cooling

B. to control the power-to-flow ratio

C. to provide reactor coolant system temperature indication

D. to prevent departure from nucleate boiling along the fuel assembly

96. The reactor coolant flow that bypasses the core and does not provide core cooling is called

A. fuel bypass flow
B. core bypass flow
C. reactor bypass flow
D. internal bypass flow

97. Core bypass flow is the reactor coolant flow that bypasses the core and

A. limits core exit temperatures to within specifications

B. provides natural circulation capability on loss of forced flow

C. provides no core cooling

D. limits the power-to-flow ratio

98. Core bypass flow can best be described as the reactor coolant flow that bypasses the core and

A. provides natural circulation capability on loss of forced flow

B. provides control of the amount of power produced compared to the RCS flow

C. provides recirculation flow to the core

D. provides no core cooling

99. Core bypass flow

A. limits the amount of core cooling during accident conditions

B. provides no core cooling

C. provides even flow distribution through the fuel

D. enhances natural circulation

100. While core bypass flow does not provide core cooling, it is important because it

A. ensures that natural circulation can be initiated when forced circulation is lost

B. provides even flow distribution through the fuel

C. provides mixing of water in the reactor vessel head

D. is the coolant whose temperature is sensed by the reactor coolant systc n RTDs.

101. Core bypass flow serves the function of

A. controlling the core power-to-flow ratio

B. providing reactor coolant system temperature indication

C. providing reactor coolant system flow indication

D. cooling various reactor vessel internal components

102. Adequate core bypass flow is needed to

A. prevent stratification of reactor coolant inside the reactor vessel

B. provide reactor coolant pump minimum flow requirements

C. cool excore nuclear instrument detectors

D. equalize temperature between the vessel and upper vessel head

103. Which one of the following must exist for natural circulation flow to occur?

A. The heat source must be larger than the heat sink.

B. The heat source must be located higher than the heat sink.

C. The heat sink must be larger than the heat source.

D. The heat sink must be located higher thant he heat source.

104. The thermal driving head for natural circulation flow through the core is developed by differences in __________between the hot leg and the cold leg.

A. water density
B. water volume
C. pipe diameter
D. piping length

105. To ensure natural circulation flow can be established in the reactor coolant system, the plant design should

A. minimize elevation difference between the core thermal center and steam generator thermal centers

B. maximize elevation difference between the core thermal center and steam generator thermal centers

C. minimize size difference between hot and cold legs

D. maximize size difference between hot and cold legs

106. Maximizing the elevation difference between the core thermal center and the steam generator thermal centers and minimizing flow restrictions in the reactor coolant system (RCS) piping are plant designs to

A. minimize the reactor coolant system volume

B. maximize the reactor coolant system flow rate during forced circulation

C. ensure a maximum RCS loop transit time

D. ensure RCS natural circulation flow can be established

107. If the steam generator thermal centers were at the same elevation as the reactor core thermal center, natural circulation flow in the reactor coolant system

A. would not be established

B. would not be affected

C. would be greater than if they were at different elevations

D. would flow in the reverse direction

108. What conditions must exist for natural circulation flow to take place? Explain how these conditions provide for natural circulation.

109. Explain how an operator can ensure that natural circulation flow is maintained.

110. Natural circulation can be enhanced by

A. increasing the elevation of the heat source to that of the heat sink

B. increasing the temperature difference between the heat sink and the heat source

C. decreasing the temperature difference between the heat sink and the heat source

D. decreasing the elevation difference between the heat source and the heat sink

111. Which of the following changes will enhance natural circulation flow in the reactor coolant system (RCS)?

A. RCS pressure decreases
B. steam generator pressure increases
C. steam generator level increases
D. pressurizer level decreases

112. Natural circulation flow rate will be greater when

A. all reactor coolant pumps run for an hour after a reactor trip, then stop

B. two reactor coolant pumps run for an hour after a reactor trip, then stop

C. one reactor coolant pump runs for an hour after a reactor trip, then stops

D. reactor coolant pumps stop at the same time the reactor trips

113. With the RCS subcooled and all reactor coolant pumps stopped, the natural circulation flow rate will not be affected by an increase in the

A. reactor coolant pressure increase
B. time after reactor trip
C. steam generator level increase
D. steam generator pressure decrease

114. Which one of the following describes the mechanism for core heat removal during reflux cooling?

A. forced coolant flow
B. natural circulation coolant flow
C. conduction with stagnant coolant flow
D. radiation with total core voiding

115. During the reflux boiling method of core cooling, the steam that is generated in the core is condensed in the __________ side of a steam generator and flows back into the core via the __________.

   A. cold leg; cold leg
   B. hot leg; hot leg
   C. cold leg; hot leg
   D. hot leg; cold leg

116. A reactor coolant system cooldown is in progress on natural circulation via the steam generator (S/G) atmospheric steam relief valves (operated in manual control). If high point voiding interrupts natural circulation, which one of the following will occur? (Assume feed flow rate, relief valve position, and decay heat level are constant.)

   A. S/G level increases and S/G pressure increases

   B. S/G level increases and S/G pressure decreases

   C. S/G level decreases and S/G pressure increases

   D. S/G level decreases and S/G pressure decreases

117. A reactor coolant system natural circulation cooldown is in progress via the steam generator (S/G) atmospheric steam relief valves (operated in manual control). If high point voiding interrupts natural circulation, which one of the following will occur? (Assume feed flow rate, relief valve position, and decay heat level are constant.) (CETC - core exit thermocouple).

   A. S/G level decreases and CETC indication decreases

   B. S/G level decreases and CETC indication increases

   C. S/G level increases and CETC indication decreases

   D. S/G level increases and CETC indication increases

118. How does the convective heat transfer coefficient vary from the bottom to the top of a fuel rod if subcooled reactor coolant enters the coolant channel and exits as superheated steam?

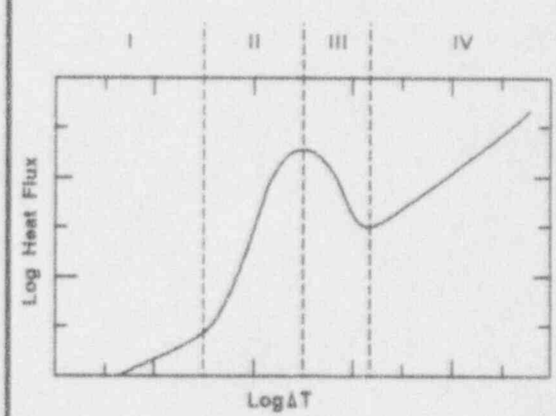
   A. increases continuously
   B. increases, then decreases
   C. decreases continuously
   D. decreases, then increases

119. Refer to the drawing of a pool boiling curve (see figure 3.8-6).

   Choose the region of the curve where transition boiling is the primary heat transfer process.

   A. Region I
   B. Region II
   C. Region III
   D. Region IV

FIGURE 3.8-6



Pool Boiling Curve

120. Increasing coolant flow rate through the reactor core improves heat transfer from the fuel because it __________ laminar flow and __________ the temperature of the coolant adjacent to the fuel.

   A. increases; increases
   B. increases; decreases
   C. decreases; increases
   D. decreases; decreases

121. The reactor is operating at 100% steady state power at end of core life with all control rods fully withdrawn. At what axial location in a typical fuel assembly will the minimum departure from nucleate boiling ratio (DNBR) occur?

   A. at the bottom of the fuel assembly

   B. between the bottom and midplane of the fuel assembly

   C. between the midplane and the top of the fuel assembly

   D. at the top of the fuel assembly

122. The reactor is operating at 100% steady state power at end of core life with all control rods fully withdrawn. At what axial location in a typical fuel assembly will the maximum departure from nucleate boiling ratio (DNBR) occur?

   A. at the bottom of the fuel assembly

   B. at the top of the fuel assembly

   C. between the bottom and midplane of the fuel assembly

   D. between the midplane and the top of the fuel assembly

123. Assuming that reactor power remains constant, steady-state to steady-state, as reactor coolant flow decreases, fuel temperature will:

   A. decrease

   B. increase

   C. remain the same, steady-state to steady-state

   D. decrease, then return to the original steady-state value

124. A reactor is producing 3400 Mw of thermal output with a vessel ΔT of 60°F and a vessel mass flow rate of 1.4×10^8 lbm/hr. If core ΔT is 63.6°F, what is core bypass flow rate?

