BOILING WATER REACTOR OPERATOR GENERIC FUNDAMENTALS TEST ITEM CATALOG

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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: Boiling Water Reactors*, NUREG-1123. 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 BWRs have been developed. 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 1123 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 purpose of a relief/safety valve is to

   A. maintain system integrity
   B. regulate system pressure
   C. throttle system flow
   D. increase system flow during transients

2. Which of the following correctly describes the operation of a safety valve installed on a high pressure steam system?

   A. A safety valve is initially lifted off its seat by system pressure, then is forced fully open by an air-operated piston.

   B. As system pressure increases to the safety set point, the pressure overcomes spring force on the valve operator, causing the valve to open.

   C. A safety valve will remain open until system pressure has been reduced to the pilot valve actuation setpoint.

   D. When the open safety valve has returned system pressure to the lifting set point, a combination of air and steam pressure above the valve disk closes the valve.

3. Which of the following statements describes the operation of reactor pressure vessel safety valves?

   A. When the activating pressure for a safety valve returns to the lift setpoint, a combination of air and steam pressure closes the valve.

   B. As reactor pressure increases to the lift setpoint, the pressure overcomes spring tension on the valve operator, causing the valve to fully open.

   C. As the disk on a safety valve lifts, less pressure is exerted on the disk, reducing the upward force on the disk, and thereby regulating the valve position.

   D. When the relief valve lift setpoint is reached, a pilot valve opens allowing reactor pressure to fully open the main valve disk.

4. Which of the following valves is designed to open if system pressure increases to a specific point, release a volume of liquid or steam, then close at a pressure equal to or just below the setpoint?

   A. lift check valve
   B. safety valve
   C. temperature control valve
   D. blowout valve

5. The function of a relief valve is to

   A. cross-connect systems

   B. limit pressure of a system

   C. maintain constant flow in a system

   D. equalize pressure across a valve prior to opening

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

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

7. The difference between the setpoint 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

8. The purpose of overpressure protection valves is to limit the internal pressure in vessels and thus protect personnel and equipment. Which of the following are overpressure protection valves?

   A. liftcheck and relief

   B. pressure regulating and temperature control

   C. relief and safety

   D. relief and pressure regulating

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

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

10. Which of the following correctly describes the relief mode of operation for a safety relief valve (SRV)?

    A. The SRV must be manually opened and manually closed using the control switch.

    B. The SRV will automatically open, but must be reset by the operator before it will close.

    C. The SRV will automatically open and close to relieve excess system pressure.

    D. The SRV must be manually opened but will automatically close to prevent system depressurization.

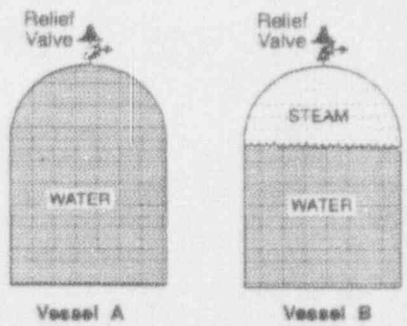
11. Refer to the drawing of two pressure vessels with relief protection (see Figure 1.1-1).

    Vessel A is completely filled with water and vessel B is in a saturated, two-phase condition. Both vessels are currently pressurized to 50 psig and are protected by identical relief valves.

    If both relief valves open simultaneously, the faster pressure reduction will occur in vessel _______ and the faster mass loss will occur in vessel _______.

    A. A; A
    B. A; B
    C. B; A
    D. B; B

FIGURE 1.1-1



Pressure Vessels with Relief Protection

12. If a pressure control valve at the outlet of a heat exchanger is opened, system flow rate will _______ and head loss will _______.

    A. increase / decrease
    B. increase / increase
    C. decrease / decrease
    D. decrease / increase

13. Given a constant speed pump with a fixed recirculation flow, what will be the effect on pump suction flow when the pump discharge valve is opened? Pump suction flow will

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

14. A manual throttle valve in a closed loop system is throttled closed one turn. What is the effect on system total flow?

    A. no change, only pressure is affected

    B. increases due to decreased resistance

    C. decreases due to increased resistance

    D. increases to a value governed by the new system head

15. A discharge valve that discharges directly to atmosphere is opened in a pressurized system. The respective pressures on the upstream and downstream side of the valve will

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

16. If a heat exchanger cooling water outlet valve is partially throttled closed, heat exchanger cooling water pressure will

    A. not be affected, but flow will decrease

    B. increase because of the system change

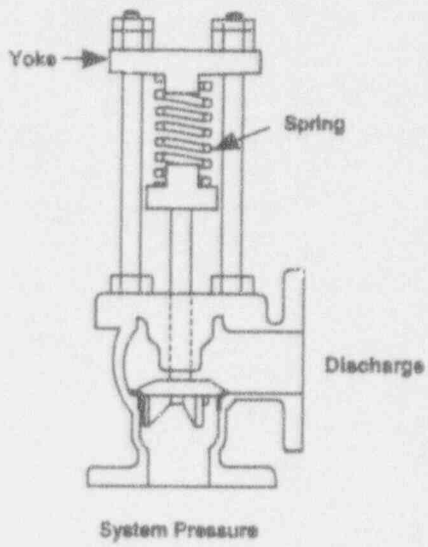
    C. decrease because less heat is being transferred

    D. fluctuate as the cooled substance reaches saturation

17. Using the drawing of a spring-loaded valve (Figure 1.1-2), describe the position of this valve following a loss of system pressure.

    A. closed
    B. open
    C. remains at previous position
    D. mid-position

FIGURE 1.1-2

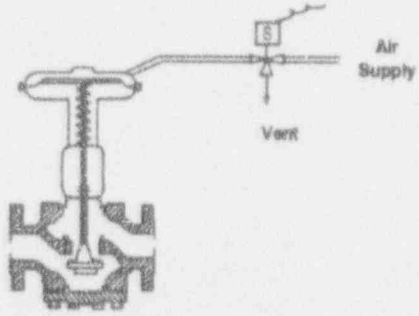


Spring-loaded Valve

18. Using the drawing of an air-operated valve (Figure 1.1-3), describe the valve position following a loss of electrical power.

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

FIGURE 1.1-3



Spring-loaded Air-operated Valve

19. Using the drawing of an air-operated valve (Figure 1.1-3), describe the valve position following a loss of air pressure caused by a leaking diaphragm.

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

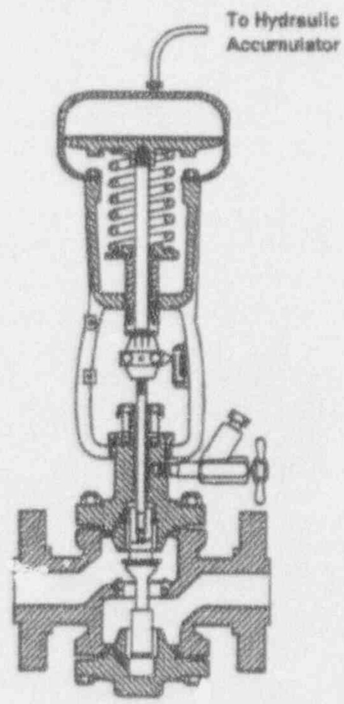
20. How will a typical motor-operated valve respond to a loss of electrical power to the valve actuator?

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

21. Using the drawing of a hydraulically operated valve (Figure 1.1-4), describe the valve position following a loss of hydraulic pressure.

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

FIGURE 1.1-4



Hydraulically-operated Valve

22. Refer to the drawing of a hydraulically-operated valve that is shown in a throttled position (Figure 1.1-4).

    Select the position of this valve following a loss of hydraulic fluid pressure.

    A. closed
    B. open
    C. remains at current position
    D. midposition

23. All of the following are acceptable methods for verifying the position of a shut manual gate valve, <u>except</u>

    A. observing the position of the valve stem using handwheel or position indicators

    B. observing indicators for plant parameters, such as temperature, pressure and level

    C. attempting to turn the handwheel in "open" direction

    D. attempting to turn the handwheel in the "close" direction

24. Which of the following is <u>not</u> a generally accepted method for locally verifying that a valve is open?

    A. Observe local flow rate instrumentation.

    B. Check the local valve position indicator to indicate "open."

    C. Turn the valve operator in the "close" direction and verify that some movement occurs.

    D. Turn the valve operator in the "open" direction and verify that no movement occurs.

25. Which of the following is <u>not</u> a generally accepted method for locally verifying that a valve is fully closed in an operating piping system?

    A. Visually observe the local valve position indicator to indicate "closed."

    B. Visually observe the valve's rising stem threading to be fully exposed.

    C. Check a downstream flow gage to be indicating zero flow.

    D. Listen to the piping downstream of the valve to indicate zero flow noise.

26. To verify the position of a fully open manual valve in an operating system, the operator should operate the valve handwheel

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

    B. to open the valve until it touches the backseat, then close the valve to the desired position.

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

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

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

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

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

    C. Cycle valves during a cooldown.

    D. Use proper closing torque to close manual valves.

28. An adjustment has just been completed on the packing gland of a valve that had a minor packing leak. The operator then attempts to operate the valve but finds that the valve is stuck. Select the most probable cause.

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

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

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

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

29. What precaution is applicable when transferring a controller for a flow control valve from automatic to manual control?

   A. Verify that both the automatic and manual controller outputs are the same prior to transfer.

   B. Verify the controller is balanced by shifting the controller to the balance mode to allow the manual control signal to automatically track the automatic control signal for several seconds.

   C. Verify that the manual controller output is slightly less than the automatic controller to prevent flow overshoot on the transfer.

   D. Verify that the manual controller output is slightly higher than the automatic controller to ensure that no loss of flow occurs on the transfer.

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

   A. Ensure that the proportional band 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 valve is completely closed before transferring from the automatic to the manual mode of control.

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

31. An operator must pay particular attention to auto/manual valve controllers left in the manual mode because

   A. the valve position in manual control is not as stable as in automatic control

   B. the valve position will no longer respond to changes in system parameters

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

   D. the valve can only be operated locally during manual control

32. When shifting from automatic to manual valve control, why should the manual output signal and the auto output signal be matched?

   A. to prevent a sudden valve repositioning upon the transfer

   B. to satisfy the control transfer interlocks

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

   D. to prevent the controller from locking up due to a large deviation

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

   A. Manual valve control is not as stable as automatic valve control.

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

   C. the position of the valve can only be determined locally during manual control.

   D. The valve can only be operated locally during manual valve control.

34. What precaution is applicable, when transferring a controller for a flow control valve from automatic to manual control?

    A. Verify that both the automatic and manual controller outputs are the same prior to transfer.

    B. Verify the controller is balanced by shifting the controller to the balance mode to allow the manual control signal to automatically track the automatic control signal for several seconds.

    C. Verify that the manual controller output is slightly less than the automatic controller's to prevent flow overshoot on the transfer.

    D. Verify that the manual controller output is slightly higher than the automatic controller's to ensure that no loss of flow occurs on the transfer.

35. When the manual declutch lever of a motor-operated valve is moved out of the normal position it ________ the motor and ________ the handwheel.

    A. disengages; engag
    B. engages; engages
    C. disengages; disengages
    D. engages; disengages

36. Complete the following statement concerning preparing for manual operation of a motor-operated valve: The manual declutch lever

    A. disengages the motor and engages the handwheel

    B. deenergizes the motor and engages the handwheel

    C. disengages the handwheel and engages the motor

    D. disengages the handwheel and energizes the motor

37. What could be damaged if an operator attempts to manually disengage the motor on a motor-operated valve while the motor is operating?

    A. limit switches
    B. valve seat
    C. torque switches
    D. clutch

38. When manually positioning a motor-operated valve, care must be taken to avoid using excessive valve seating/backseating force. Why?

    A. Limit switch settings might change.
    B. Torque switch settings might change.
    C. The motor might not re-engage.
    D. The valve might not operate on demand.

39. Check valves are used to

    A. relieve system overpressure, thereby ensuring system integrity

    B. prevent backflow through non-operating components or flow paths

    C. maintain a constant back pressure to control flow rate

    D. prevent pump cavitation by keeping systems full of liquid

40. Which of the following is <u>not</u> a type of check valve?

    A. vertical lift
    B. horizontal lift
    C. gate
    D. swing

41. What type of valve is used to control the direction of fluid flow through a system and prevent backflow?

    A. safety valve
    B. gate valve
    C. globe valve
    D. check valve

42. Emergency core cooling systems (ECCS) typically have testable check valves in the discharge lines from the pump to the vessel. How does the testable check valve operate?

    A. The valve is opened by flow and pressure from the discharge of the ECCS pump.

    B. Instrument air is applied to the valve operator when the ECCS system is shut down to close the valve and ensure no leak across the seat.

    C. The check valve cannot be opened unless the associated ECCS pump is running.

    D. An air solenoid admits air to the valve on system initiation to ensure that the valve opens.

43. 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

44. Operators should use both hands on valve handwheels when positioning manual valves to

    A. overcome the resistance of installed locking devices

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

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

    D. control lateral force to prevent bending the valve stem

45. Which statement best describes the function and use of valve backseats?

    A. Valve backseats are provided to remove pressure from the packing and stuffing box and are the normal method used to isolate the stuffing box for valve repacking.

    B. Valve backseats are provided to remove pressure from the packing and stuffing box and are only used when needed to prevent packing leakage.

    C. Valve backseats are provided as a back-up in case the primary seat leaks and are normally used during plant operations.

    D. Valve backseats are provided as a back-up in case the primary seat leaks and are only used when needed to prevent valves from leaking excessively.

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

    A. isolate system pressure from the stem packing to minimize leakage past the valve stem.

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

    C. ensure the valve is fully open by verifying that the valve disk is attached to the valve stem.

    D. reduce valve disk wear by completely removing it from the flow stream.

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

    A. in the open direction until the valve stem moves in the open direction, then reclose the valve using normal force

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

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

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

48. An operator attempts to close a manual gate valve to isolate a pump in a shutdown system. However, the operator is unable to manually rotate the handwheel.

    Which one of the following could not cause this condition?

    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.

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

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

    B. loosen the valve bonnet slightly to free the valve

    C. use a valve wrench to free the valve

    D. loosen the packing gland to force the valve

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

    A. operate the valve in the closed direction using normal force

    B. open the valve, listen for flow, then close the valve using normal force

    C. open the valve fully, then reclose it using normal force

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

51. To verify the position of an open manual valve, the operator should

    A. operate the valve in the open direction until the valve is back seated one-half turn

    B. operate the valve in the closed direction until there is stem movement, then re-open the valve

    C. fully close the valve, then reopen the valve

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

52. Gate valves are most often used

    A. to protect systems by relieving excess pressure

    B. to limit flow in a piping system to one direction

    C. as isolation valves

    D. for throttling fluid flow

53. Globe valves are used

    A. only in low pressure applications

    B. to limit flow in a piping system to one direction

    C. primarily to minimize turbulence

    D. for throttling fluid flow

54. Which of the following valves is <u>least</u> suited for throttling flow?

    A. needle
    B. ball
    C. gate
    D. globe

55. Which of the following valves is most appropriately used in throttling applications where operation is frequent?

    A. check
    B. stop-check
    C. gate
    D. globe

56. Some valve positioning (drive) devices are capable of stopping the valve between a fully open and a fully closed (throttled) position. Which of the following valves is best used for throttling?

    A. stop valve
    B. globe valve
    C. gate valve
    D. butterfly valve

57. Which of the following valves is most likely to be used with a throttling positioner?

    A. stop valve
    B. globe valve
    C. gate valve
    D. butterfly valve

58. Which of the following statements best applies to a gate valve?

    A. They are used for making relatively fine adjustments in the amount of fluids allowed to pass.

    B. They are not suited for throttling, as fluid flow through a partially closed valve may cause damage to seating surfaces.

    C. They allow no fluid in the process stream to come into contact with the valve stem or valve bonnet.

    D. They can be used to allow flow only in one direction or used as a stop valve.

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

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

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

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

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

60. 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 large pressure drop when fully open.

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

61. Globe valves are preferred over gate valves for throttling because

    A. flow control is more linear for globe valves than for gate valves.

    B. head loss from a fully open globe valve is smaller than the head loss from a fully open gate valve.

    C. valve position indication for a midpositioned valve is more reliable for globe valves than for gate valves.

    D. valve motor operators are more adaptable to glove valves than to gate valves.

62. For throttling, globe valves are preferred over gate valves because

    A. the loss coefficient is generally more linear for globe valves than for gate valves.

    B. the loss coefficient for a full open globe valve is smaller than the loss coefficient for a full open gate valve.

    C. valve position indication for a midpositioned valve is more reliable for globe valves than for gate valves.

    D. valve motor operators are more adaptable to globe valves than to gate valves.

63. Which valve type should not be used to throttle flow?

    A. gate valves
    B. ball valves
    C. needle valves
    D. globe valves

64. Gate valves are designed to

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

65. Gate valves should not be used to throttle fluid flow. Why?

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

    B. The tortuous path through a gate valve body makes flow control difficult.

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

    D. The turbulent flow created by a partially opened gate valve can cause flow restriction downstream of the valve.

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

    A. the tortuous flow path through a gate valve body makes flow control difficult.

    B. gate valves must be fully opened and backseated to prevent stem leakage.

    C. the turbulent flow created by a partially opened gate valve will cause erosion damage to the valve seat.

    D. the large size of the gate valve disk requires an oversized actuator to accurately position the disk.

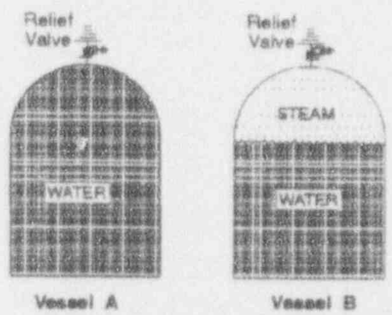
67. Refer to the drawing of two pressure vessels with relief protection (see figure 1.1-5)

    Vessel A is completely filled with water and vessel B is in a saturated, two-phase condition. Both vessels are currently pressurized to 50 psig and are protected by identical relief valves.

    If both relief valves open simultaneously, the faster pressure reduction will occur in vessel ____________ and the faster mass loss will occur in vessel______________.

    A. A; A
    B. A; B
    C. B; A
    D. B; B

FIGURE 1.1-5



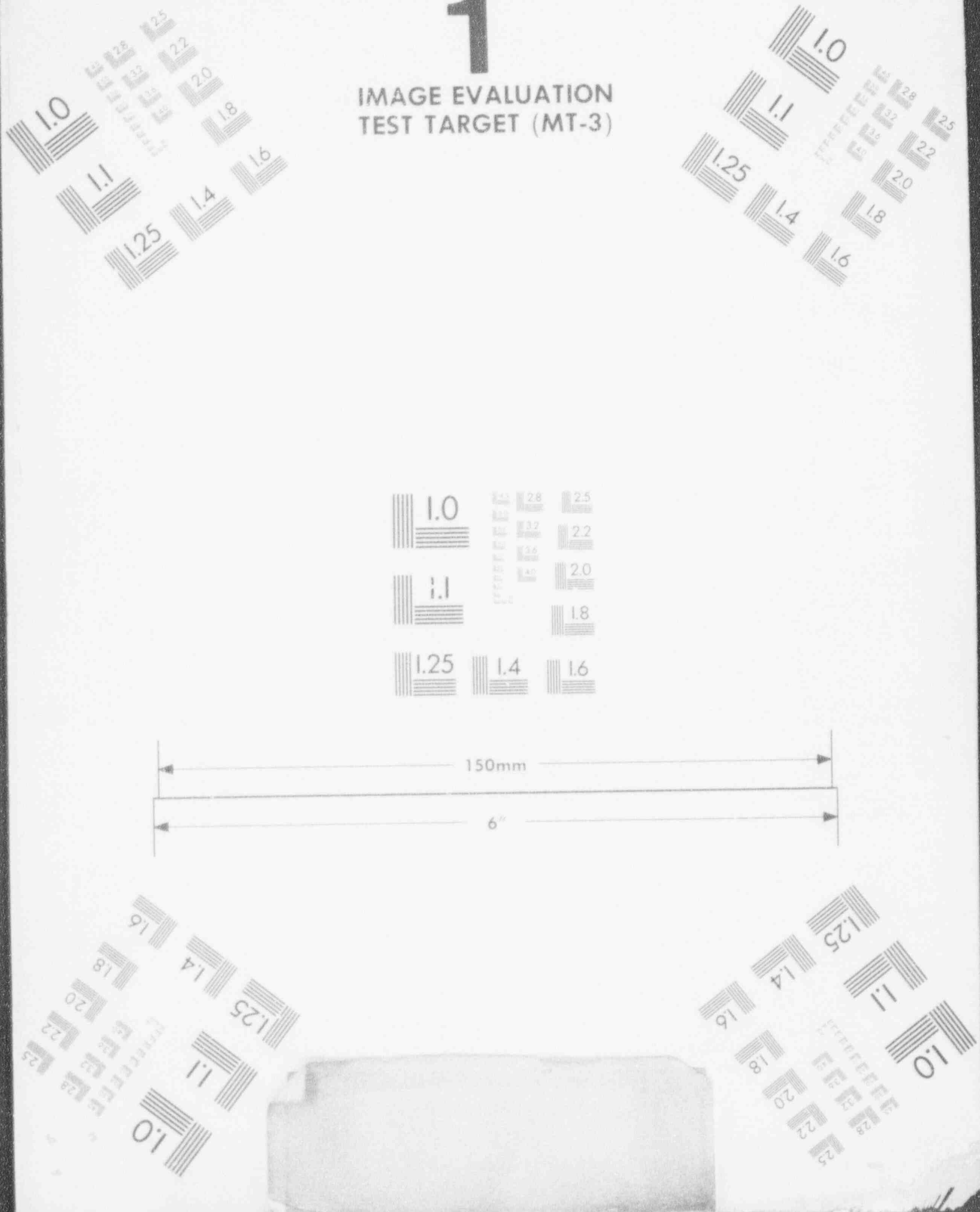
Pressure Vessels with Relief Protection

68. Which one of the following valves provides overpressure protection to limit the internal pressure in vessels and thus protect personnel and equipment?

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

1

IMAGE EVALUATION TEST TARGET (MT-3)



1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

1

IMAGE EVALUATION TEST TARGET (MT-3)

150mm

6"

69. Which one of the following statements describes the operation of reactor pressure vessel safety valves?

   A. An open safety valve will close when reactor pressure decreases enough for gravity and spring tension to overcome the effect of reactor pressure on the main valve disk.

   B. An open safety valve will close when the pilot valve senses a reduced reactor pressure and isolate reactor pressure to the main valve disk.

   C. When reactor pressure reaches the lift setpoint, the safety valve begins to open and will modulate to a position that is directly proportional to reactor pressure.

   D. When reactor pressure reaches the lift setpoint, a pilot valve closes to create a ΔP across the main valve disk which overcomes gravity and spring tension to open the valve.

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. A

Reference 14, page 7-63

2. B

Reference 14, page 7-63.

3. B

Reference 14, page 7-63

4. B

Reference 65, chapter 7, pages 125 through 132.

5. B

Reference 14, page 7-63.

6. A

Reference 14, page 7-94.

7. B

Reference 14, page 7-94.

8. C

Reference 38, appendix A, pages 18 and 22.

9. D

Reference 38, appendix A, page 18.

10. C.

Reference 38, Appendix A, page 22.

11. A

12. A

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

13. A

Reference 38, appendix A.

14. C

Reference 38, appendix A.

15. D

Reference 38, appendix A.

16. B

Reference 14, pages 7-61 through 7-90.

17. A

18. B

Reference 65, chapter 7, pages 130 through 132.

19. B

Reference 65, chapter 7, pages 130 through 132.

20. C

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

Reference 38, page 27.

21. D

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

Reference 65, chapter 7, pages 130 through 132.

22. B

Reference 65, chapter 7, page 130 through 132.

23. C

Reference 38, pages 3, 6, and 7.

24. D

To verify that a valve is open, the valve operator is to be moved a small amount in the "closed" direction until movement is detected, and then the valve operator is to be returned to the "open" position. At no time is a valve operator to be operated in the "open" position to ascertain valve position, until it has first been rotated in the "closed" direction and movement has been detected.

Reference 38, pages 7 and 8.

25. B

Reference 38, page 7.

26. D

Reference 38, page 7.

27. A

Leaving a 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 38, appendix A, page 35.

28. 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 38, appendix A, page 35.

29. A

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 55.1, chapter 5, page A-3.

30. B

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 55.1, chapter 5, page A-3.

31. 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 03, chapter 9, page 247.

32. A

Reference 72, page 16, chapter 20.

33. B

Reference 03, chapter 9, page 247.

34. A

Reference 72, page 16, chapter 20.

35. A

Reference 38, appendix A, page 30.

36. A

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

Reference 38, appendix A, page 30.

37. D

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

Reference 38, page 4; and appendix A, page 30.

38. D

The force required to unseat the valve may exceed torque switch settings, causing the valve to fail to stroke on demand.

Reference 38, page 4.

39. B

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

Reference 65, chapter 6, page 134.

40. C

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

vertical and 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 38, appendix A, page 13.

41. D

A check valve is used to control the direction of flow through a system by preventing backflow through system components.

Reference 65, chapter 6, page 134.

42. A

43. B

Reference 65, chapter 6, page 134.

44. D

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

Reference 56, page 1.4-2; and Reference 65.

45. B

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, but to ensure proper operation in the event of packing failure.

Reference 38, appendix A, page 35.

46. A

Reference 38, appendix A, page 35.

47. B

48. C

49. C

Operators should only use approved valve wrenches to free a stuck valve. Leverage devices such as cheater bars, or using multiple operators, can cause excessive lateral forces on the valve and could damage the valve or valve stem.

50. A

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 38, page 3.

51. B

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. If the valve does not move, it is probably closed and can then be opened.

Reference 38, page 3.

52. C

Reference 51, page 444.

53. D

Reference 51, page 444.

54. C

Reference 38, chapter 6, page 131.

55. D

Reference 61, chapter 4, page 6.

56. B

Reference 61, chapter 4, page 6.

57. B

Reference 61, chapter 4, page 6.

58. B

Reference 38, chapter 6, page 131.

59. B

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.

A globe valve has a relatively high pressure drop when fully open. A globe valve is designed for use in throttling applications.

Reference 65, chapter 6.

60. C

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

Reference 65, chapter 6.

61. A

Reference 65, chapter 6.

62. A

Reference 65, chapter 6.

63. A

Gate valves are designed for systems where straight-line flow and minimum flow restriction 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 65, chapter 6.

64. D

Gate valves are designed to start and stop flow.

Reference 65, chapter 6.

65. A

Gate valves are designed for systems where straight-line flow and minimum flow restriction 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 65, chapter 6.

66. C

Reference 65, chapter 6.

67. A

68. A

69. 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, 1.02 Question 1

State the purpose of an overpressure protection valve.

K1.01 Questions 2, 3, 69

Describe the operation of a safety valve.

K1.01, 1.02 Questions 4, 8,9, 68

Identify the purpose of an overpressure protection valve.

K1.01 Question 5, 6, 7

Describe the function of a relief valve.

K1.02 Questions 10, 11, 67

Describe the operation of a relief valve.

K1.03 Questions 12-16

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

K1.04 Question 17

Given a drawing, describe the fail position of a spring-loaded valve.

K1.04 Question 18

Given a drawing, describe how an air-operated valve would react to a loss of electrical power.

K1.04 Question 19

Given a drawing, describe how an air-operated valve would react to a loss of air pressure.

K1.04 Question 20

Describe how a motor-operated valve would react to a loss of electrical power.

K1.04 Question 21, 22

Given a drawing, describe how a hydraulically operated valve would react to a loss of hydraulic power.

K1.05 Question 23

Explain the significance of stem position (valve status) for gate valves.

K1.05 Questions 24, 25, 26

State the methods that can be used to determine/verify valve position locally.

K1.06 Question 27

List three methods to prevent thermal binding and/or pressure locking of valves.

K1.06 Question 28

Given a common problem encountered during valve operations or operator-performed minor maintenance and a list of potential problem causes, select the cause that best fits the problem described.

K1.07 Questions 29-34

Describe the precautions associated with transferring a valve controller between manual and automatic modes.

VALVES
Learning Objectives

K1.08 Question 35, 36

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

K1.08, 1.07 Questions 37, 38

From a list of statements, select the statement that best describes a precaution(s) to be observed while manually operating a motor operated valve (MOV).

K1.09 No questions

Valve stroke testing is guided by specific plant procedures and was determined to be not generic.

K1.10 Question 39, 43

From a list of purpose statements, select the one that best describes the purpose of a check valve.

K1.10 Question 40

Given a list of valve types, identify the common types of check valves used in power plants.

K1.10 Question 41

State the purpose or function of a check valve.

K1.10 Question 42

Describe the operation of a testable check valve

K1.11 Questions 44, 48, 49

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

K1.11 Question 45, 46

State the function and use of valve backseats.

K1.11 Questions 47, 50, 51

Describe the proper method/technique for verifying the position of manual valves.

K1.12 Questions 52, 54

Identify the function of a gate valve.

K1.12 Question 53, 55, 56, 57

Identify the function of a globe valve. Identify the characteristics of globe valve design.

K1.12 Question 58

Identify the function of a gate valve. Identify the advantages or disadvantages for the use of gate valves.

K1.12 Questions 59, 60, 61, 62, 64

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

K1.12 Question 63

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

K1.12 Question 65, 66

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

1. What happens to a fluid as it passes through a venturi?

   A. Pressure remains constant, but the velocity increases as the diameter of the venturi decreases.

   B. Pressure increases, but the velocity decreases as the diameter of the venturi decreases.

   C. Pressure decreases, but the velocity remains constant as the diameter of the venturi increases.

   D. Pressure increases, but the velocity decreases as the diameter of the venturi increases.

2. A correct statement concerning a Venturi flow device is that it

   A. develops an output signal by measuring the differential pressure of the fluid as it passes through the device

   B. can measure the rate of flow of incompressible fluids, but not of compressible fluids

   C. develops an output signal by measuring the velocity of the fluid as it passes through the device

   D. has head loss greater than the head losses produced by an orifice

3. 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, differential pressure (D/P) across the flow transmitter venturi will be approximately

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

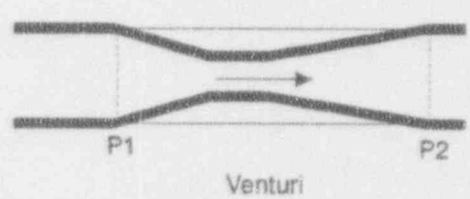
4. A cooling water system is operating at a steady-state flow rate of 700 gpm with 60 psid across the flow transmitter venturi. If cooling water flow rate is increased to 1000 gpm, differential pressure across the flow transmitter venturi will be

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

5. As a fluid flows through a venturi flow element, the __________ pressure and the __________ velocity of the fluid occurs at the throat of the venturi.

   A. highest; highest
   B. lowest; lowest
   C. lowest; highest
   D. highest; lowest

FIGURE 1.2-1



6. Refer to the drawing of a venturi (see Figure 1.2-1). A subsooled fluid is flowing through a convergent-divergent venturi. Compared to conditions at the inlet of the venturi (P1), pressure at the outlet of the venturi (P2) has __________ and system mass flow rate has __________. (Assume "real" conditions.)

   A. decreased slightly; remained the same
   B. decreased slightly; decreased slightly
   C. remained the same; decreased slightly
   D. remained the same; remained the same

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

   A. differential pressure of the fluid as it passes through the venturi

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

   C. change in the velocity of the fluid as it passes through the venturi

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

8. 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

9. A correct statement regarding the use of an orifice to measure the volume flow rate of water in a pipe is that

   A. the measured flow rate will be higher than the actual flow rate if the water temperature is lower than the calibrated temperature

   B. temperature compensation is not required to obtain accurate flow rates because water is an incompressible fluid

   C. the measured flow rate will be lower than the actual flow rate if the water temperature is lower than the calibrated temperature

   D. temperature compensation is not required because the pressure drop across the orifice is a viscous effect and is not temperature-dependent.

10. The main steam line flow indication is density-compensated to ensure that the measured change in the pressure across the flow element determines the

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

11. 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

12. Density compensation is used in flow instruments to change ______ to ______.

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

13. If the actual 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

14. 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 actual

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

15. It is necessary to density-compensate the main steam line flow indication because the measured change in pressure across the flow elements is

    A. directly proportional to the volumetric flow rate

    B. inversely proportional to the volumetric flow rate

    C. directly proportional to the mass flow rate

    D. inversely proportional to the mass flow rate

16. Given the equation for mass flow rate
    $\dot{m} = \rho \times A \times v$

    where $\dot{m}$ = mass flow rate (lb/sec)
    ρ = density of flowing fluid (lb/ft3)
    A = cross section of channel of fluid (ft2)
    v = average velocity of flowing fluid (ft/sec)

    What is the effect on mass flow rate if the liquid has air in solution? (Assume velocity of fluid is constant.)

    A. Mass flow rate would increase.

    B. Mass flow rate would decrease.

    C. Mass flow rate is not affected by air in solution.

    D. The effect on mass flow is unpredictable.

17. Given the equation for mass flow rate:

    $\dot{m} = \rho \times A \times v$

    where $\dot{m}$ = mass flow rate (lbm/sec)
    ρ = density of flowing fluid (lbm/ft3)
    A = cross section of channel of fluid (ft2)
    v = average velocity of flowing fluid (ft/sec)

    If air is introduced (dissolved) into a flowing liquid, then the mass flow rate of the liquid will __________ due to the change in the __________ of the liquid.

    A. increase; density
    B. decrease; density
    C. increase; velocity
    D. decreae; velocity

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

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

19. A fluctuating indication is observed on a liquid flow rate meter whose detector uses a differential pressure cell. The most likely cause for the fluctuation is

    A. gas or steam in the liquid flowing through the sensor

    B. a valve being closed on the high pressure tap of the detector

    C. a valve being closed on the low pressure tap of the detector

    D. failure of the diaphragm in the differential pressure cell

20. Why would gas or steam bubbles in a differential pressure (D/P) cell liquid flow detector cause flow indication fluctuations?

    A. changes in temperature
    B. changes in volume flow rate
    C. plugging D/P taps
    D. changes in pressure

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

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

22. 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

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

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

24. If the equalizing valve on a differential pressure (D/P) flow detector is opened, what will be the indications to the operator?

    A. Flow indication will increase slightly.
    B. Flow indication will decrease slightly.
    C. Flow indication will be zero.
    D. There will be no change.

25. If the orifice in a differential pressure (D/P) cell flow sensor should wear, causing the orifice to become larger, indicated flow would

    A. be higher than actual
    B. be lower than actual
    C. not change
    D. oscillate

26. A differential pressure (D/P) cell is being used to measure flow rate in a cooling water system. Flow rate is indicating 75 percent of scale. If the D/P cell diaphragm ruptures, <u>indicated</u> flow rate will

    A. go to 0 percent
    B. go to 100 percent (full-scale)
    C. remain the same
    D. move slowly to 50 percent (mid-scale)

27. A leak develops in the high-pressure side of a flow detector. As a result, the measured D/P will ______, causing indicated flow to ______.

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

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

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

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

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

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

29. 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.

30. 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.

31. Refer to the drawing of a bellows-type differential pressure detector (see Figure 1.2-2).

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

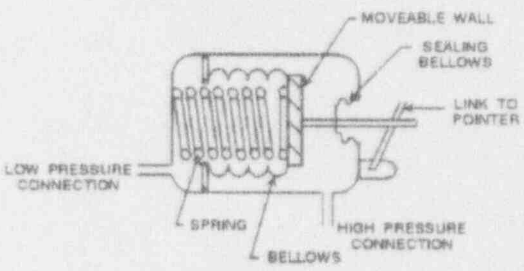
    A. Decrease, because the high pressure will compress the spring more.

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

    C. Decrease, because the spring will expand more.

    D. Increase, because the spring will expand more.

FIGURE 1.2-2

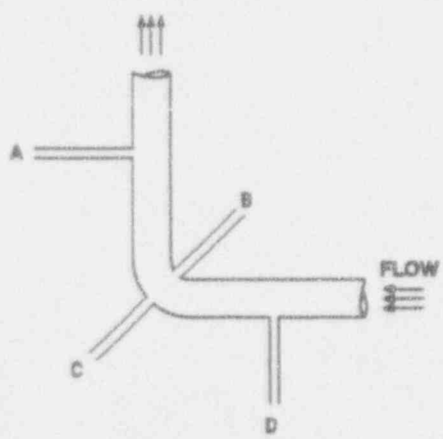


Bellows - Type Differential Pressure Detector

32. On the drawing of an elbow flow meter (Figure 1.2-3), identify the high pressure tap.

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

FIGURE 1.2-3



Pipe Elbow

33. On the drawing of an elbow flow meter (Figure 1.2-3), identify the low pressure tap.

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

34. What flow rate principle explains how an orifice, flow nozzle, and venturi tube detect fluid flow?

    A. The flow rate is <u>directly</u> proportional to the differential pressure (D/P).

    B. The flow rate is <u>inversely</u> proportional to the D/P.

    C. The flow rate is <u>directly</u> proportional to the square root of the D/P.

    D. The flow rate is <u>inversely</u> proportional to the square root of the D/P.

35. Differential pressure (D/P) across a D/P cell flow measuring device doubles. By what factor has flow increased?

    A. $\sqrt{0.5}$
    B. $\sqrt{2}$
    C. 2
    D. 4

36. If the flow rate across a differential pressure flow sensor doubles, by about what factor would the D/P increase?

    A. $\sqrt{0.5}$
    B. $\sqrt{2}$
    C. 2
    D. 4

37. How will flow rate indication be affected if the equalizing valve for the associated differential pressure detector is fully opened?

    A. increase temporarily, then return to initial value

    B. decrease temporarily, then return to initial value

    C. increase to the maximum value

    D. decrease to the minimum value

38. 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

39. A differential pressure level transmitter was calibrated for use on a tank at 100°F. If mass in the tank remains the same and the temperature is raised to 200°F, the indicated level will

    A. remain the same, but actual level would increase

    B. increase due to the expansion of the water

    C. decrease due to the decrease in density

    D. increase in direct proportion to the temperature rise

40. A differential pressure level transmitter was calibrated for use on a tank at 250°F. If the mass in the tank remained the same and the temperature were raised to 350°F, the indicated level would

    A. decrease due to the decrease in density

    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

41. A differential pressure level transmitter with its reference leg vented to atmosphere is being used in a control loop to maintain liquid level in a vented tank at 50 percent. The transmitter was calibrated at a tank temperature of 200°F. If the tank temperature gradually falls to 100°F, the control loop will cause actual level to

    A. be maintained at 50 percent

    B. increase and remain above 50 percent

    C. first increase, then decrease to 50 percent

    D. decrease and remain below 50 percent

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

    A. transmitter I

    B. transmitter II

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

    D. unable to determine, temperature must be known

43. 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 determine accurately

    D. neither, they will read the same

44. Refer to the drawing of a water storage tank with two differential pressure level indicators (see Figure 1.2-4).

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

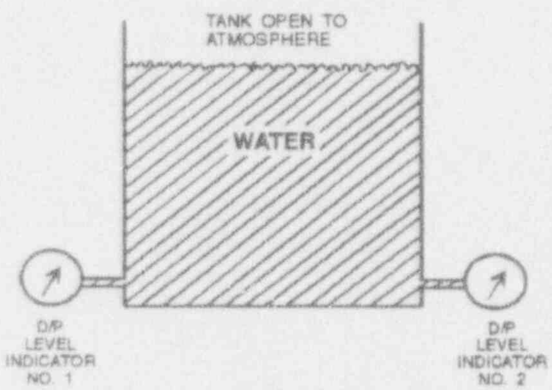
    A. indicator 1 will read greater than indicator 2

    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 1.2-4



Water Storage Tank with Two Differential Pressure Level Indicators

45. Refer to the drawing of a water storage tank with two differential pressure level indicators (see Figure 1.2-4)

    Indicator 1 was calibrated at 120°F and indicator 2 was calibrated at 180°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 readings will increase by the same amount

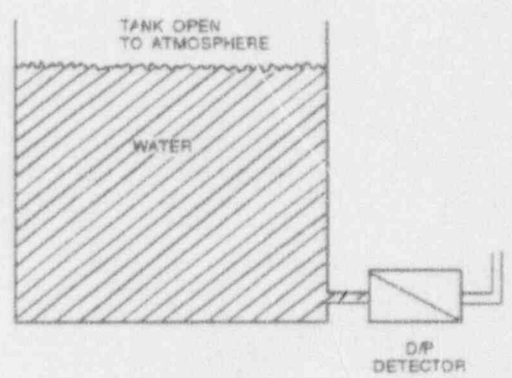
    D. indicator 1 and 2 readings will decrease

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

    The level detector is being used in a level control system that is calibrated to maintain tank level at 80 percent at the current tank temperature of 100°F. If tank temperature gradually decreases and stabilizes at 70°F, the level control system will cause actual tank level to

    A. remain at 80 percent
    B. increase and stabilize above 80 percent
    C. oscillate around 80 percent
    D. decrease and stabilize below 80 percent

FIGURE 1.2-5



Tank Differential Pressure Level Detector

47. Refer to the drawing of a tank differential pressure level detector (Figure 1.2-5).

    Tank water level indication will be lower 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

48. The theory of operation of a differential pressure level detector using a wet Reference leg may be described by the following statement: 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

49. Many reactor water-level instruments are designed with a condensing chamber in the reference leg. The purpose of the condensing chamber is to

    A. keep the reference leg filled by condensing steam

    B. provide pressure compensation for the reactor pressure exerted on the variable leg

    C. prevent reference leg flashing during a rapid depressurization of the reactor vessel

    D. alleviate the need for density compensation by keeping the reference leg temperature close to the temperature of the variable leg

50. Which of the following parameters determines the maximum level that can be indicated by a reactor water-level instrument?

    A. The elevation of the differential pressure cell in relation to the auxiliary condensing chamber.

    B. The elevation of the reference leg condensing chamber.

    C. The level at which the reference leg penetrates the reactor vessel.

    D. The level at which the variable leg penetrates the reactor vessel.

51. What is the reason for the reference leg being connected to the reactor pressure vessel (RPV) instead of being filled by a water source independent of the RPV?

    A. To provide a vent path for the prevention of a reference leg rupture during a rapid RPV depressurization.

    B. To remove the need for density compensation by keeping the reference leg at the same temperature as the variable leg.

    C. To make the indicated level proportional to the square root of the differential pressure between the reference and variable legs for all reactor pressures.

    D. To provide compensation for the RPV pressure exerted on the variable leg.

52. A differential pressure level transmitter has been calibrated for a specific gravity of one. However, the tank liquid specific gravity is less than one. The indicated tank level will be

    A. more than actual level
    B. less than actual level
    C. the same as actual level
    D. indicating less than one

53. A differential pressure cell 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 worth of
    B. a differential worth of
    C. directly proportional to
    D. inversely proportional to

54. A differential pressure cell level detector senses the differential pressure between a ________ height of liquid and the pressure at the bottom of a tank.

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

55. A differential pressure cell 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

56. If the Reference leg on a level instrument reached saturation conditions and began to boil away, indicated level would

    A. be higher than actual
    B. be lower than actual
    C. increase then decrease
    D. not be affected

57. A differential pressure cell with a wet reference leg maintained by a condensing pot is used to measure level in a closed tank. An increase in ambient pressure with no appreciable change in temperature will cause the differential pressure cell level indicator reading to

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

58. A differential pressure cell with a wet reference leg maintained by a condensing pot is used to measure level in a closed tank. A vacuum in the building that contains the tank and its level instrumentation will cause the indicated level to

    A. indicate greater than actual level
    B. indicate less than actual level
    C. indicate the actual level
    D. fluctuate continuously

59. If the variable leg temperature of a differential pressure level cell is higher than the calibration conditions, how will the indicated level respond? Assume reference leg is at calibration temperature.

    A. Indicated level will be higher than actual level.

    B. Indicated level will equal actual level if the reference leg temperature is at the calibration conditions.

    C. Indicated level will equal actual level if the reference leg temperature is the same temperature as the variable leg.

    D. Indicated level will be lower than actual level.

60. During emergency depressurization of the reactor vessel, wide-range water level indication may be inaccurate

    A. due to variable leg flashing

    B. unless the drywell is at calibration conditions

    C. if there is not jet pump flow

    D. due to reference leg flashing

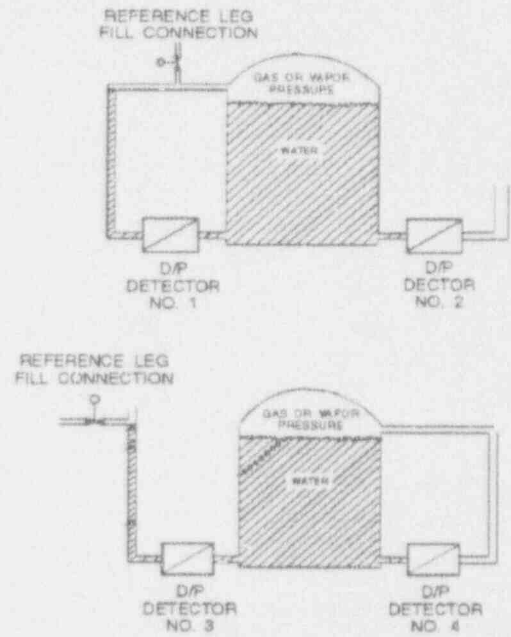
61. Refer to the drawing of four differential pressure level detectors (see Figure 1.2-6).