   A. 7.92×10^6 lbm/hr
   B. 8.40×10^6 lbm/hr
   C. 1.26×10^6 lbm/hr
   D. $1.32\ 10^8$ lbm/hr

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. B

Reference 18, page 380.

2. B

Reference 18, page 380.

3. A

Reference 63, page 3-92.

4. A

Reference 63, page 13-19.

5. A

Reference 15, pages 298 through 301.

6. D

Subcooled nucleate boiling (local boiling) begins to occur once the heated fuel rod surface reaches saturation temperature corresponding to the system pressure. Vapor bubbles form at the surface but condense quickly as they are swept into the coolant stream. Heat transfer conditions are improved and continue to improve as the subcooled condition of the coolant is reduced and bulk boiling is approached. The convective heat transfer coefficient is essentially increased.

Reference 18, pages 380-384.

7. A

The boiling occurs at the rod surface, a scrubbing action takes place improving thermal conductivity and effectively reducing the coolant's laminar layer thickness.

Reference 18, pages 380-384.

8.

The onset of nucleate boiling (ONB) improves heat transfer through three mechanisms; any two of the following will satisfy the question:

a. When the liquid water vaporizes, it absorbs the latent heat of vaporization from the fuel rod. The latent heat of vaporization is larger than the amount of heat absorbed in simply increasing liquid temperature. Thus, ONB improves heat transfer.

b. When the steam bubble expands and is swept into the turbulent coolant stream, it displaces and pushes away hot liquid near the fuel rod. This hot liquid is replaced by colder water, effectively increasing the differential temperature at the heat transfer surface and thereby improving heat transfer.

c. As the steam bubble is swept from the fuel rod surface, it agitates the laminar layer, causing an increase in turbulent flow. The mixing of the fluid in a turbulent flow increases the heat transfer rate.

Reference 63, page 3-75.

9. A

Agitation of the coolant layer next to the fuel pin increases convective heat transfer by pushing hotter water into the coolant and allowing colder water to flow into areas vacated by bubbles.

Reference 15, page 298.

10. B

Reference 33, page 346.

11. C

Nucleate boiling improves heat transfer by removing latent heat of vaporization and sensible heat, and by the rapid mixing of coolant by steam bubbles.

Reference 33, page 346.

12. D

Nucleate boiling improves heat transfer by removing latent heat of vaporization and sensible heat, and by the rapid mixing of coolant by steam bubbles.

Reference 33, page 346.

13. A

Nucleate boiling increases the heat transfer coefficient. Once DNB is reached, however, the heat transfer coefficient falls sharply.

Reference 63, pages 3-77 and 3-78.

14. A

Reference 63, pages 3-77 and 3-78.

15. A

Reference 63, pages 3-77 and 3-78.

16. D

Reference 18, page 380.

17. C

Reference 15, page 292.

18. B

Reference 18, page 381; and Reference 15, page 292.

19. D

Reference 15, page 292.

20. D

Reference 33, page 345; and Reference 15, pages 300 and 301.

21.

Nucleate boiling occurs when the fluid at the heat transfer surface is a liquid in which individual steam bubbles are formed.

If the fluid away from the heat transfer surface is below saturation temperature, the steam bubbles formed on the surface will condense when they enter the bulk fluid. This is the normal condition in a PWR at full power and is called <u>subcooled nucleate boiling</u>.

If the bulk fluid is at saturation temperature, steam bubbles will not condense, but rather will remain as steam in the bulk fluid. This condition is called <u>saturated nucleate boiling</u> or bulk boiling.

Reference 63, page 3-72 through 3-74.

22. A

Reference 33, page 344.

23. B

Reference 33, page 344; and Reference 15, page 300.

24. A

Reference 15, page 300.

25. A

Nucleate boiling entails steam bubbles forming in a liquid layer along the fuel rods. If the rods are steam blanketed, the boiling process is no longer nucleate.

26.

When a heated surface is experiencing nucleate boiling, steam bubbles formed on the surface move away and are replaced by liquid in a continuing cycle. When the departure from nucleate boiling (DNB) point is reached, bubbles form so quickly that they coalesce into a blanket of steam on the heated surface. Because the thermal conductivity of steam is much less than that of liquid water, heat transfer is degraded. As a result, the temperature of the heated surface increases significantly.

Reference 63, page 3-77.

27. B

Reference 15, page 300.

28. C

Basis of safety limit to protect the clad.

Reference 15, page 300; and Reference 33, page 348.

29. A

Clad surface temperature increases rapidly due to steam blanket insulation effects.

Reference 33, page 345.

30. A

31. D

Reference 39, page 3.4.

32. C

Reference 39, page 3.4.

33. A

Reference 39, page 3.4.

34. A

Reference 39, page 3.4.

35. A

Reference 39, page 3.4.

36. A

Reference 39, page 3.4.

37. B

Reference 39, page 3.4.

38. A

Pressurizer level has little or no effect on core power or coolant temperature, pressure, and flow, all of which directly affect margin to DNB.

39. D

The reactor coolant system (RCS) pressure will increase, increasing the DNB ratio.

Reference 39, page 3.4.

40.

The departure from nucleate boiling ratio (DNBR) is the ratio of the critical heat flux (CHF) predicted to cause DNB and the actual local heat flux. Thus, any parameter affecting actual or critical heat flux affects DNBR. Examples:

a. coolant temperature - An increase in coolant temperature could cause a shift to saturated nucleate boiling in the hottest portions of the core, bringing the core closer to DNB and lowering the DNBR.

b. coolant pressure - A decrease in pressure lowers the CHF by shifting conditions closer to saturation, thus decreasing DNBR.

c. core flow - A decrease in flow increases temperature in the hottest portions of the core, causing a reduction in DNBR.

d. reactor power - An increase in power raises the actual heat flux, decreasing DNBR.

e. power distribution - A change in power distribution causing the heat flux in the limiting region of the core to increase will decrease DNBR.

Reference 63, pages 13-23 and 13-24.

41. B

Reference 33, page 344.

42. C

Reference 15, pages 299 through 308.

43. A

Reference 15, page 303.

44. C

Because the reactor coolant temperature increases as coolant flows up through the core, the heat flux required to cause DNB decreases.

Reference 33, page 353.

45. A

Reference 33, page 353.

46. C

Reference 22, part B, Chapter 4, page 229.

47. D

Critical heat flux is dependent on amount of subcooling at a locale, RCS flow and pressure.

Reference 33, page 349.

48. A

CHF depends on coolant flow, temperature, and pressure. A higher temperature, lower flow condition reduces the critical heat flux, making it more likely that actual heat flux will reach CHF.

49. C

A decrease in reactor power is the only answer indicated that will reduce the existing heat flux and move plant conditions farther away from the critical heat flux.

Reference 33, page 349.

50. C

Reference 15, pages 300 and 301.

51. A

Reference 15, pages 300 and 301.

52. A

Reference 18, pages 380, 381.

53. B

Reference 63, page 13-19.

54. A

Reference 15, pages 300 and 301.

55. D

Reference 15, pages 300 and 301.

56. C

Reference 15, chapter 11.

57. A

Reference 15, chapter 11.

58. D

Reference 15, pages 300 and 301.

59. B

Reference 18, page 413.

60. A

Reference 18, page 413.

61. B

Reference 22, part B, chapter 4, page 229.

62. C

$$DNBR = \frac{CHF}{AHF}$$

When CHF = AHF, DNB occurs (ratio = 1.0).

Reference 18, page 413.

63. A

Reference 18, page 413.

64. B

Reference 33, page 339.

65. A

Heat transfer coefficient is greater at higher Reynolds numbers. High Reynolds numbers mean flow is turbulent.

Reference 33, page 339.

66. D

The heat transfer coefficient increases due to the increase in heat capacity of the fluid at saturation, and mechanics of boiling agitate laminar fluid layers promoting turbulent flow.

Reference 33, page 341.

67. D

Heat transfer coefficient depends on type of flow and phase changes in the coolant.

Reference 33, page 341.

68. C

Reference 33, page 339.

69. C

Reference 18, page 380.

70.

When heat is transferred from the fuel cladding to the coolant, it must pass through a laminar flow region before reaching the turbulent bulk flow region. The thickness of the laminar region, and hence the resistance to heat flow, depends on the velocity of the bulk fluid flow. As the flow rate increases, the outer portions of the laminar layer are disturbed, resulting in more turbulent flow and an increased heat transfer coefficient.

Reference 63, page 3-71.

71.

Subcooling margin (SCM) is the difference between the actual temperature of the coolant and the saturation temperature. Parameters that affect either of these temperatures will affect SCM:

a. reactor coolant temperature - The higher the temperature of the coolant, the closer it is to saturation temperature, and therefore the smaller the SCM.

b. pressurizer pressure - The higher the pressurizer (and therefore reactor coolant) pressure, the higher the saturation temperature. Thus, raising pressure will increase SCM.

Reference 15, page 408.

72. C

Reference 15, page 408.

73. C

74. B

The only factors that affect SCM are T_{sat} and T_{fluid}. Changing pressure causes T_{sat}, and therefore SCM, to change.

Reference 15, page 408.

75. A

Only T_{fluid} and T_{sat} affect SCM. Increasing pressure causes T_{sat} to increase, increasing SCM.

Reference 15, page 408.

76. D

Reference 15, page 408.

77. A

78. D

Reference 15, page 408.

79. C

80. D

From steam tables, saturation temperature for 2,235 psig (2,250 psia) is 652.67°F. Therefore, the subcooling margin is 652.67°F - 610°F or about 43°F

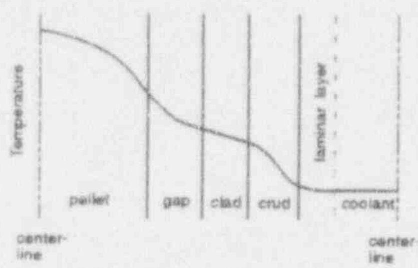
Saturation pressure for 610°F is 1,661.7 psia, or about 1,647 psig. Therefore, subcooling margin is 2,235 -1,647 = 588 psi.

81. A

82.

The temperature is highest at the fuel pellet centerline and decreases across the pellet, the pellet-clad gap, the clad, the corrosion/crud layer, and the laminar - flow layers, as shown in Figure 3.8-7.

FIGURE 3.8-7



Reference 63, page 3-57.

83. A

Reference 63, page 13-10.

84. D

85. A

$\dot{Q} = \dot{m} C p \Delta T$

If $\dot{Q}$ is held constant, a reduction in $\dot{m}$ will cause an increase in ΔT.

Reference 18, chapter 6.

86. A

$\dot{Q} = UA\,(T_{fuel} - T_{ave})$

As flow decreases, the laminar film layer becomes more pronounced, decreasing the heat transfer coefficient. With constant power and T_{ave}, a decrease in U requires an increase in T_{fuel}

Reference 63, chapter 12.

87. B

$\dot{Q} = UA\,(T_{fuel} - T_{ave})$

If $\dot{Q}$ is held constant, an increase in U resulting from the increased flow will cause a decrease in ΔT.

This will result in decreased fuel temperature.

Reference 18, chapter 6.

88. A

$\dot{Q} = UA(T_{fuel} - T_{ave})$

If $\dot{Q}$ is held constant, a decrease in U resulting from the decreased flow will cause an increase in ΔT.

89. C

All parameters except pressurizer temperature would affect $\dot{Q}$.

Reference 63, chapter 12.

90. A

91. A

Reference 63, page 13-24.

92. A

Flow resistance is seen as head loss, which is proportional to fluid velocity squared and the pipe friction factor and is inversely proportional to pipe diameter.

Reference 63, page 10-21.

93.

Resistance to fluid flow, as measured by head loss, depends on the following factors:

a. fluid velocity - Head loss increases as the square of velocity.

b. system friction - The higher the friction (resulting from pipe wall roughness as well as flow-disrupting components), the greater the head loss.

c. pipe diameter - A larger diameter pipe creates less head loss than a small diameter pipe.

Reference 63, page 10-21.

94. B

Two-phase flow resistance has been experimentally determined to exceed single-phase flow resistance.

Reference 15, page 337.

95. A

Core bypass flow bypasses the core and provides no core cooling.

Reference 61, page 1-42.

96. B

Core bypass flow bypasses the core and provides no core cooling.

Reference 61, page 1-42.

97. C

Core bypass flow bypasses the core and provides no core cooling.

Reference 61, page 1-42.

98. D

Core bypass flow bypasses the core and provides no core cooling.

Reference 61, page 1-42.

99. B

Core bypass flow bypasses the core and provides no core cooling.

Reference 61, page 1-42.

100. C

101. D

102. D

Reference 61, page 1-42.

103. D

Size of heat source or heat sink only determines flow rate. To establish natural circulation driving head, the heat sink must be above the heat source for buoyancy forces to act.

Reference 22, part B, chapter 3, section III, page 355.

104. A

Water density difference (buoyancy) must exist to establish natural circulation flow.

Reference 22, part B, chapter 3, section III, page 355.

105. B

The height difference between the core thermal center and the steam generator thermal centers is a dominant factor.

Reference 22, part B, chapter 3, section III, page 355.

106. D

Reference 22, part B, chapter 3, section III, page 355.

107. A

Reference 22, pcrt B, chapter 3, section III, page 355.

108.

Natural circulation requires a heat source and a heat sink. The heat sink must be higher than the heat source and must have a heat capacity at least as great as the heat production from the source. With this configuration, the heat source will increase the temperature of the coolant, reducing its density and tending to make it rise. The heat sink lowers coolant temperature, increasing its density and tending to make it descend. With a flow path between the source and sink, hot coolant will rise toward the sink, cool off, and descend toward the source. Flow will continue as long as the difference in coolant densities produces a driving head that exceeds the system's resistance to flow.

Reference 63, pages 14-16 and 14-17.

109.

To maintain natural circulation flow, the operator must ensure that the heat sink is removing at least as much heat as the reactor is adding to the coolant. This is done by verifying that all available methods for heat removal are functioning. Normally, this entails use of the steam dumps, but could also involve opening steam generator relief valves. The operator must also verify that the steam generator remains at a lower temperature than the core so that the thermal driving head is maintained.

Reference 63, pages 14-27 and 14-28.

110. B

To increase the thermal driving head for natural circulation, you can increase the elevation difference between the heat source and heat sink and/or increase the temperature difference between the two.

Reference 22, part B, chapter 3, section III, page 355.

111. C

Risng steam generator level increases the elevation difference between the heat source and heat sink, thus increasing the thermal driving head.

Reference 22, part B, chapter 3, section III, page 356.

112. D

Natural circulation flow rate depends on thermal driving head. The greater the heat source, the higher the thermal driving head. The decay heat level is greatest immediately after a trip and results in a higher thermal driving head.

Reference 22, part B, chapter 3, section III, page 355.

113. A

Reference 22, part B, chapter 3, section III, page 356.

114. B

Reflux cooling involves accident conditions where the steam being produced in the core during natural circulation flows up through the hot legs and condenses on the hot leg side of the steam generators. This condensed water then flows back into the core providing some cooling.

Reference 57.

115. B

Reference 57.

116. B

Reference 63, pages 14-26 through 14-29.

117. D

Reference 63, pages 14-26 through 14-29.

118. B

As coolant moves up the channel, increasing nucleate boiling causes the convective heat transfer coefficient to improve. Once departure from nucleate boiling (DNB) occurs, transition (partial film) boiling occurs and the coefficient begins to decrease.

119. C

Departure from nucleate boiling (DNB) occurs at the knee of the heat flux curve where region III begins. At this point, transition (partial film) boiling occurs as a partial film of steam begins to form on the surface of the fuel.

120. D

121. C

122. A

123. B

124. A

THERMAL HYDRAULICS
Learning Objectives

Each learning objective listed below is preceded by the associated question number(s) and by the number of its related knowledge statement.

K1.01 Questions 1-4

Distinguish between boiling processes and other heat transfer mechanisms.