    The tanks are identical and are being maintained at 17 psia and 70 percent water level (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

62. 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 pressurized to 20 psig. The detectors were all calibrated at the current tank temperature and 70°F ambient temperature. Which detectors will provide the most inaccurate level indication following an increase in tank ambient temperature from 70°F to 100°F? (Assume tank temperature does not change.)

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

63. What is the effect on level indication of a high ambient temperature at the Reference leg of a level detector's differential pressure cell? (Assume a negligible change in actual variable level and Reference leg level.)

   A. Actual level is higher than indicated level.

   B. Actual level is lower than indicated level.

   C. Actual level is same as indicated level.

   D. Indicated level slowly decreases to zero.

64. An ambient temperature <u>lower</u> than calibration conditions for a Reference leg might cause the differential pressure cell level indicator reading to

   A. be greater than actual level
   B. be less than actual level
   C. remain at a constant level
   D. fluctuate at a higher level

65. An ambient temperature <u>greater</u> than calibrated conditions for a Reference leg on a differential pressure cell level indicator might cause the instrument to indicate

   A. greater than actual level
   B. less than actual level
   C. no change from actual level
   D. in a fluctuating manner

66. A differential pressure cell level instrument has failed, indicating a low-level condition. The failure could be caused by a

   A. break on the Reference leg

   B. rupture of the diaphragm in the differential pressure cell

   C. Reference leg flashing to steam

   D. break on the variable leg

67. A break in the Reference leg of a differential pressure cell level instrument will cause the <u>indicated</u> level to

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

68. A break in the variable leg of a level detector using a differential pressure cell will cause the <u>indicated</u> level to

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

69. A rupture of the diaphragm in a level detector's differential pressure cell will cause the <u>indicated</u> level to

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

70. If the liquid in the Reference leg of a level detector's differential pressure cell boils away, the <u>indicated</u> level will

   A. be greater than actual level
   B. be less than actual level
   C. remain accurate
   D. fail as is

71. Which of the following failures could cause a differential pressure (D/P) cell level instrument to indicate lower than actual level?

   A. differential pressure cell diaphragm rupture

   B. Reference leg rupture

   C. variable leg rupture

   D. equalizing valve seat leakage

72. Flow and level detectors use differential pressure (D/P) cells to measure flow and level. When a flow instrument D/P cell diaphragm fails, the flow indication is 0. When a wet reference leg level instrument D/P cell fails, the level indication

A. will go to 0
B. will indicate 100% (full range)
C. remains the same
D. will move slowly to 50% (midrange)

73. A reactor water-level instrument uses a reference leg with a condensing chamber. Which of the following events will result in an upscale indication?

A. The reactor pressure increases rapidly.

B. The variable leg breaks and completely drains.

C. The reference leg flashes to steam.

D. The temperature of the reference leg decreases significantly.

74. Reactor feedwater flow and vessel level detectors use differential pressure (D/P) cells to measure flow and level. If a level D/P cell diaphragm fails, the level indication

A. will go to 0
B. will slowly move to 50% (midrange)
C. will indicate 100% (full range)
D. remains the same

75. What will the indication be when a level D/P cell fails (D/P = 0)?

A. 0% of full range
B. 50% of full range
C. 75% of full range
D. 100% of full range

76. Which one of the following failures of a wet reference leg differential pressure (D/P) level transmitter will cause its level indicator to indicate the lowest level?

A. The D/P cell diaphragm ruptures.
B. The reference leg ruptures.
C. The variable leg ruptures.
D. The equalizing line ruptures.

77. The bourdon tube works on the principle that when the pressure in the line decreases

A. the tube tends to straighten out

B. the free end tends to move away from the center

C. spring action of the metal tube tends to coil the tube

D. the tube expands to its original shape

78. In a bourdon tube pressure detector, pressure is measured using the change in the

A. location of the tip of the tube
B. length of the tube
C. cross-sectional area of the tube
D. volume of the tube

79. 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

80. In a diaphragm-type pressure detector, pressure is measured using diaphragm deflection due to

    A. unequal temperature across the diaphragm

    B. process pressure overcoming spring pressure

    C. temperature expansion overcoming spring pressure

    D. fluid rising in a column that does not overflow

81. A system has a simple bellows pressure detector with its low pressure side vented to containment atmosphere. If a main steam line break raises containment pressure by 40 psig, the associated pressure indication (disregarding any temperature effect on the bellows) will

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

82. 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 psig, the system pressure indication (disregarding any temperature effect on the detector) will:

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

83. A bellows-type pressure transmitter located in a building displays a downward shift in its associated system pressure indication. This downward shift could be caused by either the building's pressure ____________ or the system's pressure ___________.

    A. decreasing; decreasing
    B. decreasing; increasing
    C. increasing; increasing
    D. increasing; decreasing

84. A bourdon tube pressure detector located in a building and vented to the building's atmosphere reads 100 psig. An ambient temperature increase of 100°F will cause a _________ change in indicated pressure, and an ambient pressure increase of 40 psig will cause a __________ change in indicated pressure.

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

85. To measure level accurately, the variable leg pressure of a differential pressure (D/P) cell should

    A. be equal to the Reference leg pressure

    B. be greater than the Reference leg pressure

    C. be less than the Reference leg pressure

    D. not have any relationship to the Reference leg pressure

86. Which of the following parameters is not measured by differential pressure (D/P) cells?

    A. level
    B. temperature
    C. pressure
    D. flow

87. Which one of the following parameters requires square root compensation when measured by differential pressure (D/P) detectors?

    A. reactor vessel level
    B. condenser vacuum
    C. reactor vessel pressure
    D. recirculation pump flow rate

88. What change in level indication will be seen if the associated D/P cell's equalizing valve is opened?

    A. increase temporarily, then return to initial value

    B. increase to the maximum value

    C. decrease temporarily, then return to initial value

    D. decrease to the minimum value

89. Which of the following statements is a correct description of the response of a differential pressure detector/indicator when the high pressure input changes and the low pressure input remains constant? As the high side pressure input

    A. decreases, indicated differential pressure increases

    B. decreases, indicated differential pressure decreases

    C. increases, indicated differential pressure decreases and can become negative

    D. increases, indicated differential pressure decreases to a minimum of zero

90. Which of the following statements is a correct description of the response of a differential pressure detector/indicator when the low pressure input changes and the high pressure input remains constant? As the low pressure input

    A. decreases, indicated differential pressure decreases and could become negative

    B. changes, indicated differential pressure remains constant because the high pressure input is constant

    C. increases, indicated differential pressure increases

    D. increases, indicated differential pressure decreases and could become negative

91. Which of the following statements is a correct description of the response of a differential pressure detector/indicator when the high or low pressure input changes?

    A. As the high pressure input increases with the low pressure input remaining constant, indicated differential pressure decreases.

    B. As the high pressure input decreases with the low pressure input remaining constant, indicated differential pressure increases.

    C. As the low pressure input increases with the high pressure input remaining constant, indicated differential pressure decreases.

    D. As the low pressure input increases with the high pressure input remaining constant, indicated differential pressure increases.

92. A differential pressure indicator is used to monitor condenser pressure, with atmospheric pressure as the high pressure input, and condenser pressure as the low pressure input. Which of the following statements is correct as to indicated pressure? The indicated pressure would

   A. decrease as condenser vacuum decreases

   B. decrease as condenser vacuum increases

   C. increase as condenser absolute pressure increases

   D. decrease as condenser absolute pressure decreases

93. Refer to the drawing of a bellows-type differential pressure cell (Figure 1.2-7): The spring in this D/P cell weakens after repeated long-term use. If the actual differential (high to low) pressure was constant, how would indicated differential pressure respond as the spring weakens? Indicated D/P

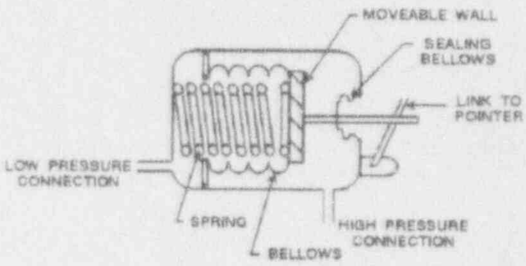
   A. would not change unless the pressure at the low pressure tap exceeded the pressure at the high pressure tap

   B. would increase because the high pressure would compress the spring more

   C. would decrease because the high pressure would compress the spring more

   D. would increase because the spring would expand more

FIGURE 1.2-7



Bellows - Type Differential Pressure Detector

94. A bourdon tube pressure detector that is indicating 50 percent of scale is suddenly exposed to a pressure transient that extends the detector 75 percent beyond its upper-range value. Actual pressure returns to its original value. Assuming the detector remains intact, the affected pressure indication will initially go offscale high and then would

   A. become unpredictable until the instrument is calibrated

   B. return to a pressure less than original pressure

   C. return to original pressure

   D. return to a pressure greater than original pressure

95. A properly adjusted 0-to-200 psig diaphragm-type pressure detector reading 100 psig develops a leak in the diaphragm. The <u>most likely</u> final pressure indication observed by an operator would be

   A. greater than 100 psig
   B. lower than 100 psig
   C. 200 psig
   D. offscale high

96. 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

97. What would typically be the result of a resistance temperature detector (RTD) shorting?

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

98. An open circuit in a thermocouple causes the temperature indication to fail

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

99. 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 inherent characteristic of metals: a change in electrical resistance occurs when a change in temperature occurs

100. An operator suspects that a steam line temperature instrument reading is not correct. A recently calibrated pressure gauge sensing steam pressure for the same steam line indicates 351 psig. Assuming the system is operating at saturation pressure, what is the temperature reading?

    A. 424°F
    B. 428°F
    C. 432°F
    D. 436°F

101. Which of the following correctly describes a characteristic of a thermocouple?

    A. Indication will fail high offscale with an open circuit.

    B. They are generally more accurate than resistance temperature detectors (RTDs).

    C. A junction between two dissimilar metals will generate a voltage proportional to temperature.

    D. A junction between two dissimilar metals will result in a change in electrical resistance proportional to temperature.

102. 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

103. In contrast to a thermocouple, a resistance temperature detector (RTD)

A. is used in high temperature applications

B. does not require an external power supply for temperature indication

C. uses a single type of metal in the sensing element

D. is commonly placed in direct contact with the monitored substance

104. 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, therby 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 course setpoint adjustments.

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

106. Describe how and why detectors operating in each of the following regions respond to incident radiation. Explain the effect of increasing applied voltage within each region.

a. ionization chamber region
b. proportional region

107. Refer to the drawing of a gas-filled detector characteristic curve (Figure 1.2-8).

Which of the following statements describes how gas-filled radiation detector, operating in the "proportional" region, functions?

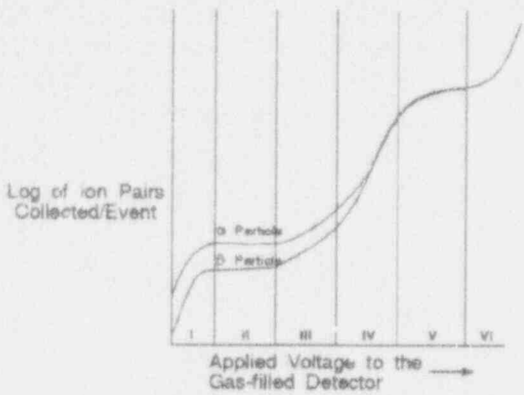
A. Essentially all of the ions from primary ionizations are collected. Ions collected from secondary ionizations are independent of applied voltage.

B. Essentially none of the ions from primary ionizations are collected. Ions collected from secondary ionizations vary directly with applied voltage.

C. Essentially all of the ions from primary ionizations are collected. Ions collected from secondary ionizations vary directly with applied voltage.

D. Essentially none of the ions from primary ionizations are collected. Ions collected from secondary ionizations are independent of applied voltage.

FIGURE 1.2-8



Gas-filled Detector Characteristic Curve

108. Refer to the drawing of a gas-filled detector characteristic curve (see Figure 1.2-8).

What is an advantage of operating a fission chamber neutron detector with a voltage at the high end (vice low end) of the proportional region?

A. Gas amplification will be minimized, which will prolong detector life.

B. The difference between the magnitude of neutron and gamma pulse heights will be larger, which improves gamma compensation.

C. The space charge effect will be minimized, which ensures that detector output is directly proportional to the number of ionizing events.

D. A greater number of primary ionizations will occur from a given radiation field, which increases the sensitivity of the detector.

109. 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

110. A fission chamber is lined with __________ and filled with __________ gas.

A. U^{238}, helium
B. U^{235}, hydrogen
C. U^{235}, argon
D. U^{238}, nitrogen

111. What is the function of the positive electrode in an ion chamber?

A. Produce ions when exposed to a radiation field.

B. Collect the electrons released during gas ionization.

C. Perform gas quenching to maximize detector sensitivity.

D. Release electrons to combine with positive ions.

112. A gamma, upon entering a fission chamber, reacts with the

A. coating on the cylinder
B. outer cylinder
C. center electrode
D. detector gas

113. Gamma radiation contributes to the output of a fission chamber by reacting primarily with the

A. U-235 coating on the detector walls
B. detector leads
C. center electrode
D. detector gas

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

    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.

115. The inner surface of a fission chamber is lined with ________, which allows neutron detection.

    A. U_3O_8 - 90 percent enriched in U235
    B. U_3O_8 - natural enrichment
    C. Pu_3O_8 - 90 percent enriched in Pu239
    D. Pu_3O_8 - natural enrichment

116. The average power range monitor display uses a scale with a range of 0-125 percent of rated

    A. main generator instantaneous capacity
    B. main generator continuous capacity
    C. reactor thermal power
    D. detector monitoring capability

117. Explain why variations in applied voltage do not significantly affect the output of the power range monitors.

118. A fission chamber reactor neutron monitoring instrument is operating in the ionization region. If the voltage supplied to the fission chamber is continuously increased, which one of the following operating regions will the detector enter next?

    A. proportional
    B. recombination
    C. limited proportional
    D. Geiger-Mueller

119. A fission chamber neutron monitoring instrument is operating in the proportional region of the gas ionization curve. If the voltage supplied to the fission chamber is continuously decreased, which one of the following operating regions will the detector enter next?

    A. Geiger-Mueller
    B. recombination
    C. limited proportional
    D. ionization

120. To prevent source range monitor detector failure during operation at power, the

    A. voltage applied to the detector is removed

    B. detector output is balanced by an equal applied reverse voltage

    C. detectors are physically shielded

    D. detectors are physically removed from the reactor

121. A fission chamber reactor neutron monitoring instrument is operating in the proportional region. If a complete loss of fission chamber gas pressure occurs, the instrument indication will fail

    A. upscale
    B. downscale
    C. as is
    D. to midscale

122. Which one of the following will cause an upscale failure of a fission chamber neutron detector?

   A. The detector electrode high voltage power supply output has decreased due to setpoint drift.

   B. The power supply to the amplifier circuits for the neutron monitoring instrument drawer has failed.

   C. The detector chamber has become flooded with water due to leakage around the electrodes.

   D. The uranium-235 in the detector coating has been transformed to uranium-236 by neutron absorption.

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

   A. Any incident radiation event causing primary ionization results in ionization of the entire detector.

   B. Geiger-Mueller tubes are longer than other radiation detector types, resulting in greater detector sensitivity.

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

   D. Kinetic energy of alpha particles can be detected, resulting in higher sensitivity.

124. 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

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

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

126. Scintillation detectors operate on the principle of

   A. photodisintegration
   B. photokinesis
   C. luminescence
   D. gas multiplication

127. Scintillation detectors convert radiation energy into light by a process known as

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

128. In an ion chamber radiation detector, if the electric field strength is increased within the ion chamber region, the total number of ions detected _________ , and the ions collected in the ion chamber are incident gamma radiation level.

   A. increases, independent of
   B. stays the same; independent of
   C. increases; proportional to
   D. stays the same; proportional to

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

   A. Alpha
   B. Beta
   C. Gamma
   D. Neutron

130. An ion chamber radiation detector is exposed to a constant gamma radiation field. If the applied voltage is increased but maintained within the ion chamber region, the rate of ion collection will

   A. increase because more secondary ionizations are occurring in the detector

   B. stay approximately the same because all of the primary ions were already being collected at the lower voltage

   C. increase because less primary ions are recombining in the detector prior to reaching the electrodes

   D. stay approximately the same because the ion chamber is operating at saturated conditions

131. Before using a portable radiation survey instrument, four checks should be performed. Which of the following is not one of the typical preoperational checks?

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

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

   A. Hold it 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 it 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.

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

   A. SRPDs can be used to record beta and gamma radiation.

   B. The output of an SRPD is a dose rate in mr/hr.

   C. SRPDs maintain their readings indefinitely when removed from a radiation field

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

134. In contrast to a thermocouple, a resistance temperature detector (RTD):

   A. is used in high temperature applications

   B. does not require an external power supply for temperature indication

   C. uses a single type of metal in the sensing element

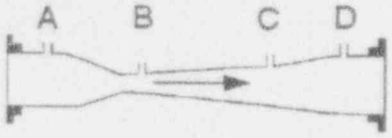
   D. is commonly placed in direct contact with the monitored substance

135. Refer to the drawing of a venturi flow element (see figure 1.2-9).

   Where should the high pressure tap of a differential pressure flow detector be connected?

   A. Point A
   B. Point B
   C. Point C
   D. Point D

FIGURE 1.2-9



Venturi Flow Element

136. Given the equation for mass flow rate:

$\dot{m} = \rho \times A \times V$, where:

$\dot{m}$ = mass flow rate (lbm/sec)

ρ = density of flowing fluid (lbm/ft^3)

A = cross section of channel of fluid (ft^2)

V = average velocity of flowing fluid (ft/sec)

If air is introduced (dissolved) into a flowing liquid, then the mass flow rate of the liquid will __________ due to the change in the __________ of the liquid.

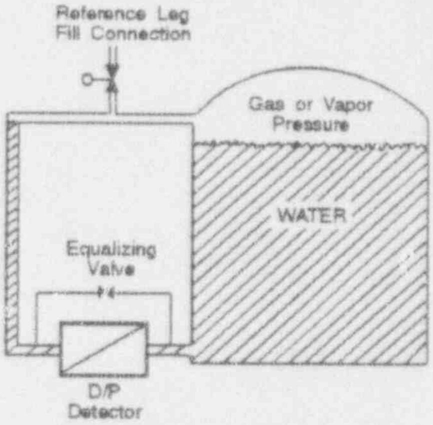
A. increase; density
B. decrease; density
C. increase; velocity
D. decrease; velocity

137. Refer to the drawing of a tank differential pressure (D/P) level detector (see figure 1.2-10).

The level detector is being used in a level control system that is calibrated to maintain tank level at 80% at the current tank temperature of 100°F. If tank temperature gradually increases and stabilizes at 150°F, the level control system will cause ACTUAL tank level to:

A. remain stable at 80%
B. increase and stabilize above 80%
C. oscillate and then stabilize at 80%
D. decrease and stabilize below 80%

FIGURE 1.2-10



Tank Differential Pressure Level Detector

138. 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

139. Upon entering a fission chamber, a neutron will most likely react with the:

A. coating on the cylinder
B. outer cylinder
C. center electrode
D. detector gas

140. A gas-filled radiation detector operating in the proportional region is exposed to a constant gamma radiation field. If the applied voltage is increased but maintained within the proportional region, the rate of ion collection will:

   A. increase because more secondary ionizations are occurring in the detector

   B. stay approximately the same because all of the primary ions were already being collected at the lower voltage

   C. increase because fewer primary ions are recombining in the detector prior to reaching the electrodes

   D. stay approximately the same because the ion chamber is operating at saturated conditions

141. Refer to the drawing of a venturi flow element (see figure 1.2-9)

   A differential pressure (D/P) detector measuring flow through the venturi should have its high-pressure tap connected at point ______ and its low-pressure tap connected at point ______ to measure the greatest D/P.

   A. A; B
   B. A; D
   C. B; C
   D. B; D

142. Refer to the drawing of a tank differential pressure (D/P) level detector (see figure 1.2-10)

   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

143. Which one of the following describes a characteristic of a Geiger-Mueller radiation detector?

   A. Radiation types can be identified by pulse height and duration.

   B. Specific radionuclides can be identified with the use of gamma spectrometry.

   C. Small voltage transients will result in large changes in detector output.

   D. A single gamma interaction will produce the maximum useful output from the detector.

144. Refer to the drawing of a reactor vessel differential pressure (D/P) level detector (see figure 1.2-11).

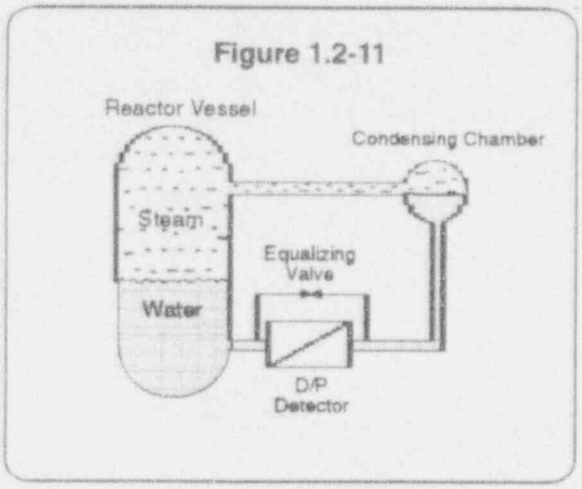
   The D/P detector was calibrated at the current conditions. Which one of the following will cause the level instrument to indicate lower than actual level? (Assume actual level remains the same.)

   A. The variable leg ruptures.

   B. The equalizing valve is opened.

   C. The reference leg temperature increases.

   D. The differential pressure cell diaphragm ruptures.



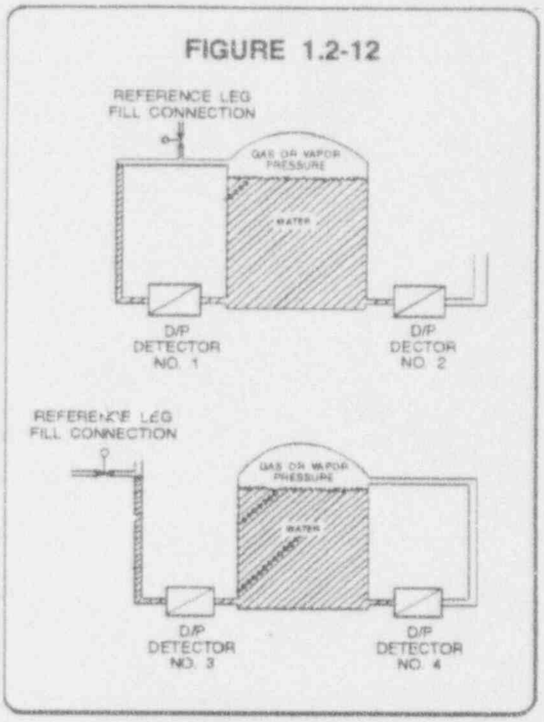
Reactor Vessel Differential Pressure Level Detector

145. Refer to the drawing of four tank differential pressure level detectors (see figure 1.2-12).

The tanks are identical and are being maintained at 17 psia and the same constant water level. They are surrounded by standard atmospheric pressure. The water in the tank and reference leg is at the same temperature.

If each detector experiences a ruptured diaphragm, which detector(s) will cause indicated tank level to decrease? (Assume actual tank water level remains constant.)

A. no. 1 and 3
B. no. 2 and 4
C. no. 1 only
D. no. 2 only



Tank Differential Pressure Level Detectors

146. Refer to the drawing of four identical tank differential pressure level detectors (see figure 1.2-12).

The tanks are identical and are presently at 2 psig overpressure and the same constant water level and a temperature of 60°F. They are surrounded by atmospheric pressure. All level detectors have been calibrated and are producing the same level indication. A leak in the top of each tank causes a complete loss of overpressure in both tanks.

Which level detector(s) will produce the lowest level indication.

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

SENSORS AND DETECTORS
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. D

The general energy equation requires that pressure decrease as velocity increases (in a converging nozzle) and that pressure increase with decreasing velocity (in a diverging nozzle).

Reference 57, chapter 5, pages 18 and 19.

2. A

Reference 57, chapter 5, pages 18 and 19.

3. D

Reference 57, chapter 5, pages 18 and 19.

4. B

Reference 57, chapter 5, pages 18 and 19.

5. C.

Reference 57, chapter 5, pages 18 and 19.

6. A

Taking into account the friction loss as the liquid flows through the pipe will result in a slight decrease in pressure.

Reference 57, chapter 5, pages 18 and 19.

7. A

Reference 57, chapter 5, pages 18 and 19.

8. 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 43, chapter 12, page 198.

9. A

Reference 43, chapter 12.

10. A

Reference 43, chapter 12.

11. C

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

Reference 43, chapter 12, page 198.

12. B

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

Reference 43, chapter 12, page 198.

13. 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 43, chapter 12, page 198.

14. D

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

Reference 43, chapter 12, page 197.

15. A

The flow element produces a D/P that is directly proportional to the volumetric flow rate. Density compensation allows conversion to mass flow rate.

Reference 43, chapter 12.

16. B

The dissolved air would decrease the density of the fluid, causing a lower mass flow rate for a given volume flow rate.

17. B

18. D

A small amount of gas passing through the flow sensor will cause pressure fluctuations. These pressure fluctuations will be picked up by the D/P cell and will show up as fluctuations on the flow meter.

Reference 43, page 199.

19. A

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

Reference 43, page 199.

20. D

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

Reference 43, page 199.

21. 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 43, page 199.

22. 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 low pressure tap reading lower than normal. This increase in D/P will cause an indicated increase in flow.

Reference 43, page 199.

23. B

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

24. C

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

Reference 53, page 1.4-3.

25. 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 due to the decrease in D/P across orifice.

26. A

With a ruptured diaphragm, the D/P cell will detect zero differential pressure and will indicate zero flow.

Reference 43, page 199.

27. A

Reference 43, page 199.

28. A

Reference 43, page 199.

29. C

Reference 43, page 199.

30. A

Reference 43, page 199.

31. B

Bellows-type differential pressure detector measures differential pressure by measuring how much the bellows compresses. If the spring weakens then indicated D/P will increase due to more compression.

32. C

Centrifugal force and impingment create a high pressure area at the outer pipe radius. Points "A" and "D" are not used in an elbow flow meter.

Reference 35, page 2-23, figure 2-19.

33. B

Centrifugal force away from the inner pipe radius creates a low pressure area. Points "A" and "D" are not used for an elbow flow meter.

Reference 35, page 2-23, figure 2-19.

34. 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 43, page 58.

35. B

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

Reference 43, page 58.

36. D

D/P is proportional to velocity squared. Therefore, if the velocity doubles, D/P would increase by a factor of 4.

Reference 43, page 197.

37. D

Reference 43, page 197.

38. C

Reference 43, page 58.

39. 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; however, the indicated level remains the same.

40. 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; however, the indicated level remains the same.

41. D

The reduction in temperature increases the water's density. Therefore, the height of water necessary to produce a given pressure at the D/P cell is reduced. The control system will maintain level at this lower value to maintain D/P at a constant value.

42. B

The detector calibrated for less dense water will always read higher.

43. B

Detector calibrated for temperatures less than actual temperature reads low.

44. A

45. B

46. D

47. B

Reference 70, chapter 2, page 87.

48. B

The D/P cell is the most 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 the level of liquid in the tank.

Reference 70, chapter 2, page 87.

49. A

50. C

51. D

52. 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 70, chapter 2, page 88.

53. D

The D/P cell is the most 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 70, chapter 2, page 87.

54. C

The D/P cell is the most 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 the level of liquid in the tank.

Reference 70, chapter 2, page 87.

55. D

The D/P cell is the most 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 the level of liquid in the tank.

Reference 70, chapter 2, page 87.

56. A

If inventory in the Reference leg is depleted, the pressure exerted would be less on the high pressure side of the D/P sensor, indicating lower D/P and therefore a higher level.

Reference 35, page 2-32.

57. C

Increasing ambient pressure has no effect on D/P cell level instruments because both sides of the D/P cell are open to the vessel or tank.

Reference 70, chapter 2, page 88.

58. C

Decreasing ambient pressure has no effect on D/P cell level instruments because both sides of the D/P cell are open to the vessel or tank.

Reference 70, chapter 2, page 87.

59. D

The higher temperature will reduce the density of the water in the variable leg. Therefore, the pressure exerted for a given height of liquid is reduced, resulting in an inaccurately low level indication.

Reference 70, chapter 2, page 87.

60. D

The depressurization could reduce pressure below saturation for the reference leg temperature, causing water in the reference leg to flash to steam.

Reference 35, page 2-32.

61. B

Reference 70, chapter 2, page 88.

62. A

Reference 70, chapter 2, page 87.

63. 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 70, chapter 2, page 87.

64. 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 70, chapter 2, page 87.

65. 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 70, chapter 2, page 87.

66. D

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

Reference 70, chapter 2, page 87.

67. A

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

Reference 70, chapter 2, page 87.

68. B

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

Reference 70, chapter 2, page 87.

69. A

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

Reference 70, chapter 2, page 87.

70. A

The pressure of the Reference leg fluid decreases when it boils off. This results in a decrease in ΔP as sensed by the D/P cell, which results in a higher indicated level.

Reference 70, chapter 2, page 88.

71. C

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

Reference 70, chapter 2, page 87.

72. B

The diaphragm failure reduces D/P to zero. A wet reference leg instrument with zero D/P indicates maximum level.

73. C

Flashing to steam reduces the pressure on the reference leg (high powered) side of the D/P cell, causing D/P to decrease and indicated level to increase.

74. C

The diaphragm failure reduces D/P to zero. A wet reference leg instrument with zero D/P indicates maximum level.

75. D

The diaphragm failure reduces D/P to zero. A wet reference leg instrument with zero D/P indicates maximum level.

76. C

A rupture in the variable leg reduces pressure on the low pressure side of the D/P cell, which indicates a correspondingly low level.

77. C

Increasing pressure tends to straighten the tube. Decreasing pressure allows the tube to coil back up.

Reference 35, page 2-12.

78. 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 78, page 11-14.

79. D

Reference 35, page 2-12.

80. B

The amount of movement of the diaphragm is proportional to the applied pressure. The axial deflection of the detector is used to generate meter movement.

Reference 78, pages 11-12 and 11-13.

81. C

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

Reference 74, pages 7-14 and 7-15.

82. D

Reference 74, pages 7-14 and 7-15.

83. D

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

Reference 74, pages 7-14 and 7-15.

84. 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 psig, the detector indication drops by 40 psig. This error could be large at reduced system pressure (e.g., 100 psig). The detector output in this case is significantly reduced.

Reference 74, pages 7-14 and 7-15.

85. C

Reference 57, page 78.

86. B

Reference 57, pages 22, 23, and 78.

87. D

Reference 57, pages 22, 23, and 78.

88. B

Minimum D/P corresponds to maximum level.

Reference 57, pages 23 and 24.

89. B

$\Delta P = P_h - P_l$

As P_h decreases, ΔP decreases (eliminates answer A).

As P_h increases, ΔP increases (eliminates answers C and D).

Reference 35, page 2-13; and Reference 36, page 9-2.

90. D

$\Delta P = P_h - P_l$

As P_l decreases, ΔP increases eliminating "A".

As P_l increases, $- P_l$ decreases; ΔP decreases and could become negative, eliminating "B" and "C."

Reference 35, page 2-13; and Reference 36, page 9-2.

91. C

$\Delta P = P_h - P_l$

As P_h increases, ΔP increases, eliminating "A."

As P_h decreases, ΔP decreases, eliminating "B."

As P_l increases, ΔP decreases, eliminating "D" and leaving "C."

Reference 35, page 2-13; and Reference 36, page 9-2.

92. A

As condenser vacuum decreases, condenser absolute pressure increases. An increase on the low pressure side of a D/P cell causes indicated differential pressure decrease.

Reference 35, page 2-13; and Reference 36, page 9-2.

93. B

The spring must be on the low pressure side so that the bellows will return to original configuration as ΔP increases; a weakened spring causes the spring to compress more and indicated ΔP to increase.

Reference 35, page 2-13; and Reference 36, page 9-18.

94. 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 percent beyond upper range without damage. At 75 percent, the gauge would be deformed and would not return to its original shape; the indication would then return to some value greater than original.

Reference 03, page 43.

95. 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 low and high pressure chambers vented to atmosphere.

Reference 03, pages 45 and 46.

96. A

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

Reference 74, chapter 6, page 10.

97. D

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

Reference 74, chapter 6, page 10.

98. B

If an open develops in a thermocouple circuit, no path for current flow exists, and no electromotive force (emf) is developed. No emf means failed low temperature indication.

Reference 03, pages 130 through 134.

99. 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 03, pages 130 through 134.

100. D

From steam tables, the saturation temperature for 365 psia (351 psig) is approximately 436°F

Reference 10.

101. C

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.

Reference 03, pages 130 through 134.

102. A

Reference 03, pages 130 through 134.

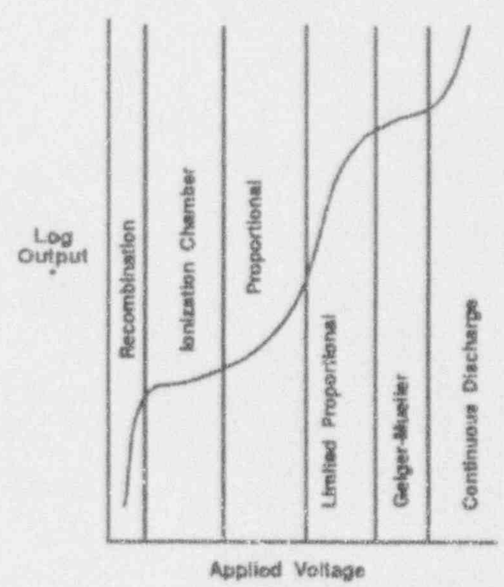
103. C

Reference 03, pages 130 through 134.

104. A

105.

FIGURE 1.2-13



* Output may be pulse height or number of ion pairs produced per event.

Reference 76, page 5-7.

106.

In all regions, incident radiation interacts with the material 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.

107. C

Reference 76, page 5-7.

108. B

Reference 21, Instrumentation and Control, page 3-11.

109. A

Neutrons react with the uranium in the coating to cause fission. The fission fragments ionize the argon gas causing electrons to be released, which are then attracted to the positive electrode for detection.

110. C

Fission chambers utilize U^{235} in oxide form with a quench gas of argon.

111. B

As a gamma enters, it causes ionization of the fill gas, releasing electrons in the vicinity of a positive potential electrode, which attracts them towards it, causing a deviation in the current applied or a current to flow.

112. D

As a gamma enters, it causes ionization of the fill gas, releasing electrons in the vicinity of a positive potential electrode which attracts them towards it, causing a deviation in the current applied or a current to flow.

113. D

114. 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 76, pages 5-12 and 5-13.

115. A

The fission chamber employs U_30_8 enriched to about 90 percent U235.

Reference 76, page 5-43.

116. C

117.

The power range monitor detectors operate in the ion chamber region of the six-region gas-filled detector characteristic curve. In this region, the applied voltage is sufficient to collect virtually all of the ion pairs created, yet is not so great as to produce secondary ionizations. Therefore, increasing the voltage will not cause collection of additional ion pairs (as long as the voltage increase does not shift the detector into the proportional region), and decreasing voltage will not prevent collection of all ion pairs (as long as voltage is not decreased into the recombination region).

Reference 21, Instrumentation and Control, page 3-11.

118. A

Reference 21, Instrumentation and Control, page 3-11.

119. D

Reference 21, Instrumentation and Control, pages 3-11.

120. D

121. B

If gas is <u>not</u> present the amplification of the signal created by the fission will not occur.

122. C

The presence of water will cause the detector to short circuit causing the signal to go upscale.

123. A

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 76, pages 5-28 and 5-29.

124. D

Answers A, B, and C are 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 76, pages 5-28 and 5-29.

125. B

Reference 76, pages 5-28 and 5-29.

126. C

Scintillation detectors operate on the principle of luminescence.

Reference 76, page 5-45 and 5-46.

127. C

Reference 76, page 5-45 and 5-46.

128. 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 constant.

Reference 76, pages 5-8, 5-13, and 5-14.

129. C

SRPDs are ion chambers and read gamma radiation.

130. B

Reference 76, pages 5-8, 5-13, and 5-14.

131. B

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

Reference 76, page 5-57.

132. 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 76, pages 5-50 and 5-51.

133. D

SRPDs are subject to discharge in a non-radiation field.

SRPDs are too thick for measuring beta radiation.

SRPDs are dose recorders in units of milliroentgen.

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

Reference 76, pages 5-32 and 5-33.

134. C

135. A

136. B

137. B

138. A

139. A

140. A

141. A

142. B

143. D

144. A

145. B

146. D

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.

K1.01 Question 1-7, 135, 141

Describe the operation of a venturi.

K1.02 Questions 8-11

Describe the operation of density compensating flow detectors.

K1.02 Questions 12, 15

State the reason for using density compensation in flow detectors.

K1.02 Questions 13, 14

Describe the operation of density compensating flow detectors.

K1.03 Questions 16-20, 136

Identify the effects of gas or steam on a liquid flow rate indication.

K1.04 Questions 21-31

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

K1.05 Questions 32-38

Explain the operation of a differential-pressure-cell-type flow detector.

K1.06 Questions 39-46, 137

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

K1.07 Questions 48-55, 142

Describe the theory and operation of level detectors.

K1.08 Question 56

State how a level instrument reading will be affected if its Reference leg boils off.

K1.08 Questions 57, 58, 61

State the effect of a change in ambient pressure on a level detector.

K1.08 Questions 59, 60

Relate level instrument performance to environmental conditions.

K1.08 Questions 47, 62-65

State the effect of a change in ambient temperature on a level detector.

K1.09 Questions 66-76, 144, 145

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

K1.10 Questions 77, 78, 79

State the basic principle of operation of a bourdon tube pressure detector.

K1.10 Question 80

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

SENSORS AND DETECTORS
Learning Objectives

K1.11 Questions 81-84

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

K1.12 Question 85, 146

State how varying parameters affect the operation of D/P cells with respect to level determination.

K1.12 Question 86, 87

State how D/P cells are used for indications.

K1.12 Question 88

Explain the principle of operation of level-measuring D/P cell.

K1.12 Questions 89-92

Describe how indicated differential pressure responds to changes in high or low input pressure for a basic differential pressure indicator.

K1.12 Question 93

Explain the operating principle of a basic differential pressure cell.

K1.13 Questions 94, 95

Identify the potential causes and effects on indication of pressure detector failure.

K1.15 Questions 96-103

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

K1.16 Question 104

Describe the failure modes of potentiometers.

K1.17 Question 138

Applications of reed switches, magnets, LVDT, potentiometers, and limit switches.

K1.18 Question 138

Applications of reed switches, magnets, LVDT, potentiometers, and limit switches..

K1.19 Questions 105, 106, 107

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

K1.19 Question 109, 139

Describe the operation of a fission chamber.

K1.19 Question 110

Describe the construction of a fission chamber.

K1.19 Questions 111

Describe the operation of an ion chamber.

K1.19 Question 114

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

K1.19 Question 112, 113, 115

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

K1.20 Question 116

Identify the units used in nuclear instrument displays.

K1.21 Question 108, 117, 118, 119

Explain the effect of voltage changes on neutron detector performance.

K1.22 Question 120, 121, 122

Explain how source range monitor detector failure is avoided during power operation.

K1.23 Questions 123, 124, 125, 140, 143

State the basic principles of operation of a Geiger-Mueller tube radiation detector.

K1.23 Question 126, 127

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

K1.23 Question 128, 129, 130

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

K1.24 Questions 131-133

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

CONTROLLERS AND POSITIONERS
Questions

1. Which type of controller uses a feedback method of control?

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

2. The difference between the setpoint and the measured parameter value is called

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

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

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

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

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

5. The purpose of a seal-in relay in a valve controller circuit that opens a valve under specified conditions is to

   A. hold the valve open even if the reset pushbutton is pressed

   B. hold the valve open even if the initiating conditions reset

   C. close the valve as soon as the initiating condition resets

   D. close the valve only when all initiating conditions reset

6. An automatic flow controller is being used to position a valve in a cooling water system. A signal from the valve, that is proportional to valve position, is returned to the controller. This signal is referred to as

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

7. 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. decrease to minimum speed

   D. cycle approximately 5 percent above and below the current speed

8. 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.

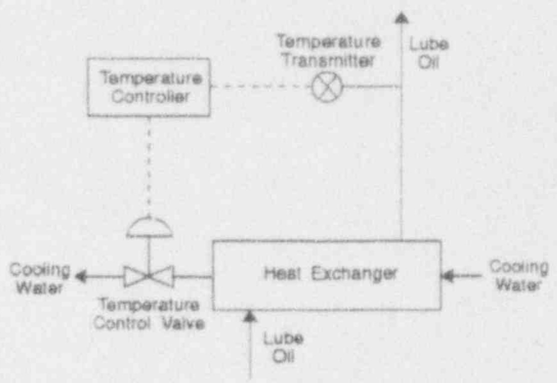
   D. The controller will develop an output signal that will remain directly proportional to the rate of change of the controlled parameter.

9. 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

10. Some valve positioning (drive) devices are capable of stopping the valve between a fully open and a fully closed (throttled) position. Which of the following valves is best used for throttling?

    A. stop valve
    B. globe valve
    C. gate valve
    D. butterfly valve

11. Which of the following valves is most likely to be used with a throttling positioner?

    A. stop valve
    B. globe valve
    C. gate valve
    D. butterfly valve

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

    A. supply control pressure to move the diaphragm piston

    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

13. Select the most correct answer concerning manual operation of motor-operated valves with manual declutch levers.

    A. The lever should be returned from manual to auto only when the motor is not operating.

    B. The lever should be depressed to engage the manual mode of operation only when the motor is not operating.

    C. It is a good operating practice to disengage the manual declutch lever during operation.

    D. The lever electrically disengages the motor operator.

14. 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 controllar output

    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

15. 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/an

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

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

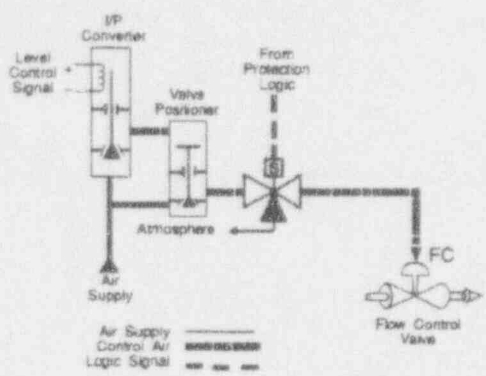
    A. a small control air pressure into a proportionally larger air pressure to adjust valve position

    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 positon

FIGURE 1.3-2



Pneumatic Control System

17. A turbine governor would cause turbine speed to _______ if the sensed turbine speed signal failed low.

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

18. A turbine governor would cause the actual speed to _______ if the sensed turbine speed signal failed high.

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

19. In a flyball weight mechanical speed governor, the purpose of the spring on the flyball mechanism is to

    A. counteract centrifugal force by driving the flyballs apart

    B. aid centrifugal force in bringing the flyballs together

    C. counteract centrifugal force by bringing the flyballs together

    D. aid centrifugal force in driving the flyballs apart

20. The governor on an emergency diesel generator regulates the amount of fuel supplied to the diesel engine to

    A. increase engine speed as load increases

    B. increase generator voltage as load increases

    C. maintain engine speed nearly constant as load changes

    D. maintain generator voltage nearly constant as load changes

21. The governor of an emergency diesel generator (D/G) senses D/G _______ and adjusts D/G _______ flow to maintain a relatively constant D/G frequency.

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

22. 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

23. Which one of the following describes the response of a direct-acting purely 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.

24. An air-operated isolation valve requires 4,800 lbf from its diaphragm actuator and 4 inches of stem travel for proper operation. The valve positioner can supply 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 03, pages 12 through 14.

2. D

Reference 03, pages 12 through 14.

3. A

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

Reference 03, pages 12 through 14.

4. C

Reference 47.

5. B

6. C

Reference 03, pages 12 through 14.

7. A

The turbine will accelerate to a point where it will trip on overspeed, because of the speed error signal developed when the speed signal was lost.

8. A

9. A

Reference 03, pages 12 through 14.

10. B

Reference 65, chapter 6.

11. B

Reference 65, chapter 6.

12. D

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

Reference 03, page 261.

13. B

The manual handwheel should not be engaged when motor operator is operating electrically.

Reference 37.

14. 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 valve actuator diaphragm are the basis of valve motion.

Reference 03, page 261.

15. C

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

16. A

17. A

Sensed speed failing low results in a mismatch between governor setpoint and sensed speed, causing governor output to go high, increasing actual turbine speed.

Reference 30, chapter 25.

18. B

Sensed speed input to a governor failing high would result in a sensed speed and governor setpoint mismatch, causing governor speed demand to decrease, resulting in actual turbine speed decrease.

Reference 30, chapter 25.

19. C

The governor shaft, which is coupled to a rotating machine, spins. The resultant centrifugal force causes the flyballs to tend to move outward, thereby compressing the spring on the shaft. The spring resists this compression, and therefore tends to counteract centrifugal force and drive the balls together.

Reference 30, chapter 25.

20. C

Load changes will tend to affect diesel speed. The governor senses speed and controls fuel flow to maintain speed (and therefore frequency) nearly constant.

21. B

Load changes will tend to affect diesel speed. The governor senses speed and controls fuel flow to maintain speed (and therefore frequency) nearly constant.

22. 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 55.1, chapter 5, page A-3.

23. D

24. B

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, 1.04 Questions 1-9, 23

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

K1.05 Questions 10-16, 24

Describe the function, application, and characteristics of valve positioners.