K1.02 Questions 5-8, 118

Explain the effect of nucleate boiling on convective heat transfer.

K1.02 Questions 9-16

Describe means by which boiling improves convection heat transfer.

K1.03 Question 17

Describe the process of bulk boiling.

K1.03 Questions 18-20

Describe the process of subcooled nucleate boiling.

K1.03 Question 21

Differentiate between subcooled and saturated nucleate boiling.

K1.03 Question 22

List the boiling processes in the correct sequence.

K1.04 Questions 23-26

Describe departure from nucleate boiling (DNB).

K1.04 Questions 27-30

Describe the effects of reaching departure from nucleate boiling (DNB).

K1.05 Questions 31-40

List the parameters that affect DNBR and describe their effects.

K1.06 Questions 41-43

Describe critical heat flux.

K1.06 Questions 44-49

Describe the factors that affect critical heat flux.

K1.07 Questions 50-53, 119

Describe transition (partial film) boiling.

K1.08 Questions 54-58

Describe film boiling.

K1.10 Questions 59-63, 121, 122

Define departure from nucleate boiling ratio (DNBR).

K1.14 Questions 64-70, 120

Describe the effects of flow and phase change on the heat transfer coefficient.

K1.15 Questions 71-79

Define and describe subcooling margin (SCM).

K1.15 Question 80

Calculate subcooling margin given reactor coolant system parameters.

K1.16 Questions 81-83

Draw and describe the temperature profile from fuel pellet centerline to coolant flow channel during power operation.

K1.16 Question 84

State the purpose of the fuel pellet-to-clad gap.

K1.17 Questions 85-88, 123

Explain the relationship between reactor coolant flow, core ΔT, fuel temperature, and reactor power.

K1.17 Question 89

Identify parameters that affect the heat transfer rate to the reactor coolant system.

K1.17 Question 90

Identify indications of reactor coolant pump cavitation.

K1.17 Question 91

Relate reactor coolant flow to departure from nucleate boiling.

K1.18 Questions 92, 93

Describe the factors affecting single-phase flow resistance.

K.1.18 Question 94

Compare single- and two-phase flow resistance.

K1.19 Questions 95-99, 124

Describe core bypass flow.

K1.20 Questions 100-102

Identify the function of core bypass flow.

K1.21 Questions 103-109

Explain the conditions that must exist to establish natural circulation.

K1.22 No questions

Specific steps to determine existence of natural circulation are plant-procedure driven and not generic. Factors involved in natural circulation are addressed under K1.21 and K1.23.

K1.23 Questions 110, 111

Describe means by which natural circulation can be enhanced.

K1.23 Questions 112, 113

Describe factors that affect natural circulation flow rate.

K1.24 Questions 114, 115

Describe the factors affecting reflux boiling.

K1.25 Questions 116, 117

Describe gas binding effects on natural circulation.

CORE THERMAL LIMITS
Questions

1. Describe what a "peaking factor" represents, how it is used in reactor operation, and the consequences of exceeding it.

2. Reactor thermal limits are established to

   A. predict core thermal performance during normal operation

   B. prevent fuel cladding damage

   C. establish optimum thermal efficiency of the plant

   D. predict the coolant temperature rise across the core

3. The integrity of the fuel cladding is ensured by

   A. maintaining core conditions less than thermal limits

   B. maximizing power density in the core

   C. periodic inspection of spent fuel assemblies

   D. use of zirconium as the clad material

4. Reactor thermal limits are established to

   A. optimize the thermal efficiency of the plant

   B. prevent exceeding core material property limitations

   C. predict the coolant temperature rise across the core

   D. establish control rod insertion limits

5. During normal operation, fuel clad integrity is ensured by

   A. the primary system relief valves
   B. core bypass flow restrictions
   C. the secondary system relief valves
   D. not exceeding core thermal limits

6. During normal operation, fuel clad integrity is ensured by

   A. secondary chemistry control
   B. the use of letdown control limits
   C. the failed fuel monitor
   D. not exceeding core thermal limits

7. If the reactor is operated within core thermal limits, then

   A. plant thermal efficiency is optimized

   B. fuel cladding integrity is ensured

   C. pressurized thermal shock will be prevented

   D. reactor vessel thermal stresses will be minimized

8. The 2200 °F maximum peak cladding temperature limit is imposed because

   A. it is approximately 500 °F below the fuel cladding melting temperature

   B. any clad temperature higher than this correlates to a fuel centerline temperature at the fuel melting point

   C. the oxidation rate of the zircalloy cladding increases sharply above 2200 °F

   D. the thermal conductivity of zircalloy decreases at temperatures above 2200 °F causing an unacceptably sharp rise in the fuel centerline temperature

9. The pellet-to-clad gap in fuel rod construction is designed to

   A. decrease fuel pellet slump
   B. attenuate fission gammas
   C. increase heat transfer
   D. reduce internal clad strain

10. Describe the effect that insertion of a bank (group) of control rods would have on the axial peaking factor.

11. In conducting safety analyses, fuel manufacturing tolerances are assumed to be at their most limiting values. List and explain four parameters for which such tolerances are considered.

12. The reactor is operating at 80% power with all control rods fully withdrawn. Compared to a 50% insertion of 1 control rod, 50% insertion of a group (or bank) of control rods will cause a _____________ increase in the axial peaking hot channel factor and a __________________ increase in the radial peaking hot channel factor. (Assume reactor power remains constant.)

    A. larger; smaller
    B. larger; larger
    C. smaller; smaller
    D. smaller; larger

13. Reactor core peaking (or hot channel) factors are used to establish a maximum reactor power level such that fuel pellet temperature is limited to prevent _________ and fuel clad temperature is limited to prevent ___________ during most analyzed transients and abnormal conditions.

    A. fuel pellet melting; fuel clad melting

    B. excessive fuel pellet expansion; fuel clad melting

    C. fuel pellet melting; excessive fuel clad oxidation

    D. excessive fuel pellet expansion; excessive fuel clad oxidation

14. The reactor is operating at 80% power at the beginning of a fuel cycle. All control rods are fully withdrawn and in manual control. Moderator temperature coefficient is negative.

    Which one of the following w[illegible]crease the axial peaking (or hot channel) factor? (Assume no subsequent operator action is taken and that turbine load and xenon distribution do not change unless stated.)

    A. RCS boron concentration is reduced by 50 ppm.

    B. Turbine load/reactor power is reduced by 20%.

    C. One bank of control rods is inserted 10%.

    D. One control rod fully inserts into the core.

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1.

A peaking factor is a ratio of some measure of the maximum localized power production to the average value of that parameter. For example, a total peaking factor can be defined as:

$$\frac{\text{maximum linear power density}}{\text{average linear power density}}$$

Plant technical specifications prescribe limits on peaking factors. The operator must not exceed these limits or fuel damage could result.

Reference 63, page 13-27 through 13-32.

2. B

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

3. A

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

4. B

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

5. D

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

6. D

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

7. B

Core thermal limits are based on protecting the fuel.

Reference 15, page 397.

8. C

Reference 63, pages 13-15 through 13-17

9. D

Reference 63, page 3-63.

10.

When a bank of rods is inserted, it initially suppresses the neutron flux in the upper portion of the core, driving the region of peak flux lower in the core. If reactor power is maintained constant, the peak power density will have to increase to compensate for reduced power densities high in the core. As a result of this change in the axial flux profile and power distribution, the axial peaking factor will increase.

Reference 63, page 13-29.

11.

The following manufacturing tolerances are assumed to be at their most limiting value in safety analyses:

a. fuel rod diameter - Larger is more limiting because of the greater distance through which heat must be transferred out and the reduction in the adjacent coolant channel.

b. fuel clad thickness - Larger is more limiting because of the greater distance through which heat must be transferred.

c. fuel enrichment - Higher is more limiting because the power density will be greater.

d. fuel pellet size - Larger is more limiting because the power produced by the pellet will be greater.

e. flow distribution - Less flow is more limiting because of reduced heat removal ability.

Reference 63, page 13-29.

12. A

13. C

14. B

CORE THERMAL LIMITS
Learning Objectives

Each learning objective listed below is preceded by the associated question number (s) and by the number of its related knowledge statement.