K1.06 Questions 17-21

Explain the function and characteristics of governors and other mechanical controllers.

K1.07 Question 22

Describe the precautions associated with transferring a valve controller from automatic to manual, or manual to automatic. (See also "Valves" K1.07.)

PUMPS
Questions

1. Which of the following changes in pump operating parameters will directly lead to pump cavitation in a centrifugal pump operating in a closed-loop system?

   A. steadily increasing pump inlet temperature

   B. steadily decreasing pump speed

   C. steadily increasing pump suction pressure

   D. steadily increasing pump discharge pressure

2. The formation of vapor bubbles that subsequently collapse and cause pitting to a pump's impeller is associated with the condition known as

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

3. Starting a centrifugal pump with the discharge valve throttled or shut results in

   A. an increased likelihood of pump runout

   B. a decreased likelihood of cavitation

   C. an increased likelihood of cavitation

   D. a decreased likelihood of reaching shutoff head

4. Select the statement that best 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 water hammer.

5. Which one of the following changes in plant status will bring the reactor recirculation system closer to the condition in which the recirculation pump will cavitate?

   A. during a plant shutdown, recirculation pump suction temperature decreases while reactor pressure remains constant

   B. recirculation pump speed increases

   C. reactor water level increases

   D. during reactor power operations, extraction steam to one of the high pressure feedwater heaters isolates

6. The presence of air in the casing prior to pump start is a condition known as

   A. vortexing
   B. pump runout
   C. head loss
   D. gas binding

7. Air binding in a centrifugal pump is an undesirable condition that may be avoided by

   A. throttling closed the suction valve prior to pump start, then opening it again

   B. opening the discharge valve fully, then starting the pump to allow air to be forced out

   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

8. A centrifugal pump is started and the following indications are observed: low flow, low discharge pressure, and minimum amps. This could mean that the pump is experiencing

   A. gas binding
   B. a locked rotor
   C. shutoff head
   D. motor overload

9. In a centrifugal pump, gas binding is a term that refers to a condition in which the pump

   A. is pumping at maximum capacity

   B. is filled with steam or air

   C. suction pressure drop is sufficient to cause the fluid to boil

   D. capacity is reduced due to vapor bubbles forming and collapsing

10. 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

11. Venting a centrifugal pump prior to operating it ensures that

    A. pump runout will not occur
    B. pump internal corrosion is reduced
    C. gas binding is reduced
    D. starting load is minimized

12. In a centrifugal pump, gas binding is a term that refers to a condition in which the pump

    A. capacity is reduced due to the presence of steam or air in the pump volute

    B. motor current increases due to dissolved noncondensible gases adding to the volume of the fluid being pumped

    C. capacity is increased due to the expansion of vapor bubbles in the pump casing

    D. suction pressure drop is sufficient to cause the fluid to vaporize

13. Which of the following is a condition that 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 shutoff head.

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

    D. The pump is imparting maximum head to the fluid.

14. What would result from operating a motor-driven centrifugal pump for extended periods of time with the discharge valve shut?

    A. no damage, since the pump and motor are designed to operate with the discharge valve shut

    B. pump overheating, cavitating, and ultimately failure

    C. excessive motor current, damage to motor windings, and ultimately motor failure

    D. pump and motor speeding excessively and tripping on high motor current

15. A low pressure injection pump that lacks minimum flow protection is usually stopped when system pressure is above pump shutoff head. This is done to prevent

A. bursting 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 once system pressure drops to a value where the pump can inject water

D. inadequate lubrication flow due to high pump differential pressure

16. Operating a motor-driven centrifugal pump for an extended period of time under no flow conditions will cause

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

17. 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

18. In the portion of a system shown in Figure 1.4-1, the flowpath through valve "A" is designed to

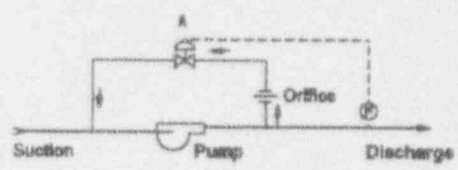
A. provide minimum recirculation flow through the pump during shutoff head conditions

B. prevent pump runout by creating a recirculation flowpath

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

D. ensure that cavitation does not occur by cooling the suction fluid

FIGURE 1.4-1



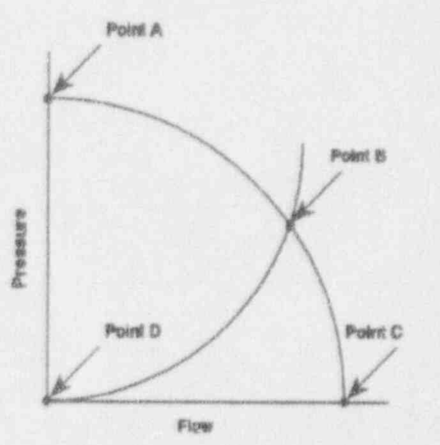
Centrifugal Pump

19. Explain the concerns associated with operating a centrifugal pump at shutoff head, and describe a typical design feature for alleviating the concerns.

20. Using the drawing of a centrifugal pump characteristic curve (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

21. A centrifugal firewater pump takes a suction on an open storage tank and discharges through a fire hose. Which one of the following will cause the pump to operate at shutoff head?

    A. The fire hose nozzle is raised to an elevation that prevents any flow.

    B. Suction temperature is increased to the point that gas binding occurs.

    C. Pump speed is adjusted to the value at which cavitation occurs.

    D. Suction pressure is adjusted until available net positive suction head is reduced to zero feet.

22. Operating characteristics for radial flow centrifugal pumps vary with pump speed. Select the choice below that completes the following "pump laws."

    ______ varies directly with speed
    ______ varies as the square of speed
    ______ varies as the cube of speed

    A. capacity, suction pressure, pump head
    B. pump head, suction pressure, capacity
    C. capacity, pump head, horsepower
    D. horsepower, pump head, capacity

23. A centrifugal pump is operating with a flow rate of 1.5×10^6 lbm/hr with a power of 300 HP and a pump head of 400 psi. If the pump speed is doubled, what is the new flow rate?

    A. 1.5×10^6 lbm/hr
    B. 3.0×10^6 lbm/hr
    C. 6.0×10^6 lbm/hr
    D. 9.0×10^6 lbm/hr

24. A centrifugal pump is operating with a flow rate of 1.5×10^6 lbm/hr with a power of 300 HP and a pump head of 400 psi. If the pump speed is doubled, what is the new head?

    A. 400 psi
    B. 800 psi
    C. 1,600 psi
    D. 3,200 psi

25. Consider a plant system with two identical centrifugal pumps in parallel, one of which is running. The idle pump is started. Assuming no other system configuration changes are made, the system flow one minute later will be

    A. double the original flow

    B. less than double the original flow

    C. greater than double the original flow

    D. the same, only the discharge head will change

26. A motor-driven centrifugal pump is operating at rated flow. How will flow, discharge pressure and power be affected if the discharge valve is throttled in the closed direction?

	Flow	Pressure	Power
A.	increase	decrease	increase
B.	decrease	increase	decrease
C.	decrease	increase	increase
D.	decrease	decrease	increase

27. Doubling the speed of a centrifugal pump will cause which of the following?

I. pump power requirements to increase by a factor of four

II. pump head to increase by a factor of four

III. flow to increase by a factor of four

IV. pump power requirements to increase by a factor of eight

V. flow to double

VI. pump head to double

A. I and VI
B. II, III, and IV
C. II, IV, and V
D. III, IV, and VI

28. The pump discharge head of a centrifugal pump will decrease if the

A. pump suction pressure is increased

B. speed of the pump increases

C. discharge valve is throttled closed

D. temperature of the fluid being pumped increases

29. A centrifugal pump is operating at rated speed with an output head of 240 psid. The speed of the pump is then decreased until the power consumption is 1/64 of its original value. What is the approximate new output head?

A. 3.75 psid
B. 15 psid
C. 30 psid
D. 60 psid

30. A multispeed centrifugal pump is operating at 1800 rpm, providing a flow of 400 gpm at 20 psid. If the pump speed is increased to 3600 rpm, the new pump differential pressure will be

A. 160 psid
B. 80 psid
C. 60 psid
D. 40 psid

31. A centrifugal pump is operating at a discharge pressure of 50 psi, flow of 200 gpm, and power consumption of 3 kW. Pump speed is increased and the flow increases to 400 gpm. Which of the following is the value of the power consumption?

A. 6 kW
B. 9 kW
C. 24 kW
D. 27 kW

32. A variable-speed centrifugal pump is operating with a flow rate of 3000 gpm. Which one of the following values most closely approximates the flow rate if the speed is decreased from 3600 to 1800 rpm?

A. 900 gpm
B. 1000 gpm
C. 1500 gpm
D. 2000 gpm

33. A variable-speed centrifugal pump is operating with a differential pressure of 50 psid. Which one of the following values approximates the differential pressure if the speed is increased from 1800 rpm to 3600 rpm?

A. 50 psid
B. 100 psid
C. 200 psid
d. 400 psid

34. A variable-speed centrifugal pump is running at 1800 rpm. The initial flow rate is 1000 gpm, total head is 100 ft., and work input is 500 hp. If the flow rate is changed to 1200 gpm, which of the following gives the correct value for new work input?

A. 550 hp
B. 778 hp
C. 864 hp
D. 912 hp

35. A cooling water pump is operating at 1800 rpm. Its capacity is 500 gpm at a pump head of 25 psi, which requires a power of 100 kW. Which one of the following lists gives the pump capacity, discharge head, and power requirements, respectively, if the pump speed is increased to 3600 rpm?

A. 100 gpm, 200 psi, 400 kW
B. 2000 gpm, 50 psi, 800 kW
C. 1000 gpm, 100 psi, 800 kW
D. 4000 gpm, 100 psi, 200 kW

36. Using the system drawing in Figure 1.4-3, how may the available net positive suction head (NPSH) for a centrifugal pump be increased?

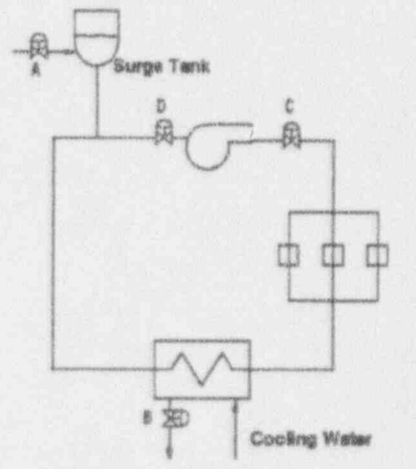
A. opening surge tank makeup valve "A" briefly

B. throttling heat exchanger cooling water valve "B" partially closed

C. throttling pump discharge valve "C" partially open

D. throttling pump suction valve "D" partially closed

FIGURE 1.4-3



Basic System

37. 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. fluid vapor pressure plus suction pressure

38. When flow from a centrifugal pump is increased by further opening the discharge valve, required net positive suction head (NPSH) ________, and available NPSH ________.

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

39. Of the following operations in a closed system, which 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 open the pump suction valve
    D. throttling open the pump discharge valve

40. A motor-driven centrifugal pump is operating at rated flow; then the discharge valve is throttled partially closed. Which of the following parameters will increase as a result of this action?

    A. volumetric flow
    B. net positive suction head available
    C. motor current
    D. net positive suction head required

41. What will increase reactor recirculation pump available net positive suction head? (Assume all other parameters remain constant.)

    A. loss of feedwater heating while at 80% power

    B. increase in reactor coolant temperature from 100 °F to 200 °F during a reactor startup

    C. decrease in reactor pressure during a normal reactor shutdown

    D. decrease in reactor water from the normal level to just below the low-level alarm level

42. Which one of the following conditions will result in a decrease in the available recirculation pump net positive suction head (NPSH)?

    A. carry-under decreases
    B. recirculation flow rate increases
    C. feedwater inlet subcooling increases
    D. feedwater flow increases

43. Which one of the following actions will result in a decrease in available net positive suction head (NPSH) for a centrifugal pump?

    A. decreasing pump suction temperature

    B. increasing the pump speed

    C. closing the pump discharge valve from 100% open to 50% open

    D. increasing the level in the system expansion tank

44. Which one of the following changes in plant status will bring the reactor recirculation system closer to the condition in which the recirculation pump will cavitate?

    A. During a plant shutdown, reactor recirculation pump suction temperature decreases while reactor pressure remains constant.

    B. Reactor recirculation pump speed is increased.

    C. Reactor water level increases.

    D. Extraction steam is isolated from one high pressure feedwater heater during power operations.

45. Which one of the following parameter changes will cause a reduction in the available net positive suction head (NPSH) to a condensate pump?

    A. Condensate depression increases.
    B. Reactor power level decreases.
    C. A second condensate pump is started.
    D. Condenser hotwell level decreases.

46. Which of the following will decrease the available net positive suction head to the reactor recirculation pumps? (Assume all other parameters remain constant.)

    A. loss of feedwater heating while at 80 percent power

    B. increase in reactor coolant temperature from 100°F to 200°F during a reactor startup

    C. increase in reactor pressure during a reactor startup

    D. increase in reactor water level from the normal level to just below the high-level alarm

47. Centrifugal pumps are usually started with their discharge valves closed. The main reason for this is to prevent

    A. overheating the pump
    B. overloading the pump motor
    C. cavitation in the pump
    D. lifting the discharge relief valve

48. When starting a centrifugal pump, the response of motor current should be

    A. low starting amps, stabilizing to a higher equilibrium running amperage

    B. low starting amps, remaining at a low equilibrium running amperage

    C. high starting amps, decaying off to a lower equilibrium running amperage

    D. high starting amps, remaining at a high equilibrium running amperage

49. A pump is circulating water at 200 °F in a closed system equipped with a surge tank. Several hours later, after system heatup and no lineup changes, the same pump is now circulating 450 °F water. Observation of pump motor amps would show that, during the system heatup, motor amps have

    A. decreased
    B. remained the same
    C. increased slightly
    D. increased by a factor of two

50. 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.

51. A constant-speed centrifugal pump motor draws the least current when the pump is

    A. at maximum rated flow conditions
    B. operating on recirculation flow only
    C. accelerating to normal speed during start
    D. at shutoff head with no recirculation flow

52. A centrifugal pump is operating at normal discharge pressure and flow conditions with the discharge valve fully open. The discharge valve is then throttled to the 50% open position. As a result,

    A. pump motor current decreases

    B. pump flow rate increases

    C. pump discharge head decreases

    D. available net positive suction head decreases

53 Refer to the drawing of a cooling water system (see Figure 1.4-4). the centrifugal pump is circulating water at 100°F. After several hours the water temperature has increased to 200°F. Assuming system flow rate (gpm) is constant, pump motor amps will have __________ because __________.

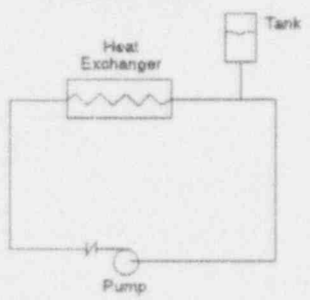
A. decreased; water density has decreased

B. increased; water density has decreased

C. decreased; pump shaft speed has increased

D. increased; pump shaft speed has increased

FIGURE 1.4-4



Cooling Water System

54. The correct way to start most larger motor-driven centrifugal pumps is with the pump discharge valve

A. in any position
B. throttled to midposition
C. fully opened
D. fully closed

55. Explain why centrifugal pumps are typically started only when their discharge valves are closed.

56. What is normally done to prevent runout when starting a centrifugal pump?

A. Close the suction valve prior to starting the pump.

B. Close the discharge valve prior to starting the pump.

C. Start the pump at low system demand.

D. Start the pump at high system demand.

57. Which of the following pumps should be started with its discharge valve shut?

A. centrifugal
B. gear pump
C. reciprocating
D. screw

58. Which of the following is not a reason for starting a centrifugal pump with the discharge piping filled and the discharge valve shut?

A. prevent water hammer

B. prevent excessive pump discharge pressure

C. prevent excessive starting current

D. prevent pump runout

59. Many large centrifugal pumps are interlocked so that the pump will not start unless its discharge valve is at least 90 percent fully closed. This interlock is provided in order to minimize

A. net positive suction head
B. inventory loss
C. pump discharge pressure
D. pump motor starting current

60. A cooling water system has two centrifugal pumps in parallel. One pump is running at 1800 rpm. The second pump is started and run at 1800 rpm. System flow will be

A. double the original flow, due to the double pump work

B. slightly less than double the original flow, due to increased flow resistance

C. the same as the original flow, but at a higher operating pressure

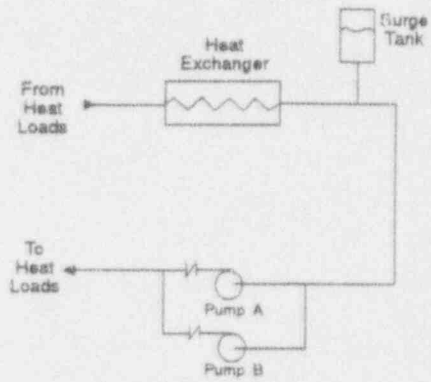
D. 50 percent greater than the original flow, due to the increased discharge head

61. Refer to the drawing of a cooling water system and the associated centrifugal pump operating curve (see Figure 1.4-5) in which pumps A and B are identical single-speed centrifugal pumps and only pump A is operating.

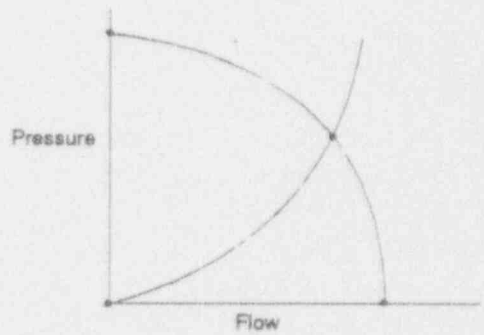
If pump B is started, system flow rate will be __________ and common pump discharge pressure will be __________.

A. the same; higher
B. higher; the same
C. the same; the same
D. higher; higher

FIGURE 1.4-5



Cooling Water System



Centrifugal Pump and System Characteristic Curves

62. In a closed system, the operating conditions for two identical positive displacement pumps running in parallel will be approximately __________ flow rate and approximately __________ discharge pressure as compared to the operating conditions when only one pump is running and the other pump is isolated.

A. the same; twice the
B. twice the; the same
C. the same; the same
D. twice the; twice the

63. Which of the following is not a possible indication of pump runout?

A. abnormally high discharge pressure
B. excessive pump motor current
C. abnormally high pump vibration
D. abnormally high indicated flow rate

64. Explain the concerns associated with operating a centrifugal pump under runout conditions.

65. Which of the following would not be an acceptable definition for pump runout?

A. the volumetric flow rate causing greater than normal currents in the pump motor windings

B. the volumetric flow rate resulting in excessive mechanical stress to the pump shaft

C. the volumetric flow rate resulting in excessive backpressure on the pump discharge

D. the volumetric flow rate for which the available net positive suction head is less than the required net positive suction head

66. A centrifugal pump is operating at maximum design flow, delivering water through two parallel valves. Valve "A" is fully open, and valve "B" is half open. If valve "B" is now also opened fully, the result could be

A. the pump immediately reaching shutoff head

B. available net positive suction head increasing

C. required net positive suction head decreasing

D. runout of the pump

67. What is caused by operating a motor-driven centrifugal pump under runout conditions?

A. pump failure due to excessive pump cavitation

B. no damage, since the pump and motor are designed to operate without failure under pump runout conditions

C. motor failure due to excessive current being drawn through the motor windings

D. pump failure due to overheating, caused by the increased impeller-to-casing friction

68. Which one of the following is an indication of pump runout

A. high discharge pressure
B. low pump motor current
C. high pump vibration
D. low pump flow rate

69. A centrifugal pump is operating at rated conditions in an open system. If a system transient results in the pump operating at runout, which one of the following indications will be present?

A. increased discharge pressure
B. decreased pump motor current
C. increased pump vibration
D. decreased pump flow rate

70. Operating a motor-driven centrifugal pump under "pump runout" conditions causes

A. pump overheating, cavitation, and ultimately pump failure

B. no damage, because the pump and motor are designed to operate without failure under pump runout conditions

C. excessive motor current to be drawn, damage to the motor windings, and ultimately motor failure

D. excessive motor current to be drawn, overheating of pump and motor bearings, and ultimately pump failure

71. If a centrifugal pump is operating at rated conditions, which of the following best describes the pump response when the discharge valve is closed?

A. Discharge pressure increases, flow decreases, motor current decreases.

B. Discharge pressure decreases, flow increases, motor current decreases.

C. Discharge pressure increases, flow increases, motor current increases.

D. Discharge pressure increases, flow decreases, motor current increases.

72. A centrifugal pump is operating at rated conditions in a closed system with all valves fully open. If the pump suction valve is throttled to 50 percent, pump discharge pressure will ______ and flow will ______.

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

73. A centrifugal pump is operating at rated conditions in an open system with all valves fully open. If the pump discharge valve is throttled to 50 perent closed, pump discharge pressure will __________ and pump motor current will __________.

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

74. A motor-driven centrifugal pump is operating in an open system with its discharge valve throttled to 50 percent. How will the pump be affected if the discharge valve is fully opened?

A. Total developed head decreases and motor current decreases.

B. Available net positive suction head decreases, and pump differential pressure decreases.

C. Total developed head increases and available net positive suction head decreases.

D. The potential for pump cavitation decreases, and pump differential pressure decreases.

75. Which of the following is correct for constant speed centrifugal pumps? (Assume an ideal system.)

    A. The flow rate is directly proportional to the square of the pump speed.

    B. As the system head increases, the flow rate increases.

    C. For two pumps in parallel, the combined flow rate for a given head is equal to the sum of the individual capacities of the two pumps at that head.

    D. For two pumps in series, the combined flow rate for a given head is equal to the sum of the individual capacities of the two pumps at that head.

76. Which of the following statements is true concerning characteristics of centrifugal pumps?

    A. The term "shutoff head" is the head developed when the pump is operating at design flow.

    B. Pump flow rate is proportional to pump speed.

    C. Raising the temperature of the fluid to be pumped is an effective method of increasing pump net positive suction head (NPSH).

    D. Cavitation occurs when available NPSH is too high.

77. The formation of vapor bubbles (in the eye of the impeller) and the subsequent collapse of these bubbles (on the trailing edge of the impeller blade) is called

    A. viscosity
    B. slip
    C. shutoff head
    D. cavitation

78. Which of the following actions will correct a cavitating centrifugal pump?

    A. increasing the pump's speed
    B. lowering the pump's suction pressure
    C. lowering the pump's suction temperature
    D. turning the pump off and on a few times

79. Draw and label a typical centrifugal pump and system characteristic curve. Label the curves, axes, and the operating point.

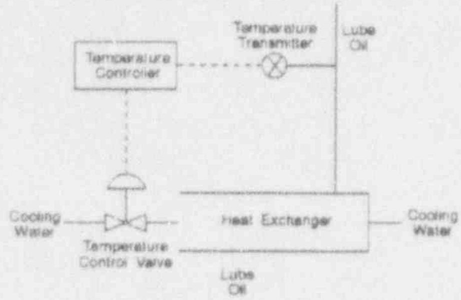
80. Draw and label a typical centrifugal pump and system characteristic curve. Show how the operating point would change if the pump discharge valve is then opened further.

81. Refer to the drawing of a lube oil temperature control system and the associated centrifugal pump operating curve (see Figure 1.4-6).

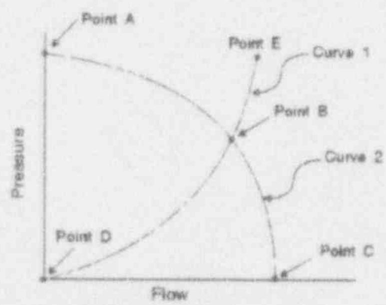
    The pump is operating at point B on the operating curve. If the temperature control valve modulates in the closed direction, operating point B will be located on curve __________, closer to point __________. (The options below assume that curves 1 and 2 are exactly as shown in Figure 1.4-6.)

    A. 1; D
    B. 2; A
    C. 1; E
    D. 2; C

FIGURE 1.4-6



Lube Oil Temperature Control System



Centrifugal Pump and System Characteristic Curves

82. Increasing the flow rate from a centrifugal pump by throttling open the discharge valve will cause pump head to

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

83. 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

84. Which of the following best 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 are used where low flows and extremely high heads are required.

 D. Positive displacement pumps deliver a constant flow over a variety of heads.

85. Which of the following conditions will result in a change in the volumetric flow rate through an ideal positive displacement pump?

 A. a change in pump speed

 B. a change in discharge valve position

 C. a change in pump net positive suction head

 D. a change in downstream system pressure

86. Select the correct statement about a single-speed, motor-driven, centrifugal pump.

A. Upon throttling open the pump discharge valve to increase flow, total developed head and motor amps decrease.

B. When the pump discharge valve is throttled open to increase flow, available net positive suction head decreases, and pump differential pressure decreases.

C. Upon throttling open the pump discharge valve, flow increases, total developed head increases, and available net positive suction head decreases.

D. When the discharge valve is throttled open, flow rate increases, pump cavitation is reduced, and total developed head decreases.

87. A single-speed centrifugal fire pump takes suction on a storage tank and discharges through a flexible fire hose. Which of the following correctly describes the response of the pump discharge flow rate?

A. remain constant as the elevation of the pump discharge piping is raised

B. increase as the elevation of the pump discharge piping is raised

C. decrease as the level in the storage tank on the pump suction is lowered

D. remain constant as the level in the storage tank on the pump suction is lowered

88. A centrifugal pump is operating at rated conditions in an open system with all valves fully open. If the pump suction valve is throttled to 50 percent closed; pump suction pressure will __________ and pump flow rate will __________.

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

89. A centrifugal pump is operating at rated conditions in an open system. If the pump recirculation valve is farther opened, pump discharge pressure will __________ and <u>pump</u> flow rate will __________.

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

90. Failing to provide adequate minimum flow requirements for a centrifugal pump can <u>directly</u> result in

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

91. What is the purpose of a centrifugal pump minimum-flow line?

A. to reduce wear on discharge piping relief valves

B. to prevent overpressurization of pump discharge piping

C. to provide a sampling point for plant chemistry

D. to ensure pump cooling requirements are met at shutoff head

92. What is the primary function/purpose of "minimum flow protection" on a centrifugal pump?

    A. ensure adequate net positive suction head

    B. prevent pump runout

    C. ensure adequate pump cooling

    D. maintain balanced pump casing torque

93. Without "minimum flow" protection, a centrifugal pump that was operated for an extended period of time at shutoff head conditions would

    A. overheat and cavitate

    B. overpressurize and damage the pump's discharge piping

    C. develop an overcurrent condition

    D. have a brake horsepower reduction

94. Centrifugal pumps are susceptible to overheating and cavitation while operating with their discharge valves closed, unless

    A. the pump is steam driven
    B. minimum flow protection is provided
    C. pump seal cooling is provided
    D. the suction valve is also closed

95. The capacity of a positive displacement pump is directly proportional to the

    A. fluid density
    B. motor size
    C. slip ratio
    D. pump speed

96. As the discharge head of a positive displacement pump is increased/raised, the flow rate out of the pump will slowly begin to decrease, due to some liquid backflowing through the internal working clearances of the pump. This phenomena is known as

    A. cavitation
    B. net positive suction head
    C. recirculation ratio
    D. slip

97. The discharge pressure developed by the standby liquid control pumps during injection is primarily a function of the

    A. reactor vessel pressure

    B. rupture point of the discharging piping

    C. rupture point of the pump suction piping

    D. coupling installed between the motor and the pump

98. As an ideal positive displacement pump's discharge head/pressure increases, its discharge flow rate will

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

99. The flow capacity of a positive displacement pump can be increased by increasing

    A. available net positive suction head
    B. pump speed
    C. recirculation ratio
    D. brake horsepower

100. 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.

101. What will occur by operating a positive displacement pump with insufficient net positive suction head?

A. slip
B. decreased pump speed
C. water hammer
D. vapor binding

102. An increase in positive displacement pump speed will cause the available net positive suction head for the pump to

A. decrease due to the decrease in suction pressure

B. increase due to the increase in discharge pressure

C. decrease due to the increase in discharge fluid temperature

D. increase due to the increase in fluid flow

103. 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

104. 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

105. The available 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 discharge pressure

106. The relationship of positive displacement pump speed to available net positive suction head (NPSH) and cavitation can be best described as which of the following?

A. As speed increases, available NPSH and the probability of cavitation increase.

B. As speed increases, available NPSH and the probability of cavitation decrease.

C. As speed increases, available NPSH increases and probability of cavitation decreases.

D. As speed increases, available NPSH decreases and probability of cavitation increases.

107. 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

108. When operating a positive displacement pump, the pump casing might rupture if the pump

A. motor fails to reach normal speed
B. drive shaft fails
C. discharge is clogged
D. cavitates

109. Which of the following best describes what may occur when operating a positive displacement pump with the discharge valve closed?

A. The pump motor could overspeed due to excessive starting current.

B. The pump casing could overheat due to excessive friction between pump components.

C. The pump motor could overheat due to loss of cooling flow.

D. The pump casing could rupture due to excessive back-pressure.

110. During operation of a positive displacement pump, the pump discharge flow path is inadvertently closed off. If the operator did not take action to stop the pump, the pump's

A. casing could rupture
B. motor could overspeed
C. impeller could start slipping
D. drive gears could overheat

111. A positive displacement pump should be started with its suction valve __________ and its discharge valve __________.

A. closed; closed
B. closed; open
C. open; closed
D. open; open

112. The capacity of an ideal reciprocating positive displacement pump depends on

A. the pump's discharge head

B. the pump's speed

C. the length of the pump's suction pipe

D. the height that the pump must force the fluid

113. A system has one operating positive displacement pump in service. A second positive displacement pump is subsequently placed into service. If the pump is in

A. series, the system flow rate doubles and the discharge pressure will remain relatively constant

B. series, the system flow rate and discharge pressure will both double

C. parallel, the discharge pressure will double and system flow rate will remain relatively constant

D. parallel, the system flow rate doubles and the discharge pressure will remain relatively constant

114. A pump that moves liquid by means of a piston within a cylinder that displaces a given volume of fluid for each stroke is a ________ pump.

A. centrifugal
B. jet
C. reciprocating
D. volute

115. Positive displacement pumps are

A. started with the discharge valve shut until the pump comes up to speed

B. started with the discharge valve open to prevent pump/piping damage

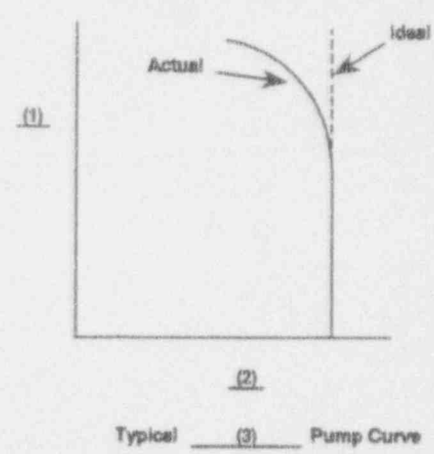
C. typically high-speed, high-capacity pumps

D. typically low-speed, high-capacity pumps

116. Select the choice that best completes the pump curve shown in Figure 1.4-7.

	(1)	(2)	(3)
A.	capacity	head	positive displacement
B.	capacity	head	centrifugal
C.	head	capacity	positive displacement
D.	head	capacity	centrifugal

FIGURE 1.4-7



117. Which of the following contains two reasons for starting a centrifugal pump with the discharge piping filled and the discharge valve shut?

A. prevent pump runout and prevent motor overspeed

B. prevent pump runout and ensure lubrication of pump seals

C. prevent water hammer and ensure adequate pump recirc flow

D. prevent water hammer and prevent excessive starting current

118. Refer to the drawing of a cooling water system (see figure 1.4-8).

The centrifugal pump is circulating water at 200°F. After several hours the water temperature has decreased to 100°F. Assuming system flow rate (gpm) has not changed during the cooldown, pump motor amps will have __________ because __________.

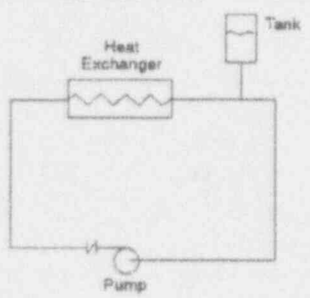
A. decreased; water density has increased

B. increased; water density has increased

C. decreased; pump shaft speed has decreased

D. increased; pump shaft speed has decreased

FIGURE 1.4-8



Cooling Water System

119. A centrifugal pump is operating in parallel with a positive displacement pump in an open system. Each pump has the same design pressure.

If a pump discharge pressure increases to the maximum design pressure of each pump, the centrifugal pump will be operating at __________ flow and the positive displacement pump will be operating at __________ flow.

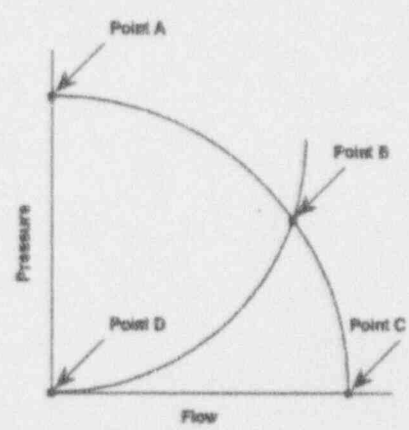
A. minimum; minimum
B. minimum; rated
C. maximum rated; minimum
D. maximum rated; rated

120. Refer to the drawing of a centrifugal pump characteristic curve (see figure 1.4-9).

At which operating point will pump runout occur?

A. Point A
B. Point B
C. Point C
D. Point D

FIGURE 1.4-9



Centrifugal Pump and System Characteristic Curves

121. Which one of the following describes the proper location for a relief valve that will be used to prevent exceeding the design pressure of a positive displacement pump and associated piping?

A. on the pump discharge piping upstream of the discharge isolation valve

B. on the pump discharge piping downstream of the discharge isolation valve

C. on the pump piping upstream of the suction isolation valve

D. on the pump suction piping downstream of the suction isolation valve

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 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 28, part B, chapter 1, page 320.

2. D

Cavitation is defined as the formation and subsequent collapse of vapor bubbles on the pump impeller.

Reference 28, part B, chapter 1, page 320.

3. B

Starting the pump with the discharge valve throttled closed will cause suction pressure also to be slightly higher. This gives greater margin regarding cavitation.

Reference 28, part B, chapter 1, page 320.

4. B

This is the universally accepted description for what causes cavitation damage.

Reference 28, part B, chapter 1, page 320.

5. B

Reference 28, part B, chapter 1, page 320.

6. D

Reference 28, part B, chapter 1, page 320; and reference 58, page 34.

7. C

The common practice for removing air or trapped gases (steam, etc.) from a pump casing is to open the pump 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 40, page 13-10.

8. A

Reference 12.

9. B

Reference 28, part B, chapter 1, page 320.

10. A

Reference 28, part B, chapter 1, page 320.

11. C

Reference 28, part B, chapter 1, page 320.

12. A

Reference 28, part B, chapter 1, page 320.

13. D

Shutoff head is generally defined as the maximum value of head (D/P) that a pump can produce.

Reference 28, part B, chapter 1, page 320.

14. B

Reference 40, pages 2-172 through 2-174.

15. B

Overheating of a pump is a likely consequence of inadequate flow through a pump.

Reference 30, chapter 19.

16. B

Reference 30, chapter 19.

17. D

Reference 30, chapter 19.

18. A

Normal design of pumps often includes a minimum flow recirculation flow path from discharge back to suction through an orifice. This will ensure sufficient flow through the pump to prevent overheating.

Reference 30, chapter 19.

19.

At shutoff head, the pump is unable to overcome downstream pressure, and therefore no flow is produced. However, friction causes the pump and fluid temperature to increase and could lead to overheating and damage to the pump and bearings.

To avoid overheating, some systems incorporate recirculation lines that run from the pump discharge piping to the pump suction or some other point in the system. These recirculation lines allow sufficient flow to prevent overheating.

Reference 78, page 10-43.

20. A

Reference 78, chapter 10, page 43.

21. A

Reference 78, chapter 10, page 43.

22. C

Reference 57, chapter 6.

23. B

Flow is proportional to speed.

$1.5 \times 10^6 \times (2) = 3.0 \times 10^6$ lbm/hr

Reference 57, chapter 6.

24. C

Head is proportional to speed squared.

400 psig $\times (2)^2 =$ 1,600 psig

Reference 57, chapter 6.

25. B

Increased head loss due to the higher flow will prevent flow from doubling.

Reference 57, chapter 6.

26. B

Reference 57, chapter 6.

27. C

Application of pump laws:

Flow is proportional to pump speed.
Pump head is proportional to $speed^2$
Pump power is proportional to $speed^3$.

Reference 57, chapter 6.

28. D

29. B

Speed is proportional to the square root of head and the cube root of power. Therefore:

$(head_1/head_2)^{1/2} = (power_1/power_2)^{1/3}$

$head_2 = [(head_1)^{1/2}/(power_2/power_1)^{1/3}]^2$

$= [(240)^{1/2}/(64)^{1/3}]^2$

$= 15$ psid

Reference 57, chapter 6.

30. B

Head is proportional to speed squared. Therefore:

$head_1/head_2 = (speed_1/speed_2)^2$

$head_2 = (head_1)(speed_2/speed_1)^2$

$= (20 \text{ psid}) (3600/1800)^2$

$= 80$ psid

Reference 57, chapter 6

31. C

Pump speed is proportional to flow and to the cube root of power. Therefore:

$flow_1/flow_2 = (power_1/power_2)^{1/3}$

$power_2 = (power_1)(flow_2/flow_1)^3$

$= (3kW) (400/200)^3$

$= 24$ kW

Reference 57, chapter 6.

32. C

Speed is proportional to flow. Therefore:

$speed_1/speed_2 = flow_1/flow_2$

$flow_2 = (flow_1)(speed_2/speed_1)$

$= 3000 \text{ gpm} (1800/3600)$

$= 1500$ gpm

Reference 57, chapter 6.

33. C

DP is proportional to speed squared. Therefore:

$DP_1/DP_2 = (speed_1/speed_2)^2$

$DP_2 = (DP_1)(speed_2/speed_1)^2$

$= (50 \text{ psid}) 3600/1800)^2$

$= 200$ psid

Reference 57, chapter 6.

34. C

Power is proportional to flow cubed. Therefore:

$power_1/power_2 = (flow_1/flow_2)^3$

$power_2 = (power_1)(flow_2/flow_1)^3$

$= (500 \text{ hp})(1200/1000)^3$

$= 864$ hp

Reference 57, chapter 6.

35. C

Flow is proportional to speed.
Head is proportional to speed squared.
Power is proportional to speed cubed.

$Flow_2 = (Flow_1)(speed_2/speed_1)$
$= (500 \text{ gpm})(3600/1800)$
$= 1000$ gpm

$Head_2 = (Head_1)(speed_2/speed_1)^2$
$= (25 \text{ psi})(3600/1800)^2$
$= 100$ psi

$Power_2 = (Power_1)(speed_2/speed_1)^3$
$= (100 \text{ kW})(3600/1800)^3$
$= 800$ kW

Reference 57, chapter 6.

36. A

Opening valve A raises surge tank level, creating greater static head at the pump suction.

All other choices would decrease available NPSH.

Reference 48, pages 34 through 36.

37. C

Mathematical expression of NPSH is
$P_{suction} - P_{sat}$

Reference 48, pages 34 through 36.

38. D

Available NPSH goes down due to flow increasing and suction pressure decreasing. Required NPSH as specified by the pump manufacturer will increase as flow increases.

Reference 48, pages 34 through 36.

39. 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 78, chapter 10, page 56.

40. B

Reference 78, chapter 10, page 43.

41. A

Loss of feedwater heating will lower the temperature of the water entering the reactor vessel, causing a temperature decrease at the recirculation pump suction. This will increase the margin to saturation, increasing available NPSH.

Reference 57, chapter 7, pages 94 through 97.

42. B

At higher recirculation flow rates, there is greater head loss as the fluid approaches the pump suction. This results in lower suction pressure and reduced NPSH.

Reference 57, chapter 7, pages 94 through 97.

43. B

As pump speed and fluid velocity increase, head loss of the fluid approaching the pump suction increases, causing a reduction in available NPSH.

Reference 78, page 10-55.

44. B

As pump speed and fluid velocity increase, head loss of the fluid approaching the pump suction increases, causing a reduction in available NPSH.

Reference 78, page 10-55.

45. D

One contributor to available NPSH is the static pressure at the pump suction. For a condensate pump, the hotwell level provides this static pressure. A lower level causes a lower pressure and thus a decrease in NPSH.

Reference 78, page 10-55.

46. B

Reference 78, page 10-55.

47. B

Possible pump runout may occur if a pump is started with its discharge open. This could result in an overcurrent/overload condition.

Reference 48, pages 17 through 20.

48. C

Normal response (electrical) to starting a pump is high (momentary, five to six times normal operating current) starting amps, dropping off to a lower equilibrium value.

Reference 48, chapter TS-10, pages 17 through 20.

49. A

Motor amps will decrease due to the pump moving less mass per unit volume. Less work is required to move a less-dense fluid.

Reference 48, page 26.

50. D

Runout would create the greatest current draw by the pump motor.

Reference 48, pages 17 through 20.

51. D

The pump is doing no useful work when running at shutoff head. Therefore, its current is least.

Reference 78, page 86.

52. A

By closing the valve partially, flow is reduced, meaning less work is being done. As a result, current decreases.

Reference 78, page 86.

53. A

Reference 78, page 86.

54. D

Starting a centrifugal pump with its discharge valve closed minimizes starting current in the pump motor.

Reference 57, chapter 7.

55.

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.

56. B

Reference 57, chapter 6.

57. A

Reference 57, chapter 6.

58. B

Reference 57, chapter 6.

59. D

Reference 57, chapter 7, pages 1 through 23.

60. B

The second pump attempts to double the flow. However, the increasing flow causes increased head loss, resulting in a final flow less than double the initial flow.

Reference 78, page 10-46.

61. D

Reference 78, page 10-46.

62. B

Reference 78, page 10-46.

63. A

High discharge pressure is the opposite of what would be seen during runout conditions.

All other answers are possible runout symptoms.

Reference 48, pages 18 through 20.

64.

At runout, a centrifugal pump is operating at a maximum possible flow, typically as a result of reduced downstream pressure. The high flow rate means pump speed, and therefore motor current, are also at a maximum. Thus, not only does the pump experience stress, the motor could be damaged by overheating resulting from the high current drawn.

Reference 78, page 10-44.

65. C

A, B, and D are all definitions of pump runout.

A: Excessive currents are generated in the motor winding to offset the increase in pump speed above its synchronous speed.

B: The pump impeller tries to turn faster than the motor shaft, causing twisting and possible failure.

D: Excessive flow causes a decrease in suction pressure, resulting in a decrease in available NPSH while required NPSH increases.

C is correct because in a runout condition, head pressure is not high but is actually lower than suction pressure.

Reference 78, page 10-44.

66. D

If the pump is already at maximum rated flow, then opening another similarly sized flow path may result in runout.

Reference 48, page 30.

67. C

Reference 78, page 10-44.

68. C

Reference 78, page 10-44.

69. C

Reference 78, page 10-44.

70. C

Reference 78, page 10-44.

71. A

Reference 78, pages 10-41 and 10-49.

72. D

Reference 28, part B, chapter 1, pages 320 through 325.

73. A

Reference 28, part B, chapter 1, pages 320 through 325.

74. B

Reference 28, part B, chapter 1, pages 320 through 325.

75. C

Combined head-capacity curves are drawn by adding the capacities of the pumps operating in parallel.

Reference 57, chapters 4 and 6; and reference 40, pages 239 and 240.

76. B

Reference 57, chapter 6.

77. D

Cavitation occurs when static pressure falls below saturation pressure of the fluid (in the eye of the impeller), causing the liquid to boil and forming thousands of tiny vapor pockets. These vapor pockets are carried downstream to a region of higher pressure (the trailing edges of the impeller blade) where they suddenly collapse.

Reference 57, chapter 6.

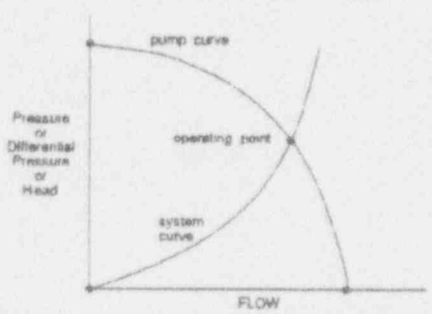
78. C

Lowering the temperature at the pump suction will increase the available NPSH, preventing cavitation.

Reference 57, chapter 6.

79.

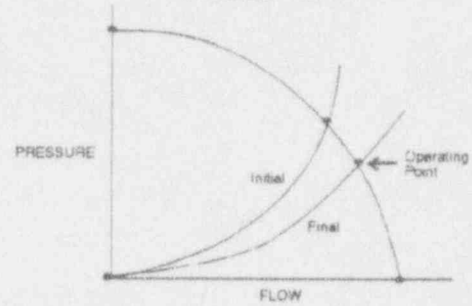
FIGURE 1.4-10



Reference 78, page 10-41.

80.

FIGURE 1.4-11



Reference 78, page 10-41.

81. B

Reference 78, page 10-41.

82. B

Opening the discharge valve reduces pressure at the pump discharge, resulting in lower head.

Reference 28, part B, chapter 1, pages 320 through 325.

83. C

Positive displacement pumps are designed to ensure a set, positive flow rate unless their speed or stroke is changed. Repositioning the discharge valve will change head only.

Reference 28, part B, chapter 1, pages 320 through 325.

84. D

The differences between the characteristic design of each pump is tested.

Positive displacement pumps deliver constant flows regardless of head.

Reference 28, part B, chapter 1, pages 320 through 325.

85. A

Reference 78, chapter 10, page 52.

86. B

A is incorrect because motor amps will increase.
C is incorrect because total developed head decreases.
D is incorrect because pump cavitation is increased.

Reference 78, chapter 10, page 37.

87. C

The pump discharge flow rate depends on the pump head (effectively constant) and the difference in elevation head between the tank level and the discharge hose level. Lowering the tank level reduces the elevation head and therefore the flow rate.

Reference 78, pages 10-4 through 10-6.

88. D

Reference 78, chapter 10.

89. B

Reference 78, chapter 10.

90. D

Reference 57, chapter 6.

91. D

Reference 57, chapter 6.

92. C

Reference 57, chapter 6.

93. A

Reference 57, chapter 6.

94. B

Reference 57, chapter 6.

95. D

Reference 57, chapter 7, page 103.

96. D

Reference 57, chapter 7, page 103.

97. A

Reference 57, chapter 7, page 103.

98. C

Reference 57, chapter 7, page 103.

99. B

Reference 57, chapter 7, page 103.

100. B

Reference 57, chapter 7, page 103.

101. D

Reference 57, chapter 7.

102. 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 pump discharge pressure.
C: NPSH is not a function of discharge fluid temperature.
D: NPSH decreases with increased flow as described for A above.

Reference 40, and reference 57, chapter 6.

103. 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 is incorrect because net positive suction head will decrease 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 40; and reference 57, chapter 6.

104. C

A, B, and D are incorrect because:
A: incomplete -- does not include saturation head
B: minimum NPSH definition
D: differential pressure definition

Reference 40; and reference 57, chapter 6.

105. C

Reference 40; and reference 57, chapter 6.

106. 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 40; and reference 57, chapter 6.

107. C

Reference 40; and reference 57, chapter 6.

108. C

Reference 40; and reference 57, chapter 6.

109. D

A is incorrect because, if anything, the pump will slow down or stall due to the high back pressure.

B is incorrect because friction and heat cannot be generated if the pump components cannot move, or move very slowly due to the high back pressure.

C is incorrect because cooling water flow will not change.

D is correct because the pump will continue to pump the same amount of fluid, pressurizing the discharge line to the closed valve and resulting in an eventual failure of the pump casing.

Reference 40; and reference 57, chapter 6.

110. A

A is correct because of the high internal pressures caused by the continuous pumping of fluid by the PD pump.

B is incorrect since the pump will more likely slow down, if not stop, due to the high resistance to flow.

C is incorrect because there is virtually no fluid slip in a PD pump due to design.

D is incorrect because if the pump stalls or slows down, friction heat will not be generated in the pump drive unit.

Reference 40; and reference 57, chapter 6.

111. D

Reference 57, chapter 6.

112. B

Reference 57, chapter 6.

113. D

Reference 57, chapter 6.

114. C

Reference 57, chapter 6.

115. B

Reference 57, chapter 6.

116. C

Reference 57, chapter 6.

117. D

118. B

119. B

120. C

121. A

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 1,3, 5

Descri[illegible] the conditions associated with pump opera[illegible] that may lead to cavitation in the pum[illegible]

K1.01 Questions 2,4

Identify the processes occurring during pump cavitation.

K1.02 Questions 6, 9, 12

Define the term "gas binding" as it relates to pumps.

K1.02, 1.03 Questions 7, 10, 11

Explain how air binding in a pump is avoided prior to pump start.

K1.02, 1.03 Question 8

Identify the symptoms associated with gas binding in centrifugal pumps.

K1.04, 1.11 Questions 13-17

Describe the conditions associated with pump shutoff head.

K1.04 Questions 18, 19

Explain how centrifugal pumps are protected from shutoff head conditions.

K1.04, 1.11 Question 20, 21

Define "pump shutoff head."

K1.05 Questions 22, 25-28

Discuss relationships among head, flow, speed and power (centrifugal pumps).

K1.05 Questions 23, 24, 29-35

Perform calculations involving pump speed, flow, head, and power.

K1.06 Question 36

Explain how net positive suction head (NPSH) is maintained for centrifugal pumps.

K1.06 Question 37

Define net positive suction head (NPSH).

K1.06 Questions 38-46

Identify the response of a centrifugal pump's available NPSH to changes in fluid parameters.

K1.07 Questions 47, 50

Describe the effects of improper operation of pumps upon motor current.

K1.07 Questions 48, 49, 51, 52, 53, 118

Identify the different responses of motor current when operating a centrifugal pump at various flows and pressures.

K1.08 Questions 54-59, 117

Discuss the reason for starting a centrifugal pump with the discharge valve closed.

PUMPS
Learning Objectives

K1.09 Question 60, 61, 62

Describe the effects of parallel pump operation on flow.

K1.12 Question 63, 64, 67, 68, 69, 70

Identify the conditions associated with pump runout.

K1.12 Question 65

Define pump "runout."

K1.12 Questions 66, 120

Identify those pump operating conditions that may lead to pump runout.

K1.13 Questions 71-78, 119

Explain the principles of operation and characteristics of a centrifugal pump.

K1.13 Questions 79-81

Draw and explain pump and system characteristic curves.

K1.14 Questions 82, 84, 87

Explain the relationship between pump flow and pump head for a centrifugal pump.

K1.14 Questions 83, 85, 86, 88, 89

Describe the operational characteristics of various types of pumps related to flow and suction head.

K1.15 Questions 90-91

Explain the purpose of pump minimum flow requirements (centrifugal pumps).

K1.15 Questions 92-94

State why "minimum flow protection" is provided for centrifugal pumps.

K1.16 Questions 95-100

State the characteristics of a positive displacement pump.

K1.17 Question 101

Describe the consequences of operating a positive displacement pump with inadequate net positive suction head.

K1.17 Questions 102, 103

Describe the effect of fluid parameters on the available net positive suction head of a positive displacement pump.

K1.17 Question 104, 105

Define available net positive suction head.

K1.17 Questions 106, 107

Describe the relationship of positive displacement pump speed to available NPSH and cavitation.

K1.18, 1.20, 1.21 Questions 108-111, 121

Describe a consequence of operating a positive displacement pump against a closed flowpath.

K1.19 Questions 112-116

Explain the functions and characteristics of positive displacement pumps.

MOTORS AND GENERATORS
Questions

1. All of the following are indications of a locked motor-driven pump rotor <u>except</u>

   A. pump discharge pressure drop

   B. high motor current with possible breaker trip

   C. decreased flow in affected system

   D. leakage through pump seals

2. If a locked rotor occurred with a motor-driven pump, motor amps will change. Which of the following best describes how and why the affected pump motor amps change?

   A. increase due to mechanical binding load

   B. increase due to the increase in counter electromotive force (CEMF)

   C. decrease due to the decrease in pump flow

   D. decrease due to the increase in counter electromotive force (CEMF)

3. A locked motor-driven pump rotor can be differentiated from a sheared rotor primarily by

   A. system flow indications
   B. pump ammeter indications
   C. system differential temperatures
   D. pump discharge pressure indications

4. Which of the following best describes the pump motor current response to a locked rotor event?

   A. increase
   B. decrease
   C. remains the same
   D. fluctuates

5. If a locked rotor occurs on an operating motor-driven pump, motor amps will

   A. increase due to the decreased pump flow

   B. increase due to the increased mechanical load

   C. decrease due to the decreased pump flow

   D. decrease due to the increased mechanical load

6. Which of the following best describes the initial response to a sheared motor-driven pump rotor?

   A. decreased pump suction pressure
   B. increased pump discharge temperature
   C. loss of system inventory
   D. decreased pump motor current

7. Which of the following is <u>not</u> a consequence of motor and generator electrical insulation overheating?

   A. discoloration of parts
   B. blown fuses
   C. increased insulation impedance
   D. electrical grounds

8. Which of the following consequences may result from motor and generator electrical insulation overheating?

   A. increased cable resistance
   B. decreased equipment life
   C. increased insulation impedance
   D. decreased power interruptions

9. Decreased motor and generator bearing life may result from

   A. overheating
   B. overvoltage
   C. under-excitation
   D. nominal loading

10. Excessive motor currents can be caused by

    A. overvoltage
    B. undervoltage
    C. low motor load
    D. low ambient temperatures

11. Excessive A.C. motor currents cannot 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

12. Which of the following is not a cause of excessive motor current?

    A. undervoltage
    B. overload
    C. mechanical binding
    D. low ambient temperatures

13. A positive displacement pump with a three-phase AC induction motor is operating to maintain 1600 psig in a hydraulic fluid system. If the voltage supplied to the pump motor is slowly reduced by 20 percent, the pump motor current will __________ and motor winding temperature will __________. (Assume the motor does not stall.)

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

14. If the real load supplied by an A.C. generator in an isolated system is held constant while voltage is decreased, the current supplied by the generator will

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

15. Excessive A.C. generator currents can be caused by

    A. overvoltage
    B. undervoltage
    C. overloading
    D. all of the above

16. 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

17. Centrifugal pump motor current will ________ as pump speed is increased to double the flow rate.

    A. remain constant
    B. increase by a factor of two
    C. increase by a factor of four
    D. increase by a factor of eight

18. Given the following conditions for a variable-speed motor-driven centrifugal pump:

    Flow rate = 2000 gpm
    Motor current = 100 amperes

    If the flow rate is increased to 4000 gpm, which one of the following motor current values most closely approximates the actual value?

    A. 200 amperes
    B. 400 amperes
    C. 800 amperes
    D. 1600 amperes

19. A centrifugal pump has a flow rate of 3,000 gpm and a current requirement of 200 amperes. If the speed is reduced such that the flow rate is 2,000 gpm, what is the final current requirement at the new lower speed?

    A. 59 amperes
    B. 89 amperes
    C. 133 amperes
    D. 150 amperes

20. A centrifugal pump is operating at 600 rpm with the following parameters:

    current = 10 amperes
    pump head = 50 psi
    pump flow rate = 880 gpm

    What will be the new value of pump head if speed is increased such that the current requirements are now 640 amperes?

    A. 600 psi
    B. 800 psi
    C. 750 psi
    D. 1,200 psi

21. Assuming pump flow remains constant, an increase in the stator temperature of a centrifugal pump motor will cause the motor current requirement to

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

22. Assuming pump flow and applied voltage remain constant, an increase in the stator temperature of an operating centrifugal pump motor will cause the motor current to

    A. increase because stator resistance increases

    B. increase because stator resistance decreases

    C. decrease because stator resistance increases

    D. decrease because stator resistance decreases

23. A centrifugal pump has been running at an elevated temperature due to insufficient 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

24. Starting current in a large A.C. 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

25. The average starting current for an alternating current motor is approximately __________ its normal running current.

    A. the same as
    B. two to three times
    C. five to six times
    D. ten to fifteen times

26. Which one of the following describe the motor current indications that would be observed during the start of a large AC motor-driven centrifugal pump with a closed discharge valve?

    A. Current immediately increases to the full-load value and gradually decreases to the no-load value over several minutes.

    B. Current rapidly increases to the no-load value over several seconds and stabilizes.

    C. Current immediately increases to many times the no-load value and then rapidly decreases to the value after several seconds.

    D. Current immediately increases to many times the no-load value and then gradually decreases to the no-load value after several minutes.

27. High induced rotor currents due to maximum slip, and amps five to six times normal full-load running current, describe the response of a large A.C. 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

28. Which of the following best describes the ammeter response during the normal start of a large A.C. motor-driven centrifugal pump? Assume discharge valve is closed.

    A. The amps will stay on scale (because motor start is the basis for range selection) and then return to the no-load value.

    B. The amps will go offscale high and then return to the no-load value as the pump comes up to speed.

    C. The amps will rise to the full-load value and then return to the no-load value as the pump comes up to speed.

    D. The amps will go offscale high and then return to the full-load value because the pump is operating at shutoff head.

29. Explain why a limit exists on the frequency of starts of large A.C. induction motors.

30. 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

31. 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 shaft torque is generated during motor startup

    C. starting currents usually exceed the amperage rating of the supply bus

    D. the starting torque increases bearing wear

32. 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 during repeated motor starts.

    B. Running current is much higher than starting current.

    C. Limiting the number of starts increases the life of the motor.

    D. Limiting the number of starts decreases the possibility of insulation failure during motor startup.

33. Which of the following best explains the 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. The technical manual imposes this restriction.

    D. This practice prevents overheating of windings.

34. 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 voltage supply to the motor during full-load operation

    D. decreasing the number of stator poles during the start sequence

35. For large electric motors, why must the number of starts over a period of time be limited?

    A. protect the power supply cables from insulation breakdown due to high starting current

    B. protect the motor windings from overheating

    C. prevent motor thrust-bearing damage due to lack of lubrication

    D. prevent rotor seizure due to thermal expansion of the windings

36. The frequency of large AC motor starts should be limited to prevent excessive

    A. torsional stresses on the motor shaft.

    B. wear of pump thrust bearings.

    C. arcing and degradation of motor breaker contacts.

    D. heat buildup within the motor

37. The term "volt" refers to

    A. electrical potential difference
    B. electron flow
    C. electron magnitude
    D. power transfer

38. A difference in electrical potential is measured in what units?

    A. amperes
    B. volts
    C. ohms
    D. volt-amps reactive

39. The term "amperes" refers to the flow of

    A. neutrons
    B. neutrinos
    C. electrons
    D. protons

40. A flow of electrons is measured in what units?

    A. volt-amps reactive
    B. ohms
    C. volts
    D. amperes

41. Current that is continually oscillating above and below electrical zero is called

    A. rectified current
    B. direct current
    C. alternating current
    D. applied current

42. Current that flows from point A to point B continuously is called

    A. direct current
    B. dielectric current
    C. distributed current
    D. divisional current

43. Frequency is measured in units of

    A. volts
    B. amps
    C. waves
    D. hertz

44. Hertz is a unit of

    A. resistance
    B. current
    C. frequency
    D. voltage

45. A generator is paralleled to the grid with excitation that produces no reactive power. Which of the following statements correctly states the effect of lowering the output voltage controls?

	Generator Excitation	Power Factor
A.	overexcited	leading
B.	underexcited	lagging
C.	underexcited	leading
D.	overexcited	lagging

46. A generator is paralleled to the grid with excitation that produces no reactive power. Which of the following statements correctly states the effect of raising the output voltage controls?

	Generator Excitation	Power Factor
A.	overexcited	leading
B.	underexcited	lagging
C.	underexcited	leading
D.	overexcited	lagging

47. Which of the following correctly describes the effects on generator excitation with the generator paralleled to the grid?

    A. Increasing field current increases excitation and shifts power factor from lagging toward leading.

    B. Increasing field current increases excitation and shifts power factor from leading toward lagging.

    C. Decreasing field current increases excitation and shifts power factor from leading toward lagging.

    D. Decreasing field current increases excitation and shifts power factor from lagging toward leading.

48. Which of the following statements correctly describes how a generator paralleled to the grid with no reactive load can be adjusted to supply VARs out?

    A. Decrease excitation and shift to a leading power factor.

    B. Increase excitation and shift to a lagging power factor.

    C. Decrease excitation and shift to a lagging power factor.

    D. Increase excitation and shift to a leading power factor.

49. A generator is paralleled to the grid; its real power (MWe) is constant, and its reactive power (MVAR) is indicating VARs out. Decreasing the generator excitation has which of the following effects?

    A. apparent power decreases, reactive power increases

    B. apparent power increases, reactive power increases

    C. apparent power decreases, reactive power decreases

    D. apparent power increases, reactive power decreases

50. The main generator is connected to the grid. Which of the following characteristics will an underexcited generator exhibit?

    A. negative megavars (VARs in) and a leading power factor

    B. positive megavars (VARs out) and a leading power factor

    C. positive megavars (VARs out) and a lagging power factor

    D. negative megavars (VARs in) and a lagging power factor

51. A main generator that is operating on the grid has the following indications

    100 MWe
    0 MVAR
    2,900 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

52. The main generator is operating on the grid with the following indications

    100 MWe
    100 MVAR (VARs out)
    2,800 amps

    If main generator excitation is increased slightly, amps will __________ and MWe will __________.

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

53. The main generator is connected to the grid with VARs out (positive VARs). Increasing main generator excitation will cause main generator current to __________ and main generator VARs to __________.

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

54. A 24,000 VAC generator is operating at 800 MWe, 20,700 amperes, and a negative 325 MVAR (VARs in). What is the power factor.

    A. 0.93 leading
    B. 0.93 lagging
    C. 0.81 leading
    D. 0.81 lagging

55. A 4160 volt diesel generator (D/G) is loaded to 2850 kW with a 0.85 lagging power factor. What is the kVAR load on the D/G?

    A. 3353 kVAR
    B. 2850 kVAR
    C. 1766 kVAR
    D. 503 kVAR

56. The force that causes electrons to flow in an electrical circuit is called:

    A. current
    B. power
    C. resistance
    D. voltage

57. A diesel generator (D/G) is the only power source supplying an electrical bus. If D/G frequency is increased from 60 to 60.5 Hertz, then D/G kW will be __________ and D/G amps will be __________. (Disregard the effect of the frequency change on individual loads.)

    A. the same; higher
    B. the same; the same
    C. higher; higher
    D. higher; the same

58. A 125 volt DC load is rated at 10 kW. What is the current rating of the load?

    A. 8.9 amps
    B. 46.2 amps
    C. 80.0 amps
    D. 138.6 amps

59. A motor-driven centrifugal pump exhibited indications of pump failure while being started. Which one of the following pairs of indications will occur if the pump failure is a sheared impeller shaft?

    A. Excessive duration of high starting current and motor breaker trips.

    B. Excessive duration of high starting current and no change in system flow rate.

    C. Lower than normal running current and motor breaker trips.

    D. Lower than normal running current and no change in system flow rate.

60. Continuous operation of a motor at rated load with a loss of required cooling to the motor windings will eventually result in:

    A. cavitation of the pumped fluid

    B. failure of the motor overcurrent protection devices

    C. breakdown of the motor insulation and electrical grounds

    D. phase current imbalance in the motor and overspeed trip actuation

MOTORS AND GENERATORS
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. D

A locked rotor would <u>not</u> typically cause seal failure.

Reference 39, page 193.

2. A

A locked rotor will cause pump amps to increase as the mechanical (binding) load causes the rotor speed to decrease.

Reference 39, page 193.

3. B

System response to a sheared or locked rotor event will be the same. The primary indicator will be the effect on pump amps. If the rotor shears, the motor amps decrease to a minimum. If the rotor locks, motor amps will increase.

Reference 39, page 193.

4. A

A locked rotor will cause pump amps to increase as the mechanical (binding) load causes rotor speed to decrease.

Reference 39, page 193.

5. B

Reference 39, page 193.

6. D

Removing the load on the motor results in less current being drawn.

Reference 39, page 193.

7. C

Overheating of equipment results in decreased equipment life due to the physical breakdown of any insulation material. Degeneration of the insulating material could lead to grounds or shorts.

Reference 71, chapter 3, pages 1, 3, and 16; and reference 64, page 72.

8. B

Overheating of equipment results in decreased equipment life due to the physical breakdown of any insulation material.

Reference 71, chapter 3, pages 1, 3, and 16; and reference 64, page 72.

9. 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 71, chapter 9, pages 1, 9, and 47; and reference 64, page 72.

10. B

An undervoltage condition will cause excessive current because in order to supply a constant torque (load), current must increase as voltage decreases.

Reference 39, page 194.

11. 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 39, page 194.

12. D

The causes of excessive motor current are undervoltage, overload and mechanical binding.

Reference 39, page 194.

13. D

Reference 39, page 194.

14. C

By the definition of real power, a decrease in voltage must be accompanied by an increase in current.

Reference 64, page 124.

15 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 21, chapter 5.

16. D

flow α speed

head α speed squared

power α speed cubed α current

Reference 78, chapter 10, page 36; and reference 02, page 10.

17. D

speed α flow

$speed^3$ α power α current

$current_2 = current_1 \; (flow_2)^3/(flow_1)^3$

Assuming initial flow rate is 1 and initial current is 1 then

c' ent$_2$=(1) $(2)^3 / (1)^3$

$current_2 = 8$

Reference 78, chapter 10, page 36; and reference 02, page 10.

18. C

Current is proportional to speed (and therefore flow) cubed.

$current_2 = current_1 \; (flow_2)^3/(flow_1)^3$
$= (100 \text{ amp}) \; (4000)^3/(2000)^3$
$= 800 \text{ amp}$

Reference 78, page 10-36

19. A

power α current

pump flow α pump speed

$current_2 = current_1\ (speed_2)^3 / (speed_1)^3$

$current_2 = current_1\ (flow_2)^3 / (flow_1)^3$

$current_2 = 200\ amp\ (2000\ gpm)^3 / (3000\ gpm)^3$

$current_2 = 59$ amperes

Reference 78, chapter 10, page 36; and reference 02, page 10.

20. B

$current_2 = current_1\ (speed_2)^3 / (speed_1)^3$

$speed_2^3 = [(current_2)\ (speed_1)^3] / (current_1)$

$speed_2^3 = [(640)\ (600)^3] / (10)$

$speed_2 = 2{,}400$ RPM

$head_2 = head_1\ (speed_2)^2 / (speed_1)^2$

$head_2 = 50\ psi\ (2{,}400)^2 / (600)^2$

= 800 psi

Reference 78, chapter 10, page 36; and reference 02, page 10.

21. A

As temperature of copper wire located in stator rises, the resistance of the stator rises. This will produce heating in the stator requiring non-useful power to be produced to further accommodate the increased heating load.

22. C

23. B

24. C

Observed/measured parameter.

Reference 39, page 194.

25. C

Reference 39, page 194.

26. C

Starting current is typically five or six times the full-load rated current.

Reference 39, page 194.

27. A

Motor starting currents are typically five to six times full-load current with maximum (100%) slip.

Reference 39, page 194.

28 B

Motor starting currents are typically five to six times full-load current (2/3 of meter range). Therefore, amps will go off scale high and then return to the no-load value since the pump is operating at shutoff head.

Reference 39, page 194.

29.

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.

30. C

Because starting current is five to six times higher than normal running current, excessive heating of windings will result due to I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist, increasing the overheating problem.

Reference 39, page 194; and reference 72, chapter 4, page 20.

31. A

Because starting current is five to six times higher than normal running current, excessive heating of windings will result due to I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist, increasing the overheating problem.

Reference 39, page 194; and reference 72, chapter 4, page 20.

32. B

Starting current is five to six times greater than normal running current.

Reference 39, page 194; and reference 72, chapter 4, page [illegible].

33. D

Because starting current is five to six times higher than normal running current, excessive heating of windings will result due to I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist, increasing the overheating problem.

Reference 39, page 194; and reference 72, chapter 4, page 20.

34. B

Because starting current is five to six times higher than normal running current, excessive heating of windings will result due to I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist, increasing the overheating problem.

Reference 39, page 94; and reference 72, chapter 4, page 20.

35. B

Because starting current is five to six times higher than normal running current, excessive heating of windings will result due to I^2R losses in windings. As windings increase in temperature, increased starting current requirements will exist, increasing the overheating problem.

Reference 39, page 94; and reference 72, chapter 4, page 20.

36. D

Reference 39, page 94; and reference 72, chapter 4, page 20.

37. A

A volt is a difference in potential.

Reference 47.

38. B

A volt is a difference in potential.

Reference 47.

39. C

The term "amp" refers to the number of electrons passing a point per given time.

Reference 47.

40. D

The term "amp" refers to the number of electrons passing a point per given time.

Reference 47.

41. C

Reference 47.

42. A

None of the other "D" word answers describes current flowing at a constant magnitude.

Reference 47.

43. D

"Cycles per second" is not offered as a possible answer.

Reference 47.

44. C

"Hertz" does not apply to resistance, current, or voltage.

Reference 47.

45. C

Lowering voltage controls causes underexcitation and a leading power factor.

Reference 34, chapter 7, page 62a.

46. D

Raising output voltage controls increases reactive load by going to the overexcited state and producing a lagging power factor.

Reference 34, chapter 7, page 62a.

47. B

Decreasing field current decreases excitation, eliminating "C" and "D."

Increasing field current increases excitation, shifts toward lagging power factor, eliminating "A."

Reference 34, chapter 7, page 62a.

48. B

In the overexcited region, lagging power factor supplies positive VARs.

Reference 34, chapter 7, page 60.

49. C

Decreasing excitation decreases reactive load, eliminating "A" and "B."

Decreasing reactive load while maintaining real load constant causes a reduction in apparent power due to the Pythagorean relation in the power triangle, eliminating "D," leaving "C."

Reference 34, chapter 7, page 60.

50. A

Reference 34, chapter 7, page 60.

51. D

Any change in excitation will change generator current. When excitation is reduced the machine is increasing under excitation, therefore, current increases. Changing the excitation has little effect on real power.

Reference 34, chapter 7.

52. D

Increasing excitation causes generator to increase overexcitation, therefore increasing current. Changing excitation has little effect on real power.

Reference 34, chapter 7.

53. B

Same as above. Reactive power increases with increase in overexcitation.

Reference 34, chapter 7, page 60.

54. A

PF = Real Power/Apparent Power
$AP = \sqrt{3}$ x Amps x Volts
Negative VARs (VARs in) indicates a leading power factor.

Reference 34, chapter 7.

55. C

PF = Real Power/Apparent Power
AP = Real Power/Power Factor
AP = 2850/.85
AP = 3352 MVA
$AP = \sqrt{P^2 + Q^2}$
$Q^2 = AP^2 - P^2$
$Q = \sqrt{(3353)^2 - (2850)^2}$
Q = 1766 kVAR

Reference 34, chapter 7.

56. D

57. B

58. C

59. D

60. 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 1,2,4,5

State the indications of a locked motor-driven pump rotor.

K1.01 Questions 3,6

Differentiate between the indications of a locked motor-driven pump rotor and a sheared rotor.

K1.02 Questions 7-9, 60

Identify the potential consequences of overheating motor and generator electrical insulation.

K1.03 Questions 10-13

State the causes of excessive current in motors.

K1.03 Questions 14,15

State the causes of excessive current in generators.

K1.04 Questions 16, 18-20

Calculate the relationship that exists between centrifugal pump motor current and the following associated parameters.

1) pump fluid flow rate
2) pump head
3) pump speed

K1.04 Questions 17, 21-23

Identify the relationship that exists between centrifugal pump motor current and the following associated parameters.

1) pump fluid flow rate
2) pump head
3) pump speed
4) stator temperature

K1.05 Questions 24-28, 59

Identify the observed indication differences between starting and running current in a motor.

K1.06 Questions 29-36

Identify the reasons for limiting the number of motor starts allowed in a given time period.

K1.07 Questions 37, 38, 56

Define the term "volt."

K1.07 Questions 39, 40

Define the term "ampere."

K1.07 Question 41

State the definition of "alternating correct."

K1.07 Question 42

State the definition of "direct current."

K1.07 Questions 43, 44

Define the term "hertz."

K1.08, 1.09 Questions 45-55

Describe the effect of changing the excitation of a generator paralleled to the grid on its reactive loading.

K1.07 Questions 57, 58

Interrelationships of the following: VARs, watts, amps, volts, power factor.

HEAT EXCHANGERS AND CONDENSERS
Questions

1. As steam (shell) and liquid (tube) heat exchangers are put into service, the

   A. steam side is valved in before the water side to minimize scale buildup on the heat exchanger tubes

   B. steam side is valved in before the water side to ensure that the cooldown rate does not exceed 100°F/hr

   C. water side is valved in before the steam side to ensure adequate venting

   D. water side is valved in before the steam side to prevent thermal shock from occurring

2. When placing a heat exchanger in service, care must be taken to introduce both fluids gradually to

   A. prevent excessive thermal stresses in the heat exchanger

   B. maximize heat exchanger efficiency

   C. minimize fouling of the heat exchanger tubes

   D. provide maximum control of cooling water outlet temperture

3. Whenever possible, a heat exchanger should be placed in service by introducing both fluids gradually and simultaneously to

   A. minimize 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. maximize temperature control of the system being cooled

4. An improperly filled and vented heat exchanger can result in which of the following problems?

   A. increased heat transfer surface area
   B. reduced tube fouling
   C. increased ΔT from inlet to outlet
   D. reduced ability to transfer heat

5. A reduction in a heat exchanger's ability to transfer heat may be a consequence of

   A. improper filling and venting

   B. pressure fluctuations in the system

   C. opening the heat exchanger inlet valve before the outlet valve

   D. a cracked tube

6. A liquid-to-liquid heat exchanger containing trapped air on the shell side will be less efficient because the air

   A. causes more turbulent fluid flow

   B. increases the differential temperature across the tubes

   C. reduces heat transfer surface area

   D. causes pressure oscillations

7. The proper filling and venting of a shell and tube heat exchanger results in

   A. reduced fouling of the tubes
   B. higher pressure on the shell side
   C. minimum flow through the shell
   D. elimination of trapped air

8. Poor heat exchanger efficiency may be the result of

   A. tube wall thinning
   B. improper filling and venting
   C. increased ΔT across the tube surface
   D. turbulent flow in the tubes

9. Why is proper venting of a shell-and-tube heat exchanger important?

   A. An air bubble reduces the heat transfer coefficient of the heat exchanger.

   B. An air buble causes pressure transients within the tubes as heat load changes.

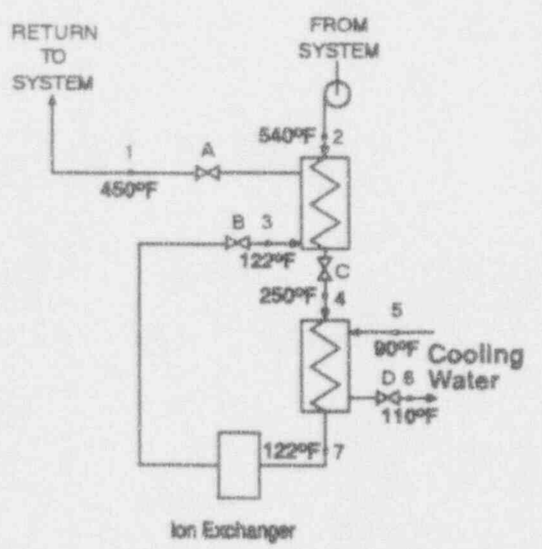
   C. An air bubble will cause thermal shock as it moves through the heat exchanger.

   D. An air bubble will cause corrosion in the heat exchanger.

10. 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, closed
    D. D, closed

FIGURE 1.6-1



Water Cleanup System

11. Refer to Figure 1.6-1 for the following question:

    Valves A, B, and C are fully open. Valve D is 20 percent open. All temperatures are as shown. Valve D is then quickly opened to 100 percent. The temperature at point

    A. 3 will increase
    B. 4 will increase
    C. 5 will decrease
    D. 7 will decrease

12. 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 <u>lower</u> the temperature at point 7, the operator should adjust valve ____ in the open direction.

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

13. The direction of heat transfer between two fluids is

    A. determined by fluid speed

    B. from the lower viscosity fluid to the higher viscosity fluid

    C. dependent upon the type of heat exchange

    D. from the higher temperature fluid to the lower temperature fluid

14. Given the formula, $\dot{Q}_{core} = \dot{m}_{core}(h_{out} - h_{in})$, which of the following causes the initial change in heat transfer rate from the core during a minor (3%) steamline break?

A. h_{out} decreases
B. h_{out} increases
C. $\dot{m}_{core}$ decreases
D. $\dot{m}_{core}$ increases

15. The rate of heat transfer between two liquids in a heat exchanger will be increased if the: (Assume single-phase conditions and a constant specific heat capacity.)

A. temperature of both liquids is decreased by 20°F

B. temperature of both liquids is increased by 20°F

C. flow rate of the colder liquid is decreased by 10%

D. flow rate of the hotter liquid is increased by 10%

16. Refer to the drawing of a water cleanup system (Figure 1.6-1).

Valves A, B, and D are fully open. Valve C is 20% open. all temperatures are as shown. Valve C is then opened to 50%. How will the temperature at points 3 and 6 be affected?

	Point 3	Point 6
A.	Increase	Increase
B.	Decrease	Increase
C.	Increase	Decrease
D.	Decrease	Decrease

17. Which of the following would <u>increase</u> the system fluid's temperature downstream of a heat exchanger?

A. Increase cooling water flow rate to the system's heat exchanger.

B. Increase system bypass flow around the heat exchanger.

C. Reduce cooling water bypass flow around the heat exchanger.

D. Reduce the temperature of the cooling water supplied to the heat exchanger.

18. Which of the following would <u>reduce</u> the system fluid's temperature downstream of a heat exchanger?

A. Increase system bypass flow around the heat exchanger.

B. Increase the speed of the system's pump.

C. Increase the flow rate of cooling water to the heat exchanger.

D. Increase system net positive suction head.

19. If the flow rate of cooling water to a heat exchanger remains constant, and the system's heat exchanger bypass valve is throttled open an additional two turns, the temperature of the fluid in the system will

A. increase to a new higher value

B. increase temporarily, then return to the initial value

C. decrease to a new lower value

D. decrease temporarily, then return to the initial value

20. Decreasing the temperature of a cooled system using a shell-and-tube heat exchanger is normally accomplished by

   A. increasing the cooling system flow
   B. increasing the cooled system flow
   C. decreasing the cooling system flow
   D. decreasing the cooled system flow

21. A counterflow lube oil cooler is in operation. Oil is cooled from 110 °F to 100 °F; cooling water flows at 16,667 lbm/ hr to cool the oil and rises in temperature from 70 °F to 100 °F. The cooling water flow is then reduced to one-half of its former value. Indicate whether each of the following will increase, decrease or remain the same. (Assume cooling water inlet temperature remains the same.)

	Lube Oil Outlet Temperature	Lube Oil Inlet Temperature	Cooling Water Outlet Temperature
A.	Increase	Decrease	Increase
B.	Decrease	Increase	Decrease
C.	Increase	Increase	Increase
D.	Remain the Same	Remain the Same	Remain the Same

22. If the temperature of the fluid in a flowing system increases while volume flow rate remains constant, the mass flow rate will

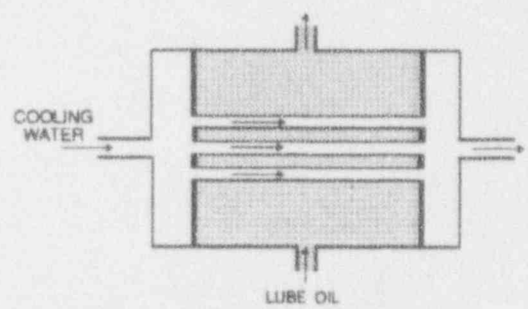
   A. increase
   B. decrease
   C. remain constant
   D. fluctuate

23. Refer to the drawing of a lube oil heat exchanger (Figure 1.6-2).

   Considering a lube oil heat exchanger for which the inlet oil and inlet cooling water temperatures are constant, decreasing the oil flow rate through the heat exchanger will cause the oil outlet temperature to __________ and the cooling water outlet temperature to __________.

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

FIGURE 1.6-2



Lube Oil Heat Exchanger

24. Refer to the drawing of a lube oil heat exchanger (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 __________.

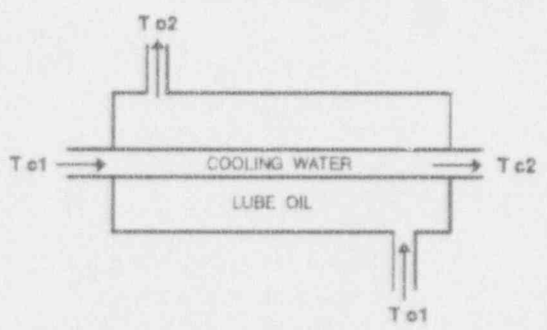
   A. increase; increase
   B. increase; decrease
   C. decrease; increase
   D. decrease; decrease

25. Using the information provided below, and referring to Figure 1.6-3, determine the approximate differential temperature (ΔT) of the cooling water in this counterflow lube oil heat exchanger.

$\dot{Q}_{oil} = 9.9 \times 10^5$ BTU/hour
$C_p oil = 1.1$ BTU/lbm - °F
C_p water = 1.0 BTU/lbm - °F
$T_{o_1} = 170$ °F
$T_{o_2} = 120$ °F
$\dot{m}_{oil} = 1.8 \times 10^4$ lbm/hour
$\dot{m}_{water} = 1.65 \times 10^4$ lbm/hour

A. 45 °F
B. 50 °F
C. 55 °F
D. 60 °F

FIGURE 1.6-3



Counterflow Lube Oil Heat Exchanger

26. A counterflow heat exchanger has a heat transfer rate of 1.0×10^7 BTU/hour and inlet and outlet fluid temperatures of 170 °F and 134 °F, respectively. The specific heat capacity of the fluid is known to be 1.0 BTU/lbm - °F. Determine the approximate mass flow rate of the fluid.

A. 5.9×10^4 lbm/hour
B. 7.4×10^4 lbm/hour
C. 2.8×10^5 lbm/hour
D. 1.0×10^7 lbm/hour

27. 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

28. A severe stress in a mechanical component, induced by a sudden, unequally distributed temperature reduction, is a description of

A. heat stress
B. thermal shock
C. thermal strain
D. heat strain

29. Which of the following will result in thermal shock to a pressure vessel?

A. vessel "soak"
B. rapid change in temperature
C. rapid change in power
D. rapid change in flow

30. The major thermodynamic concern resulting from rapidly cooling a pressure vessel is

A. loss of subcooling margin
B. condensation
C. loss of shutdown margin
D. thermal shock

31. The reactor is shutdown at 400°F with all control rods fully inserted. The major adverse consequence resulting from rapidly reducing the reactor coolant/moderator temperature is

    A. excessive stress in the ceramic fuel pellets of the reactor core

    B. excessive stress on pressure vessel wall

    C. uncontrolled reactor criticality

    D. loss of subcooling

32. Steam has been admitted to a condenser for 25 minutes with no cooling water during a condenser startup. Initiating cooling water at this time will

    A. reduce the stress on the shell of the heat exchanger by gradually warming the shell

    B. reduce the stress on the tubes of the heat exchanger by gradually warming the tubes

    C. induce rapid thermal stresses on the welds joining the tubes to the tubesheet

    D. induce rapid thermal stresses on the shell of the heat exchanger

33. Condensers are heat exchangers that are designed to remove which of the following types of heat?

    A. latent and sublimation heat
    B. sensible and sublimation heat
    C. latent and sensible heat
    D. sensible heat only

34. Which one of the following does not affect condenser vacuum?

    A. turbine speed
    B. non-condensable gas buildup
    C. circulating water temperature
    D. air in-leakage

35. Condenser vacuum is affected by changes in circulating water temperature, air inleakage, and circulating water flow. For the following indicated changes in these three parameters, how does condenser vacuum respond?

	Circulating Water Temperature Increases	Air Inleakage Decreases	A Circulating Water Pump Is Stopped
A.	increases	decreases	decreases
B.	decreases	increases	decreases
C.	decreases	increases	increases
D.	decreases	decreases	decreases

36. Which of the following is not a function of a plant's main condenser?

    A. condense turbine exhaust steam for reuse

    B. provide a heat sink for circulating water

    C. reduce back pressure at turbine exhaust to improve overall plant thermal efficiency

    D. deaerate condensate to ensure low levels of dissolved oxygen

37. Which of the following changes will decrease subcooling of the condensate water?

    A. isolate one bay of the condenser circulating water system

    B. decrease circulating water temperature

    C. increase circulating water flow

    D. decrease the main turbine generator megawatt load

38. During normal reactor operation, a main condenser develops an air leak which decreases vacuum at a rate of 1 in Hg/min. Which of the following would increase because of this condition?

    A. extraction steam flow rate
    B. condensate hotwell temperature
    C. LP turbine exhaust steam moisture content
    D. steam cycle efficiency

39. A condenser vacuum indication of 26" Hg vacuum corresponds to a condenser absolute pressure value of approximately

    A. 0" Hg
    B. 4" Hg
    C. 26" Hg
    D. 30" Hg

40. A condenser absolute pressure of 4" Hg corresponds to a condenser vacuum of approximately

    A. 0" Hg vacuum
    B. 6" Hg vacuum
    C. 26" Hg vacuum
    D. 30" Hg vacuum

41. During full power plant operations, a small air leak occurs in the main condenser(s), which causes condenser vacuum to begin to degrade. As condenser vacuum degrades, condenser absolute pressure will

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

42. During full power plant operations, a small air leak occurs in the main condenser(s), which causes condenser absolute pressure to begin to increase. As condenser absolute pressure increases, condenser vacuum will

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

43. Condenser vacuum is approximately ______ when condenser absolute pressure is 7" Hg.

    A. 0" Hg vacuum
    B. 7" Hg vacuum
    C. 23" Hg vacuum
    D. 30" Hg vacuum

44. 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

45. A steam-driven turbine exhausts to a condenser. As condenser vacuum is increased, the turbine backpressure will __________ and the turbine power output will __________.

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

46. Using steam tables, determine the saturation pressure associated with coolant at 440 °F.

    A. 381.54 psia
    B. 414.09 psia
    C. 449.40 psia
    D. 454.03 psia

47. Using steam tables, determine the saturation pressure for coolant at 548 °F.

    A. 1,014.49 psia
    B. 1,014.94 psia
    C. 1,024.89 psia
    D. 1,028.49 psia

48. Using steam tables, determine the saturation temperature for coolant at 450.00 psia.

   A. 423.14 °F
   B. 443.82 °F
   C. 456.28 °F
   D. 463.17 °F

49. What is the saturation temperature for a boiling water reactor (BWR) operating at 920 psig.? [Use steam tables]

   A. 532.6 °F
   B. 533.9 °F
   C. 536.5 °F
   D. 538.4 °F

50. Using steam tables, determine the state of water at 20 psia and 250 °F.

   A. subcooled liquid
   B. saturated liquid
   C. mixture of saturated liquid and vapor
   D. superheated vapor

51. Which of the following best defines the term fluid hammer (sometimes referred to as water hammer or liquid hammer)?

   A. the overall effect of pressure transients in a piping system caused by rapid temperature changes

   B. the shock imposed on a pressurized, closed system due to the ramp increase in speed of a variable speed pump

   C. the overall effect of pressure transients in a piping system caused by a rapid change in system flow

   D. the overall effect of rapid volumetric changes in a piping system's mass, caused by fluid density changes

52. What is the reason for ensuring that a piping system is completely filled and vented prior to initiating system flow?

   A. minimize system head loss

   B. ensure all non-condensables are removed from the piping system to reduce system corrosion

   C. preclude a reduction in the system's overall heat transfer coefficient

   D. minimize the potential for a water hammer

53. The primary reason for slowly opening or jogging open the discharge valves of large pumps is to minimize the

   A. net positive suction head requirements

   B. potential for a water hammer

   C. cycle efficiency reductions

   D. potential for scale breakaway and subsequent fouling of heat exchanger tubes

54. Which of the following actions is not a precaution/action that is implemented to minimize the potential for water hammer?

   A. Slowly open discharge valves of large pumps.

   B. Start centrifugal pumps with their discharge valves closed.

   C. Maintain pump minimum flow protection.

   D. Ensure systems are properly filled and vented following maintenance.

55. The discharge valve for a large operating centrifugal pump should be positioned slowly to minimize the

    A. change in available net positive suction head

    B. potential for causing water hammer

    C. differential pressure stress exerted on the valve disk and stem

    D. mechanical wear on the valve seat and stem packing.

56. Tube fouling in a heat exchanger will cause heat transfer to decrease because

    A. fluid velocity on the shell side of the exchanger increases

    B. mass flow through the tube side of the exchanger increases

    C. the total heat transfer coefficient is decreased

    D. the total heat transfer coefficient is increased

57. Tube fouling inside a heat exchanger causes the heat transfer rate to

    A. increase
    B. decrease
    C. vary erratically
    D. remain the same

58. Fouling of heat exchanger tubes in closed cooling water systems should be minimized to

    A. prevent excessive heat transfer rates

    B. prevent the cooling water outlet temperature from exceeding design limits

    C. maximize the pressure drop across the heat exchanger

    D. maximize the heat transfer rate

59. The major effect of fouling on the main condenser tubes would be

    A. a decrease in plant efficiency
    B. a decrease in condenser pressure
    C. an increase in reactor pressure
    D. an increase in condensate subcooling

60. Which of the following is <u>not</u> true concerning heat exchanger performance?

    A. Scale buildup on heat exchanger tube surfaces decreases heat transfer.

    B. Tube fouling in the heat exchanger tubes reduces the total heat transfer coefficient.

    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-condensable gasses improves heat exchanger performance.