K1.01, 1.02, 1.03 No questions

Peaking factors are defined and calculated differently for different fuel vendors and are therefore not generic.

K1.04 Question 1

Describe what a "peaking factor" represents.

K1.05 Questions 2-7

State the reason thermal limits are necessary.

K1.05 Question 8, 13

State the basis for the limit on peak cladding temperature.

K1.06 No questions

Core protection calculators are not generic to all PWRs.

K1.07 Questions 9-12, 14

Describe factors affecting peaking factors.

BRITTLE FRACTURE AND VESSEL THERMAL STRESS
Questions

1. Brittle fracture can be defined as the fragmentation of metal

   A. resulting from the application of a stress, but with little or no plastic deformation

   B. resulting from the application of a stress much greater than the material's yield stress

   C. into two or more pieces under the application of a force

   D. from the application of a stress characterized by severe plastic deformation

2. Brittle fracture is the fragmentation of metal resulting from the application of ________ stress at relatively ________ temperatures.

   A. compressive; high
   B. compressive; low
   C. tensile; high
   D. tensile; low

3. Which of the following increases the probability of brittle fracture?

   A. using stainless steel rather than carbon steel

   B. a tensile stress rather than a compressive stress

   C. a high temperature rather than a low temperature

   D. crack initiation rather than crack propagation

4. Brittle fracture of the RCS pressure boundary is most likely to occur at

   A. 120 °F, 2200 psig
   B. 120 °F, 400 psig
   C. 400 °F, 2200 psig
   D. 400 °F, 400 psig

5. Metal failure characterized by a rapid rate of crack propagation and little or no plastic deformation describes

   A. ductile fracture
   B. crack initiation
   C. brittle fracture
   D. compressive fracture

6. Which of the following statements best describes the relationship between brittle fracture and nil ductility temperature?

   A. Below the nil ductility temperature, the probability of brittle fracture increases significantly.
   B. The probability of brittle fracture at high temperatures decreases as the nil ductility temperature increases.
   C. Brittle fracture is more likely to occur above the nil ductility temperature.
   D. The probability of brittle fracture is not significantly affected by the nil ductility temperature.

7. Why is brittle fracture more of a concern in reactor operation than ductile fracture?

8. Describe the difference between the ductile and brittle modes of metal failure.

9. The probability of brittle fracture is increased by all of the following <u>except</u>

   A. the presence of a pre-existing flaw

   B. the presence of a tensile stress

   C. operation at low temperatures

   D. low copper concentration in the reactor vessel

10. A sudden rupture of a reactor vessel wall due to rapid crack propagation is an example of

    A. brittle fracture
    B. ductile fracture
    C. fretting failure
    D. buckling failure

11. The nil-ductility transition temperature is that temperature

    A. above which the probability of brittle fracture significantly increases

    B. below which failure stress is greater than the yield stress of the metal

    C. below which the probability of brittle fracture significantly increases

    D. below which the yield stress of the metal is higher than the critical fracture stress

12. The nil-ductility transition temperature is that temperature

    A. below which the probability of brittle fracture significantly increases

    B. determined by fracture mechanics to be equivalent to reference transition temperature

    C. determined by charpy V-notch test to be equivalent to reference transition temperature

    D. below which the yield stress of the metal is inversely proportional to Young's modulus of elasticity

13. Define nil-ductility transition temperature.

14. The reference temperature for nil-ductility transition (RT_{NDT}) is the temperature above which

    A. a large compressive stress can result in brittle fracture

    B. a metal exhibits more ductile tendencies

    C. the probability of brittle fracture increases

    D. no appreciable deformation occurs prior to failure

15. The nil-ductility transition temperature (NDT) of the reactor vessel is the temperature

    A. below which the reactor vessel metal will elastically deform as reactor coolant system pressure decreases

    B. below which the reactor vessel metal loses its ability to elastically deform as reactor coolant system pressure increases

    C. above which the reactor vessel metal loses its ability to deform with ductility as reactor coolant system pressure increases

    D. above which the reactor vessel metal will elastically deform as reactor coolant system pressure decreases

16. Reactor cooldown rate limitations are procedurally established to prevent

    A. excessive reactivity additions

    B. brittle fracture of the reactor vessel

    C. impurities from precipitating out of solution in the reactor vessel

    D. excessive reactor coolant system subcooling

17. Compressive stress on the <u>outside</u> surface of the reactor vessel wall results from

    A. neutron embrittlement
    B. contained pressure
    C. reactor coolant system cooldown
    D. reactor coolant system heatup

18. The stress that is compressive on the inner wall of the reactor pressure vessel during an RCS heatup is

    A. thermal stress
    B. pressure stress
    C. embrittlement stress
    D. yield stress

19. Stress on the reactor vessel inner wall is greater during cooldown than heatup because

    A. both pressure stress and cooldown stress are tensile at the inner wall

    B. heatup stresses totally offset pressure stress at the inner wall

    C. cooldown stresses and heatup stresses are both tensile at the inner wall, but cooldown stresses are greater in magnitude

    D. the tensile cooldown stress at the inner wall is greater in magnitude than the compressive pressure stress at the same location

20. Pressure stress on the reactor vessel wall is

    A. compressive across the entire wall
    B. tensile across the entire wall
    C. tensile at the inner wall, compressive at the outer wall
    D. compressive at the inner wall, tensile at the outer wall

21. The potential for brittle fracture is minimized by placing limits on the cooldown rate to limit stress due to

    A. differential pressure
    B. neutron embrittlement
    C. residual conditions
    D. thermal gradients

22. The likelihood of brittle fracture failure of the reactor vessel is reduced by

    A. increasing vessel age
    B. reducing vessel pressure
    C. reducing vessel temperature
    D. reducing gamma flux exposure

23. The probability of reactor vessel brittle fracture is decreased by minimizing

    A. oxygen content in the reactor vessel coolant

    B. the time taken to cool down the reactor coolant system

    C. operation at high temperatures

    D. the amount of copper in the reactor vessel

24. Operating with which of the following conditions is <u>least</u> effective in preventing brittle fracture in the RCS?

    A. operating within prescribed heatup and cooldown rate limitations

    B. operating with RCS temperature greater than nil ductility temperature

    C. operating with RCS pressure low when RCS temperature is low

    D. operating with a ramped RCS temperature as power level varies

25. Plant technical specifications typically include a curve showing pressure-temperature limitations during plant heatup. Explain why this curve is applicable only up to a certain heatup rate and vessel age.

26. Why are more restrictive limitations placed on pressurizer pressure during RCS cooldown than during steady-state operation?

27. The two factors that have the greatest effect on the Reference temperature for nil ductility transition (RT_{NDT}) of the reactor vessel are over its life

    A. thermal neutron fluence and vessel copper content

    B. thermal neutron fluence and vessel carbon content

    C. fast neutron fluence and vessel copper content

    D. fast neutron fluence and vessel carbon content

28. How and why does the nil-ductility transition temperature change as the plant ages?

29. A curve showing allowable plant pressure versus temperature undergoes changes over the life of the plant. Explain how and why.

30. The reactor vessel nil ductility transition temperature will increase as a result of

    A. heatup/cooldown cycles
    B. pressure tensile stress
    C. neutron irradiation
    D. thermal compressive stress

31. Which one of the following irradiation sources most significantly reduces the ductility of the metal of a reactor pressure vessel?

    A. beta
    B. thermal neutrons
    C. gamma
    D. fast neutrons

32. Prolonged exposure of the reactor vessel to a fast neutron flux will cause the Reference temperature for nil ductility transition (RT_{NDT}) to

    A. increase due to the propagation of existing flaws

    B. decrease due to the propagation of existing flaws

    C. increase due to changes in the material properties of the vessel wall

    D. decrease due to changes in the material properties of the vessel wall

33. Fast neutron irradiation of the reactor vessel results in ______________ stresses within the vessel metal, thereby ___________ the nil-ductility transition temperature.

    A. increased, increasing
    B. increased, decreasing
    C. decreased, increasing
    D. decreased, decreasing

34. Fast neutron irradiation adversely affects the reactor pressure vessel primarily by causing

    A. metal embrittlement
    B. brittle fracture
    C. flaw initiation
    D. flaw propagation

35. The part of the reactor pressure vessel that is most affected by fast neutron irradiation is the

    A. vessel wall
    B. vessel upper head
    C. vessel lower head
    D. core barrel

36. Over core life, the reactor vessel nil-ductility temperature (NDT)

    A. increases continuously
    B. decreases continuously
    C. increases, then decreases
    D. decreases, then increases

37. After several years of operation the maximum allowable stress to the reactor pressure vessel is more limiting on the inner wall than the outer wall because

    A. the inner wall experiences more neutron-induced embrittlement than the outer wall

    B. there is a temperature gradient across the reactor pressure vessel wall

    C. the inner wall has a smaller surface area than the outer wall

    D. the inner wall experiences more tensile stress than the outer wall

38. Pressurized thermal shock is a condition that can occur following a __________ of the reactor coolant system (RCS) if RCS pressure is rapidly __________.

    A. cooldown; decreases
    B. cooldown; increased
    C. heatup; decreased
    D. heatup; increased

39. Pressurized thermal shock (PTS) is a rapid cooldown in combination with

    A. high auxiliary (emergency) feed water flow

    B. safety injection

    C. high pressure

    D. core uncovery

40. Describe the changes in RCS parameters that could result in pressurized thermal shock.

41. Pressurized thermal shock could most likely be a concern during

    A. an uncontrolled cooldown followed by a rapid repressurization

    B. an uncontrolled depressurization followed by a rapid repressurization

    C. an uncontrolled cooldown followed by rapid depressurization

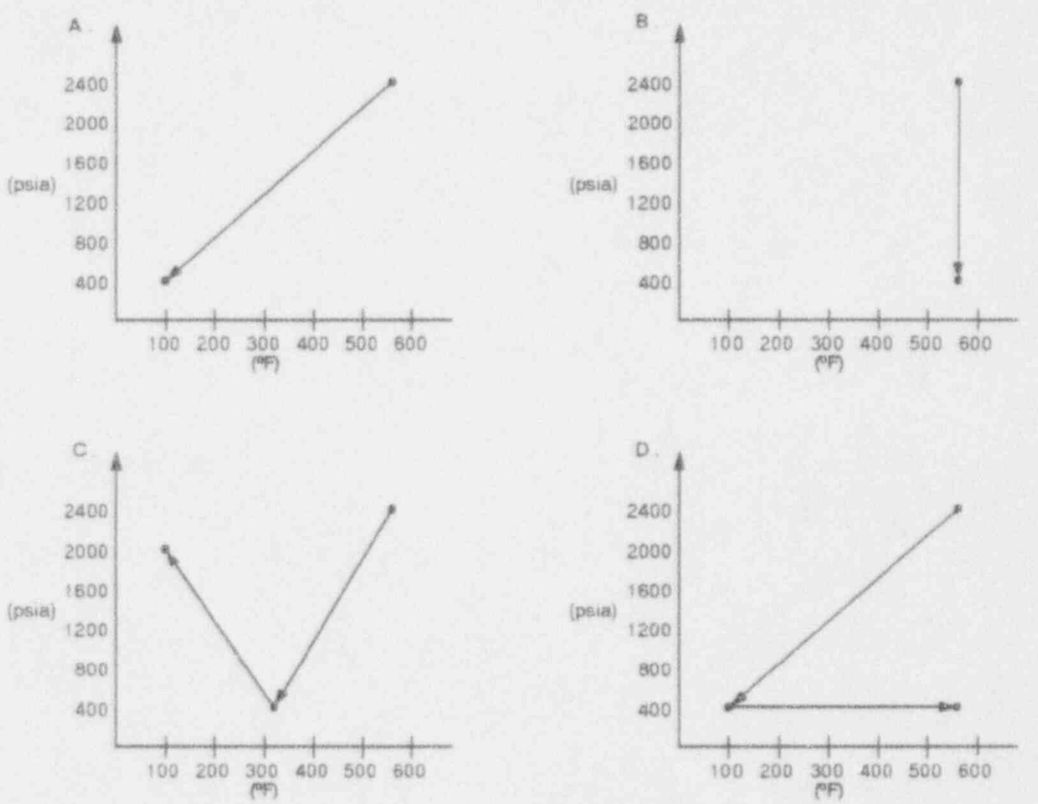
    D. an overpressurization from a low-temperature, low-pressure condition

42. Transients that result in a cooldown and depressurization followed by a rapid repressurization can result in a condition known as

   A. severe thermal shock
   B. pressurized thermal shock
   C. thermal overpressurization
   D. pressure vessel stress

43. Of the four pressure-temperature transients shown in Figure 3.10-1, which would most likely represent a pressurized thermal shock transient?

FIGURE 3.10-1



Pressure Temperature Transients

44. Pressurized thermal shock is a condition that may result in

   A. brittle fracture
   B. ductile transition
   C. intergranular stress corrosion
   D. fluence shift

45. Which of the following is the primary concern related to pressurized thermal shock?

   A. creep of the vessel wall
   B. plastic deformation of the vessel wall
   C. fatigue of the vessel wall
   D. brittle fracture of the vessel wall

46. A pressure stress applied to the reactor vessel is

    A. tensile at the inner wall, compressive at the outer wall

    B. compressive at the inner wall, tensile at the outer wall

    C. tensile across the entire wall

    D. compressive across the entire wall

47. An uncontrolled cooldown is an operational concern because it creates a large

    A. compressive stress at the inner wall of the reactor vessel

    B. tensile stress at the inner wall of the reactor vessel

    C. compressive stress at the outer wall of the reactor vessel

    D. tensile stress at the outer wall of the reactor vessel

48. An uncontrolled cooldown is most likely to cause brittle fracture when a

    A. rapid depressurization accompanies it
    B. rapid repressurization follows it
    C. rapid depressurization follows it
    D. loss of inventory accompanies it

49. During a severe overcooling transient, which of the following would be a major concern to the operator?

    A. accelerated zirconium hydriding

    B. loss of reactor vessel water level

    C. loss of reactor coolant pump net positive suction head

    D. brittle fracture of the reactor vessel

50. During an uncontrolled cooldown of the RCS, the component most susceptible to pressurized thermal shock (PTS) is the

    A. reactor vessel
    B. steam generator tube sheet
    C. loop RTD penetration
    D. cold leg accumulator penetration

51. The stress that is compressive on the outer wall of the reactor pressure vessel during an RCS cooldown is

    A. thermal stress
    B. pressure stress
    C. embrittlement stress
    D. yield stress

52. A heatup stress applied to the reactor vessel is

    A. compressive at the inner wall, tensile at the outer wall

    B. tensile at the inner wall, compressive at the outer wall

    C. tensile across the entire wall

    D. compressive across the entire wall

53. Why is a plant cooldown generally a more limiting transient than a heatup?

54. Which one of the following comparisons will result in a higher probability of brittle fracture of the reactor vessel?

    A. a high coolant oxygen content rather than a low oxygen content

    B. a rapid 100°F cooldown at a high temperature rather than at a low temperature

    C. a high material strength rather than a high material ductility

    D. a high gamma flux rather than a high neutron flux

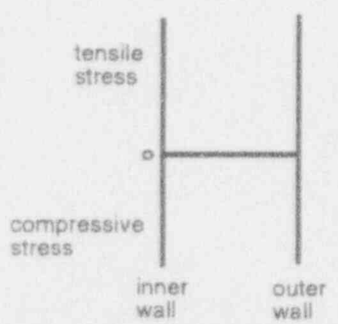
55. Explain the difference in thermal stress on the reactor vessel between heatup and cooldown transients.

56. List and state the cause of each of the stresses that combine to produce total reactor vessel stress.

57. Using a diagram such as that in Figure 3.10-2, draw and label curves representing the following stresses on the reactor vessel wall during a reactor heatup:

    a. residual (manufacturing) stress
    b. pressure stress
    c. embrittlement stress
    d. heatup stress
    e. total stress

FIGURE 3.10-2



Reactor Vessel Wall

58. Using a diagram such as that in Figure 3.10-2, draw and label curves representing the following stresses on the reactor vessel wall during a reactor cooldown:

    a. residual (manufacturing) stress
    b. pressure stress
    c. embrittlement stress
    d. cooldown stress
    e. total stress

59. Two identical reactors have been in operation for the last 10 years. Reactor A has experienced 40 heatup/cooldown cycles with an average power capacity of 50%. Reactor B has experienced 30 heatup/cooldown cycles with an average power capacity of 60%.