61. Scale buildup on heat exchanger tubes causes the heat transfer rate to

    A. increase
    B. decrease
    C. vary erratically
    D. remain the same

62. Tube scaling in a parallel flow heat exchanger causes heat transfer to decrease because the

    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

63. The buildup of scale on heat-transfer surfaces in the reactor vessel

    A. results in lower fuel temperature, which increases the nuclear fuel cycle efficiency

    B. is controlled by complying with core thermal limits

    C. is controlled by utilizing reactor water cleanup (RWCU) system and condensate system demineralizers

    D. results in higher coolant temperature, which increases overall plant efficiency

64. Referring to Figure 1.6-4, determine the effect on the system of a tube failure in the heat exchanger.

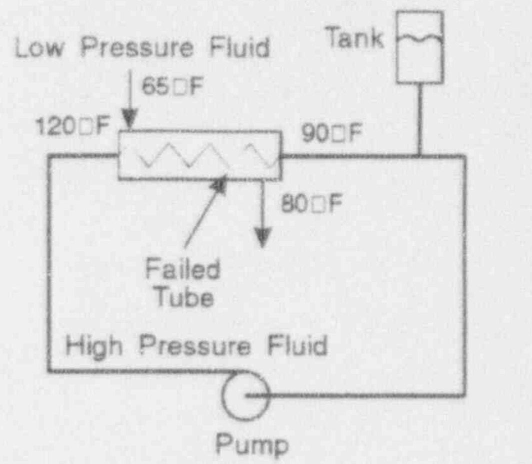
    A. Level in the tank decreases.

    B. Flow in the high-pressure system reverses.

    C. Pressure in the low pressure system decreases.

    D. Level in the tank increases.

FIGURE 1.6-4



Basic Fluid System

65. Refer to the drawing of an operating cooling water system (Figure 1.6-4).

    Which of the following effects would occur as a result of a tube failure in the heat exchanger?

    A. High pressure fluid flow rate decreases.

    B. Flow in the low pressure system reverses.

    C. Temperature in the low pressure system increases.

    D. Level in the tank increases.

66. Which of the following is always a consequence of a heat exchanger tube failure?

    A. shell rupture
    B. radioactive release
    C. fluid mixing
    D. increased vacuum

67. 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

68. The plant is operating normally at 50% power. Which one of the following will result from a cooling water tube failure in the main condenser?

    A. increased condenser vacuum

    B. increased condensate conductivity

    C. decreased condensate pump net positive suction head (NPSH)

    D. decreased condensate pump flow rate

69. A crack in the shell of the main condenser will cause cooling water outlet temperature to __________ and hotwell temperature to __________.

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

70. If air and non-condensables are not continuously removed during normal operation, condenser absolute pressure will

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

71. If air and non-condensables are not continuously removed during normal operation, the condenser vacuum will

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

72. During power plant operation, stopping systems that remove air and non-condensables from the main condenser(s) will increase

    A. condenser vacuum
    B. the power output of the turbine generator
    C. reactor power
    D. condenser absolute pressure

73. During power plant operation, stopping systems that remove air and non-condensables from the main condenser(s) will <u>not</u>

    A. decrease condenser vacuum

    B. decrease cycle efficiency

    C. increase the power output of the turbine generator

    D. increase condenser backpressure

74. The admission of air into the main condenser will reduce the plant's efficiency by

    A. reducing steam flow into the condenser

    B. cooling down the steam that enters the condenser

    C. causing the steam to enter the condenser at a higher pressure

    D. slowing down the speed of the steam entering the condenser

75. Proper venting of a shell-and-tube heat exchanger is important because an air bubble

    A. reduces the heat transfer ability of the heat exchanger

    B. causes pressure transients within the tubes as heat load changes

    C. causes thermal shock as it moves through the heat exchanger

    D. causes flow restriction within the heat exchanger

76. The rate of heat transfer between two liquids in a heat exchanger will be decreased if the: (Assume single-phase conditions and a constant specific heat capacity.)

    A. temperature of both liquids is decreased by 20°F

    B. temperature of both liquids is increased by 20°F

    C. flow rate of the colder liquid is decreased by 10%

    D. flow rate of the hotter liquid is increased by 10%

77. A pressure gauge on a condenser reads 2 psiv. What is the absolute pressure corresponding to this vacuum?

    A. 2 psia
    B. 13 psia
    C. 15 psia
    D. 17 psia

HEAT EXCHANGERS AND CONDENSERS
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 the Appendix B.

1. D

2. A

3. A

4. D

Reference 49, chapter 7.

5. A

Reference 49, chapter 7.

6. C

Reference 49, chapter 7.

7. D

Reference 49, chapter 7.

8. B

Reference 49, chapter 7.

9. A

Reference 49, chapter 7.

10. 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 28, chapter 2, pages 337 through 350.

11. D

Opening valve D provides additional cooling water flow to the non-regenerative heat exchanger, reducing the temperature at point 7.

Reference 28, chapter 2, pages 337 through 350.

12. D

Opening valve D increases cooling water flow to the non-regenerative heat exchanger, removing more heat and reducing the temperature at point 7.

Reference 28, chapter 2, pages 337 through 350.

13. D

Reference 30, chapter 11, pages 11 through 16.

14. D

Reference 28, chapter 2, pages 337 through 350.

15. D

Reference 28, chapter 2, pages 337 through 350.

16. A

Opening valve C will increase the flow rate through the regenerative and non-regenerative heat exchangers. The temperature at point 4 will increase causing the temperature at point 6 and 7 to increase. The increase in temperature at point 7 will result in a temperatue increase at point 3.

Reference 28, chapter 2, pages 337 through 350.

17. B

If the bypass valve around the system's heat exchanger(s) is throttled open further, less of the system's fluid will actually flow through the heat exchanger, and the temperature of the system's fluid will subsequently begin to increase

Reference 57, chapter 8.

18. C

Increased cooling water flow will result in greater cooling and thus a lower temperature.

Reference 57, chapter 8.

19. A

If the bypass valve around the system's heat exchanger(s) is throttled open further, less of the system's fluid will actually flow through the heat exchanger, and the temperature of the systems fluid will subsequently increase to a new higher value.

Reference 57, chapter 8.

20. A

21. C

Lube Oil Outlet - With cooling water flow reduced, less heat will be removed from the oil so the outlet temperature will increase.

Lube Oil Inlet - Initially lube oil will enter at the same temperature, but as higher temperature oil passes through the system, this temperature will increase.

Cooling Water Outlet - Cooling water spends more time in the heat exchanger, increasing the outlet temperature

Reference 49, chapter 7, page 34.

22. B

As fluid temperature increases, fluid density decreases, causing mass flow rate to decrease.

Reference 57, chapter 5, pages 10 and 11.

23. D

Reference 49, chapter 7, page 34.

24. A

Reference 49, chapter 7, page 34.

25. D

$\dot{Q}_{oil} = \dot{Q}_{water}$

$\dot{Q}_{oil} = (\dot{m}_{oil})(Cp_{oil})(\Delta T_{oil})$

$= (1.8 \times 10^4 \text{ lbm/hr})(1.1 \text{ BTU/lbm °F})(170\text{°F} - 120\text{°F})$

$= 9.9 \times 10^5 \text{ BTU/hr}$

$\dot{Q}_{water} = (\dot{m}_{water})(Cp_{water})(\Delta T_{water})$

$9.9 \times 10^5 \text{ BTU/hr} = (1.65 \times 10^4 \text{ lbm/hr})(1.0 \text{ BTU/lbm°F})(\Delta T)$

ΔT water = 60 °F

Reference 57, chapter 8, pages 8 through 62.

26. C

$\dot{Q} = \dot{m}\ Cp\ \Delta T$

$$\dot{m} = \frac{1.00376 \times 10^7}{(1.0)(36)}$$

$\dot{m} = 2.7882 \times 10^5$ lbm/hour

Reference 57, chapter 8, pages 8 through 62.

27. A

Thermal shock occurs when heat exchanger components are exposed to temperature changes that result in excessive stresses being induced.

28. B

Reference 69, pages 1,063 and 1,201.

29. B

Reference 79, page 1.

30. D

Reference 80, volume 1, page 5.

31. B

Reference 79, page 1.

32. C

Reference 79, page 1.

33. C

Reference 49, chapter 7.

34. A

Reference 49, chapter 7.

35. B

Reference 49, chapter 7.

36. B

Reference 49, chapter 7.

37. A

Isolating circulating water from a condenser bay will reduce the heat transfer from the condensate to the circulating water. Therefore, condensate temperature will increase, and subcooling will decrease.

38. B

The loss of condenser vacuum means condenser pressure is increased. Therefore, saturation temperature is simultaneously increased, resulting in an increase in hotwell temperature.

39. B

Condenser backpressure is measured in inches of mercury absolute, condenser vacuum is measured in inches of mercury vacuum. As condenser vacuum decreases, absolute condenser pressure increases and condenser backpressure increases.

Perfect vacuum = 29.92 in Hg vac = 0 in Hg abs = 0 in Hg backpressure

Atmospheric pressure = 0 in Hg vac = 29.92 in Hg abs = 29.92 in Hg backpressure

Reference 57.

40. C

Condenser backpressure is measured in inches of mercury absolute, condenser vacuum is measured in inches of mercury vacuum. As condenser vacuum decreases, absolute condenser pressure increases and condenser backpressure increases.

Perfect vacuum = 29.92 in Hg vac = 0 in Hg abs = 0 in Hg backpressure

Atmospheric pressure = 0 in Hg vac = 29.92 in Hg abs = 29.92 in Hg backpressure

Reference 57.

41. A

As condenser vacuum decreases, absolute condenser pressure increases and condenser backpressure increases.

Reference 57.

42. D

Reference 57.

43. C

Condenser backpressure is measured in inches of mercury absolute, condenser vacuum is measured in inches of mercury vacuum. As condenser vacuum decreases, absolute condenser pressure increases and condenser backpressure increases.

Perfect vacuum = 29.92 in Hg vac = 0 in Hg abs = 0 in Hg backpressure

Atmospheric pressure = 0 in Hg vac = 29.92 in Hg abs = 29.92 in Hg backpressure

Reference 57.

44. B

Reference 57.

45. C

Reference 57.

46. A

Reference 10, page 9.

47. D

Reference 10, page 10.

48. C

Reference 10, page 13.

49. C

Reference 10, page 13.

50. D

Reference 10, page 15.

51. C

Reference 57, chapter 7, page 66.

52. D

Reference 57, chapter 7, page 66.

53. B

Reference 57, chapter 7, page 66.

54. C

Reference 57, chapter 7, page 66.

55. B

Reference 57, chapter 7, page 66.

56. C

Tube fouling causes partial blockage of heat exchanger tubes and reduces the flow of cooling fluid through the tubes. The heat transfer coefficient (U) is reduced; therefore, the heat transfer rate is reduced.

Reference 78, chapter 9, pages 18 and 19.

57. B

Tube fouling reduces the heat transfer rate in a heat exchanger by reducing the effective heat transfer surface area and disrupting flow through the exchanger tubes.

Reference 78, chapter 9, pages 18 and 19.

58. D

Elimination of fouling would improve the heat transfer process by improving the heat transfer coefficient and removing flow disturbances.

Reference 78, page 9-19.

59. A

Condenser fouling degrades the heat transfer process in the condenser. As a result, condenser temperature and pressure increase, reducing the work done by the turbine and therefore reducing plant efficiency.

Reference 78, page 7-68.

60. D

Air and non-condensable gasses reduce the total heat transfer rate inside of a heat exchanger.

Reference 78, chapter 9, pages 24 and 25.

61. B

Scale buildup creates an insulating layer on the heat exchanger tubes. The heat transfer rate decreases as the scale layer increases in thickness.

Reference 78, chapter 9, pages 18 and 19.

62. C

Tube scaling causes the effective heat transfer coefficient to decrease.

Reference 78, chapter 9, pages 18 and 19.

63. C

Reference 78, chapter 9, pages 18 and 19.

64. A

Fluid will flow from the high pressure (tube-side) system to the low pressure (shell-side) system. This loss of fluid from the high pressure system causes tank level to fall.

65. C

66. C

In specific circumstances, tube failure could result in shell rupture, radioactive release, or increased vacuum. However, in all cases, fluid mixing between the shell and tube sides will occur.

67. A

68. B

69. C

70. A

Gas blanketing of condenser tubes creates a layer of thermal insulation to the tube surface.

Reference 55, chapter 5, pages 3 and 4.

71. B

Gas blanketing of condenser tubes creates a layer of thermal insulation to the tube surface.

Reference 55, chapter 5, pages 3 and 4.

72. D

Gas blanketing of condenser tubes creates a layer of thermal insulation to the tube surface.

Reference 57.

73. C

Gas blanketing of condenser tubes creates a layer of thermal insulation to the tube surface.

Reference 57.

74. C

Less cooling of exhaust steam means higher exhaust steam pressure. Higher exhaust steam pressure means higher exhaust steam enthalpy. Higher exhaust steam enthalpy means less turbine work ($W_t = \dot{m}\,(h_{in} - h_{out})$).

$$\text{Plant efficiency} = \frac{\text{turbine power}}{\text{reactor power}}$$

Therefore, plant efficiency decreases.

Reference 55, chapter 5, pages 3 and 4.

75. A

Reference 57.

76. C

77. B

HEAT EXCHANGERS AND CONDENSERS
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, 3

Describe startup of a heat exchanger.

K1.02 Questions 4-6, 8, 9

Identify the consequences of improper filling and venting of shell and tube heat exchangers.

K1.02 Question 7

Explain the proper filling of a shell and tube heat exchanger.

K1.03, K1.04 Questions 10-12, 14-16, 76

Apply the principles of fluid flow and heat transfer to heat exchanger operation.

K1.07 Question 13

Identify the principles of heat transfer.

K1.07 Questions 17-20

Apply the principles of fluid flow and heat transfer to heat exchanger temperature control.

K1.08 Question 21

Given initial conditions in a heat exchanger, determine the changes in temperature and/or flow that result from a change in conditions.

K1.08 Question 22-24

Identify the relationship between mass flow rate and temperature of a flowing fluid.

K1.08 Questions 25, 26

Given a list of equations that includes the equation, $\dot{Q} = \dot{m}\ Cp\ \Delta T$, and all but one of the variables, determine the value of the remaining variable.

K1.09 Question 27

Identify the definition of "thermal shock" as it applies to heat exchangers.

K1.09 Questions 28-32

Identify the definition of "thermal shock."

K1.10 Questions 33-35

Identify the principles of operation of condensers.

K1.10 Question 36

Identify the function of condensers.

K1.10 Questions 37, 38

Identify the effect of operating changes on the condenser.

K1.11 Questions 39-45, 77

Identify the relationship between condenser vacuum and condenser absolute pressure.

K1.12 No questions

Natural circulation is addressed in the Thermal Hydraulics section.

K1.13 Questions 46, 47

Given steam tables, determine saturation pressure for a given temperature.

K1.13 Questions 48, 49

Given steam tables, determine saturation temperature for a given pressure.

K1.13 Question 50

Given steam tables and a value of coolant temperature and pressure, determine whether water exists as a subcooled liquid, a mixture of saturated liquid and vapor, or a superheated vapor.

K1.14 Question 51

Identify the definition of "fluid hammer/water hammer."

K1.14 Questions 52-55

Identify the precautions/actions which can be taken to prevent the occurrence of a fluid hammer/water hammer in a piping system.

K1.15 Questions 56-60

Identify the effects of tube fouling on heat exchanger operation.

K1.16 Questions 61, 62, 63

Explain the effects of tube scaling on heat exchanger operation.

K1.17 Questions 64-69

Describe the consequences of a heat exchanger tube failure.

K1.18 Questions 70-75

State the reasons for air and non-condensable gas removal in a condenser.

NOTE: Many of the following questions deal with mixed bed ion exchangers that use resin beads and can be regenerated. Plants that do not use such ion exchangers should selectively delete or modify questions that do not apply.

1. Operation of a demineralizer with excessive differential pressure could result in all of the following, except

   A. channeling
   B. resin breakdown
   C. higher flow rates
   D. high outlet conductivity

2. 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

3. High differential pressure in a demineralizer could be caused by all of the following except

   A. resin exhaustion
   B. resin coagulation
   C. crud buildup
   D. high flow rates

4. 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

5. All of the following are causes of high demineralizer differential pressure except

   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

6. Channeling in a demineralizer is defined as

   A. layering of weakly acidic cation resin above strongly acidic resin

   B. uneven movement of water through beds along pockets of least resistance

   C. the property of some resins to selectively remove certain ions from the flowstream

   D. mechanical degradation of the resin and subsequent release of "fines" into the flowstream

7. Which of these operational conditions will not lead to channeling in a demineralizer?

   A. suspended solids and colloids forming a mat on the bed's surface

   B. accumulation of gas bubbles (CO_2, O_2, etc.) about the resin beads

   C. exhaustion of the bed due to high inlet conductivity

   D. operation of the bed at higher than design flow rates

8. An effect of channeling in a demineralizer is

   A. increased outlet conductivity
   B. flow oscillations or "chugging"
   C. greatly reduced demineralizer flow rates
   D. formation of gas bubbles

9. Channeling in a demineralizer is undesirable because

   A. resin beads will slump to the bottom of the demineralizer causing a flow blockage

   B. the resulting high velocity fluid flow can cause mechanical damage to system piping and components

   C. the resulting high velocity fluid flow causes erosion of the resin beads and the release of ions

   D. portions of the resin bed will be completely bypassed causing outlet conductivity to increase

10. In a demineralizer, what adverse effect occurs due to channeling?

    A. resin dryout and cracking because the resin is essentially bypassed

    B. reduction in demineralization efficiency because the resin is essentially bypassed

    C. loss of resin due to agitation as a result of increased velocity through the demineralizer

    D. resin damage due to the increased velocity of fluid through the demineralizer

11. The condition in which large portions of a demineralizer bed are bypassed, allowing waterborne impurities to reach the outlet, is called

    A. channeling
    B. seizing
    C. leakage
    D. mineralization

12. The purpose of a demineralizer is to

    A. maintain a basic pH at its outlet

    B. replace cations and anions with hydrogen ions and hydroxide ions

    C. filter out suspended solids and colloids

    D. coagulate and precipitate water impurities

13. When water is purified such that cations are exchanged for hydrogen ions, and anions are exchanged for hydroxide ions, the process is called

    A. softening
    B. coagulation
    C. demineralization
    D. sedimentation

14. Unwanted ions in water systems are replaced with hydrogen and hydroxide ions in a

    A. clarifier
    B. charcoal filter
    C. recombiner
    D. demineralizer

15. Which of the following is <u>not</u> a function performed by a demineralizer?

    A. remove oxygen from fluid systems
    B. filter corrosion products
    C. replace positive ions with hydrogen ions
    D. produce high purity water

16. Which of the following would <u>not</u> be treated using a demineralizer?

    A. condensate
    B. oily water
    C. reactor water
    D. makeup water

17. Which of the following most accurately describes the purpose of a demineralizer?

    A. to increase number of ions in water

    B. to reduce the conductivity of water while maintaining nearly neutral pH

    C. to increase the pH of water by reducing the number of positively charged ions in it

    D. to remove particles and suspended solids from water

18. 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

19. Which of the following purposes is not a design feature of a mixed-bed demineralizer?

    A. to reduce the conductivity of the water without affecting pH

    B. to remove suspended particles from the water

    C. to remove positive ions from the water

    D. to remove negative ions from the water

20. What is a purpose of a mixed-bed demineralizer?

    A. to remove both positively and negatively charged ions

    B. to reduce the resistivity without affecting the pH of water

    C. to increase pH by reducing the number of positively charged ions in the water

    D. to increase the conductivity of the water to greater than 1.0 micromhos

21. 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)

22. The degree of exhaustion of a demineralizer resin bed can be 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

23. 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

24. To determine the demineralization factor for a demineralizer, the two parameters that must be monitored are inlet and outlet

    A. temperature
    B. conductivity
    C. pressure
    D. flow rate

25. The efficiency of a condensate demineralizer can be determined by

    A. performing a chemical analysis on the outlet of the demineralizer to detect silicate

    B. sampling the inlet and outlet of the demineralizer to determine the change in conductivity

    C. sampling the inlet and outlet of the demineralizer to detect a difference in radioactivity

    D. monitoring the change in differential pressure across the demineralizer

26. Which one of the following statements describes the method used to determine demineralizer efficiency?

    A. Outlet only is sampled.

    B. Inlet and outlet are sampled and the results are compared.

    C. Inlet is sampled and each sample is compared to the previous sample.

    D. Inlet only is sampled.

27. 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

28. 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, thereby 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

29. There exists an upper limit on the temperature of water passing through a demineralizer because hot water

    A. gives up its ions faster

    B. is less dense, allowing less water to flow through the bed

    C. will not contain as many ions

    D. may damage demineralizer resin

30. There is a temperature limit on the water entering a demineralizer because hot water

    A. increases the potential for channeling

    B. will dislodge and wash the resin fines off the filter element

    C. will decompose the resin beads

    D. causes the filter element to swell and release the resin

31. Water should have a temperature no greater than 140 °F before entering a demineralizer because

    A. ions release from cooler water more quickly

    B. this ensures the temperature is below that at which resin decomposes

    C. water will boil at this temperature in the demineralizers

    D. the resin will begin to sink in 140 °F density water

32. There are flow limits on demineralizers because too much flow could cause each of the problems listed below <u>except</u>

    A. decomposition of the resin
    B. carry-through of fines
    C. reduced ion exchange rate
    D. channeling in the bed

33. Resin fines carried through into the reactor vessel can be prevented by

    A. keeping flow rates through the demineralizers at design values

    B. keeping resin bead or particle size very small

    C. keeping makeup water pure

    D. regenerating the resin bed before it becomes exhausted

34. Demineralizers work on the principle of

    A. reverse osmosis
    B. ion exchange
    C. precipitation
    D. filtration

35. The anion resin in a mixed-bed demineralizer releases ______ ions into solution while removing ______ charged ions from solution.

    A. hydroxide; negatively
    B. hydroxide; positively
    C. hydrogen; negatively
    D. hydrogen; positively

36. The cation resin in a mixed-bed demineralizer releases ________ ions into solution while removing ________ charged ions from solution.

    A. hydroxide; negatively
    B. hydroxide; positively
    C. hydrogen; negatively
    D. hydrogen; positvely

37. If a solution of sodium chloride in water is passed through an ideal mixed-bed demineralizer, the effluent stream would consist of

    A. a sodium hydroxide solution
    B. a hydrogen chloride solution
    C. a sodium hypochlorite solution
    D. pure water

38. A large pressure drop across a demineralizer indicates that the bed

    A. has channeling
    B. is depleted
    C. is clogged
    D. has been regenerated

39. 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 temperature rise in the effluent
    D. a large conductivity drop across the bed

40. A lower than expected differential pressure across a mixed bed 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

41. 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.

42. As the operating time of a demineralizer increases, the differential pressure across the demineralizer

    A. decrease due to resin bead surface erosion
    B. increases due to depletion of ion exchange sites
    C. decrease due to resin breakdown
    D. increases due to trapping of suspended solids

43. A demineralizer that is continuously exposed to flowing water with high concentrations of suspended solids will first develop an increase in

    A. conductivity at the demineralizer outlet
    B. decontamination factor across the demineralizer
    C. differential pressure across the demineralizer
    D. pH at the demineralizer outlet

44. A demineralizer is being used in a water purification system. How will accumulation of suspended solids in the demineralizer affect performance of the demneralizer?

    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.

45. A result of proper demineralizer operation on water with impurities is that the exiting water will always have

    A. lower conductivity
    B. higher conductivity
    C. lower pH
    D. higher pH

46. Feedwater with low conductivity is indicative of

    A. acidic water
    B. proper demineralizer operation
    C. demineralizer bed degeneration
    D. suspended impurities in the water

47. Water, with positive and negative impurity ions, is sent through a properly operating demineralizer, resulting in

    A. no change in conductivity
    B. lower conductivity
    C. increased conductivity
    D. zero conductivity

48. The conductivity of water exiting a demineralizer is affected by several factors. Which of the following statements concerning effluent conductivity is correct?

    A. The first indication of resin depletion is a decrease in the effluent conductivty.

    B. The conductivity of the effluent increases as the ionic concentration increases.

    C. A decrease in the pH of the effluent will not affect its conductivity.

    D. As the effluent conductivity increases, the water contains a lower ionic content.

49. Which one of the following is the first indication of resin depletion 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. An increase in the differential pressure across the demineralizer.

50. A condensate demineralizer differential pressure (D/P) gauge indicates 4.0 psid at 50% flow. Over the next two days plant power changes have caused condensate flow to vary between 25% and 100%.

    Which one of the following combinations of condensate flow and demineralizer D/P observed during the power changes indicate an increase in the accumulation of corrosion products in the demineralizer?

	CONDENSATE FLOW	DEMINERALIZER D/P (PSID)
A.	25%	2.0
B.	60%	5.0
C.	75%	9.0
D.	100%	15.0

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 63, page 5-3.

2. D

Reference 63, page 5-3.

3. A

Reference 63, page 5-3.

4. B

Reference 63, page 5-3.

5. C

Reference 63, page 5-3.

6. B

Reference 63, page 5-4.

7. C

Reference 63, page 5-4.

8. A

Reference 63, page 5-4.

9. D

Reference 63, page 5-4.

10. B

Reference 63, page 5-4.

11. A

Reference 63, page 5-4.

12. B

Reference 63, page 5-2.

13. C

Reference 63, page 5-2.

14. D

Reference 63, page 5-2.

15. A

Reference 63, page 5-2.

16. B

Reference 63, page 5-2.

17. B

Reference 63, page 5-2.

18. B

Reference 63, page 5-2.

19. B

Reference 63, page 5-2

20. A

Reference 63, page 5-2.

21. C

$$DF = \frac{\text{INLET Conductivity}}{\text{OUTLET Conductivity}}$$

Reference 27, chapter 1C, page 62.

22. D

Reference 27, chapter 1C, page 62.

23. C

Ratio of INLET to OUTLET conductivity is a measure of a demineralizer's effectiveness.

Reference 27, chapter 1C, page 62.

24. B

$$DF = \frac{\text{INLET Conductivity}}{\text{OUTLET Conductivity}}$$

Reference 27, chapter 1C, page 62.

25. B

Reference 27, chapter 1C, page 62.

26. B

Reference 27, chapter 1C, page 62.

27. A

Reference 27, chapter 1C, page 62.

28. D

Reference 27, chapter 1C, page 62.

29. D

The effect of high temperature on resin beads or powders is to melt them, changing the porous, high-surface-area particles to smooth, low-surface-area particles.

Reference 27, chapter 1C, page 62.

30. C

The effect of high temperature on resin beads is to melt them, changing the porous, high-surface-area bead to a smooth, low-surface-area bead.

Reference 27, chapter 1C, page 62.

31. B

The effect of high temperature on resin beads or powders is to melt them, changing the porous, high-surface-area particles to smooth, low-surface-area particles.

Reference 27, chapter 1C, page 62.

32. A

Resin may decompose due to excessive temperature, not excessive flow rates.

Reference 27, chapter 1C, page 62.

33. A

Keeping flow rates within limits minimizes the D/P that would force beads through elements, septa or joints between elements.

Smaller resin beads increase the likelihood of resin fine breakthrough.

Feedwater purity has nothing to do with resin fine breakthrough.

Regenerating the resin bed frequently only increases the risk of unseating an element and thus increasing the chance of resin fine breakthrough.

Reference 27, chapter 1C, page 62.

34. B

Reference 27, Volume IV, page 1-60.

35. A

Reference 27, Volume IV, page 1-60.

36. D

Reference 27, Volume IV, page 1-60.

37. D

Reference 27, Volume IV, page 1-60.

38. C

Channeling decreases the pressure drop across a demineralizer. Depletion refers to exhaustion of ion exchange sites. Regeneration, if done successfully, causes a low differential pressure across a demineralizer. Fouling is the adherence of solid material, usually corrosion products, to the outer layer of resin, causing a higher differential pressure across a demineralizer.

Reference 63, page 5-4.

39. A

Fouling causes <u>low</u> 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 63, page 5-4.

40. 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 63, page 5-4.

41. C

Fouling of a resin bed adds to the material that the water must pass through, increasing the differential pressure across the bed.

Reference 63, page 5-4.

42. D

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 63, page 5-4.

43. C

Reference 63, page 5-4.

44. D

Reference 63, page 5-4.

45. A

46. B

47. B

48. B

49. C

50. A

Given that flow is proportional to the square root of the differential pressure (d/p), the following relationship is established:

$$\text{Flow} = k \times (d/p)^{1/2}$$

Solving for k in the stated condition of 50% flow at a d/p of 4 psid yeilds:

$$50\% = k \times (4)^{1/2}$$

$$k = 50\% / 2 = 25\%$$

For the condition of 2 psid stated in answer A, the expected flow rate would be:

$$\text{Flow} = k \times (2)^{1/2} = 35\%$$

A flow rate of only 25% is an indication of an accumulation of corrosion products in the demineralizer.

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, 2, 4

State the effect of excessive differential pressure on demineralizer performance.

K1.01 Questions 3, 5

State possible causes of high demineralizer differential pressure.

K1.02 Questions 6, 11

Define the term "channeling" as it applies to a demineralizer.

K1.02 Question 7

State the operational conditions that can cause channeling to occur in a demineralizer.

K1.02 Questions 8-10

State the effects of channeling in a demineralizer.

K1.03 Questions 12, 14-20

State the purpose of a demineralizer.

K1.03 Question 13

Define demineralization.

K1.04 Question 21

Define the term "demineralization factor (DF)" as it applies to a demineralizer (deionizer).

K1.04 Questions 22-27

State the reason for sampling both the inlet and outlet of a demineralizer.

K1.06 Questions 28-31

State the reason for demineralizer temperature limits.

K1.06 Questions 32, 33

State the reason for demineralizer flow limits.

K1.07 Questions 34-37

Describe principles of demineralizer operation.

K1.08, 1.05 Questions 38-44, 50

State how the differential pressure across a demineralizer is an indicator of resin bed condition.

K1.09 Questions 44-49

State the effect a demineralizer has on water conductivity.

BREAKERS, RELAYS, AND DISCONNECTS
Questions

1. 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

2. To deenergize a component for maintenance, the component circuit breaker should be

   A. racked in and tagged in open position

   B. racked in and tagged in closed position

   C. racked out and tagged in racked-out position

   D. in test position and tagged in test

3. Which of the following describes the most common method for deenergizing a breaker control circuit?

   A. placing the breaker control switch in pull-to-lock

   B. fully racking out the breaker

   C. placing the breaker in test position

   D. removing the control power fuses

4. Which one of the following describes the safest 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

5. The reason for racking out circuit breakers and pulling their control power fuses, as opposed to tagging a control switch, is

   A. to ensure that indication of circuits remain energized for breaker position verification

   B. to maintain availability of the control switch and control power for testing

   C. that tagging a control switch would render the equipment inoperable and out of service

   D. that the equipment and its control and indication circuits would be deenergized

6. What is normally done to completely electrically deenergize a component, including its control and indication power?

   A. Rack out the component's circuit breaker, remove its control power fuses, and tag the breaker control switch open and fuses pulled.

   B. Open the component's circuit breaker and tag it out.

   C. Lift the leads to the component at its supply breaker to ensure complete deenergization.

   D. Tag the control switch open and post a watch.

7. While locally investigating the condition of a large circuit breaker, the 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.

   - Load-sic ter indicates zero volts.

   - Load-side ammeter indicates zero amperes.

   Based on this indication, the operator should report that the circuit breaker is

   A. open, rac n, and overload condition indicated

   B. open, racked in, and no overload condition indicated

   C. open, racked out, and overload condition indicated

   D. open, racked out, and no overload condition indicated

8. Which of the following available local circuit breaker indications would be a positive method of identifying a circuit breaker's actual condition (closed, open)?

   A. overcurrent trip flags and load-side ammeter

   B. OPEN/CLOSED mechanical flag indication and load-side voltmeter

   C. OPEN/CLOSED indicating lights and overcurrent trip flags

   D. load-side ammeter and OPEN/CLOSED indicating lights

9. Which of the following local circuit breaker indications must be reset after operation to ensure reliable indication is being provided?

   A. OPEN/CLOSED mechanical flag
   B. OPEN/CLOSED indicating lights
   C. overcurrent trip flags
   D. spring CHARGE/DISCHARGE flag

10. While locally investigating the condition of a large circuit breaker, the operator observes the following indications:

    - OPEN/CLOSED mechanical flag indication shows closed.

    - OPEN/CLOSED indicating lights do not indicate open or closed.

    - Load-side voltmeter indicates normal voltage.

    - Load-side ammeter indicates zero amps.

    Based on this indication, the operator should report that the circuit breaker is

    A. open, and report problems

    B. closed, and report problems

    C. tripped open due to overcurrent conditions

    D. (insufficient information to determine the breaker conditions)

11. Which one of the following describes circuit breaker local overcurrent trip flag indicators?

    A. When actuated, they indicate that the breaker overcurrent trip relay has been reset.

    B. When actuated, they indicate that the associated circuit breaker has failed to trip open.

    C. They actuate prior to breaker tripping to warn of imminent protective action.

    D. They indicate breaker overcurrent trip actuation during and after breaker trip actuation.

12. Which one of the following local breaker indications will provide the most reliable information for determining the position of a 4160 volt bus feeder breaker?

    A. open/closed indicating lights and load-side voltage

    B. open/closed mechanical flag indication and load-side voltage

    C. open/closed indicating lights and load-side current

    D. open/closed mechanical flag and load-side current

13. Which one of the following will cause a loss of indication from the local breaker position indicating lights associated with a typical 4160 VAC load supply breaker?

    A. loss of breaker line voltage
    B. locally opening the breaker
    C. racking the breaker to the "test" position
    D. loss of breaker control power

14. Which of the following is not an indication of a loss of circuit breaker control power?

    A. loss of remote red/green indicating lights

    B. failure of charging springs to charge following local operation

    C. inability to remotely trip a circuit breaker

    D. actuation of protective device trip

15. Which of the following conditions would result in an inability to remotely trip a circuit breaker concurrent with loss of position indicating (red/green) lights?

    A. loss of breaker control power
    B. failure of breaker closing coil
    C. mechanical binding of breaker
    D. breaker in "test" position

16. If breaker control power is lost to a supply breaker for an operating pump motor, the breaker will

    A. trip on undervoltage

    B. remain closed until tripped locally by an operator

    C. remain closed unless a fault trip occurs

    D. remain closed until tripped remotely by an operator

17. Which of the following would be a consequence of a loss of breaker control power?

    A. Motor ammeter indication would be zero regardless of actual breaker status.

    B. Breaker position would remotely indicate closed regardless of actual breaker status.

    C. Breaker would trip due to actuation of protective device trip.

    D. Closing charging springs would not charge following local operation of breaker.

18. Which of the following would not be a consequence of a loss of breaker control power?

    A. loss of all remote breaker controls

    B. loss of all breaker protective trips

    C. inability to manually close breaker locally

    D. loss of local and remote breaker status lights

19. 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

20. Loss of breaker control power will

    A. remove all local indication of breaker position

    B. prevent local tripping of the breaker

    C. remove the remote breaker tripping capability

    D. prevent the breaker from tripping on overcurrent

21. For a motor, which conditions would not require a thermal protection device to function?

    A. Running speed is too low.
    B. Starting current is too high.
    C. Ambient temperature is too high.
    D. Motor winding temperature is too low.

22. In motors, thermal cutout/overload devices protect against the degrading effects of

    A. reduced starting torque
    B. low winding temperatures
    C. high winding temperatures
    D. inductive current

23. Which of the following is not a purpose of a thermal overload protective device on a motor?

    A. protecting motor windings from becoming excessively hot
    B. stopping the motor
    C. protecting against an overcurrent condition
    D. protecting against an overvoltage condition

24. What is the definition of a thermal overload device?

    A. a balanced circuit that compares actual current to a fixed over-current signal which, when exceeded, actuates a tripping relay

B. an in-line coil that, when subjected to a high current, overheats and actuates a circuit-interrupting device

C. a temperature monitor that senses the temperature of the operating equipment and trips the circuit breaker if the temperature exceeds preset limits

D. an in-line induction coil that generates a secondary current proportional to the primary current, closing the trip circuit contacts for an overcurrent condition

25. Which of the following is <u>not</u> a purpose of a thermal overload protective device on a motor?

A. deenergize the motor until reset locally

B. stopping an excessively high current condition

C. protecting motor windings from getting too hot

D. reducing starting torque

26. A thermal overload device for a large motor protects the motor from

A. sustained overcurrent by magnetically opening motor line contacts at the motor

B. instantaneous overcurrent by magnetically opening motor line contacts at the motor

C. sustained overcurrent by opening the motor breaker

D. instanta ieous overcurrent by opening the moto: breaker

27. Refer to Figure 1/8-1. Assume the K-3 relay will send an "OPEN" signal to a valve with contacts 1 and 2 closed. The K-3 relay will

A. hold the valve open even if the reset pushbutton is pressed

B. hold the valve open even if the initiating condition is clear

C. close the valve as soon as either initiating condition clears

D. close the valve only when both initiating conditions are clear

28. Which statement best describes the function of the #3 contact in Figure 1.8-1?

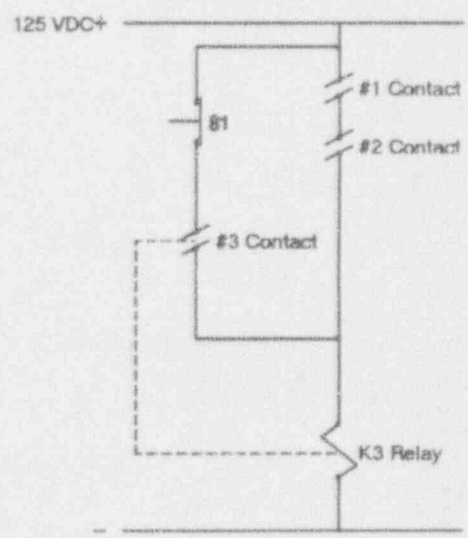
A. to keep the relay energized

B. to initially energize the relay

C. to test the operation of the K3 relay

D. to momentarily energize then deenergize the relay

FIGURE 1.8-1



Typical Valve Control Circuit

29. 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

30. Referring to the circuit diagram shown in Figure 1.8-1, select the correct statement regarding the operation of relay K3.

    A. energized when the #1 or #2 contacts close

    B. energized when the #1 and #2 contacts close

    C. deenergized when the #1 and #2 contacts close

    D. energized when pushbutton S1 is depressed

31. What best describes the arrangement of contacts in Figure 1.8-1?

    A. 1 and 2 in series and in parallel with 3
    B. 1 and 3 in series and in parallel with 2
    C. 1 and 2 in parallel and in series with 3
    D. 1 and 3 in parallel and in series with 2

32. Refer to the drawing of a typical valve control circuit (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

33. Refer to the drawing of a typical valve control circuit for a 480 VAC motor-operated valve with K3 relay energized, #3 contact closed, and contacts #1 and #2 are open. (Figure 1.8-1).

    The valve is currently open with the contact configuration as described. 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

34. Which of the following describes the proper breaker status for a 480 VAC breaker that is to be racked out of a motor control center/load center?

    A. open

    B. closed

    C. trip free

    D. closed until the disconnect position is reached and then trip free or open

35. Never open or close a high voltage (greater than 750 volts) disconnect unless

    A. the current flowing through it is approximately zero

    B. the current flowing through it is less than its design current carrying capability

    C. the load it supplies is already open

    D. a parallel path exists for current flow

36. Which of the following statements best describes the reason for not opening a high voltage (greater than 750 volts) disconnect under load?

    A. High voltage disconnects usually have a lower current carrying capability than a circuit breaker; therefore, the circuit breaker is always used to break the circuit.

    B. High voltage disconnects are typically opened one phase at a time, which could cause loads to "single phase"; therefore, the circuit breaker is always used to break the circuit.

    C. Disconnect operation cannot be supervised from the control room; therefore, the circuit breaker is mandated to ensure proper switching.

    D. The current-carrying contacts of a disconnect open slowly as compared to a circuit breaker, which opens quickly.

37. In a situation where a low voltage (less than 750 volts) disconnect is in series with a circuit breaker, which statement is correct regarding the proper sequence to isolate power to the load?

    A. Open disconnect first, then breaker.

    B. Open breaker first, then disconnect.

    C. Sequence is not important provided the load is off.

    D. Either is opened alone to provide isolation.

38. Which of the following is <u>not</u> a recommended safety precaution associated with racking out a 480 volt or greater circuit breaker?

    A. Circuit breaker must be open.
    B. Control power should be disconnected.
    C. Depress local breaker trip button to ensure breaker is tripped.
    D. Attempt to close the breaker after it is racked out.

39. Which of the following describes the proper breaker status for a 480 VAC breaker that is to be racked out of a motor control center/load center?

    A. open

    B. closed until the test position is reached and then open

    C. trip-free

    D. closed until the discount position is reached and then trip-free

40. While paralleling a three-phase generator to the grid, closing the generator output breaker 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

41. While paralleling a three-phase AC 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

42. 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 on a bus that has an open-circuit fault

    D. closing the output breaker on a bus that has a short-circuit fault

43. If a generator output breaker is closed with generator frequency lower than grid frequency, what will result? (Assume that no generator relay protection is actuated.)

    A. the generator will motorize

    B. the voltage of the generator will decrease to compensate for the lower frequency

    C. the generator will accept too much load

    D. the entire connected system will operate at the frequency of the lowest frequency (the oncoming) generator

44. Closing a circuit breaker between two electrical generating systems that are out of phase will result in

    A. negating the reverse power protection on the lagging frequency system

    B. rapid phase alignment which could damage generators and loads connected to the system

    C. a voltage reduction in both generating systems

    D. reduction of the frequency of the combined generating system

45. While paralleling a three-phase generator to the grid, closing the generator output breaker with the generator output voltage ________ the grid voltage will result in the generator picking up reactive current in the ________ direction.

    A. equal to, vars positive (lagging)
    B. higher than, vars negative (leading)
    C. lower than, vars negative (leading)
    D. lower than, vars positive (lagging)

46. While paralleling a three-phase 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. a possible reverse power trip of the generator output breaker

47. 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

48. During paralleling operations of the main generator to the grid, closing the generator output breaker with the frequency of the generator at 61.0 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

49. 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

50. 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 as the synchroscope pointer reaches 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 MWe load transfer to the generator due to out-of-phase voltages

51. 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

52. For a circuit breaker placed in the test position, which of the following statements is correct?

    A. Control power is available to the breaker and functions normally to open and close the breaker.

    B. The test position can only be used to test a circuit breaker on a dead bus.

    C. The main power contacts remain connected to the load, but the breaker trips free when tested.

    D. The test position disables the overload devices, allowing them to be set during normal operation.

53. If a breaker is racked in/out to the "test" position, the

    A. normal breaker opening and closing operations cannot be tested because the test position is for overload testing only

    B. breaker can only be operated remotely from its associated remote control panel

    C. remote position indication for the breaker is still operational

    D. electrical jumpers must be connected to the operating coils to operate the breaker

54. The following remote indications are observed for a 480 VAC load supply breaker (The breaker is normally open.)

    Red indicating light is on
    Green indicating light is off
    Load voltage indicates 0 volts
    Line 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

55. Which of the following describes the function of high voltage electrical disconnects?

    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

56. High voltage electrical disconnects should <u>not</u> be used to

    A. electrically connect buswork sections
    B. interrupt circuits under load
    C. electrically ground buswork
    D. isolate equipment electrically

57. High voltage electrical disconnects

    A. usually operate automatically requiring no operator action

    B. require a remote means of indication to determine actual position

    C. should never be used to interrupt a circuit under load

    D. should be connected so that they short the buswork to ground

58. High voltage electrical disconnects function to

    A. adjust the voltage output from a main power transformer

    B. trip open before bus feeder breakers upon electrical bus faults

    C. provide equipment isolation under no load conditions

    D. bypass and isolate an electrical bus while maintaining the downstream buses energized

59. High voltage electrical disconnects function to

    A. protect against overload conditions
    B. interrupt high voltage conditions
    C. disconnect circuits under load
    D. isolate equipment electrically

60. A typical 120 VAC manual circuit breaker has tripped due to overload. Which of the following <u>must</u> 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.

61. Prior to connecting the main generator to the power grid, generator voltage should be __________ grid voltage and generator frequency should be __________ grid frequency.

    A. equal to; higher than
    B. higher than; higher than
    C. equal to; equal to
    D. higher than; equal to

62. 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?

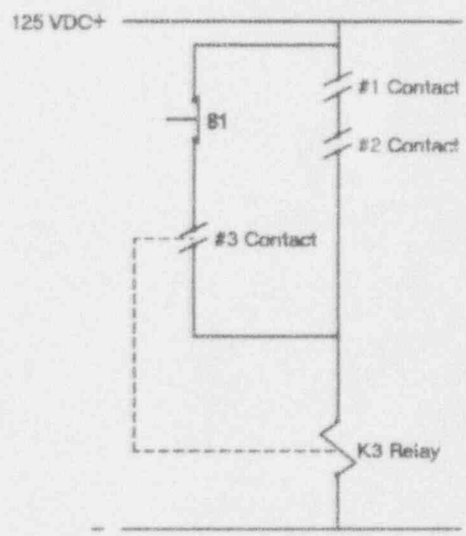
    A. Loss of 125 VDC

    B. Both #1 and #2 contacts open

    C. Either #1 or #2 contact opens

    D. Depressing the S1 push-button with the initiating condition present

FIGURE 1.8-2



Typical Valve Control Circuit

63. Which one of the following describes a benefit of using charged springs (in lieu of a solenoid operator) to close some 4160 volt breakers?

    A. Springs produce faster breaker closing.

    B. Springs can be repaired or replaced without removing the breaker from service.

    C. Springs provide stored energy to allow local cycling of the breaker upon loss of control power.

    D. Springs will keep the breaker contacts firmly seated after closing to minimize arcing.

64. Which one of the following is an unsafe practice if performed by an electrician working on or near energized electrical equipment?

    A. Using two hands for balance and to prevent dropping tools onto energized equipment.

    B. Standing on insulating rubber material to increase the electrical resistance of the body to ground.

    C. Having a person stand by to deenergize the equipment in the event of an emergency.

    D. Covering exposed energized circuits with insulating material to prevent inadvertent contact.

65. 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. A

Circuit breakers are racked out to protect personnel and equipment.