    Which reactor will have the lowest reactor vessel nil-ductility transition temperature?

    A. Reactor A due to the greater number of heatup/cooldown cycles.

    B. Reactor A due to the lower average power capacity.

    C. Reactor B due to the fewer number of heatup/cooldown cycles.

    D. Reactor B due to the higher average power capacity.

60. Which one of the following will cause the nil-ductility transition temperature of the reactor vessel to increase?

    A. decreasing RCS operating pressure
    B. decreasing RCS average temperature
    C. increasing fast neutron exposure
    D. increasing gamma radiation exposure

61. The plant is shutdown with the RCS at 1200 psia and 350°F. Which one of the following would be most likely to cause pressurized thermal shock of the reactor vessel?

    A. a rapid heatup followed by a rapid pressurization

    B. a rapid cooldown followed by a rapid pressurization

    C. a rapid depressurization followed by a rapid heatup

    D. a rapid depressurization followed by a rapid cooldown

62. During cooldown, the thermal stress on the reactor vessel is:

    A. tensile across the entire wall

    B. compressive across the entire wall

    C. tensile at the inner wall, compressive at the outer wall

    D. compressive at the inner wall, tensile at the outer wall

63. Which one of the following reduces the probability of brittle fracture of the reactor vessel?

    A. The presence of a pre-existing flaw

    B. The presence of a tensile stress

    C. Operation at low temperatures

    D. Small heatup and cooldown rates

In addition to the correct answer, a brief explanation of the answer (if needed for clarity), is provided along with a Reference for each question/answer. Reference numbers are keyed to the list of References in Appendix B.

1. A

B, C, and D are incorrect because

B - definition of ductile failures
C - definition of fracture only
D - definition or characteristic of ductile failure

A is correct because brittle fracture generally occurs at a very low yield stress with little or no deformation.

Reference 63, page 13-58.

2. D

3. B

A, C, and D are incorrect because the conditions decrease the probability of brittle fracture.

Reference 63, pages 13-58 through 13-60.

4. A

Brittle behavior occurs at lower temperatures; failure is more likely to occur at high pressure.

5. C

Reference 63, page 13-60.

6. A

The probability of brittle fracture increases as temperature decreases.

Reference 63, page 13-60.

7.

Ductile failure occurs when stress much greater than a material's yield stress is applied. Brittle fracture, on the other hand, occurs with an applied stress well below the yield stress. This lower value of stress required to cause brittle fracture is the reason that brittle failure is an operational concern. The reactor vessel and primary system are designed to prevent stresses as high as the yield stress, so ductile failure is not an operational concern.

Reference 63, pages 13-58 through 13-60.

8.

Ductile failure occurs when a stress in excess of a material's yield stress causes the metal to break into two or more pieces. Ductile failure is preceded and accompanied by plastic deformation of the material (a permanent change in the shape of the material).

Brittle failure occurs at a stress less than the yield stress. There is little or no plastic deformation before or during brittle failure, and the growth of the crack(s) is rapid. Brittle failure occurs at relatively low temperatures.

Reference 63, pages 13-58 through 13-60.

9. D

Reference 63, page 13-60.

10. A

Reference 63, page 13-60.

11. C

Choice C is a definition of nil-ductility transition temperature.

Reference 63, page 13-60.

12. A

Choice A is a definition of nil-ductility transition temperature.

Reference 63, page 13-60.

13.

Nil-ductility transition temperature is the temperature at and below which a material exhibits brittle behavior.

Reference 63, page 13-60.

14. B

Reference 63, page 13-60

15. B

Reference 63, page 13-60.

16. B

The basis for cooldown limitations on the reactor coolant system is to prevent thermal shock/brittle fracture.

Reference 04, page 28.

17. C

All other choices will result in a tensile stress being applied to the outer wall.

Reference 63, pages 13-64 through 13-66.

18. A

Reference 63, page 13-64.

19. A

The cooldown transient is the most limiting because the com bination of tensile pressure stress and tensile cooldown stress at the inner wall is greatest.

Reference 63, page 13-58.

20. B

Pressure stress is always tensile across a convex vessel wall.

Reference 63, page 13-58.

21. D

Pressure, embrittlement, and residual stress are not significantly affected by heatups and cooldowns; however, heatups and cooldowns produce thermal stresses due to thermal gradients. The larger the temperature rate of change, the larger the gradient, and the larger the thermal stresses.

Reference 18, chapter 11.

22. B

A lower pressure reduces stress on the vessel, decreasing the chance of vessel failure.

23. D

The presence of copper in a pressure vessel's material has been shown to increase the vessel's susceptibility to brittle fracture.

24. D

25.

During a plant heatup, a thermal gradient exists across the reactor vessel wall. This difference in temperature between the vessel inner and outer wall creates a thermal stress across the wall. The amount of the temperature difference, and thus the amount of thermal stress, depends on the heatup rate. Therefore, the curve is valid only up to a certain specified heatup rate.

The reason for imposing pressure limits is to avoid brittle failure. Brittle failure becomes more likely as the reactor vessel is embrittled by years of fast neutron exposure. Therefore, reactor vessel "age" is another restriction on the validity of the pressure-temperature curve.

Reference 63, chapter 13.

26.

During plant cooldown, a thermal gradient is created through the reactor vessel wall. This gradient produces a thermal stress that increases the total stress on the vessel. To avoid subjecting the vessel to excessive stress, restrictions are placed on allowable pressure (and therefore pressure stress) for any given temperature.

Reference 63, chapter 13.

27. C

Fast neutron fluence is the integral effect of fast neutron flux over time. This, along with the increased percentage of copper content in the vessel, will cause the Reference temperature for nil ductility transition to increase.

Reference 04, page 28.

28.

As the reactor operates, the reactor pressure vessel is subjected to bombardment by fast neutrons leaking out of the core. These neutrons collide with nuclei in the lattice structure of the vessel metal, causing displacements to occur and resulting in embrittlement of the metal. Therefore, with increasing exposure to fast neutrons, the vessel will become increasingly brittle, and its nil-ductility transition temperature will increase.

Reference 63, page 13-61.

29.

The curve of pressure-temperature limitation is designed to preclude conditions that lead to brittle fracture. As the reactor vessel is exposed to fast neutrons over its life, the vessel becomes embrittled and its nil-ductility transition temperature is increased. As a result, the minimum temperature for a given pressure is increased. Conversely, the maximum pressure allowed for a given temperature is reduced.

Reference 63, page 13-61 through 13-68.

30. C

Prolonged neutron flux will cause embrittlement of the reactor vessel due to the formation of thermal spikes, vacant sites, and interstitial point defects.

Reference 63, chapter 13.

31. D

Reference 63, pages 13-61.

32. C

RT_{NDT} will increase (occur earlier) due to changes in the grain structure of the vessel steel.

33. A

The dislocations in the metal lattice structure caused by fast neutrons increase the stress in the metal, embrittling it. The result is that the metal is brittle at higher temperatures.

Reference 63, page 13-61.

34. A

The fast neutrons cause dislocations in the metal lattice structure, embrittling it.

Reference 63, page 13-61.

35. A

Reference 63, page 13-62.

36. A

Reference 63, page 13-62.

37. A

38. B

39. C

40.

Pressurized thermal shock is an event caused by a rapid, severe cooldown of (at least a portion of) the reactor pressure vessel coincident with high or increasing RCS pressure.

Reference 65, section 2, page 4.

41. A

Reference 21, pages 1 through 11.

42. B

Reference 21, pages 1 through 11.

43. C

Reference 21, pages 1 through 11.

44. A

Brittle fracture is the primary concern when the combination of high pressure and low temperature is present.

Reference 64, page 1.

45. D

Brittle fracture is the primary concern when the combination of high pressure and low temperature is present.

Reference 65, pages 1 through 11; and reference 9.

46. A

Cooldown stress is tensile at the inner wall and compressive at the outer wall.

Reference 63, page 13-65.