Reference 05, page 9.

2. C

Breaker must be fully racked out to deenergize control circuits.

Reference 05, page 9.

3. D

Most control circuits are deenergized by pulling control power fuses.

Reference 05, page 9.

4. C

Reference 05, page 9.

5. D

Circuit breakers are racked out and control power fuses pulled to deenergize components and associated control and indication circuits.

Reference 05, page 9.

6. A

Circuit breakers are racked out and control power fuses pulled to deenergize components and associated control and indication circuits.

Reference 05, page 9.

7. A

*Note: Each facility should review this question for applicability to their switchgear.

These indications reveal 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.

Reference 05, page 242.

8. B

*Note: Each facility should review this question for applicability to their switchgear.

Choice B is correct because mechanical flag indication is a positive means of determining breaker position as supported by load-side volt meter indication.

A&C Overcurrent trip flags are not a positive indication of breaker position since they normally must be reset after each actuation.

D OPEN/CLOSED indicating lights are not available without breaker control power and therefore are not always truly indicative of breaker positions. Ammeter indication provides no indication of an open breaker (e.g., the breaker might be closed with no load operating).

Reference 05, page 242.

9. 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.

Reference 05, page 242.

10. B

Mechanical OPEN/CLOSED flag indication, coupled with load voltage indicating normally, indicates breaker is closed.

Reference 05, page 242.

11. D

12. B

Reference 05, page 242.

13. D

Reference 05, page 242.

14. D

Protective device trips require breaker control power to energize the trip coil; therefore, if a protective device trip is actuated, control power must be available.

Reference 05, page 242.

15. A

A loss of breaker control power will result in inability to trip the breaker (remotely, automatically, or on fault) concurrent with loss of indicating lights (local and remote).

Reference 05, page 242.

16. B

A loss of breaker control power will result in inability to trip the breaker (remotely, automatically, or on fault) concurrent with loss of indicating lights (local and remote).

Reference 05, page 242.

17. D

Control power supplies the charging motors for breaker operation and therefore the motor will not charge if manually operated (OPEN/CLOSED). Ammeter indication is not control-power-dependent so will indicate amps if load is on. Remote breaker position indication is not available. The breaker will not trip due to protective actuation if no power is available to the trip coil.

Reference 05, page 242.

18. C

Even with a loss of control power, a circuit breaker can be manually closed by local operation (even if manual charging of closing springs is necessary).

Reference 05, page 242.

19. D

Reference 05, page 242.

20. C

Reference 05, page 242.

21. D

Identifying different conditions that can cause thermal overloads to function shows how different parameters can affect the operation of a motor and/or gives a choice of controllable parameters to help prevent damaging motors.

Reference 50, pages 152 and 153.

22. C

Identifying different conditions that can cause thermal overloads to function shows how different parameters can affect the operation of a motor and/or gives a choice of controllable parameters to help prevent damaging motors.

Reference 50, pages 152 and 153.

23. D

Overloads are not overvoltage protective devices.

Reference 50, pages 152 and 153.

24. B

Reference 50, page 152 and 153.

25. D

Too low a value for starting torque will not cause a high temperature condition requiring a thermal overload device.

Reference 50, pages 152 and 153.

26. C

Reference 50, pages 152 and 153.

27. B

Reference 06.

28. A

Closing contacts #1 and #2 completes series circuit energizing relay coil K3, which closes seal-in contact #3. If the conditions that closed contacts #1 or #2 clear, relay coil #3 will remain energized until pushbutton S1 is depressed, breaking the seal-in.

Reference 06.

29. B

Closing contacts #1 and #2 completes series circuit energizing relay coil K3, which closes seal-in contact #3. If the conditions which closed contacts #1 or #2 clear, relay coil #3 will remain energized until pushbutton S1 is depressed, breaking the seal-in.

Reference 06.

30. B

Closing contacts #1 and #2 completes series circuit energizing relay coil K3, which closes seal-in contact #3.

Reference 06.

31. A

Reference 06.

32. A

Reference 06.

33. B

Reference 06.

34. A

Breakers must be in the open position prior to being racked out of the switchgear.

Reference 19, chapter 4, page 2; and Reference 062, chapter 30.

35. C

A fundamental rule of disconnect operation is never open or close a disconnect unless the circuit breaker in series with it is open.

Reference 11, page 67; and Reference 062, chapter 30.

36. D

Reference 11, page 67; and Reference 062, chapter 30.

37. B

Reference 11, page 67; and Reference 062, chapter 30.

38. D

Reference 19, chapter 4, page 2; and Reference 062, chapter 30.

39. A

Reference 19, chapter 4, page 2; and Reference 062, chapter 30.

40. A

Closing a generator output breaker during parallel operations with currents or voltages out of phase will result in large current flow across the breaker.

Reference 05, page 302.

41. B

A higher frequency on the incoming source will result in the generator picking up load.

Reference 05, page 302; and reference 39, page 182.

42. D

Circuit breakers and generators are designed to be tripped under full design load without damage. An open circuit fault will deenergize the downstream loads, reducing current.

Reference 05.

43. A

Reference 05, page 302.

44. B

Reference 05, page 302.

45. C

An underexcited machine when paralleled to the grid will pick up reactive load in the vars in or leading direction.

Reference 05, page 302; and reference 39, page 182.

46. D

Generator output breakers equipped with reverse power trips will open if the grid is sensed to be supplying the generator with power.

Reference 05, page 302; and reference 39, page 182.

47. C

Reference 05, page 302.

48. A

Reference 05, page 302.

49. C

Reference 05, page 302.

50. B

Reference 05, page 302.

51. A

Reference 05, page 302.

52. A

Reference 05.

53. C

Reference 05.

54. D

Reference 05.

55. A

Disconnects should only be used to isolate circuits that are not under load.

Reference 11, page 66.

56. 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, page 66.

57. C

Disconnects should never be operated to interrupt a circuit that 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, page 66.

58. C

Disconnects may be used manually to isolate equipment electrically only after it is unloaded; disconnects have no automatic protective actuations.

Reference 11, page 66.

59. D

Disconnects have no protective actuations and are only used to isolate equipment after it has been unloaded.

Reference 34, chapter 9, page 27.

60. A

61. A

62. A

63. C

64. A

65. C

BREAKERS, RELAYS, AND DISCONNECTS
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

State the purposes for racking out breakers.

K1.02 Questions 7-13

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 Questions 14-20

Identify potential indications of loss of circuit breaker control power.

K1.04 Questions 60, 63

Operation of various push buttons, switches, and handles and the resulting action on breakers.

K1.05 Questions 21, 22

Identify conditions for which thermal overload protection function is used in motors.

K1.05 Questions 23-26

Describe the function of a thermal overload protection device.

K1.06 Questions 27, 33, 62

Given a typical one-line logic diagram, describe the function of the identified components.

K1.07 Questions 34, 38, 39, 64

State the safety precautions associated with circuit breaker (450 volts or greater) operation.

K1.07 Questions 35, 36

State the safety precautions associated with operation of high voltage electrical disconnects (greater than 750 volts).

K1.07 Question 37

State the safety precautions associated with operation of low voltage electrical disconnects (less than 750 volts).

K1.08 Questions 40-51, 61, 65

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

K1.09 Questions 52-54

Identify the effects of placing a circuit breaker in the "test" position.

K1.10 Questions 55-59

Identify the function and methods of control of high voltage electrical disconnects.

NEUTRONS
Questions

1. A neutron that is born within 10^{-14} seconds of the fission event is called a __________ neutron.

   A. thermal
   B. delayed
   C. prompt
   D. fast

2. A prompt neutron is one that

   A. has reached thermal equilibrium with its surrounding medium

   B. is born within 10^{-14} seconds of the fission event

   C. is born later than 12 seconds after the fission event

   D. is created by the decay of fission fragments

3. _________ neutrons are born from first excited daughters generated from the fission process.

   A. prompt
   B. thermal
   C. delayed
   D. fast

4. Delayed neutrons are neutrons that

   A. have reached thermal equilibrium with the surrounding medium

   B. are born within 10^{-14} seconds of the fission event

   C. are born with an average kinetic energy of less than 1 MeV

   D. are responsible for the majority of U-235 fissions

5. Describe the production mechanisms of prompt and delayed neutrons.

6. What type of neutron has an average neutron generation time of 12.5 seconds?

   A. prompt
   B. delayed
   C. fast
   D. thermal

7. Which of the following is the best definition of the term "prompt neutron"?

   A. a high-energy neutron emitted from a neutron precursor, immediately after the fission process

   B. a neutron with an energy level greater than 0.1 MeV, emitted in less than 10^{-4} seconds following a nuclear fission

   C. a neutron emitted in less than 10^{-14} seconds following a nuclear fission

   D. a neutron emitted as a result of a gamma-n or alpha-n reaction

8. The term "neutron generation time" is defined as the average time between

   A. neutron absorption and resulting fission

   B. the production of a delayed neutron and subsequent neutron thermalization

   C. neutron absorption producing a fission and absorption of resultant neutrons

   D. neutron thermalization and subsequent neutron absorption

9. Prompt neutrons may be most correctly defined as

   A. low-energy neutrons, less than 0.1 MeV

   B. neutrons occurring directly from nuclear fission

   C. high-energy neutrons, greater than 2.0 MeV

   D. neutrons occurring indirectly from fission through fission-fragment decay

10. A neutron that is born within 10^{-14} seconds of the fission event is called a __________ neutron.

    A. subcritical
    B. supercritical
    C. prompt
    D. fast

11. A thermal neutron is a neutron that

    A. is produced only from a delayed neutron precursor

    B. travels in a straight line to thermalization

    C. is in thermal equilibrium with its surrounding medium

    D. is produced only by a thermal fission

12. A _______ neutron has reached the same energy as its surrounding medium.

    A. delayed
    B. prompt
    C. thermal
    D. fast

13. Which of the following is a characteristic of thermal neutrons?

    A. They are born within 10^{-14} seconds of the fission event.

    B. They are born greater than 12 seconds following the fission event.

    C. They are created by the decay of fission fragments.

    D. They are at the same energy level as the surrounding medium.

14. A neutron that possesses the same kinetic energy as its surroundings is called a/an ____________ neutron.

    A. slow
    B. intermediate
    C. fast
    D. thermal

15. In the definition of a thermal neutron, a relationship is established between the neutron and its environment. Which of the following statements best describes this relationship?

    A. Thermal neutron possesses lower kinetic energy than its environment.

    B. Thermal neutron possesses same kinetic energy as its environment.

    C. Thermal neutron possesses higher kinetic energy than its environment.

    D. Kinetic energy is not part of the relationship.

16. A neutron is "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 fission of a U-235 atom

    D. its cross-section for absorption in the fuel undergoes a sudden decrease

17. Which one of the following ranges contains the energy level of thermal neutrons in a reactor operating at full power?

    A. 0.001 to 0.01 eV
    B. 0.01 to 0.1 eV
    C. 0.1 to 1 eV
    D. 1 to 10 eV

18. A neutron reaches thermal equilibrium with its surroundings through

    A. collisions with atoms
    B. radioactive decay
    C. compton scattering
    D. radiolytic decomposition

19. Which of the following parameters would not have an effect on the moderation of neutrons in an operating reactor?

    A. type of moderator
    B. initial neutron energy
    C. ionic charge of particles in the moderator
    D. temperature of the moderator

20. Which of the following best describes the term "moderation"?

    A. slowing down of neutrons

    B. absorption of neutrons

    C. distribution of energy per unit time of the neutron flux

    D. net vector distance between thermalization and absorption

21. The interaction in the reactor core that is most efficient in thermalizing neutrons for fission occurs with the

    A. hydrogen atoms in the water molecules
    B. oxygen atoms in the water molecules
    C. boron atoms in the control rods
    D. zirconium atoms in the fuel cladding

22. During neutron moderation, a neutron is most susceptible to resonant absorption when it is a/an ____________ neutron.

    A. slow
    B. fast
    C. epithermal
    D. thermal

23. Neutron moderation describes

    A. a decrease in the core neutron population from thermal neutron absorption

    B. an increase in the neutron multiplication factor due to a reduction in neutron poisons

    C. the loss of fission neutrons from the core by leakage

    D. the reduction of neutron energy due to scattering reactions

24. Select the circumstance that will increase the amount of neutron moderation in a BWR operating at saturated conditions.

    A. increasing moderator temperature

    B. reducing reactor recirculation system flow

    C. reducing reactor pressure vessel (RPV) pressure

    D. reducing feedwater inlet temperature

25. A description of a good moderator is a moderator that is

    A. dense and is composed of large atoms

    B. not dense and is composed of large atoms

    C. dense and is composed of small atoms

    D. not dense and is composed of small atoms

26. A good moderator has a __________ macroscopic absorption cross section, a _________ macroscopic scattering cross section, and a _________ average logarithmic energy decrement.

    A. small, small, small
    B. small, small, large
    C. small, large, large
    D. large, large, large

27. Describe three nuclear characteristics of a good neutron moderator.

28. The best neutron moderator is __________ and is composed of __________ atoms.

    A. dense; large
    B. not dense; large
    C. dense; small
    D. not dense; small

29. The best neutron moderator is

    A. dense and is composed of large atoms

    B. not dense and is composed of large atoms

    C. dense and is composed of small atoms

    D. not dense and is composed of small atoms

30. Which one of the following describes the energy level of a thermal neutron in a reactor operating at full power?

    A. The kinetic energy of the neutron has decreased until it is nearly in equilibrium with its surroundings.

    B. The potential energy of the neutron has decreased to nearly zero as the neutron approaches equilibrium with its surroundings.

    C. The kinetic energy of the neutron has decreased sufficiently to allow the neutron to be resonantly absorbed by U-238.

    D. The potential energy of the neutron has decreased to a level that will allow the neutron to be absorbed by U-235.

NEUTRONS
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

Reference 21, chapter 3, page 21.

2. B

Reference 21, chapter 3, page 21.

3. C

Reference 21, chapter 3, page 21.

4. C

Reference 21, chapter 3, page 21.

5.

Prompt neutrons are emitted from fission fragments within 10^{-14} seconds of the fission event. Delayed neutrons are produced later, from the decay of a daughter product of fission fragment decay. The fission fragment decays to an excited daughter, which then decays by neutron emission.

Reference 73, page 7-23.

6. B

Reference 31, chapter 3, page 33; and reference 07, chapter 3, page 27.

7. C

Reference 21, chapter 3, page 21.

8. C

Reference 21, chapter 3.

9. B

Reference 21, chapter 3, page 21.

10. C

Reference 21, chapter 3, page 21.

11. C

Reference 21, chapter 3.

12. C

A thermal neutron is one that has lost energy through numerous collisions and has reached an energy level where it will either gain or lose energy on its subsequent collision to stay in the same energy state as its surrounding medium.

Reference 21.

13. D

A thermal neutron is one that has lost energy through numerous collisions and has reached an energy level where it will either gain or lose energy on its subsequent collisions to stay in the same energy state as its surrounding medium.

Reference 21.

14. D

Reference 31, appendix G, page 35.

15. B

Reference 31, appendix G, page 35.

16. B

Reference 21.

17. B

Reference 21.

18. A

Neutrons give up energy through collisions with other atoms, especially atoms with low atomic numbers. After enough energy is given up through collisions, the neutron's kinetic energy will be comparable to that of surrounding atoms.

Reference 21.

19. C

Neutrons are not charged particles. Therefore, when a neutron comes in close proximity to a charged particle, no effect will be exhibited on the neutron.

Reference 21, chapter 4, page 5.

20. A

A is the correct response since moderation is the process of slowing neutrons down.

Reference 21, chapter 4, page 5.

21. A

Reference 21, chapter 4, page 5.

22. C

Reference 21.

23. D

Reference 21.

24. D

Reducing feedwater inlet temperature will increase moderator density and the increased density will increase neutron moderation.

Reference 21, chapter 4, page 5.

25. C

A small atom will allow the largest transfer of energy per collision and the more dense the moderator is, the more collisions there will be.

Reference 21, chapter 4, page 5.

26. C

A good moderator absorbs few neutrons, has a high probability for scattering neutrons, and thermalizes a neutron in few collisions.

Reference 73, page 4-77.

27.

A good neutron moderator has a small macroscopic absorption cross section and therefore absorbs few neutrons. It has a large probability of undergoing scattering reactions, reflected by a large macroscopic scattering cross section. And its large average logarithmic energy decrement results in a large energy loss per collision; therefore, a neutron requires relatively few collisions to be thermalized.

Reference 73, page 4-77.

28. C

Reference 21.

29. C

Reference 21.

30. A

NEUTRONS
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 1-10

Define "prompt neutrons" and "delayed neutrons."

K1.03 Questions 11-17, 30

Define "thermal neutrons."

K1.04 Questions 18-23

Describe neutron moderation.

K1.04 Question 24

Describe operational conditions that affect neutron moderation.

K1.05 Questions 25-29

Identify characteristics of good moderators.

NEUTRON LIFE CYCLE
Questions

1. A reactor with an effective multiplication factor (K_{eff}) slightly greater than one is

   A. subcritical
   B. critical
   C. supercritical
   D. prompt critical

2. 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, quantized state
   D. greater than 1, thermal neutron supply

3. 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. $K_{eff} = 0$; $\Delta k/k = 1$

4. 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

5. 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. $\frac{\text{no. of neutrons from fission in one generation}}{\text{no. of neutrons in previous generation}}$

   D. $\frac{\text{no. of neutrons in previous generation}}{\text{no. of neutrons in present generation}}$

6. The "number of neutrons from fission in the present generation compared to the number of neutrons in the previous generation" is the

   A. reproduction factor
   B. fast fission factor
   C. neutron generation factor
   D. effective multiplication factor

7. Select the word that best completes the following definition of the effective multiplication factor (K_{eff}).

   "The number of neutrons produced from fission in the second generation divided by the number of neutrons produced in the ________ generation."

   A. first
   B. second
   C. third
   D. fourth

8. Is the following statement true or false? Explain your reasoning

   "A reactor can have an effective multiplication factor equal to one and yet not be critical."

9. A reactor with a K_{eff} of 1.002 would be considered

   A. supercritical
   B. critical
   C. subcritical
   D. prompt critical

10. K_{eff} is not dependent on

    A. core dimensions
    B. core burnout
    C. moderator-to-fuel ratio
    D. installed neutron sources

11. Which of the following is the multiplication factor of a reactor?

    A. shutdown margin
    B. $K_{effective}$
    C. $K_{infinity}$
    D. K_{excess}

12. Effective multiplication factor is defined as "the number of fission neutrons in the present generation" divided by "the number of neutrons produced in the previous generation" and is represented by the symbol

    A. L_{TH}
    B. K_{ex}
    C. K_{eff}
    D. β_{eff}

13. Select the formula that defines effective multiplication factor (K_{eff}).

    A. $\frac{\text{no. of neutrons produced by fast fissions}}{\text{no. of neutrons from thermal fissions}}$

    B. $\frac{\text{no. of neutrons born in the fuel area}}{\text{no. of neutrons born in the moderator area}}$

    C. $\frac{\text{no. of neutrons in previous generation}}{\text{no. of neutrons in present generation}}$

    D. $\frac{\text{no. of neutrons from fission at end of generation}}{\text{no. of neutrons at end of previous generation}}$

14. Which one of the following, if changed, will not affect K_{eff}?

    A. fuel enrichment

    B. control rod worth

    C. neutron contribution from neutron sources

    D. shutdown margin when the reactor is subcritical

15. Which one of the following, if decreased, will not affect K_{eff}?

    A. fuel enrichment

    B. control rod worth

    C. neutron contribution from neutron sources

    D. shutdown margin when the reactor is subcritical

16. The term "K-excess" is defined as

    A. the fractional change in neutron population per generation

    B. the amount by which K_{eff} exceeds 1.0 in a supercritical operating reactor

    C. the amount of reactivity that must be inserted to bring a shutdown reactor to criticality

    D. the amount by which the total installed core K_{eff} exceeds 1.0

17. Why is a reactor designed to have a positive K_{excess}?

18. Which of the following contribute to the value of a reactor's K_{excess}?

    A. fuel
    B. control rods
    C. fission product poisons
    D. burnable poisons

19. Explain how the term "shutdown margin" can be applied to an <u>operating</u> reactor.

20. Shutdown margin (SDM) is a measure of how much

    A. a reactor is subcritical compared to K_{eff} equal to 1.0

    B. reactivity must be inserted to maintain K_{eff} less than 1.0

    C. difference exists between K_{eff} at beginning and end of life

    D. reactivity is inserted when all controls rods are fully inserted

21. When determining shutdown margin for an operating reactor, how many control rods are assumed to remain fully withdrawn?

    A. a single control rod of the highest reactivity worth

    B. a symmetrical pair of control rods of the highest reactivity worth

    C. a single control rod of average reactivity worth

    D. a symmetrical pair of control rods of average reactivity worth

22. Shutdown margin (SDM) is defined as the amount a cold, xenon-free reactor at 68°F would be subcritical with all control rods

    A. withdrawn, assuming the average worth rod remains stuck fully inserted

    B. inserted, assuming the average worth rod remains stuck fully withdrawn

    C. withdrawn, assuming the highest worth rod remains stuck fully inserted

    D. inserted, assuming the highest worth rod remains stuck fully withdrawn

23. Shutdown margin (SDM) is defined as the amount a cold, xenon-free reactor at 68°F would be subcritical if all control rods were inserted, assuming the control rod of the ___________ worth remains fully withdrawn.

    A. lowest reactivity
    B. highest reactivity
    C. lowest activity
    D. highest activity

24. The phrase "the amount a cold, xenon-free reactor at 68°F would be subcritical if all control rods were inserted, assuming the control rod of the highest worth remains fully withdrawn" is the definition of shutdown

    A. deficit
    B. defect
    C. margin
    D. coefficient

25. The fractional change in neutron population from one generation to the next is called

    A. beta
    B. K_{eff}
    C. lambda
    D. reactivity

26. Which one of the following is the most accurate definition of the term "reactivity"?

    A. the rate of change of reactor power in neutrons per second

    B. the ratio of the number of neutrons at some point in a generation to the number of neutrons at the same point in the previous generation

    C. the factor by which the neutron population changes per unit time

    D. the fractional change in the nearness of the reactor to a critical condition

27. Reactivity is defined as

    A. the fractional change in neutron population per generation

    B. the number of neutrons by which neutron population changes per generation

    C. the rate of change of reactor power in neutrons per second

    D. the change in the number of neutrons per second that cause a fission event

28. In a subcritical reactor, K_{eff} was increased from 0.85 to 0.95 by rod withdrawal. Which one of the following is closest to the amount of reactivity that was added to the core?

    A. 0.099 $\Delta k/k$
    B. 0.124 $\Delta k/k$
    C. 0.176 $\Delta k/k$
    D. 0.229 $\Delta k/k$

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. Select the term that is defined by the following phrases

    "The fractional change in neutron population per generation"

    "A measure of a reactor's departure from criticality"

    A. reproduction factor
    B. reactor period
    C. reaction rate
    D. reactivity

31. The spent fuel storage pool is designed to ensure K_{eff} remains <0.95. What is the value of reactivity associated with this K_{eff}?

    A. - 0.0005 $\Delta k/k$
    B. - 0.0027 $\Delta k/k$
    C. - 0.0526 $\Delta k/k$
    D. - 0.0864 $\Delta k/k$

32. With K_{eff} equal to 0.983, how much reactivity must be added to make the reactor exactly critical?

    A. 1.70% $\Delta k/k$
    B. 1.73% $\Delta k/k$
    C. 3.40% $\Delta k/k$
    D. 3.43% $\Delta k/k$

33. The shutdown margin (SDM) immediately following a reactor scram from full power is ____________ the SDM immediately prior to the scram.

    A. less than
    B. equal to
    C. greater than
    D. independent of

34. Which one of the following events would decrease shutdown margin in a BWR?

    A. fuel depletion

    B. buildup of samarium-149

    C. depletion of gadolinium

    D. increasing moderator temperature 10°F during shutdown

35. List five parameters or design features whose change would affect a shutdown reactor's criticality condition (margin of shutdown). And, explain the reactivity effect of an increase in each one.

36. The shutdown margin (SDM), upon full insertion of all control rods following a reactor scram from full power, is __________ the SDM immediately prior to the scram.

    A. equal to
    B. less than
    C. greater than
    D. independent of

37. The effective multiplication factor (K_{eff}) describes the ratio of the number of fission neutrons at the end of one generation to the number of fission neutrons at the __________ of the _________ generation.

    A. end; previous
    B. beginning; previous
    C. end; next
    D. beginning; next

38. One hour ago, the reactor scrammed from 100% steady state power due to an instrument malfunction. All systems operated normally.

    Given the following absolute values of reactivities added since the scram, assign a (+) or (–) as appropriate and choose the current value of shutdown margin.

Xenon	= ( ) 1.0% ΔK/K
Fuel Temperature	= ( ) 2.0% ΔK/K
Control Rods	= ( ) 14.0% ΔK/K
Voids	= ( ) 3.0% ΔK/K

    A. –8.0% ΔK/K
    B. –10.0% ΔK/K
    C. –14.0% ΔK/K
    D. –20.0% ΔK/K

39. The following are combinations of critical conditions that exist for the same reactor operating at 20% power at different times in core life. Which combination indicates the largest amount of excess reactivity exists in the core?

	CONTROL ROD POSITION	REACTOR RECIRCULATION FLOW
A.	25% rod density	25%
B.	50% rod density	50%
C.	25% rod density	50%
D.	50% rod density	25%

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 supercritical when K_{eff} is > 1.

Reference 73, chapter 5, page 19.

2. 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 73, chapter 5, page 19.

3. A

A reactor is exactly critical when K_{eff} = 1 and reactivity = 0.

Reference 73, chapter 5, page 19.

4. B

A reactor is supercritical when K_{eff} is > 1, subcritical when K_{eff} is < 1, and critical when

K_{eff} = 1.

Reference 73, chapter 5, page 19.

5. C

K_{eff} is defined as

<u>number of fission neutrons in one generation</u>
number of neutrons in previous generation

Reference 73, chapter 5, page 16.

6. D

K_{eff} is defined as

<u>number of fission neutrons in one generation</u>
number of neutrons in previous generation

Reference 73, chapter 5, page 16.

7. A

K_{eff} is defined as

<u>number of fission neutrons in one generation</u>
number of neutrons in previous generation

Reference 73, chapter 5, page 16.

8.

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 73, page 5-19.

9. A

Reference 73, chapter 5, page 19.

10. D.

K_{eff} is a measure of the probability that one fission event will cause another fission. This probability is affected by core size and materials. It is not affected by the introduction of non-fission neutrons.

Reference 73, chapter 5.

11. B

Reference 73, chapter 5, page 16.

12. C

The symbol for the effective multiplication factor is "K_{eff}."

Reference 73, chapter 5, page 16.

13. D

Effective multiplication factor K_{eff} is defined as

$$\frac{\text{number of fission neutrons in one generation}}{\text{number of neutrons in previous generation}}$$

Reference 73, chapter 5, page 16.

14. C

Reference 73, chapter 5, page 16.

15. C

Reference 73, chapter 5.

16. D

The built-in reactivity of a new core must exceed a K_{eff} of 1.0 to compensate for negative reactivity that will be inserted by fuel burnup, fission product poison buildup, and temperature increases. Without some excess reactivity, the reactor could attain criticality briefly, but would not be able to sustain criticality as fuel depletes and poisons increase.

Reference 77, page 2-7.

17.

The built-in reactivity of a new core must exceed a K_{eff} of 1.0 to compensate for negative reactivity that will be inserted by fuel burnup, fission product poison buildup, and temperature increases. Without some excess reactivity, the reactor could attain criticality briefly, but would not be able to sustain criticality as fuel depletes and poisons increase.

Reference 77, page 2-7.

18. A

Reference 77, page 2-7.

19.

"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 rod fails to insert.

Reference 77, page 7-13.

20. A

Reference 21, chapter 3.

21. A

SDM is defined as the amount a cold, xenon-free reactor would be subcritical at cold shutdown (68°F) conditions if all control rod assemblies were tripped, assuming the highest worth assembly remained fully withdrawn.

Reference 77, page 7-13; and reference 15, chapter 8, page 9-8.

22. D

SDM is defined as the amount a cold, xenon-free reactor would be subcritical at cold shutdown (68°F) conditions if all control rod assemblies were tripped, assuming the highest worth assembly remained fully withdrawn.

Reference 77, page 7-13; and reference 15, chapter 8, page 9-8.

23. B

SDM is defined as the amount a cold, xenon-free reactor would be subcritical at cold shutdown (68°F) conditions if all control rod assemblies were tripped, assuming the highest reactivity worth assembly remaining fully withdrawn. Reactivity is relevant to SDM, whereas activity is not.

Reference 77, page 7-13; and reference 15, chapter 8, page 9-8.

24. C

SDM is defined as the amount a cold, xenon-free reactor would be subcritical at cold shutdown (68°F) conditions if all control rod assemblies were tripped, assuming the highest worth assembly remained fully withdrawn.

Reference 77, page 7-13; and reference 15, chapter 8, page 9-8.

25. D

Reference 77, page 2-54.

26. D

Reference 73, chapter 5, pages 21 through 53.

27. A

Reactivity is defined as the fractional change in neutron population per generation. It is a measure of a reactor's departure from criticality.

Reference 77, page 2-54.

28. B

Reference 77, page 2-54.

29. A

Reactivity is mathematically defined as $\frac{K-1}{K}$

Reference 73, chapter 5, pages 21 through 53.

30. D

Reactivity is defined as the fractional change in neutron population per generation or a measure of a reactor's departure from criticality.

Reference 77, page 2-54.

31. C

The definition of reactivity is $\rho = (K - 1) / K$

$\rho = (.95 - 1) / .95 = -.05263\ \Delta k / k = -5.26\%\ \Delta k / k$

Reference 73, chapter 5, pages 21 through 53.

32. B

Reference 73, chapter 5.

33. B

The SDM immediately following the reactor trip is equal to the SDM immediately prior to the reactor trip because SDM is defined as the amount a cold, xenon-free reactor would be subcritical at CSD conditions (68°F) if all control rod assemblies were inserted, assuming that the highest worth control rod assembly remained fully withdrawn. This definition assumes no changes in xenon concentration occur immediately upon trip.

Reference 77, page 7-13; and reference 15, chapter 8, page 9-8.

34. C

Depletion of the burnable poison gadolinium will insert positive reactivity, decreasing the shutdown margin.

Reference 77, page 7-13.

35.

Any five of the following parameters and explanations will satisfy this question:

- moderate temperature - An increase would insert negative reactivity, 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.
- control rod position - A withdrawal would add positive reactivity, decreasing the shutdown margin.
- xenon 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 77, pages 7-13 through 7-19.

36. A

Reference 77, pages 7-13 through 7-19.

37. A

38. B

39. D

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 1-4

Define "critical" and "subcritical" in terms of the effective multiplication factor.

K1.08 Questions 5-15, 37

Define "effective multiplication factor" with respect to its relationship to the state of a reactor.

K1.09 Questions 16-18, 39

Define "K_{excess}."

K1.10 Questions 19-24

Define "shutdown margin."

K1.11 Questions 25-28, 30

Define "reactivity."

K1.12 Questions 29, 31-32

Relate reactivity and the effective multiplication factor.

K1.14 Questions 33-36, 38

Predict the change in shutdown margin due to changes in plant parameters.

REACTOR KINETICS AND NEUTRON SOURCES
Symbols and Terms

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 the response of a subcritical reactor's neutron population to an insertion of positive reactivity that is insufficient to bring the reactor critical?

   A. increases continually
   B. increases briefly, then levels off
   C. decreases continually
   D. decreases briefly, then levels off

2. Which of the following statements is true concerning subcritical multiplication?

   A. Time to reach equilibrium count rate increases as K_{eff} approaches one.

   B. Source range count rate is directly proportional to K_{eff}.

   C. Source strength increases as K_{eff} approaches one.

   D. Adding additional neutron sources increases K_{eff}.

3. Explain how the neutron population in a subcritical reactor can be made to increase.

4. 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, and that the reactor reaches a stable condition before each reactivity insertion.

5. 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.

6. Which of the following is <u>not</u> 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 longer for the equilibrium subcritical neutron population level to be reached as K_{eff} approaches 1.

   C. If an addition of 1×10^{-3} percent Δ K/K positive reactivity to a subcritical reactor causes the count rate to increase by 10 CPS, then an addition of 2×10^{-3} percent Δ K/K positive reactivity will cause count rate to increase by 20 CPS.

   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 plus the number of fission neutrons in the next generation.

7. A reactor startup is in progress. Which one of the following statements describes the response to control-rod withdrawal when taking the reactor critical?

   A. The nuclear instrumentation will take longer to stabilize at each new subcritical level.

   B. The reactor will be critical when the period and power level remain constant, with no further rod withdrawal.

   C. Each complete control-rod withdrawal will result in the same amount of change in subcritical power level.

   D. Each control-rod withdrawal results in an initial negative period followed by a strong positive period.

8. Which of the following statements best describes subcritical multiplication during a reactor startup?

   A. Subcritical multiplication is the process of using source neutrons to maintain a self-sustaining reaction when K_{eff} is less than 1.

   B. As k_{eff} approaches unity, a smaller change in neutron level occurs for a given change in k_{eff}.

   C. The equilibrium subcritical neutron level is dependent on the source strength and the time between successive reactivity insertions.

   D. As k_{eff} approaches unity, less time is required to reach the equilibrium neutron level for a given change in k_{eff}.

9. Of the following conditions, which group is necessary for subcritical multiplication to occur and be detected?

   A. neutron source, moderator, and fissionable material

   B. k_{eff} less than one, moderator, and control rods

   C. moderator, neutron source, and k_{eff} greater than one

   D. fissionable material, moderator, and k_{eff} less than one

10. During a reactor startup under xenon-free conditions, rod withdrawal is stopped at the -0.02% Δ K/K position and the power is allowed to stabilize. No additional operator actions are taken. In the hour after stabilization, reactor power level will:

    A. rapidly decrease to its pre-startup level

    B. remain essentially constant

    C. slowly decrease because it is subcritical

    D. slowly increase due to long-lived delayed neutrons

11. 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

12. A reactor startup is being performed with xenon-free conditions. Rod withdrawal is stopped just prior to criticality and neutron count rate is allowed to stabilize. No additional operator actions are taken.

    During the next 30 minutes count rate will

    A. remain essentially constant

    B. slowly decrease and stabilize due to long-lived delayed neutron precursors

    C. slowly decrease to its pre-startup level due to buildup of xenon-135

    D. slowly increase to criticality due to long-lived delayed neutron precursors.

13. Assume your reactor is being taken critical by periodically withdrawing equal reactivity control-rod increments. Which one of the following statements is correct as K_{eff} approches unity?

    A. The neutron level change for successive rod increment pulls becomes smaller.

    B. A longer period of time is required to reach the equilibrium neutron level after each rod withdrawal.

    C. A rod withdrawal will result in the reactor becoming slightly supercritical, due to a "prompt jump," and then return to a subcritical level.

    D. If the rod withdrawal is stopped for several hours, the neutron level will decrease to source level.

14. Which one of the following 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 K_{eff} approaches unity.

    D. An incremental withdrawal of any given control rod will produce an equivalent equilibrium count rate increase, whether K_{eff} is 0.88 or 0.92.

15. A subcritical reactor has an initial K_{eff} of 0.8000. Positive reactivity is added until the subcritical count rate is doubled. What reactivity addition caused the count rate to double?

    A. .0139 Δ K/K
    B. .0361 Δ K/K
    C. .1389 Δ K/K
    D. .3611 Δ K/K

16. A reactor is shutdown by 1.8 percent Δ K/K. 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. .9820
    B. .9912
    C. .9955
    D. .9991

17. The delayed neutron fraction for a fissionable nuclide (β)is defined as

    A. $\frac{\text{number of neutrons born delayed}}{\text{number of neutrons born prompt}}$

    B. $\frac{\text{no. of delayed neutrons that reach thermal energy}}{\text{total no. of fission neutrons reaching thermal energy}}$

    C. $\frac{\text{number of neutrons born delayed}}{\text{total number of neutrons born from fission}}$

    D. $\frac{\text{no. of delayed neutrons that reach thermal energy}}{\text{no. of prompt neutrons that reach thermal energy}}$

18. The average effective delayed neutron fraction ($\bar{\beta}_{eff}$) is defined as

    A. $\frac{\text{number of neutrons born delayed}}{\text{number of neutrons born prompt}}$

    B. $\frac{\text{no. of fissions caused by delayed neutrons}}{\text{total no. of fissions caused by fission neutrons}}$

    C. $\frac{\text{number of neutrons born delayed}}{\text{total number of neutrons born from fission}}$

    D. $\frac{\text{no. of delayed neutrons that reach thermal energy}}{\text{no. of prompt neutrons that reach thermal energy}}$

19. What is the definition for delayed neutron fraction (β)?

    A. fraction of the total number of delayed neutrons produced from fission, born from delayed neutron precursors

    B. fraction of the total number of fast neutrons produced from fission, born from delayed neutron precursors

    C. fraction of the total number of neutrons produced from fission, born from delayed neutron precursors

    D. fraction of the total number of thermal neutrons produced from fission, born from delayed neutron precursors.

20. Define and contrast the delayed neutron fraction (β), the effective delayed neutron fraction (β_{eff}), and the average effective delayed neutron fraction ($\bar{\beta}_{eff}$)

21. Explain the difference between β (delayed neutron fraction) and β_{eff} (effective delayed neutron fraction).

22. The difference between delayed neutron fraction and effective delayed neutron fraction is that the

    A. delayed neutron fraction is based on a finite-sized reactor and the effective delayed neutron fraction is based on an infinite-sized reactor

    B. effective delayed neutron fraction will remain constant over core life but the delayed neutron fraction changes due to fuel changes that occur as the core ages

    C. delayed neutron fraction considers neutrons at their birth while the effective delayed neutron fraction considers neutrons causing fission

    D. delayed neutron fraction is a weighted average of various fission products and the effective delayed neutron fraction is not

23. The ratio, $\frac{\text{number of neutrons born delayed}}{\text{total number of neutrons born from fission}}$ is the definition of

    A. multiplication factor
    B. effective delayed neutron fraction
    C. effective multiplication factor
    D. delayed neutron fraction

24. How does the effective delayed neutron fraction vary over core life?

    A. increases due to the burnup of U-238
    B. decreases due to the buildup of Pu-239
    C. increases due to the buildup of Pu-239
    D. decreases due to the burnup of U-238

25. The time in seconds required for power to change by a factor of "e" (or 2.71873) is called the

    A. startup rate
    B. reactor period
    C. shutdown margin
    D. doubling time

26. Which of the following terms defines reactor period?

    A. the time for reactor power to change by a factor of "e" (or 2.71873)

    B. the rate of change of reactor power expressed in decades per minute (DPM)

    C. the time for reactor power to change by a factor of 10

    D. the rate of change of reactor power expressed in decades per second (DPS)

27. The rate of change of reactor power by factors of "e" measured in seconds is expressed by the

    A. startup rate
    B. shutdown margin
    C. reactor period
    D. power coefficient

28. Which of the following phrases defines "reactor period"?

    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 time required for reactor power to change by a factor of 10, expressed in minutes

    D. the time required for reactor power to change by a factor of "e," expressed in seconds

29. If reactor power is changing by a factor of "e" every minute, it is said to have a ___________ of 60 seconds.

    A. doubling time
    B. reactor period
    C. startup rate
    D. generation rate

30. Stating that a reactor has a period of 60 seconds indicates that, over a one-minute time period, _________ will increase by a factor of __________.

    A. K effective, "e"
    B. K effective, log 10
    C. reactor power, "e"
    D. reactor power, 10

31. A reactor whose _________ is changing by a factor of 2.7187 each minute is said to have a period of 60 seconds.

    A. power level
    B. reactor period
    C. multiplication factor
    D. doubling time

32. As core age increases, the reactor response to a given reactivity addition will become _______ due to the buildup of isotopes that have a _______ delayed neutron fraction.

    A. quicker, smaller
    B. slower, smaller
    C. quicker, larger
    D. slower, larger

33. Without delayed neutrons in the neutron cycle, when positive reactivity is added to a critical reactor, the reactor will

    A. not be able to attain criticality

    B. begin an uncontrollable rapid power increase

    C. experience a rapid but controllable power increase

    D. experience a prompt jump in power level followed by a decrease to the initial power level

34. Why do delayed neutrons have such a dominant effect upon reactor period?

    A. short delayed neutron lifetime
    B. long delayed neutron lifetime
    C. short delayed neutron generation time
    D. long delayed neutron generation time

35. Explain why delayed neutrons are important in reactor control.

36. A small amount of reactivity is added to a critical reactor in the source/startup 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 reactor period achieved for this reactivity addition?

    A. moderator temperature coefficient
    B. fuel temperature coefficient
    C. prompt neutron lifetime
    D. average effective decay constant

37. Which of the following is true of a critical reactor brought to a prompt critical condition?

A. The reactivity addition exceeded the fast neutron fraction.

B. The prompt critical condition was achieved primarily, but not exclusively, on prompt neutrons.

C. The amount of reactivity required to achieve prompt criticality varies over core life.

D. Flux rises at a steady, consistent rate once prompt criticality is achieved.

38. Explain why a "prompt jump" occurs when a step insertion of positive reactivity is made in a critical reactor.

39. Explain why a "prompt drop" occurs when a step insertion of negative reactivity is made in a critical reactor.

40. Explain what is meant by the term "prompt critical."

41. A reactor is critical with the following data:

Moderator temperature coefficient = -5×10^{-2} % Δ K/K/°F

Decay constant (λ) = .08 sec^{-1}

Average effective delayed neutron fraction = .0065

How much reactivity would be needed to take this reactor "prompt critical"?

A. 5×10^{-2} % Δ K/K
B. .08 % Δ K/K
C. .65 % Δ K/K
D. 1.7 % Δ K/K

42. A critical reactor will become "prompt critical" if the reactivity added is equal to the

A. shutdown margin
B. effective delayed neutron fraction
C. effective decay constant (l)
D. worth of the most reactive rod

43 A critical reactor will become prompt critical if the reactivity added is equal to the

A. effective delayed neutron decay constant

B. effective delayed neutron fraction

C. effective prompt neutron decay constant

D. effective prompt neutron fraction

44. A small but rapid increase in neutron population in response to control rod motion is called a prompt

A. neutron
B. drop
C. criticality
D. jump

45. As the core ages, the amount of positive reactivity required to make the reactor prompt critical will ________ because the average effective delayed neutron fraction ________ .

A. increase; increases
B. increase; decreases
C. decrease; increases
D. decrease; decreases

46. A reactor is operating at a power level of 120 watts. A control rod is 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 rod insertion?

A. 27 watts
B. 32 watts
C. 49 watts
D. 54 watts

47. The reactor is on a stable 50-second period at 40 on range 2 of the intermediate monitors. The point of adding heat is normally three decades higher, at 40 on range 8 of the intermediate range monitors. Which of the following is the time needed for power to reach the point of adding heat if the period remains constant?

    A. 2.8 minutes
    B. 3.8 minutes
    C. 5.8 minutes
    D. 6.2 minutes

48. Reactor power increases from 5 percent to 30 percent in 12 minutes. What reactor period was required for this transient?

    A. .01 seconds
    B. 21.5 seconds
    C. 2.5 minutes
    D. 6.7 minutes

49. After initial criticality, the reactor period is stabilized. The source range detectors are repositioned so that the count rate is 100 cps. Sufficient positive reactivity is added to establish a 120-second period. How much time will it take for the count rate to increase to 10,000 cps with no additional operator action?

    A. 1.2 minutes
    B. 4 minutes
    C. 9.21 minutes
    D. 15.82 minutes

50. A reactor is at 37 percent of rated power. If a uniform reactivity addition occurs, resulting in a continuous period of ÷300 seconds, which one of the following is the expected reactor power level after 5 minutes?

    A. 37.62 percent
    B. 57.06 percent
    C. 100.58 percent
    D. 370 percent

51. During a reactor startup, the intermediate range monitor (IRM) readings go from 30 percent to 65 percent on the same range in 2 minutes with no operator action. Which of the following is the average reactor period during the power increase?

    A. 120 seconds
    B. 155 seconds
    C. 173 seconds
    D. 357 seconds

52. A critical reactor is at a power level of 53 watts, when a reactivity addition causes reactor power to increase on a constant period of 93 seconds. Assuming that the power increase lasts for 2.6 minutes, what will be the resulting final power?

    A. 311 watts
    B. 284 watts
    C. 96 watts
    D. 55 watts

53. Reactor power has increased from 387 MW to 553 MW in a time period of 10 seconds. What was the reactor period for this power increase?

    A. 3 seconds
    B. 24 seconds
    C. 28 seconds
    D. 35 seconds

54. Reactor power is decreased from 225 MW to 120 MW on a reactor period of -30 seconds. How long did it take to accomplish this power decrease?

    A. 2 seconds
    B. 13 seconds
    C. 19 seconds
    D. 47 seconds

55. Reactor power is increased over a 25-second time span on a reactor period of 135 seconds. If the final reactor power is 430 MW, what was the initial reactor power?