47. B

Rapid cooldown creates large tensile stresses at the inner wall and compressive stresses at the outer wall.

It is the combination of this tensile stress with other stresses, like pressure stresses, that is of primary concern.

Reference 63, page 13-67.

48. B

Brittle fracture is caused by a combination of excessive cooldown and subsequent repressurization.

Reference 63, page 13-65.

49. D

Following an overcooling transient, the vessel ductility would be drastically reduced and brittle fracture would be a major concern.

Reference 63, chapter 13.

50. A

51. A

Reference 63, page 13-64.

52. A

Reference 63, page 13-64.

53.

Both cooldowns and heatups produce thermal gradients through the reactor pressure vessel wall. However, the resultant thermal stress for a cooldown is tensile on the inner portion of the vessel wall, while the heatup stress is compressive on the inner wall.

Tensile stresses due to neutron embrittlement and system pressure combine to produce a relatively high tensile stress on the inner wall surface. Cooldown stress adds to this, producing an even higher tensile stress. Heatup stress, being compressive, would reduce the inner wall tensile stress. Therefore, due to the additive nature of the resulting thermal stress, plant cooldown is more limiting than heatup.

Reference 63, page 13-67.

54. C

Reference 63, pages 13-63 through 13-68.

55.

In a heatup, the inner wall of the reactor vessel will be hotter than the outer wall. The inner wall will attempt to expand, pushing on (and producing a tensile stress on) the outer wall. The outer wall will resist the expansion of the inner wall, producing a compressive stress at the inner wall.

In a cooldown, the situation is reversed. The inner wall cools first, trying to contract and producing a compressive stress on the resisting outer wall. The outer wall consequently imposes a tensile stress on the inner wall.

Reference 63, pages 13-63 through 13-68.

56.

Total reactor vessel stress comprises:

a. residual (manufacturing) stress - Tensile stress resulting from the manufacturing process due to cold working, heating/cooling, and/or electrodeposition.

b. pressure stress - Tensile stress resulting from the high internal pressure relative to the pressure external to the vessel.

c. embrittlement stress - Tensile stress resulting from the effect of exposure to fast neutron flux.

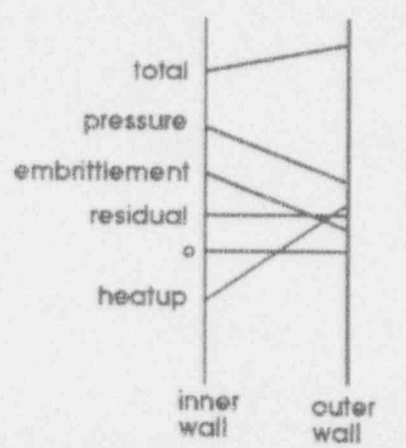
d. thermal stress - Tensile and compressive stress resulting from the thermal gradient through the vessel wall caused by reactor heatup or cooldown.

Reference 63, pages 13-60 through 13-68.

57.

Figure 3.10-3 shows the various stresses on the reactor vessel wall during heatup.

FIGURE 3.10-3



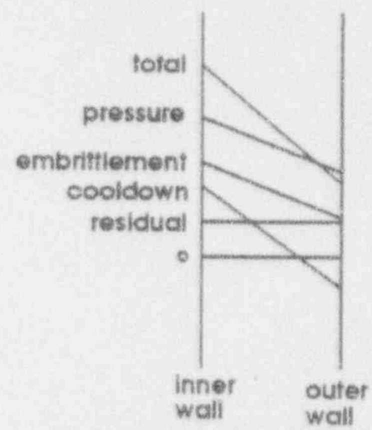
Reactor Vessel Stress During Heatup

Reference 63, pages 13-60 and 13-66.

58.

Figure 3.10-4 shows the various stresses on the reactor vessel wall during cooldown.

FIGURE 3.10-4



Reactor Vessel Stress During Cooldown

Reference 63, pages 13-60 and 13-67.

59. B

60. C

61. B

62. C

63. D

BRITTLE FRACTURE AND VESSEL THERMAL STRESS
Learning Objectives

Each learning objective listed below is preceded by the associated question number (s) and by the number of its related knowledge statement.

K1.01 Questions 1, 2, 5, 10

Define brittle fracture.

K1.01 Questions 3, 4, 9, 63

State the conditions that affect the probability of brittle fracture.

K1.01 Question 6

Describe the relationship between brittle fracture and nil ductility temperature.

K1.01 Questions 7, 8

Contrast brittle and ductile failure.

K1.02 Questions 11-15

Define nil-ductility transition temperature.

K1.04 Questions 16-26

State how the possibility of brittle fracture is minimized by operating limitations.

K1.05 Questions 27-30, 59, 60

Identify factors affecting the value of the Reference temperature for nil ductility transition.

K1.05 Questions 31-37

State the effect of fast neutron irradiation on reactor vessel materials.

K1.06 Questions 38-43, 61

Describe conditions leading to pressurized thermal shock.

K1.06 Questions 44, 45

State the failure mode associated with pressurized thermal shock.

K1.07 Questions 46-50

State the operational concerns of an uncontrolled cooldown.

K1.07 Questions 51-58, 62

Describe stresses on the reactor vessel during temperature changes.

APPENDIX A

REFERENCE EQUATIONS AND FACTS

REFERENCE EQUATIONS AND FACTS

$P = P_o \, 10^{SUR(t)}$

$P = P_o \, e^{t/T}$

$SUR = 26 / T$

$SUR = 26 \, (\bar{\lambda}\rho) / (\bar{\beta}_{eff} - \rho)$

$\rho = (k_{eff} - 1) / k_{eff}$

$\rho = (l^* / T) + \bar{\beta}_{eff} / (1 + \bar{\lambda} T)$

$\Delta\rho = (k_2 - k_1) / k_2 k_1$

$P = P_o \bar{\beta}_{eff} / (\bar{\beta}_{eff} - \rho)$

Neutron production rate = $S / (1 - k_{eff})$

$CR_1 (1 - k_{eff})_1 = CR_2 (1 - k_{eff})_2$

Shutdown margin = $(1 - k_{eff}) / k_{eff}$

$\dot{Q} = \dot{m} \, c_p \, \Delta T$

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

$\dot{Q} = \dot{m} \, \Delta h$

Carnot efficiency = $(T_h - T_c) / T_h$

1 MW = 3.41×10^6 BTU/hr

Notes:

1. $\bar{\beta}_{eff}$ is the average effective delayed neutron fraction.
2. l^* is the prompt neutron lifetime.
3. $\bar{\lambda}$ is the avernge decay constant.
4. Examinees may also use calculators, steam tables, Mollier diagrams, and graph paper during the examination.

APPENDIX B

LIST OF REFERENCES CITED

LIST OF REFERENCES CITED

The following references are cited by number in the answer for one or more questions.

The information presented below for each reference includes (as applicable) the following: author, title, publisher, address, and date of publication.

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APPENDIX C

FEEDBACK FORM

NATIONAL ACADEMY FOR NUCLEAR TRAINING

PWR OPERATOR
GENERIC FUNDAMENTALS TEST ITEM CATALOG
FEEDBACK FORM

This form can be copied and used by branches of the National Academy for Nuclear Training to provide comments based on experience with this catalog. Such comments may arise from any of several activities, including review of the catalog by subject matter experts, review of the catalog by instructional technologists, and use by trainees. The National Academy for Nuclear Training welcomes constructive criticisms of this catalog and its contents and requests suggested resolutions to problems noted.

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Proposed resolution:

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February 8, 1994

MEMORANDUM FOR: Darlene Huyer
Anstec, Inc.

FROM: Tremaine Donnell, INPO Coordinator
Records and Archives Services Section
Information and Records Management Branch
Division of Information Support Services

SUBJECT: ESTABLISHMENT OF DATA RECORD FOR INPO DOCUMENTS

The Records and Archives Services Section has received the attached INPO Document.

Distribution Code: NXF2

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Tremaine Donnell

Tremaine Donnell, INPO Coordinator
Records and Archives Services Section
Information and Records Management Branch
Division of Information Support Services, IRM

Enclosure: As stated

PLEASE NOTE: Hard copy is available from the NRC File Center.

cc: JDorsey

Add PDR