    A. 72 MW
    B. 254 MW
    C. 302 MW
    D. 357 MW

56. Reactor power is lowered from 563 MW to 320 MW in two minutes. What is the reactor period during this load decrease?

    A. -3 seconds
    B. -35 seconds
    C. -90 seconds
    D. -212 seconds

57. The term "doubling time" is defined as the time necessary to double

    A. reactivity
    B. reactor period
    C. reactor power
    D. control rod density

58. The equation, $P = P_o e^{t/T}$, may be used alone to calculate the

    A. amount of reactivity required to increase power from one specified level to another

    B. relationship between reactor period and the amount of time required for reactor power to double

    C. amount of energy created by an increase from one specified power level to another

    D. relationship between reactor period and reactivity

59. The relationship between reactor period and the amount of time required to increase reactor power by a factor of two can be derived from which of the following equations?

    A. $T = (l^* / \rho) + (\bar{\beta}_{eff} - \rho) / \bar{\lambda} \rho$

    B. $T = l^* / (\rho - \bar{\beta}_{eff})$

    C. $P = P_o e^{t/T}$

    D. $\rho = (l^* / T) + \bar{\beta}_{eff} / (1 + \bar{\lambda} T)$

60. During a startup, the reactor is critical at 3000 cps. A control rod is notched out, resulting in a doubling time of 85 seconds. Which of the following is the best estimate of reactor period?

    A. 9 seconds
    B. 58 seconds
    C. 123 seconds
    D. 170 seconds

61. During a reactor startup, the reactor is critical at 3000 counts per second. A control rod is notched out, resulting in a doubling time of 85 seconds. How much time is required for the reactor to reach 888,000 cps?

    A. 341 seconds
    B. 483 seconds
    C. 698 seconds
    D. 965 seconds

62. The reactor power level is increased from 50 kW to 370 kW in 2 minutes. Select the estimate of the doubling time.

    A. 42 seconds
    B. 60 seconds
    C. 86 seconds
    D. 120 seconds

63. The doubling time formula is used to determine

    A. Xe-135 peaking time after scram from other than full reactor power

    B. radiation shielding when source is a point source

    C. startup rate (SUR) for a given reactor period

    D. reactor period during a stable period transient

64. A correct statement regarding reactor period is that it can be calculated by multiplying the time (in seconds) that it takes the power to double by

    A. 0.500
    B. 0.693
    C. 1.334
    D. 1.443

65. Calculate the doubling time for a reactor with a stable 100-second period.

    A. 55.0 seconds
    B. 60.1 seconds
    C. 69.3 seconds
    D. 1.4 minutes

66. Calculate the period for a reactor with a 60-second doubling time.

    A. 60.0 seconds
    B. 86.6 seconds
    C. 1.5 minutes
    D. 6.0 minutes

67. A reactor is operating at 50 percent power with the following conditions

    Power defect = 0.03% $\Delta K/K$
    Shutdown margin = 0.05% $\Delta K/K$
    Effective delayed neutron fraction = 0.007
    Effective prompt neutron fraction = 0.993

    How much positive reactivity must be added to take this reactor "prompt critical"?

    A. 0.03% $\Delta K/K$
    B. 0.05% $\Delta K/K$
    C. 0.7% $\Delta K/K$
    D. 0.993% $\Delta K/K$

68. If reactor power changes from 10^{-5}% to 10^{-6}% in 5 minutes the average reactor period is:

    A. negative 80 seconds
    B. positive 80 seconds
    C. negative 130 seconds
    D. positive 130 seconds

69. Positive reactivity is continuously added to a critical reactor. Which one of the following values of K_{eff} will first result in a <u>prompt</u> critical reactor.

    A. 1.0001
    B. 1.001
    C. 1.01
    D. 1.1

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

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. This steady-state population will be greater when the reactor is closer to critical.

Reference 73, chapter 8, page 66.

2. A

The number of generations required before a new equilibrium count rate is reached increases as K_{eff} approaches 1. Therefore, it takes longer to reach a new steady-state power level as K_{eff} approaches 1.

Reference 73, chapter 8.

3.

In a subcritical reactor, the fission process is not self-sustaining anu 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 73, pages 8-83 and 8-4.

4.

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 73, pages 8-48 through 8-55.

5.

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 32 pages 190 and 191, and reference 73, page 8-48.

6. C

Reference 73, chapter 8, page 66.

7. A

The number of generations required before a new equilibrium power level is reached increases as K_{eff} approaches 1. Therefore, a longer time is required for the nuclear instrumentation indication to stabilize.

Reference 73, chapter 8.

8. A

Reference 73, chapter 8, page 66.

9. A

Reference 73, chapter 8, page 13.

10. B

Once a subcritical equilibrium count rate is established, it will only change in response to a change in reactivity or source strength.

Reference 73, chapter 8, page 18.

11. B

Reference 73.

12. A

Reference 73.

13. B

Reference 73.

14. A

Reference 73.

15. C

$CR_1 (1-K_{eff1}) = CR_2 (1-K_{eff2})$

$1 (1-0.8) = 2 (1-K_{eff2})$

$K_{eff2} = .9$

$\Delta\rho = K_2 - K_1 / K_2 K_1$

$= \frac{.9 - .8}{(.9)(.8)}$

$= .1389$

Reference 07 , chapter 5, page 11.

16. D

$\Delta K / K = K_{eff} -1 / K_{eff} = -.018$

$K_{eff} = .9823$

$CR_1 (1-K_{eff1}) = CR_2 (1-K_{eff2})$

$1 (1-.9823) = 20 (1-K_{eff2})$

$K_{eff2} = .9991$

Reference 07, chapter 5, page 14.

17. C

The delayed neutron fraction is a ratio of the number of neutrons born delayed to the total number of neutrons born from fission without considering how many reach thermal energy.

Every fissionable nuclide has a specific value of its delayed neutron fraction.

Reference 21, chapter 3, page 29.

18. B

The average effective delayed neutron fraction is a ratio of the number of fissions caused by neutrons born delayed to the total number of fissions caused by neutrons born from fission.

Reference 21, chapter 3, page 29.

19. C

Reference 21, chapter 3, page 29.

20.

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 BWR $\beta_{eff} < \beta$.

The average effective delayed neutron fraction ($\bar{\beta}_{eff}$) is a weighted average of the β for each fuel isotope in a given core. Because $\bar{\beta}_{eff}$ 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 73, pages 7-28 through 7-38.

21.

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 73, pages 7-28 through 7-38.

22. C

The two ratios reflect the same relationship of parameters but the effective fraction considers the difference in the probability of causing fission due to the delayed neutron's lower birth energy.

Reference 21, chapter 3, page 29.

23. D

Reference 21, chapter 3, page 29.

24. B

Reference 21.

25. B

Reactor period is defined as the time required for reactor power to change by a factor of "e."

Reference 75, chapter 1, page 3.15.

26. A

Reference 75, chapter 1, page 3.15.

27. C

Period is defined as the time in seconds required for reactor power to change by a factor of "e."

Reference 75, chapter 1, page 3.15.

28. D

Reference 01, page 84.

29. B

Reference 01, page 84.

30. C

Reference 01, page 84.

31. A

Reference 01, page 84.

32. A

The buildup of Pu-239 over core life and the depletion of U-235 will cause the increased response rate of the reactor to a given reactivity addition. Pu-239 has a smaller β than U-235.

Reference 21, chapter 3, page 30.

33. B

The absence of delayed neutrons would mean a critical reactor is critical strictly on prompt neutrons (prompt critical). This an uncontrollable state due to the absence of delayed neutrons and the resulting short neutron generation time.

Reference 21, chapter 3, page 38.

34. D

Reference 31, chapter 3, page 33.

35.

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 73, pages 7-29 and 7-30.

36. D

Reference 73.

37. C

C is correct because the amount of reactivity required for prompt criticality depends on the delayed neutron fraction, which varies over core life.

Distractors:

Flux rises in an unpredictable and difficult to control manner. Critical condition is achieved on prompt neutrons alone. Reactivity is equal to or greater than the fraction of delayed neutrons.

Reference 21, chapter 3.

38.

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 73, pages 7-62 through 7-66.

39.

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 73, page 7-68.

40.

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 73, pages 248 and 249.

41. C

Prompt criticality is defined as the condition where $\rho = \overline{\beta}_{eff}$.

Reference 21, chapter 3.

42. B

Prompt criticality is defined as the condition where $\rho = \overline{\beta}_{eff}$.

43. B

Prompt criticality is defined as the condition where $\rho = \overline{\beta}_{eff}$.

44. D

In the instant just after a control rod begins to move, there is a small but rapid increase in the prompt neutron population called a prompt jump.

Reference 22, page 32.

45. D

Over core life, Pu-239 (with a relatively small delayed neutron fraction) builds up, and U-235 depletes. This causes the average effective delayed neutron fraction to decrease, with a consequent decrease in the reactivity needed for prompt criticality.

Reference 21, chapter 3, page 38.

46. A

$P = P_o e^{t/T}$

$= (120 \text{ watts})\ e^{-120/80}$

$= 27$ watts

Reference 21, chapter 3.

47. C

$P = P_o e^{t/T}$

$P/P_o = e^{t/T}$

$10^3 = e^{t/50}$

$t = 345$ seconds

$= 5.8$ minutes

Reference 21, chapter 3.

48. D

$P = P_o e^{t/T}$

$30 = 5e^{720/T}$

$T = 402$ seconds

$= 6.7$ minutes

Reference 21, chapter 3.

49. C

$P = P_o e^{t/T}$

$10{,}000 = 100\ e^{t/120}$

$t = 553$ seconds

$= 9.21$ minutes

Reference 21, chapter 3

50. C

$P = P_o e^{t/T}$

$= (37\%)e^{600/300}$

$= 100.58\%$

Reference 21, chapter 3.

51. B

$P = P_o e^{t/T}$

$65\% = (30\%)e^{120/T}$

$T = 155$ seconds

Reference 21, chapter 3.

52. B

$P = (53 \text{ watts}) \times (e^{156 \text{ sec}/93 \text{ sec}})$

$P = (53 \text{ watts}) \times (e^{1.68})$

$P = 53 \text{ watts} \times (5.37)$

$P = 284$ watts

Reference 21, chapter 3.

53. C

$553 = 387\ e^{10/T}$

$1.42 = e^{10/T}$

$.356 = {}^{10}/_{T}$

T = 28 seconds

Reference 21, chapter 3.

54. C

120 MW = (225 MW) x ($e^{t/30 \text{ seconds}}$)

$.553 = e^{t/30 \text{ seconds}}$

.629 = t/30 seconds

t = 19 seconds

Reference 21, chapter 3.

55. D

$430 \text{ MW} = Po\ e^{25/135}$

$430 \text{ MW} = Po\ e^{.185}$

430 MW = (Po) (1.2)

Po = 357 MW

Reference 21, chapter 3.

56. D

$320 \text{ MW} = (563 \text{ MW})\ e^{120/T}$

$.568 = e^{120/T}$

$T = \frac{120}{-.565}$

T = -212 seconds

Reference 21, chapter 3.

57. C

Reference 21, chapter 3, page 19.

58. B

This equation can be used to derive the equation DT x 1.443 = T, which is the relationship between reactor period and the amount of time it takes reactor power to double.

Reference 21, chapter 3, page 19.

59. C

This equation can be used to derive the equation DT x 1.443 = T, which is the relationship between reactor period and the amount of time it takes reactor power to double.

Reference 21, chapter 3, page 19.

60. C

doubling time = (ln 2)T

85 seconds = .693 T

T= 123 seconds

Reference 73, page 7-18.

61. C

$DT = .693\ T$

$T = (85)/(.693)$

$= 122.7$ seconds

$P = P_o e^{t/T}$

$888{,}000 = (3{,}000)e^{t/122.7}$

$t = 698$ seconds

Reference 73, page 7-18.

62. A

$P = P_o e^{t/T}$

$370 = (50)\ e^{120/T}$

$T = 60$ seconds

$DT = (\ln 2)T$

$= (.693)\ (60)$

$= 42$ seconds

Reference 73, page 7-18.

63. D

If the time required for power to double is divided by the natural logarithm of 2, the result is the reactor period.

Reference 73, page 7-18.

64. D

$DT = (0.693)\ T$

$T = (1.443)\ DT$

Reference 73, page 7-18.

65.

$P = P_o e^{t/T}$

$2P_o = P_o e^{t/T}$

$2 = e^{t/T}$

$\ln 2 = t/100$

$(100)\ (.693) = t$

$t = 69.3$ seconds

Reference 31, chapter 3, pages 3 through 19.

66. B

$P = P_o e^{t/T}$

$2P_o = P_o e^{60/T}$

$2 = e^{60/T}$

Reference 31, chapter 3, pages 3 through 19.

67. C

Reference 31.

68. C

$P/P_o = e^{t/T}$

$\ln (P/P_o) = t/T$

$T = t / \ln (P/P_o)$

$T = 5 \text{ minutes} / \ln (10^{-6} / 10^{-5})$

$T = 360 \text{ seconds} / -2.3$

$T = -130$ seconds

69. 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 1-14

Explain the concept of subcritical multiplication.

K1.01 Questions 15, 16

Perform calculations relating subcritical count rates and reactivity.

K1.04 Questions 17-24

Define the terms "delayed neutron fraction," "effective delayed neutron fraction" and "average effective delayed neutron fraction"; explain why they are different.

K1.05 Questions 25-31, 68

Define "reactor period."

K1.06 Questions 32-36

Explain the effect of delayed neutrons on reactor period.

K1.07 Questions 37-44, 69

Explain prompt critical, prompt jump, and prompt drop.

K1.07 Question 45

Explain the variation in prompt critical reactivity over core life.

K1.08 Questions 46-56

Given the power equation, solve problems for power changes and period.

K1.09 Questions 56-64

Define doubling time and calculate it using the power equation.

K1.09 Questions 65-67

Given the mathematical relationship between period and power (the power equation), and selected data, calculate the unknown.

REACTIVITY COEFFICIENTS
Questions

1. The change in reactivity produced by a unit change in reactor coolant temperature defines which reactivity coefficient?

   A. void
   B. moderator
   C. power
   D. doppler

2. The moderator temperature coefficient (αT) measures a change in _____ resulting from a change in _____.

   A. reactivity, moderator temperature
   B. K effective, moderator temperature
   C. moderator temperature, reactivity
   D. moderator temperature, K effective

3. The moderator temperature coefficient (αT) is expressed in units of

   A. ΔK effective per degree Fahrenheit, moderator

   B. ΔK effective per degree Fahrenheit, moderator and fuel

   C. ΔK/K per degree Fahrenheit, moderator

   D. ΔK/K per degree Fahrenheit, moderator and fuel

4. The amount of reactivity added to a reactor for each degree Fahrenheit increase in the moderator temperature, with all other parameters held constant, is referred to as the

   A. isothermal temperature coefficient of reactivity

   B. moderator temperature coefficient of reactivity

   C. heatup coefficient of reactivity

   D. temperature reactivity defect

5. Which of the following would indicate a <u>negative</u> moderator temperature coefficient (αT)?

   A. A decrease in moderator temperature results in an increase in core reactivity.

   B. An increase in moderator temperature results in an increase in core reactivity.

   C. A decrease in moderator temperature results in a decrease in core reactivity.

   D. An increase in moderator temperature has no effect on core reactivity.

6. A one degree Fahrenheit increase in moderator temperature in a reactor with a negative moderator temperature coefficient (αT) will insert

   A. negative reactivity resulting in a decrease in core reactivity

   B. positive reactivity resulting in an increase in core reactivity

   C. positive reactivity resulting in a decrease in core reactivity

   D. negative reactivity resulting in an increase in core reactivity

7. Addressing each term in the six-factor formula, explain why a change in moderator temperature causes a change in core reactivity.

8. 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°F.

   A. void coefficient
   B. pressure coefficient
   C. fuel temperature coefficient
   D. moderator temperature coefficient

9. If the plant has operated steady-state at 100% power for the past six months, the moderator temperature coefficient (αT) most likely has:

   A. changed very little
   B. become less negative
   C. become more negative
   D. become less negative, turned, and become more negative

10. The plant is currently at end-of-life in its fuel cycle, and it will be refueled next month. How will the refueled core's moderator temperature coefficient (αT) compare to its present value?

   A. will be less negative
   B. will be more negative
   C. will not be much different
   D. A comparison cannot be made with the available information.

11. Which of the following describes the change in the moderator temperature coefficient (αT) during a plant cooldown?

   A. The moderator temperature coefficient continually becomes less negative.

   B. The moderator temperature coefficient continually becomes more negative.

   C. The moderator temperature coefficient changes very little during a plant cooldown.

   D. The moderator temperature coefficient becomes more negative, then turns, and becomes less negative.

12. The plant is currently at beginning-of-life in its fuel cycle. During plant heatup, the moderator temperature coefficient will

   A. become less negative
   B. become more negative
   C. remain effectively constant
   D. become more negative, then turn and become less negative

13. In regard to the magnitude of change, which one of the following statements describes the response of the moderator temperature coefficient?

   A. Below the power range, the moderator temperature coefficient becomes more negative as control rods are withdrawn.

   B. The moderator temperature coefficient becomes less negative as fuel temperature increases.

   C. In the range of 1 percent to 100 percent power, very little negative reactivity is inserted due to moderator temperature change.

   D. The moderator temperature coefficient becomes negligible below 1 percent power.

14. Which of the following conditions would cause the moderator temperature coefficient of reactivity to become more negative?

   A. inserting rods from 50 percent control-rod density to 75 percent rod density

   B. fuel temperature decreases from 1500°F to 1200°F

   C. core age increases

   D. moderator temperature decreases from 500°F to 450°F

15. Which one of the following statements explains the change in the moderator temperature coefficient of reactivity over core life?

    A. The increased void length per fuel bundle drives the utilization down; thus, the moderator coefficient becomes more negative.

    B. The increased void length develops an undermoderated core and draws the moderator coefficient more positive.

    C. The increased amount of fission product poisons decreases the thermal utilization of neutrons; thus, the moderator coefficient becomes more positive.

    D. the utilization of thermal neutrons increases, thus making the moderator coefficient less negative.

16. A BWR power plant is operating at 90 percent power, and the steam to a feedwater heater string is isolated. Reactor power increases due to

    A. increased void formation in the core
    B. increased fuel temperature
    C. decreased reactor pressure
    D. increased inlet subcooling

17. As the moderator temperature increases, the moderator temperature coefficient becomes

    A. less negative because the increased neutron velocities require more collisions to thermalize

    B. more negative because the microscopic cross section for capture increases

    C. less negative because moderator density increases

    D. more negative because the slowing-down length increases more

18. Explain how and why the moderator temperature coefficient changes over core life.

19. Explain how and why the moderator temperature coefficient changes with increasing moderator temperature.

20. 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

21. 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

22. The reactor is currently at end-of-life in its fuel cycle, and it will be refueled next month. In comparison to the current moderator temperature coefficient (MTC), the MTC after refueling will be

    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.

23. Which one of the following statements is <u>not</u> true of resonance absorption? As fuel temperature increases

    A. resonance absorption continues to add negative reactivity

    B. resonance peak height increases

    C. one resonance peak can broaden and overlap with another

    D. at low fuel temperatures, the change in resonance absorption is greater per °F fuel temperature increase than at high fuel temperatures

24. Neutrons that are most likely to be resonantly absorbed are classified as _______ neutrons.

    A. epithermal
    B. thermal
    C. fast
    D. slow

25. Which of the following nuclides are primarily recognized as major resonant absorbers?

    A. Pu-239 and U-235
    B. Pu-240 and U-235
    C. Pu-240 and U-238
    D. Pu-239 and U-238

26. When considering the resonance absorption of a neutron into a nucleus, factors that can affect this process may include neutron:

    A. potential energy, binding energy of the nucleus, and the excitation energy that the neutron supplies

    B. electric charge, kinetic energy of the nucleus, and the excitation energy that the neutron supplies

    C. kinetic energy, kinetic energy of the nucleus, and the electrical charge of the atom

    D. kinetic energy, kinetic energy of the nucleus, and the excitation energy that the neutron supplies

27. Factors that affect resonance absorption of a neutron into a nucleus include

    A. kinetic energy of the nucleus, kinetic energy of the neutron, and excitation energy of the nucleus

    B. kinetic energy of the neutron, excitation energy of the nucleus, and excitation energy of the neutron

    C. excitation energy of the nucleus, excitation energy of the neutron, and kinetic energy of the nucleus

    D. excitation energy of the neutron, kinetic energy of the nucleus, and kinetic energy of the neutron

28. Explain resonance absorption, and state the two nuclides responsible for most reasonance absorption.

29. As fuel temperature is increased, the effective "resonant absorption peaks" exhibited by U-238 will

    A. decrease in height and decrease in width
    B. decrease in height and increase in width
    C. increase in height and decrease in width
    D. increase in height and increase in width

30. Which of the following statements concerning Doppler broadening is correct?

    A. Resonance peaks broaden more per degree increase in fuel temperature for a given temperature change at low fuel temperatures as compared to high fuel temperatures.

    B. Resonance peaks broaden less per degree increase in fuel temperature for a given temperature change at low fuel temperatures as compared to high fuel temperatures.

    C. Resonance peak broadening will decrease the overall microscopic cross section for neutron absorption.

    D. Resonance peak broadening will impact neutron absorption throughout all neutron energy levels.

31. Doppler broadening is affected by fuel temperature. Given an increase in fuel temperature, which one of the following statements is correct?

    A. As fuel temperature increases, absorption of neutrons in U-240 decreases; thus, the overall Doppler coefficient decreases.

    B. In the modified capture cross section curve, the peaks are flattened, but the overall area under the curve remains essentially the same and neutron capture in U-238 will remain essentially the same at any temperature.

    C. At higher fuel temperatures, the resonant peaks are already broad; and a relatively large percentage of resonant-energy neutrons are being absorbed. Therefore, the effect of a further increase in temperature is relatively small, and the magnitude of the Doppler coefficient is reduced.

    D. As fuel temperature increases, the magnitude of the Doppler coefficient increases, due to the effect of self-shielding.

32. Explain how and why an increase in fuel temperature causes a change in core reactivity.

33. Explain self-shielding and its impact on the Doppler coefficient.

34. Self-shielding can be described as an effect that

    A. reduces primary containment dose rates

    B. prevents resonant neutrons from penetrating to the interior of the fuel pellet

    C. results from the temperature differential across a fuel bundle

    D. decreases control rod worth due to adjacent control rods

35. Which of the following accounts for the increase in resonant neutron capture as fuel temperature increases?

    A. buildup of poisons in the fuel pellet
    B. reduction of fuel pellet self-shielding
    C. thermal expansion of the fuel pellet
    D. U-235 depletion in the fuel pellet

36. Which of the following best describes the effect known as Doppler broadening? Resonant peaks become

    A. lower and narrower
    B. lower and wider
    C. higher and narrower
    D. higher and wider

37. As fuel temperature increases, the absolute value of the Doppler coefficient of reactivity decreases. This effect is best explained by which of the following?

    A. reduction in fuel pellet self-shielding

    B. buildup of fission product poisons within the fuel pellet

    C. reduction in Doppler broadening per degree change

    D. neutron embrittlement of the fuel pellets

38. Which one of the following pairs of fuel isotopes contain the largest contributors to the total neutron resonance capture in the core

    A. U-235 and Pu-239
    B. U-235 and Pu-240
    C. Pu-239 and U-238
    D. Pu-240 and U-238

39. The Doppler temperature coefficient (αD) measures

    A. the change in $K_{effective}$ due to change in reactor power

    B. the change in reactivity due to a change in reactor power

    C. the change in $K_{effective}$ due to a change in the fuel temperature

    D. the change in reactivity due to a change in the fuel temperature

40. The correct units of measure of the Doppler temperature coefficient (αD) are:

    A. $\Delta K/K$ per °F, fuel temperature

    B. $\Delta K_{effective}$ per °F, fuel temperature

    C. $\Delta K/K$ per percent reactor power

    D. $\Delta K_{effective}$ per percent reactor power

41. The amount of reactivity added to a reactor for each 1 °F change in fuel temperature is referred to as the _____ temperature coefficient.

    A. moderator
    B. Doppler
    C. power
    D. void

42. In the definition of Doppler temperature coefficient of reactivity (αD), °F refers to:

    A. clad temperature
    B. fuel temperature
    C. incore thermocouple temperature
    D. moderator temperature

43. Which of the following phrases defines the Doppler temperature coefficient (αD)?

    A. the incremental change in reactivity due to an incremental change in reactor power

    B. the total change in reactivity due to 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

44. Which of the following nuclides are the major contributors to the Doppler coefficient?

    A. U-235 and Pu-240
    B. U-238 and Pu-240
    C. U-238 and Pu-241
    D. U-238 and U-235

45. The term Doppler coefficient is defined as the change in reactivity per unit change in

    A. overall reactor pressure
    B. overall core void volume
    C. fuel temperature
    D. moderator temperature

46. An increase in which of the following is most likely to cause the Doppler coefficient to become less negative?

    A. core age
    B. moderator temperature
    C. fuel temperature
    D. void fraction

47. The Doppler coefficient of reactivity is the reactivity associated with the

    A. heating of U-238

    B. addition of Sm-149 during power changes

    C. heating of B-10

    D. addition of Pu-239 as the core ages

48. Which one of the following describes how the magnitude of the Doppler coefficient of reactivity is affected over core life?

    A. It becomes more negative due to the buildup of Pu-240.

    B. It becomes less negative due to the buildup of fission products.

    C. It becomes more negative initially due to gadolinium burnout, then less negative due to fuel depletion.

    D. It remains essentially constant.

49. Which one of the following statements best describes the response of the void coefficient of reactivity to a change in the core?

    A. It becomes less negative as the core void fraction increases

    B. It becomes less negative with decreasing fuel temperature.

    C. It becomes less negative as gadolinium burns out.

    D. It is not significantly affected by control rod movement.

50. The void coefficient of reactivity is the change in reactivity produced by a

    A. change in the volume fraction of steam bubbles to liquid coolant in the core

    B. unit change in the moderator temperature

    C. unit change in the core average exit quality

    D. change in the mass fraction of vaporized coolant to liquid coolant in the core

51. Addressing each term in the six-factor formula, explain why a change in void fraction causes a change in core reactivity.

52. The primary effect of the void coefficient of reactivity (αV) is best described as the negative reactivity added due to an increased void fraction, which

    A. increases the number of neutrons absorbed in the control rods

    B. increases the number of neutrons that achieve thermal energy

    C. increases the number of neutrons that leak from the core or are resonantly absorbed

    D. decreases neutron moderation and increases neutron absorption in xenon

53. Which of the following is a <u>false</u> description of the result of an increase in void fraction in the core?

    A. increases neutron absorption in xenon

    B. decreases neutron moderation

    C. increases the number of neutrons that leak from the core

    D. increases the number of neutrons that are resonantly absorbed

54. The void coefficient of reactivity (αV) is defined as the

    A. change in reactivity caused by a unit change in void quality

    B. change in reactivity caused by a unit change in void fraction

    C. change in reactivity caused by a unit change in reactor vessel steam pressure

    D. change in reactivity caused by a unit change in core flow

55. An increase in voids results in increased neutron absorption by

    A. the control rods

    B. fission product poisons (xenon and samarium)

    C. uranium 238

    D. burnable poisons

56. Which of the following <u>best</u> describes the mechanism by which an increase in voids adds negative reactivity?

    A. increases reactor pressure
    B. diminishes fuel pellet temperature
    C. increases neutron slowing down time
    D. alters the axial flux profile

57. Changes in voids affect core reactivity through changes in

    A. reproduction factor and fast fission factor

    B. fast fission factor and leakage

    C. resonance absorption and leakage

    D. resonance absorption and reproduction factor

58. Which one of the following is the primary reason the void coefficient becomes less negative with core burnup toward the end of core life?

    A. The thermal neutron flux increases.

    B. The thermal diffusion length decreases.

    C. The fuel centerline temperature increases.

    D. The control rod density decreases.

59. In regard to the void coefficient of reactivity, which one of the following statements is correct?

    A. The void coefficient becomes more negative as control rods are withdrawn from the core.

    B. The magnitude of the void coefficient is essentially the same at 10 percent core voids as at 70 percent core voids.

    C. The magnitude of void coefficient increases with an increase in void fraction.

    D. The void coefficient becomes less negative with increasing fuel temperatures.

60. As the percent of the voids in the core increases, the void coefficient

    A. becomes more negative

    B. remains unchanged beyond 15% void percent

    C. remains the same

    D. becomes less negative

61. Explain how and why the void coefficient of reactivity varies with an increase in void fraction.

62. The magnitude of the void coefficient will change with an increasing void fraction. Which statement most accurately describes how and why this change occurs?

    A. more negative due to the voids building into areas of the core with higher neutron flux

    B. more negative due to larger change in moderator density at higher power levels

    C. less negative due to greater absorption of neutrons in fuel since neutrons will spend a longer time in the thermal energy range

    D. less negative due to the increased absorption of neutrons in U-238

63. As the void content of the core increases, the absolute value of the void coefficient of reactivity

    A. increases
    B. decreases
    C. remains constant
    D. increases, then decreases

64. Which of the following statements best describes why the void coefficient of reactivity is negative? As the core void fraction increases, the number density of the moderator nuclei decreases, which

    A. increases the thermal utilization factor

    B. decreases the thermal non-leakage factor

    C. increases the fast non-leakage factor

    D. decreases the resonance escape probability

65. As the void content of the core decreases, the absolute value of the void coefficient of reactivity

    A. increases
    B. decreases
    C. remains constant
    D. decreases, then increases

66. As core void fraction increases, the boiling boundary in the core shifts downward into a region of higher neutron flux. Due to the poor moderation properties of steam, neutrons remain epithermal longer. This results in the neutrons having a higher probability of being resonantly absorbed. This best explains why, as void fraction increases

    A. the absolute value of the void coefficient decreases

    B. the absolute value of the Doppler (fuel temperature) coefficient decreases

    C. the absolute value of the moderator temperature coefficient increases

    D. the absolute value of the void coefficient increases

67. Assume a BWR plant is at 20 percent power. Power is increased to 30 percent by control rod withdrawal. Which one of the following statements best describes the change in void fraction?

    A. Void fraction initially decreases, then linearly increases with rod worth increase.

    B. Void fraction increases.

    C. Void fraction decreases.

    D. Void fraction remains the same.

68. Which one of the following conditions will cause the void coefficient of reactivity to become less negative?

    A. Fuel temperature increases.
    B. Gadolinium concentration decreases.
    C. Control rod density decreases.
    D. Void fraction increases.

69. When a BWR is in the process of heating up to operating temperatures, rod withdrawal results in a rapid power increase. Which of the following coefficients would respond first to turn power and reduce the rate of the power increase?

    A. pressure coefficient
    B. void coefficient
    C. moderator coefficient
    D. doppler coefficient

70. Given a reactor at low power with the following coefficient magnitudes

    Doppler = 1×10^{-5} ΔK/K/°F
    Moderator temperature = 1×10^{-4} ΔK/K°F
    Void = 1×10^{-3} ΔK/K/% void

    If the fuel temperature increases 1000°F, the moderator temperature increases 400°F, and voids increase by 20 percent, what is the expected net change in reactivity?

    A. -7×10^{-2} ΔK/K
    B. $+4.2 \times 10^{-2}$ ΔK/K
    C. $+7 \times 10^{-2}$ ΔK/K
    D. -2.8×10^{-1} ΔK/K

71. Assume a reactor had been shut down for a shift, and shutdown cooling is in service. Which of the following coefficients of reactivity will act first to change core reactivity upon a loss of shutdown cooling?

    A. moderator temperature coefficient
    B. doppler coefficient
    C. void coefficient
    D. pressure coefficient

72. During a hot reactor startup with the reactor coolant at 520°F, excessive rod withdrawal results in a 10 second reactor period. Without any further operator action, the __________ coefficient will respond first to reduce the rate of the power increase.

A. pressure
B. void
C. moderator
D. Doppler

73. Which of the following operating conditions is associated with a less negative fuel temperature coefficient?

A. increase in moderator temperature
B. increase in fuel temperature
C. increase in core age
D. increase in void concentration

74. Given the following abnormality, "the isolation of two main steam lines, with the plant at normal, full-power conditions, " which reactivity coefficient would react first? Would the coefficient add positive or negative reactivity to the reactor?

A. void, negative
B. void, positive
C. moderator temperature, positive
D. moderator temperature, negative

75. Given the following abnormality, "isolation of a heater string with associated string bypass valve opening, with the plant at normal, full-power conditions," which reactivity coefficient would react first? Would the coefficient add positive or negative reactivity to the reactor?

A. Doppler, negative
B. void, positive
C. void, negative
D. moderator temperature, positive

76. Given the following abnormality, "control rod drop from '00' to '36', with the plant at normal full-power conditions," which reactivity coefficient would react first? Would the coefficient add positive or negative reactivity to the reactor?

A. Doppler, negative
B. void, negative
C. Doppler, positive
D. void, positive

77. The reactor is critical and above the point of adding heat. Control rod withdrawal occurs. Other than the reactivity effects associated with the control rod, which reactivity coefficient reacts first?

A. moderator temperature coefficient
B. void coefficient
C. pressure coefficient
D. Doppler/(fuel temperature) coefficient

78. Rank the following reactivity coefficients in decreasing order of magnitude. State a typical value for each

- moderator temperature
- fuel temperature (Doppler)
- void

79. During a normal power increase from 20 percent to 100 percent, the smallest negative reactivity addition is caused by the change in

A. fuel temperature
B. moderator temperature
C. xenon concentration
D. void content

80. The plant is being returned to operation following a refueling outage. Fuel preconditioning requires reactor power to be increased from 10 percent to full power gradually over a 1 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 increases
    D. moderator temperature increase

81. Which one of the following describes the change in moderator temperature coefficient (MTC) of reactivity over core life? (Assume 100% power for all cases.) (NOTE: EOC = end of fuel cycle)

    A. Control rod withdrawal results in increased thermal neutron utilization, which results in a less negative MTC at EOC.

    B. Fission product poison buildup results in decreased thermal neutron utilization, which results in a more negative MTC at EOC.

    C. Burnup of U-235 results in decreased thermal neutron utilization, which results in a more negative MTC at EOC.

    D. Decreased voiding in the core results in increased thermal neutron utilization, which results in a less negative MTC at EOC.

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 54, chapter 8.3, page 1.

2. A

Reference 54, chapter 8.3, page 1.

3. C

The moderator temperature coefficient reflects the change in reactivity (not K effective) per degree change in moderator temperature only (not fuel).

Reference 54, chapter 8.3, page 1.

4. B

Reference 54, chapter 8.3, page 1.

5. A

A negative moderator temperature coefficient means reactivity decreases as temperature increases or reactivity increases as temperature decreases.

Reference 54, chapter 8.4, page 2.

6. A

With a negative moderator temperature coefficient, an increase in moderator temperature inserts negative reactivity, thereby decreasing core reactivity.

Reference 22, page 38.

7.

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 - Decreases, because the less-dense moderator allows thermal neutrons to travel further, increasing their chance of reaching and being absorbed by control rods. This is a significant effect.

reproduction factor - no change.

Reference 27, Volume II, chapter 4.

8. D

Reference 54.

9. B

As fuel depletes over core life, the core shifts toward an overmoderated condition. Therefore, the moderator temperature coefficient becomes less negative.

Reference 21, chapter 4, page 29.

10. B

Reference 21, chapter 4, page 29.

11. A

The change in moderator density per °F (and therefore the change in moderator temperature coefficient) decreases as moderator temperature decreases. Therefore, the moderator temperature coefficient becomes less negative during a cooldown.

Reference 21, chapter 4, page 28.

12. B

The change in moderator density decrease per °F change in temperature increases with increasing temperature.

Reference 22, page 39.

13. C

Because the moderator temperature does not change much during BWR power operation, the effect of moderator temperature change on reactivity is small.

14. A

An increase in moderator temperature increases the distance traveled by neutrons. With an increase in control rod density, the effect of a temperature increase is more pronounced because the neutrons, traveling farther, will have a greater chance of being absorbed in a control rod.

15. D

Rods are withdrawn over core life, decreasing the amount of this neutron poison in the core. Therefore, there is a decrease in the likelihood of a neutron being absorbed in a control rod as a result of traveling farther when moderator temperature increases.

16. D

The reduction in feedwater heating results in colder feedwater entering the vessel, inserting positive reactivity and increasing power.

17. D

The higher the temperature of water, the greater the change in its density resulting from a 1°F change in temperature. The greater density change causes a greater increase in neutron slowing down length, making the moderator coefficient more negative.

18.

As fuel depletes over core life, the core shifts toward an overmoderated condition. This effect tends to make the moderator coefficient less negative. In addition, as the core ages, control rods are withdrawn. With fewer rods inserted, the effect of a moderator density change on the number of neutrons reaching a control rod is reduced, also causing the moderator coefficient to be less negative.

Reference 27, Volume II, chapter 4.

REACTIVITY COEFFICIENTS
Answers

19.

The reactivity effects of a change in moderator temperature are caused by changes in moderator density.

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.

20. D

Reference 27.

21. A

Reference 27.

22. B

Reference 27.

23. B

Resonant peak heights decrease and broaden as fuel temperature increases.

Reference 18, chapter 4, page 89-91.

24. A

Broadening of resonance peaks affects neutrons that are in their epithermal energy range.

Reference 21, chapter 4, page 26.

25. C

Reference 21, chapter 4, page 26.

26. D

Electrical charge and potential energy have no effect on resonance absorption.

Reference 21, chapter 4, page 27.

27. A

Reference 21.

28.

Resonance absorption refers to a phenomenon in which certain nuclides have very high microscopic capture cross-sections for neutrons of specific epithermal energies. When a neutron with energy equal to the resonance energy encounters such a nuclide, its probability of capture is very high.

The major resonance absorber early in life is U-238. Later in life, Pu-240 has built up and is a significant resonance absorber.

Reference 27, volume II, chapter 4.

29. B.

Reference 21, chapter 4, pages 4 through 29.

30. A

Reference 21, chapter 4, page 30.

31. C

32.

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 one of these target atoms is equal to the energy of a resonant peak in 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.

Therefore, as fuel temperature increases, the resonance escape probability decreases, decreasing K_{eff} and inserting negative reactivity.

33.

The concept of "self-shielding" refers to the fact that the fuel in the center of a fuel pellet does not "see" any resonance-energy neutrons. Virtually all resonance neutrons are captured by resonance absorbers near the surface of the fuel.

When fuel temperature increases, the resonance peaks become lower and broader. The broadening permits capture of neutrons whose energies are "off-resonance"; but at the same time, the lowering results in some resonance neutrons escaping capture. Thus, the degree of self-shielding is reduced, and the resonance neutrons travel further into the fuel pellet before being captured.

The overall effect of a fuel temperature increase is increased resonance absorption resulting from the resonance peak broadening and the reduction in self-shielding. This accounts for the negative value of the Doppler coefficient.

34. B

Self-shielding describes the effect on resonant neutron absorption due to differing fuel temperatures from pellet inside to outside.

Reference 21, chapter 4, page 32.

35. B

This is the explanation of the Doppler coefficient with respect to loss of self-shielding.

Reference 31, chapter 4, pages 4 through 23.

36. B

Reference 31, chapter 4, pages 28 through 32.

37. C

Reference 31, chapter 4, page 33.

38. D

Reference 31.

39. D

Doppler coefficient measures reactivity change, not $K_{effective}$. Doppler coefficient measures against fuel temperature, not reactor power.

Reference 54, chapter 8.2, page 1.

40. A

Reference 54, chapter 8.2, page 1.

41. B

Reference 54, chapter 8.2, page 1.

42. B

Doppler coefficient measures against fuel temperature.

Reference 54, chapter 8.2, page 1.

43. C

Doppler coefficient measures incremental changes, not total changes. Doppler coefficient measures against fuel temperature, not reactor power.

Reference 54, chapter 8.2, page 1.

44. B

Reference 21, chapter 4, page 26.

45. C

Reference 54, chapter 8.2, page 1.

46. C

Reference 31, chapter 4, page 33.

47. A

Reference 54, chapter 8.2, page 1.

48. A

Reference 54.

49. B

An increase in voids results in increased slowing-down length, allowing more neutrons to be lost in resonance capture. However, with lower fuel temperature, resonance capture is less likely, reducing the voids' effect.

50. A

51.

The effect of an increase in void fraction on 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 change 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, especially when boron is dissolved in the moderator.

reproduction factor - No change.

Reference 27, volume II, chapter 4.

52. C

Decreasing moderator density by increasing the void fraction increases the neutron slowing down length, which causes the neutrons to spend a longer amount of time in the epithermal region. This increases resonance absorption. Increasing the amount of time necessary to reach thermal energy causes the chance of leakage to increase.

Reference 21, chapter 4, page 17.

53 A

Increasing neutron absorption in Xenon is a false statement. The void coefficient reflects effects during neutron slowing-down (leakage, resonance absorption), while Xenon is predominantly a thermal neutron absorber.

Reference 21, chapter 4, page 17.

54 B

Reference 31, chapter 4, pages 4 through 18.

55 C

Reference 31, chapter 4, pages 18 through 24.

56. C

As core voids increase, moderator density diminishes, which causes neutron slowing down time to increase. As a result, neutrons now spend more time at "intermediate energy levels", where resonance capture occurs, and more neutrons will be lost to resonance capture in U-238 and Pu-240.

Additionally, the greater slowing down time results in greater leakage.

57. C

Reproduction factor is set and is not affected by void fraction changes.

Fast fission factor does not involve epithermal or thermal neutrons so void fraction changes do not significantly affect fast fission.

Reference 31, chapter 4, pages 18 through 24.

58. D

Reference 31.

59. C

With low void fraction, most voids are at the top of the core, a low neutron flux region. At higher void fractions, more voids are in higher flux areas, causing more effect.

Reference 21, chapter 4, page 19.

60. A

With low void fraction, most voids are at the top of the core, a low neutron flux region. At higher void fractions, more voids are in higher flux areas, causing more effect.

Reference 21, chapter 4, page 19

61.

At a low void fraction, most voids are in the upper region of the core, where neutron flux is relatively low. An increase in voids in this region has a relatively small impact due to the low flux.

At higher void fractions, some of the voids are lower in the core, an area of higher neutron flux. Thus an increase in voids when void fraction is already high will be "seen" by more neutrons and therefore have a greater effect.

As a result, the magnitude of the void coefficient increases with void fraction.

Reference 21, chapter 4.

62. A

At higher void content, and therefore higher power levels, the voids build into a higher flux area of the core. Therefore, they depress neutron flux.

Reference 21, chapter 4, page 19.

63. A

Reference 31, chapter 4, pages 19 and 20.

64. D

As void fraction increases, the number density of the moderator decreases (submoderation). Therefore, neutrons remain epithermal longer, which results in increased resonance absorption. The resonance escape factor decreases.

Reference 31, chapter 4, page 20.

65. B

Reference 31, chapter 4, pages 19 and 20.

66. D

The void coefficient is affected by void fraction in the following way: As boiling boundary drops, it enters a region of higher flux, so there is more effect. Core becomes undermoderated, which increases time neutrons are epithermal. Hence the resonance escape probability drops.

Reference 31, chapter 4, pages 19 and 20.

67. B

Reference 31.

68. C

As rods are withdrawn, neutron flux shifts down in the core, further from the area of voids.

69. D

The increased fission rate affects fuel temperature first.

Reference 31, chapter 4.

70. A

Fuel temperature:

$(+1{,}000^\circ F) \times (-1\times10^{-5}\ \Delta K/K/^\circ F) =$
$-1\times10^{-2}\ \Delta K/K$

Moderator temperature:

$(+400^\circ F) \times (-1\times10^{-4}\ \Delta K/K/^\circ F) =$
$-4\times10^{-2}\ \Delta K/K$

Voids:

$(+20\%) \times (-1\times10^{-3}\ \Delta K/K/\%) =$
$-2\times10^{-2}\ \Delta K/K$

Summary:

$(-1 \times 10^{-2}) + (-4 \times 10^{-2}) + (-2 \times 10^{-2}) =$
$-7 \times 10^{-2}\ \Delta K/K$

71. A

The loss of heat removal from the coolant first affects moderator temperature.

72. D

The increased fission rate affects fuel temperature first.

Reference 31, chapter 4.

73. B

The amount of resonance peak broadening that occurs at high temperature is less than at low temperature.

Reference 21, chapter 4.

74. B

The main steam line isolation will collapse voids by increasing reactor pressure. Decreased voiding will increase moderation and reduce the amount of leakage and resonant absorption; therefore, positive reactivity will be added.

Reference 21, chapter 4.

75. D

Increased subcooling by a heater string bypass will lower moderator temperature, and the increased moderation will decrease the amount of resonant absorption and leakage, adding positive reactivity.

Reference 21, chapter 4.

76. A

The rod drop will insert positive reactivity due to removal of a poison. The increased power will increase fuel temperature, which increases the amount of resonant absorption and adds negative reactivity.

Reference 21, chapter 4.

77. D.

Reference 31, chapter 4.

78.

Typical values, in decreasing order of magnitude, are as follows:

void coefficient: -1×10^{-3} ΔK/K/%

moderator temperature coefficient: -1×10^{-4} ΔK/K/°F

Doppler coefficient: -1×10^{-5} ΔK/K/°F

Reference 27, volume II, chapter 4

79. B

Reference 21.

80. B

Reference 21.

81. A

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," including its units of measure.

K1.02 Questions 9-22, 81

Describe the effect on the magnitude of the moderator temperature coefficient of reactivity from changes in moderator temperature and core age.

K1.03 Questions 23-28

Explain resonance absorption.

K1.03 Question 29

Describe the process of resonance absorption as it relates to nuclear fuel.

K1.04 Questions 30-38

Describe Doppler broadening and self-shielding as it relates to the nuclear fuel.

K1.05 Questions 39-45, 47, 48

Define the "fuel temperature (Doppler) coefficient of reactivity," including its units of measure.

K1.08 Question 46

State the effect of fuel temperature on the magnitude of the Doppler coefficient.

K1.10 Questions 50-55, 57, 58

Define the "void coefficient of reactivity."

K1.10 Questions 56, 64

Explain how changes in core void fraction affect reactivity.

K1.11 Questions 59-63, 65, 66, 67

Describe how changes in the void fraction affect the magnitude of the void coefficient of reactivity.

K1.12 Question 49

State the effect of fuel temperature on the magnitude of the void coefficient.

K1.13 Question 68

Explain the effect of core age on the void coefficient.

K1.14 Questions 69-80

Compare the relative magnitude of the moderator temperature, Doppler (fuel temperature), and void coefficients of reactivity.

CONTROL RODS
Questions

1. A notch movement of a control rod represents a rod travel of ________ inches.

   A. 2
   B. 3
   C. 6
   D. 12

2. A control rod at notch 48 is

   A. fully inserted
   B. fully withdrawn
   C. at an intermediate deep rod position
   D. at an intermediate shallow rod position

3. Withdrawal of a control rod from notch "00" to "48" represents a total rod travel of ______ feet.

   A. 24
   B. 18
   C. 12
   D. 6

4. A fully inserted control rod is at notch

   A. 00
   B. 12
   C. 24
   D. 48

5. A control rod halfway in the core will be at notch ______ and represent a rod travel of ______ feet.

   A. 12, 6
   B. 12, 9
   C. 24, 6
   D. 24, 9

6. Rod movement from notch "00" to "36" represents actual rod travel of ______ feet.

   A. 6
   B. 9
   C. 12
   D. 18

7. The most common isotope used in control rods for thermal neutron absorption is

   A. ^{10}B, boron-10
   B. ^{7}Li, lithium-7
   C. ^{12}C, carbon-12
   D. ^{4}He, helium-12

8. Where is boron-10 predominately used in the reactor?

   A. cladding
   B. coolant
   C. fuel elements
   D. control rods

9. Control rods contain boron-10 primarily to

   A. absorb fast neutrons
   B. absorb thermal neutrons
   C. scatter fast neutrons
   D. scatter thermal neutrons

10. What properties of boron-10 make it ideal for use in control rods?

    A. low capture cross section for thermal neutrons

    B. high capture cross section for thermal neutrons

    C. low fission cross section for fast neutrons

    D. high fission cross section for fast neutrons

11. Control rods contain ______ to absorb thermal neutrons.

    A. uranium
    B. helium
    C. boron
    D. zirconium

12. Which one of the following materials is used in the construction of control rods?

    A. xenon
    B. gadolinium
    C. boron
    D. cesium

13. The most common isotope used in control rods for thermal neutron absorption is

    A. B-10 (Boron-10)
    B. C-12 (Carbon-12)
    C. Xe-135 (Xenon-135)
    D. U-235 (Uranium-235)

14. The reverse power effect or reverse reactivity effect occasionally observed when a shallow control rod is withdrawn one or two notches is due to a relatively

    A. large local power increase being offset by a moderator temperature-related power decrease

    B. small local power decrease due to the shadowing effect of nearby control rods

    C. small local power decrease due to increased local Doppler effects

    D. large local power increase being offset by a void-related power decrease

15. Withdrawing a deep control rod is used to control which of the following?

    A. flux shaping
    B. rod shadowing
    C. radial power distribution
    D. reverse power effect

16. Shallow control rods can exhibit a phenomenon called the reverse power effect. Describe this phenomenon and explain how it occurs.

17. The reactor is exactly critical below the point of adding heat. A control rod is withdrawn a short distance. Reactor power will

    A. increase until the effect of rising temperature is seen

    B. increase during the rod motion, then return to its original value

    C. increase to a new equilibrium value below the point of adding heat

    D. decrease temporarily, then return to its original value

18. The reactor is exactly critical below the point of adding heat. A control rod is manually inserted for 5 seconds. Reactor power will

    A. decrease to a shutdown power level low in the source (startup) range

    B. decrease temporarily, then return to the original value due to the resulting 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

19. The reactor is exactly critical below the point of adding heat. A control rod is inserted a short distance. Reactor power will

    A. increase to a new higher level

    B. increase temporarily then return to original value

    C. decrease to a new lower value

    D. decrease temporarily then return to original value

20. 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 5 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 stable critical power level at the POAH

    D. increase temporarily, then decrease and stabilize below the original value

21. The reactor is critical at 50% power. A deep control rod is withdrawn a short distance. Assuming that all systems function as intended and that turbine load and recirculation flow remain constant, reactor power will

    A. increase to a new higher level

    B. increase temporarily then return to original value

    C. decrease to a new lower value

    D. decrease temporarily then return to original value

22. The reactor is operating at steady-state 50 percent power. A control rod is inserted a short distance (from notch 08 to notch 02). Assuming that recirculation flow remains constant, reactor power will

    A. increase and stabilize at a higher value

    B. increase temporarily, then return to the original value

    C. decrease and stabilize at a lower value

    D. decrease temporarily, then return to the original value

23. The reactor is subcritical with all rods inserted. A center control rod is then fully withdrawn from the core. Neutron population will

    A. increase to a new higher level

    B. increase temporarily then return to original value

    C. decrease to a new lower value

    D. decrease temporarily then return to original value

24. Rod density is defined as the

    A. total inserted notches divided by the total available notches

    B. total withdrawn notches divided by the total available notches

    C. amount of boron loading divided by the total possible boron loading in the control rod

    D. amount of remaining active fuel loading divided by the total fuel loading in the fuel rod

25. The reactor has been shutdown with all control rods fully inserted. What is the rod density?

    A. 0%
    B. 25%
    C. 75%
    D. 100%

26. During a reactor startup, rods are withdrawn, producing what is known as a "black-and-white" rod pattern. What is the approximate rod density at this time?

    A. 100%
    B. 75%
    C. 50%
    D. 25%

27. During a reactor startup, when control rods are being withdrawn, control rod density

    A. increases only until 25% of the rods are withdrawn

    B. decreases only until 25% of the rods are withdrawn

    C. increases whenever any of the rods are withdrawn

    D. decreases whenever any of the rods are withdrawn

28. During a reactor shutdown, when control rods are being inserted, control rod density

    A. increases until all the rods are inserted

    B. decreases until all the rods are inserted

    C. increases only until 50% of the rods are inserted

    D. decreases only until 50% of the rods are inserted

29. Rod density is a measure of the

    A. percentage of control rods withdrawn from the core

    B. percentage of control rods inserted into the core

    C. number of control rods withdrawn compared to the number of control rods fully inserted

    D. control rod worth compared to the shutdown margin at 100 percent core flow

30. Rod density is a measure of the total number of control rod notches __________ the core compared to the total number of control rod notches __________ the core.

    A. withdrawn from; available in
    B. inserted into; available in
    C. withdrawn from; inserted into
    D. inserted into; withdrawn from

31. A rapid, automatic insertion of all control rods, in response to an abnormal reactor plant condition, is referred to as a reactor

    A. runback
    B. isolation signal
    C. scram
    D. select rod insert (SRI)

32. Choose the statemnnt that best defines a reactor scram.

    A. a rapid, full insertion of all control 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

33. A rapid, full insertion of all control rods in response to an abnormal condition defines a reactor

    A. runback
    B. scram
    C. isolation signal
    D. select rod insert (SRI)

34. From the list of choices below, select the choice that best completes the following definition of a reactor scram.

"A rapid, _________ insertion of _______ control rods in response to an abnormal condition"

A. full, specific
B. partial, specific
C. full, all
D. partial, all

35. 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

36. 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

37. 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

38. 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

39. 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. excess reactivity
C. integral rod worth
D. reference reactivity

40. A control rod is inserted 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

41. During a reactor start-up and heat-up, as the moderator temperature increases from 175°F to 545°F, control rod worth will

A. increase until moderator temperature reaches 545°F

B. decrease until moderator temperature reaches 545°F

C. increase until moderator temperature reaches 300°F

D. decrease until moderator temperature reaches 300°F

42. Control rod worth increases as moderator temperature increases due to a

    A. shorter slowing down length and thermal diffusion length

    B. longer slowing down length and thermal diffusion length

    C. decrease in thermal neutron population

    D. shorter thermal migration length

43. As void fraction increases, control rod worth

    A. increases
    B. remains the same
    C. decreases
    D. initially increases then decreases

44. Control rod worth decreases with an increase in void fraction because there are ______ neutrons in the vicinity of the rod.

    A. more fast
    B. fewer fast
    C. more thermal
    D. fewer thermal

45. As xenon concentration increases, control rod worth

    A. increases
    B. decreases
    C. stays the same
    D. initially increases and then decreases

46. Control rod worth decreases with a corresponding

    A. increase in moderator temperature
    B. decrease in voids
    C. decrease in xenon concentration
    D. increase in control rod density

47. A correct statement regarding control rod worth during a reactor startup is that

    A. central control rod worth will be higher during a peak xenon startup than during a xenon-free startup

    B. peripheral control rod worth will be higher during a peak xenon startup than during a xenon-free startup

    C. peripheral control rod worth will be lower during a peak xenon startup than during a xenon-free startup

    D. both control rod worths will be the same regardless of core xenon conditions

48. In regard to core parameters that affect control rod worth, which of the following statements is correct?

    A. Control rod worth decreases when the temperature of the fuel decreases.

    B. Control rod worth increases with an increase in voids.

    C. Control rod worth increases with an increase in fast neutron flux.

    D. Control rod worth decreases when approaching end of core life (EOL).

49. Which of the following statements describes the relationship between control rod worth and moderator temperature change?

    A. Control rod worth is not affected by moderator temperature change.

    B. As moderator temperature increases, the neutrons travel farther during the slowing-down process; thus, control rod worth increases.

    C. As moderator temperature changes, control rod worth is inversely proportional, due to neutron velocity changes.

    D. As moderator temperature increases, the fuel temperature increases, changing the Doppler; the control rod worth decreases.

50. The effect of a change in moderator temperature on control rod worth is to

    A. increase control rod worth with a decrease in temperature

    B. have little effect on control rod worth

    C. increase control rod worth for an increase in temperature at beginning of life (BOL) but decrease control rod worth at end of life (EOL)

    D. increase control rod worth with an increase in temperature

51. Which one of the following statements explains changes in control rod worth as xenon concentration increases?

    A. The xenon increase has no effect on control rod worth because worth is a function of position.

    B. The xenon increase will decrease control rod worth because the xenon competes for thermal neutrons with the control rods.

    C. The xenon increase will increase the thermal utilization, and control rod worth increases.

    D. The xenon increase does not affect control rod worth until the xenon peaks; after the peak, the control rod worth increases.

52. An increase in which one of the following will increase control rod worth?

    A. the percent voids
    B. increasing fuel temperature
    C. core age from 5,000 to 10,000 MWd/ton
    D. moderator temperature

53. Which one of the following conditions will cause control rod worth to increase?

    A. During a control rod pattern adjust, the local flux surrounding a control rod decreases while the core average flux remains the same.

    B. During a power decrease by control rod withdrawal, the fuel temperature decreases.

    C. Prior to reactor startup, the coolant temperature is heated from 100°F to 200°F.

    D. During a small power decrease, the total percentage of voids in the core increases.

54. Which one of the following will cause a decrease in the reactivity worth of a single control rod?

    A. The xenon-135 concentration around the rod decreases.

    B. The moderator temperature increases.

    C. An adjacent control rod is withdrawn.

    D. The void content around the rod increases.

55. Which of the following events will cause control rod worth to decrease?

    A. Control rods are periodically inserted to offset reactivity gain due to burnout of xenon.

    B. The moderator is heated from 170°F to 215°F during a startup.

    C. Reactor power is increased from 70 percent to 90 percent by increasing recirculation flow.

    D. Early in core life, the concentration of burnable poison (gadolinium) decreases.

56. Explain how and why differential control rod worth is affected by an increase in moderator temperature.

57. Explain how and why differential control rod worth is affected by an increase in void fraction.

58. Explain how and why differential control rod worth is affected by an increase in control rod density.

59. Explain how and why differential control rod worth is affected by an increase in the concentration of xenon.

60. If the void fraction surrounding centrally located fuel bundles increases, the worth of the associated control rod(s) will

    A. decrease, because more neutrons are able to travel from one fuel bundle to the next without being absorbed by the control rod

    B. increase, because thermal neutrons will travel farther resulting in a larger fraction of thermal neutrons being absorbed by the control rod

    C. decrease, because more neutrons are resonantly absorbed in the fuel as they are being thermalized resulting in fewer thermal neutrons to be absorbed by the control rod

    D. increase, because control rods are epithermal neutron absorbers and neutrons remain at higher energies longer due to the longer slowing down length

61. The primary purpose for performing control rod program changes is to

    A. evenly burn up the fuel
    B. evenly burn up the control rods
    C. even the wear on control rods
    D. minimize control rod worth

62. Which of the following control rods will have the largest effect on radial flux shaping?

    A. shallow rods
    B. deep rods
    C. peripheral rods
    D. intermediate rods

63. Which of the following control rods, when repositioned, will have the largest effect on axial flux shaping?

    A. peripheral rods
    B. intermediate rods
    C. shallow rods
    D. deep rods

64. Periodic adjustments to radial and axial flux shapes are desirable to

    A. minimize control rod worth

    B. minimize the build up of xenon in the core

    C. evenly burn up control rods throughout the core

    D. evenly burn up fuel throughout the core

65. Even fuel burn up and fuel economy are enhanced by which two methods?

    A. flux shaping and reduced feedwater heating

    B. pre-conditioning and gadolinium loading

    C. rod sequencing and flux shaping

    D. rod sequencing and pre-conditioning the fuel

66. The reason for sequencing control rods is to allow

    A. equal flow through all fuel bundles
    B. more fuel to be loaded
    C. improved flux shaping
    D. equal wear on rod drives

67. The reason for flux shaping is to

    A. minimize the potential of moving high-worth control rods

    B. allow thermal leakage to control thermal power by keeping periphery control rods farther out of the core

    C. equalize wear and required maintenance

    D. reduce thermal leakage by keeping periphery control rods farther into the core

68. Neutron flux shaping within a reactor core is designed to

    A. minimize the effects of rod shadowing

    B. ensure that more power is generated in the lower portion of the core

    C. ensure that local core power limits are not exceeded

    D. minimize the effects of an ejected rod

69. Describe the benefits that result from proper flux shaping.

70. Which one of the following statements describes the purpose of neutron flux shaping?

    A. to produce more power in the lower regions of the core so that excore instruments can monitor neutron levels

    B. to increase the length of time required before refueling

    C. to maintain a uniform power distribution and ensure power limits are not exceeded

    D. to minimize the effects of rod shadowing

71. The term "deep rod" refers to a control rod that is typically used to adjust

    A. power and radial flux

    B. power and axial flux

    C. radial and axial flux

    D. local power and adjust for low shutdown margin values

72. The radial flux profile for a reactor at low power would be most affected by a one-notch position change in which of the following areas?

    A. fully inserted to 1/4 withdrawn
    B. 3/4 out to fully withdrawn
    C. 1/2 out to 3/4 withdrawn
    D. 1/4 out to 1/2 withdrawn

73. Describe and explain the effect of deep control rod motion on axial and radial flux distributions when operating at power.

74. Describe and explain the effect of shallow control rod motion on axial and radial flux distributions when operating at power.

75. Axial flux would be most affected by a one-notch position change in which of the following areas?

    A. fully inserted to 1/4 withdrawn
    B. 3/4 out to fully withdrawn
    C. 1/2 out to 3/4 withdrawn
    D. 1/4 out to 1/2 withdrawn

76. The term "shallow rod" refers to a control rod that is typically used to adjust

    A. power and axial flux
    B. power and radial flux
    C. axial flux
    D. radial flux

77. Given the three categories of control rods--shallow, intermediate, and deep--which one of the following statements is accurate?

    A. At the end of core life (EOL), all categories of control rods are fully withdrawn and neutron flux is peaked toward the top of the core.

    B. Deep control rods are inserted less than one-third into the core, while shallow rods are inserted greater than two-thirds into the core.

    C. Intermediate control rods are used to increase gross core power distribution, while shallow rods are used to increase gross core power.

    D. Because power response to intermediate control rod movement is difficult to predict, it is more desirable to position control rods in a deep or shallow position.

78. The main function of withdrawing a deep control rod is to control

    A. axial flux shaping
    B. rod shadowing
    C. radial power distribution
    D. reverse power effect

79. Deep control rods generally affect total core power output because the power increase is

    A. largely due to the minimal rod shadowing present in the area of withdrawal

    B. largely due to the low void content present in the area of withdrawal

    C. spread throughout the core by the relatively high void content in the area of withdrawal

    D. spread throughout the core by the relatively high moderator temperature in the area of withdrawal

80. Which one of the following best describes why withdrawal of shallow control rods generally do not affect total core power output?

    A. The relatively large local power increase is offset by an increase in void content.

    B. The power increase is small due to the high void content present in the top of the core.

    C. The power increase is small due to the shadowing effect of nearby control rods.

    D. The relatively large local power increase is offset by an increase in fuel temperature.

81. Explain the difference between the positions of deep and shallow control rods.

82. A control rod located at notch position __________ in the core would be considered a __________ control rod.

    A. 36; deep
    B. 36; intermediate
    C. 12; intermediate
    D. 12; deep

83. 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

84. If a control rod is fully inserted (from the fully withdrawn position), the normalized axial neutron flux shape in the core will undergo a relatively minor distortion because

    A. the fully inserted control rod adds effectively zero reactivity

    B. the fully inserted control rod is an axially uniform poison

    C. the upper and lower core halves are loosely coupled

    D. power production in the fuel adjacent to the control rod is essentially unchanged.

85. During reactor power operations, the axial neutron flux shape is affected most by withdrawal of __________ control rods and the radial neutron flux shape is affected most by withdrawal of __________ control rods.

    A. shallow; shallow
    B. deep; shallow
    C. shallow; deep
    D. deep; deep

86. When a control rod is moved from notch 16 to notch 22, it is being:

    A. inserted 18 inches
    B. withdrawn 18 inches
    C. inserted 36 inches
    D. withdrawn 36 inches

87. Which one of the following control rods, when repositioned, will have the largest effect on axial flux shape?

    A. shallow rods at the periphery of the core
    B. deep rods at the periphery of the core
    C. shallow rods at the center of the core
    D. deep rods at the center of 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. C

Total rod travel from full-in to full-out is 12 feet. There are a total of 24 rod positions numbered from "00" (full-in) to "48" (full-out). A one-notch movement of a control rod represents six inches of travel.

Reference 60, page 228; and reference 30, chapter 13, page 18.

2. B

A control rod fully inserted is at notch "00." A control rod fully withdrawn is at notch "48." Total rod travel from full-in to full-out is 12 feet.

Reference 60, page 228; and reference 30, chapter 13, page 18.

3. C

Total rod travel from notch "00" to notch "48" is 12 feet.

Reference 60, page 228; and reference 30, chapter 13, page 18.

4. A

A control rod fully inserted is at notch "00." A control rod fully withdrawn is at notch "48."

Reference 60, page 228; and reference 30, chapter 13, page 18.

5. C

Total control rod travel is 12 feet from fully inserted (notch "00") to fully withdrawn (notch "48").

Reference 60, page 228; and reference 30, chapter 13, page 18.

6. B

Total rod travel from notch "00" to "48" is 12 feet.

Reference 60, page 228; and reference 30, chapter 13, page 18.

7. A

Boron-10 is the most commonly used material for thermal neutron absorption in control rods.

Reference 30, chapter 10, page 15.

8. D

Boron-10 is the most commonly used material for thermal neutron absorption in control rods.

Reference 30, chapter 10, page 15.

9. B

Boron-10 is the most commonly used material for thermal neutron absorption in control rods.

Reference 30, chapter 10, page 15.

10. B

Boron-10 has a large absorption cross section for thermal neutrons.

Reference 30, chapter 10, page 15.

11. C

Boron-10 has a large absorption cross section for thermal neutrons.

Reference 30, chapter 10, page 15.

12. C

Boron-10 is the most commonly used material for thermal neutron absorption in control rods.

Reference 30, chapter 10, page 15.

13. A

Reference 30, chapter 10.

14. D

The increased power in the region vacated by the rod will cause more steam bubbles to be produced. These bubbles will travel up the fuel bundle, increasing the void fraction and decreasing power at the top of the bundle. The reverse power effect occurs when that power decrease exceeds the initial power increase.

Reference 25, page 4-2.

15. C

Reference 25, page 4-2.

16.

The reverse power (reactivity) effect occurs when a small withdrawal of a shallow control rod inserts negative instead of positive reactivity.

When the rod is withdrawn a few steps, power in the region vacated by the rod increases, causing an increase in steam bubble formation. These steam bubbles travel up the fuel bundle, increasing the void fraction in the higher regions of the bundle. This void increase causes a reduction in the power produced in the upper portion of the bundle. If this void-induced power decrease is greater than the rod-induced increase, a net decrease in power and reactivity will occur. This is the reverse power effect.

Reference 25, page 4-2.

17. A

Withdrawing control rods adds positive reactivity. This positive reactivity establishes a positive reactor period and causes reactor power to increase. (It will stabilize at POAH.)

18. A

Reference 25.

19. C

Inserting control rods adds negative reactivity. This negative reactivity will cause reactor power to decrease. (It will stabilize in the source range with the reactor subcritical.)

20. C

Reference 25.

21. A

Withdrawing a control rod at power with a constant recirculation flow and turbine load adds positive reactivity. This will cause power to increase and with the other constants will tend to increase reactor pressure. The electrohydraulic control system will act to maintain a constant pressure by opening a bypass valve. The total effect would be an increase in reactor power to a new higher value.

22. C

23. A

Withdrawing a rod from the core will add positive reactivity. This will cause neutron population to increase. By design, the reactor will remain subcritical, and neutron population will stabilize at a new, higher subcritical equilibrium level.

24. A

Rod density is defined as a percentage of the number of notches all control rods are inserted into the core divided by the total number of notches available with all rods fully inserted into the core.

25. D

Rod density is defined as a percentage of the number of notches all control rods are inserted into the core divided by the total number of notches available if all the rods were fully inserted into the core.

26. C

Rod density is defined as a percentage of the number of notches all control rods are inserted into the core divided by the total number of notches available with all rods fully inserted into the core. In a "black-and-white" rod pattern, half the rods are fully inserted, and the other half are fully withdrawn.

27. D

[illegible]ensity is defined as a percentage of the number of notches all control rods are inserted into the core divided by the total number of notches available with all rods fully inserted into the core. As rods are withdrawn, rod density decreases.

28. A

Rod density is defined as a percentage of the number of notches all control rods are inserted into the core divided by the total number of notches available with all rods fully inserted into the core. Rod density increases as rods are inserted.

29. B

30. B

31. C

A rapid shutdown of a reactor in the event of an emergency is referred to as a scram.

Reference 32, page 280.

32. A

Reference 32, page 280.

33. B

Reference 32, page 280.

34. C

Reference 32, page 280.

35. A

Differential rod worth is defined as the change in reactivity resulting from a unit change in rod position. Answer B is not correct because 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 because fast fissions will not change unless a reactivity change is made first.

Reference 77, page 6-14.

36. 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 because 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 because it includes reactor power. Answer D is incorrect because it includes a total change in rod position.

Reference 77, page 6-14.

37. 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 because 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 because it is with respect to power, not rod motion.

Reference 77, page 6-16.

38. C

Differential control rod worth is defined as the change in reactivity per unit change in rod position.

Reference 77, page 6-14.

39. 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 because differential rod worth is a rate of change of reactivity, not a total reactivity insertion. Answer B is incorrect because excess 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 because reference reactivity is a term used in the calculation of shutdown margins.

Reference 77, page 6-16.

40. D

Reference 77.

41. A

Rod worth increases with an increase in moderator temperature due to longer neutron slowing down and thermal diffusion lengths, allowing a greater number of neutrons to reach the control rods.

Reference 29, chapter 3, pages 10 through 14.

42. B

Rod worth increases with an increase in moderator temperature due to longer neutron slowing down and thermal diffusion lengths, allowing a greater number of neutrons to reach the control rods.

Reference 29, chapter 3, pages 10 through 14.

43. C

Control rod worth decreases as void fraction increases due to relatively low thermal neutron flux in areas of higher voiding.

Reference 29, chapter 3, pages 10 through 14.

44. D

Control rod worth decreases as void fraction increases due to relatively low thermal neutron flux in areas of higher voiding.

Reference 29, chapter 3, pages 10 through 14.

45. B

Rod worth decreases in areas of high xenon concentrations due to xenon absorbing thermal neutrons and competing with the control rods. As a result, there are fewer thermal neutrons available for control rods to absorb.

Reference 29, chapter 3, pages 10 through 14.

46. D

Control rod worth decreases with a corresponding:

- decrease in moderator temperature (shorter slowing down length and thermal diffusion length)
- increase in voids (less thermal neutrons available in areas of voiding)
- increase in xenon concentration (xenon competing with control rods for thermal neutrons)
- increase in control rod density (control rod sees fewer thermal neutrons)

Reference 29, chapter 3, pages 10 through 14.

47. B

Rod worth depends on the relative magnitude of neutron flux at the tip of the rod. In a peak-xenon startup, more xenon will be in the core center (where power was concentrated) than at the periphery, suppressing flux in the center. Therefore, the peripheral rod worth will be higher.

48. D

49. B

50. D

A moderator temperature increase causes neutrons to travel farther during the slowing down process. Neutrons are therefore more likely to encounter control rods, and rod worth increases.

Reference 29, chapter 3, pages 10 through 14.

51. B

52. D

A moderator temperature increase causes neutrons to travel farther during the slowing down process. Neutrons are therefore more likely to encounter control rods, and rod worth increases.

Reference 29, chapter 3, pages 10 through 14.

53. C

A moderator temperature increase causes neutrons to travel farther during the slowing down process. Neutrons are therefore more likely to encounter control rods, and rod worth increases.

Reference 29, chapter 3, pages 10 through 14.

54. D

Rod worth decreases as voids increase because of the relatively low thermal neutron flux in the area of increased voids.

Reference 29, chapter 3, pages 10 through 14.

55. C

56.

An increase in moderator temperature causes a decrease in density. This causes a neutron to travel farther while slowing down and after thermalization. As a result, more neutrons leak out of the fuel bundle into the vicinity of the control rod. This causes the average thermal flux around the rod to increase, increasing rod worth.

57.

An increase in void fraction near the tip of a control rod causes a decrease in the moderation in that area, resulting in a lower thermal flux. This localized reduction in flux causes the rod to have less effect, reducing rod worth.

58.

An increase in control rod density reduces the worth of each control rod. The surrounding control rods suppress the thermal flux in the region so that a given rod will be exposed to fewer thermal neutrons. Thus, its effect is reduced.

59.

An increase in the concentration of poisons (such as xenon) in the vicinity of a control rod causes a reduction in the thermal neutron flux in that region. The control rod is therefore exposed to fewer thermal neutrons, reducing its effect and decreasing rod worth.

60. C

61. A

Rod program changes are performed in order to shift control rods to expose new fuel areas (nodes).

Periodic rod sequencing serves to even fuel depletion throughout the core.

Reference 29, chapter 4, pages 1 through 5.

62. B

Deep control rod adjustments affect flux in the upper part of the core and therefore have a greater affect on radial flux shaping.

Reference 29, chapter 4, pages 1 through 5.

63. C

Shallow control rod adjustments will have the greatest affect on axial flux shaping due to affecting flux in the lower part of the core and shifting axial flux up and down the entire length of the core.

Reference 29, chapter 4, pages 1 through 5.

64. D

Shifting axial and radial flux to different areas of the core lends itself to a more evenly distributed fuel burn-up.

Reference 29, chapter 4, pages 1 through 5.

65. C

Flux shaping and rod sequencing are two methods used to even out fuel burn up throughout the core.

Reference 29, chapter 4, pages 1 through 5.

66. C

The sequence in which control rods are moved is controlled to improve flux distribution in the core.

Reference 29, chapter 4, pages 1 through 5.

67. A

Flux shaping evens the neutron flux distribution in the core. By avoiding significant flux peaks, flux shaping prevents excessive control rod worth.

68. C

Reference 25, page 23-9.

69.

In general, a properly shaped neutron flux profile is flat. This results in a relatively uniform distribution of power throughout the core, which has the dual benefits of equalizing fuel burnup and avoiding potentially limiting power peaks. Similarly, a uniform flux profile prevents significant peaks in control rod worth, facilitating operation and protection of the reactor.

Reference 25, page 23-9.

70. C

Reference 25.

71. A

Reference 31, chapter 5, page 22.

72. A

Reference 31, chapter 5, pages 21 and 22.

73.

When a deep control rod is moved, its tip moves through the upper region of the core, an area of high void content. It will have a significant effect on power for two reasons: (1) there is little rod shadowing to reduce its worth, and (2) the negative power effect will not be seen because of the relatively short section of channel above the rod tip. Therefore, the rod motion will have a significant affect on the radial flux and power distribution.

This rod motion will not have a significant affect on the axial flux distribution because of the high void content near the tip of the rod.

Reference 25, page 4-2.

74.

When a shallow control rod is moved, its tip passes through the lower region of the core. Because the rod density is relatively high low in the core, there is significant rod shadowing, which minimizes the effect of the rod motion on radial flux distribution.

However, there will still be a change in the flux in the vicinity of the rod tip, and an offsetting effect higher in that fuel bundle. For example, if the rod is withdrawn, local power will increase, but this will produce more voids as the coolant flows up the bundle. This void increase will reduce flux higher in the bundle, resulting in a shift in the axial flux distribution.

Reference 25, page 4-2.

75. B

Reference 31, chapter 5, page 25.

76. C

Reference 31, chapter 5, page 22.

77. D

78. C

79. C

80. A

Reference 31, chapter 5, pages 21 and 22.

81.

A "deep" control rod is one that is inserted far into the reactor. Typically, a rod inserted two-thirds or further into the core is considered a deep rod.

Shallow rods are those inserted a relatively short distance. Typically, a rod inserted less than one-third into the core is considered a shallow rod.

Reference 25, page 23-3.

82. D

Reference 25.

83. B

Reference 25.

84. B

Reference 25.

85. C

Reference 25.

86. B

87. C

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.

K1.01 Questions 1-6, 86

Explain the relationship between notch movement and rod position.

K1.02 Questions 7-13

Identify the material used for thermal neutron absorption in control rods.

K1.04 Questions 14-23

Given a set of initial conditions and a rod position change, predict the effect of this position change on reactor power.

K1.05 Questions 24-30

Define and explain rod density.

K1.06 Questions 31-34

Define a reactor scram.

K1.07 Questions 35-40

Define and relate differential and integral control rod worth.

K1.09 Questions 41-60

Explain how and why changes in moderator temperature, void fraction, control rod density, and xenon affect control rod worth.

K1.10 Questions 61-70

State the purpose of flux shaping and rod sequencing.

K1.12 Questions 71-73

Describe effects of deep rods on axial and radial flux distribution.

K1.11 Questions 74-76, 87

Describe effects of shallow rods on axial and radial flux distribution.

K1.11, 1.12 Questions 77-85

Discuss application of deep and shallow control rods.

FISSION PRODUCT POISONS
Questions

1. Fission fragments or daughters that have a substantial neutron absorption cross section and are not fissionable are called

   A. fissile materials
   B. fission product poisons
   C. fissionable nuclides
   D. burnable poisons

2. A fission product poison is defined as a

   A. neutron poison that is loaded into the core during fabrication to control power

   B. fission product that absorbs a neutron and fissions

   C. fission product that has a substantial neutron absorption cross section and does not fission

   D. fission product 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 daughter that absorbs neutrons and does not fission

   B. fission fragment or daughter that absorbs neutrons and fissions

   C. fission fragment or daughter that emits neutrons and does not fission

   D. fission fragment or daughter that emits neutrons and fissions

4. Fission products that have appreciable neutron capture cross sections are called

   A. delayed neutron precursors
   B. fission product daughters
   C. radioactive fission products
   D. fission product poisons

5. A definition of 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

6. Which one of the following is the definition of the term fission product poison?

   A. a poison, produced by fission, having high microscopic cross section for scatter of fast neutrons

   B. a poison added to the fuel to extend cycle life

   C. a poison, produced by fission, having high microscopic cross section for thermal neutron absorption

   D. a poison, produced by fission, with low microscopic cross section for thermal neutron fission

7. Which of the following fission-product poisons has the most significant effect on reactor operation?

   A. Pm-149
   B. I-131
   C. Xe-135
   D. Sm-141

8. Which one of the following is the major fission product poison?

   A. Sm-149
   B. Xe-135
   C. Co-60
   D. Hf-178

9. What are the substances in the correct order, from largest to smallest, of microscopic cross section (thermal neutrons) for capture?

   A. U-235, H_2O, Xe-135
   B. U-235, Xe-135, H_2O
   C. Xe-135, U-235, H_2O
   D. Xe-135, H_2O, U-235

10. Compared to other poisons in the core, the two characteristics of Xe-135 that result in it being a major reactor poison are its relatively ______ rate of production and relatively ______ absorption cross section.

   A. small; large
   B. small; small
   C. large; large
   D. large; small

11. Compared to other poisons in the core, the two characteristics that cause Xe-135 to be a major reactor poison is its relatively __________ absorption cross section and its relatively __________ variation in concentration for large reactor power changes.

   A. small; large
   B. small; small
   C. large; small
   D. large; large

12. What two characteristics of xenon 135 result in it being a major reactor poison/neutron absorber?

   A. low rate of production and large absorption cross section
   B. low rate of production and small absorption cross section
   C. high rate of production and large absorption cross section
   D. high rate of production and small absorption cross section

13. 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

14. The fission product poison xenon 135 is produced in the reactor

   A. directly from fission and radioactive decay
   B. directly from fission and radiative capture
   C. from radioactive decay and radiative capture
   D. from radiative capture and alpha emission

15. Which of the following is <u>not</u> a characteristic of the fission product poison xenon 135?

   A. The concentration of xenon 135 is related to thermal neutron flux.
   B. Xenon 135 has a large cross section for thermal neutron absorption.
   C. Xenon 135 is a non-resonant absorber.
   D. Xenon 135 is produced from the radioactive decay of barium 135.

16. Xenon 135 is considered a major fission product poison because it has a large

   A. fission cross section
   B. capture cross section
   C. elastic scatter cross section
   D. inelastic scatter cross section

17. State and explain two characteristics that make xenon 135 a significant fission product poison.

18. 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. iodine 135
C. cesium 135
D. barium 135

19. Xenon is produced in the reactor by two methods. One is directly from fission, the other is from the following β- decay chain:

$$\text{tellurium} \xrightarrow{\beta-} \underline{\qquad\quad} \xrightarrow{\beta-} \text{xenon} \xrightarrow{\beta-} \text{cesium}$$

What isotope goes in the blank?

A. iodine
B. barium
C. promethium
D. gadolinium

20. Which of the decay chains describes the production of xenon 135?

A. $Ba^{135} \xrightarrow{\beta+} Cs^{135} \xrightarrow{\beta+} Xe^{135}$
B. $Xe^{136} \xrightarrow{n} Xe^{135}$
C. $Te^{135} \xrightarrow{\beta-} I^{135} \xrightarrow{\beta-} Xe^{135}$
D. $Ba^{139} \xrightarrow{\alpha+} Xe^{135}$

21. Following a reactor trip, xenon 135 concentration in the reactor will

A. initially decrease because xenon is produced directly from fission

B. initially 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

D. decrease immediately, then slowly increase due to the differences in the half lives of iodine and xenon

22. The major contributor to the production of xenon-135 in a reactor operating at full power is

A. the radioactive decay of iodine
B. the radioactive decay of promethium
C. direct production from fission of U-235
D. direct production from fission of U-238

23. Which of the following pairs presents the two major methods for Xe-135 production in the core?

A. decay of fission products and activation of U-233

B. decay of Sm-149 and activation of oxygen

C. decay of iodine and fission

D. decay of iodine and activation of oxygen

24. Which of the following are the relative production of mechanisms Xe-135 in an operating power reactor?

    A. primarily from fission, secondarily from iodine decay

    B. primarily from fission, secondarily from promethium decay

    C. primarily from iodine decay, secondarily from fission

    D. primarily from promethium decay, secondarily from fission

25. The reactor has been shut down for two weeks following extended power operation. What control rod movement is required to maintain 10% stable power immediately after startup?

    A. small amounts of rod insertion to compensate for LPRM chamber depletion

    B. small amounts of rod withdrawal to compensate for samarium buildup

    C. small amounts of rod insertion to compensate for installed poison burnout

    D. small amounts of rod withdrawal to compensate for xenon buildup

26. A correct statement regarding the production of xenon and samarium in an operating reactor is that xenon is produced

    A. by the fission of uranium-238 and that samarium is produced by the decay of tellurium-135

    B. by the decay of beryllium-135 and that most of the samarium is produced by the fission of uranium-238

    C. by the decay of promethium-149 and that most of the samarium is produced by the fission of uranium-135

    D. by the fission of uranium-235 and by the decay of iodine-135, and that most of the samarium is produced from the decay of promethium-149

27. A reactor has been operating at 50% power for two weeks, when power is quickly ramped to 100%. The xenon 135 produced directly from fission will ________, and the xenon produced from radioactive decay of iodine will ________.

    A. increase with power, decrease initially until iodine concentration builds in

    B. decrease with power, undergo little change initially until iodine concentration builds in

    C. increase with power, not change because iodine concentration is constant

    D. increase with power, undergo little change initially until iodine concentration builds in

28. Describe the xenon 135 production mechanisms in an operating reactor.

29. A reactor has been operating at full power for several weeks. Xenon-135 is being produced as a fission product in approximately __________% of all fissions.

    A. 0.3
    B. 3.0
    C. 30
    D. 100

30. One method of xenon 135 removal from an operating reactor is radioactive decay to

    A. iodine 135
    B. cesium 135
    C. tellurium 135
    D. lanthanum 135

31. Xenon is removed from the reactor by neutron capture and the following decay chain:

    $$\text{Iodine} \xrightarrow{\beta-} \text{Xenon} \xrightarrow{\beta-} \_\_\_\_\_\_ \xrightarrow{\beta-} \text{Barium}$$

    Select the correct isotope in the β^- decay chain.

    A. tellurium
    B. promethium
    C. cesium
    D. gadolinium

32. Xenon-135 is removed from an operating reactor by neutron capture and radioactive decay to

    A. Iodine-135
    B. Lanthanum-135
    C. Tellurium-135
    D. Cesium-135

33. Describe the xenon 135 removal mechanism in an operating reactor.

34. In a shutdown reactor, which decay chain describes the primary means of removing xenon 135?

    A. $Xe^{135} \xrightarrow{\beta-} Cs^{135}$
    B. $Xe^{135} \xrightarrow{n} Xe^{134}$
    C. $Xe^{135} \xrightarrow{\alpha} Te^{131}$
    D. $Xe^{135} \xrightarrow{\beta-} I^{135}$

35. Following a reactor trip from sustained high power operation, the major xenon 135 removal process is

    A. ion exchange
    B. beta minus decay
    C. neutron capture
    D. alpha decay

36. One method of xenon 135 removal in an operating reactor is $\beta-$ decay to cesium 135. What is the other method?

    A. beta capture
    B. alpha decay
    C. ion exchange
    D. neutron capture

37. The two methods of Xe-135 removal from a reactor operating at full power are

    A. neutron scatter and beta decay
    B. alpha decay and neutron absorption
    C. fission and alpha decay
    D. beta decay and neutron absorption

38. Which one of the following values most closely approximates the half-life of Xe-135?

    A. 19 seconds
    B. 6.6 hours
    C. 9 hours
    D. 30 hours

39. Which one of the following is the best explanation for the xenon-135 concentration change immediately following a power increase from equilibrium conditions?

    A. Xenon concentration will initially decrease due to the Doppler coefficient increase, thus increasing the thermal utilization.

    B. Xenon concentration will initially decrease due to the increased absorption of thermal neutrons by xenon-135.

    C. Xenon concentration will initially increase due to the large increase in production from fission.

    D. Xenon concentration will initially increase due to the decrease in thermal utilization as core flow increases.

40. Reactor power is increased from 50% to 60% in 1 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

41. Following a two-week shutdown, a reactor is taken critical and ramped to full power in six hours. How long will it take to achieve an equilibrium xenon condition after the reactor reaches full power?

    A. 1 to 2 hours
    B. 8 to 10 hours
    C. 40 to 50 hours
    D. 100 to 120 hours

42. The equilibrium value of xenon concentration is dependent on the reactor

    A. pressure
    B. flux level
    C. temperature
    D. water level

43. Which one of the following is <u>not</u> a condition required for xenon to be in equilibrium?

    A. The reactor flux is constant.

    B. The reactor has been operated at a steady-state power level for 40 to 50 hours.

    C. The concentration of iodine 135 has reached equilibrium.

    D. The reactor is operating at 100% power.

44. 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

45. A reactor has been operating at a steady-state condition for 40 to 50 hours and flux level is constant. Which of the following xenon conditions is occurring?

    A. xenon peaking
    B. xenon oscillation
    C. transient xenon
    D. equilibrium xenon

46. Which one of the following statements is the best definition or explanation of the term equilibrium xenon?

    A. a steady-state condition when the production rate equals the removal rate

    B. a steady-state condition when the production rate equals the burnout rate

    C. the point in time during startup when the positive reactivity of control rod withdrawal equals the negative reactivity addition of xenon buildup

    D. the point in time during steady-state power operation when xenon is not being produced, but is being removed rapidly

47. Equilibrium xenon concentration at 100% power is

    A. twice the concentration at 50% power

    B. more than twice the concentration at 50% power

    C. the same as the concentration at 50% power

    D. less than twice the concentration at 50% power

48. A reactor has been operating at 50% power for 1 week when power is ramped in 4 hours to 100%. Which one of the following describes the new equilibrium xenon concentration?

    A. twice the 50% value

    B. less than twice the 50% value

    C. more than twice the 50% value

    D. remains the same because it is independent of power

49. A reactor has been operating at 100% power for 1 week when power is ramped in 4 hours to 50%. Which one of the following describes the new equilibrium xenon concentration?

    A. one-half the 100% value

    B. less than one-half the 100% value

    C. more than one-half the 100% value

    D. remains the same because it is independent of power

50. If equilibrium reactor power level is increased from 50% to 100%, equilibrium xenon concentration will increase to a level that is

    A. less than twice the 50% power concentration

    B. equal to twice the 50% power concentration

    C. more than twice the 50% power concentration

    D. unpredictable unless the exact duration of operation at the two power levels is known

51. Which one of the following statements best explains why xenon peaks after a scram?

    A. The existing iodine-135 decays to xenon-135, and the iodine at shutdown has a greater activity than xenon.

    B. The existing xenon-135 decays to iodine-135, and iodine at shutdown has a smaller activity than xenon.

    C. Iodine-135 production increases after a scram, thereby increasing the concentration of xenon.

    D. Xenon-135 increases due to an increase in the number of delayed neutrons after a scram.

52. A reactor at 50% power has equilibrium xenon conditions. A 30% power change caused by increased recirculation flow occurs over a 10-minute period. As a result, the xenon concentration

    A. will immediately increase due to direct fission yield

    B. commences an immediate linear increase, following the power increase

    C. initially decreases due to neutron flux increase

    D. remains at the low power concentration until the flow increase is terminated

53. Which one of the following statements best explains why xenon concentration will increase after a power decrease?

    A. The migration length changes as moderator density increases.

    B. Fewer thermal neutrons are available to burn out xenon.

    C. The amount of xenon from fission does not decrease until the reactor is on a positive period.

    D. The amount of Xe-135 produced from Sm-149 decreases for six hours after power changes.

54. Explain how, why, and over what time frames xenon 135 concentration changes when reactor power is increased. Assume equilibrium initial conditions.

55. Explain how, why, and over what time frames xenon 135 concentration changes when reactor power is decreased from 100% to 50%. Assume equilibrium initial conditions.

56. A reactor has been operating at 50% power for a week when power is quickly ramped (over four hours) to 100% power. How would the xenon concentration in the core respond?

    A. decrease, then build up to a new equilibrium concentration in 40 to 50 hours

    B. increase to a new equilibrium concentration in 40 to 50 hours

    C. decrease, then quickly build up to a new equilibrium concentration in eight to 10 hours

    D. remain the same because xenon concentration is independent of flux level

57. A reactor has been operating at 50% power for a week when power is quickly ramped (over four hours) to 100% power. Which one of the following statements best describes the new equilibrium xenon concentration?

    A. The new xenon equilibrium value will be twice the 50% value.

    B. The new xenon equilibrium value will be greater, but less than twice the 50% value.

    C. The new xenon equilibrium value will be half the 50% value.

    D. The xenon equilibrium value will remain the same; it is independent of the power.

58. A reactor has been operating at 100% power for a week when power is quickly ramped (over four hours) to 50% 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 sharply then drop off to a new lower equilibrium value in about 40 to 50 hours.

D. The xenon level would remain the same; xenon concentration is independent of flux level.

59. A reactor has been operating at 100% power for a week when power is quickly ramped (over four hours) to 25% power. Which of the following statements best describes the new equilibrium xenon concentration?

A. The new xenon equilibrium value will be about 25% of the 100% power value.

B. The new xenon equilibrium value will be 50 to 60% of the 100% power value.

C. The new xenon equilibrium value will be about 80% of the 100% power value.

D. The xenon equilibrium value will remain the same; it is independent of power.

60. A reactor has been operating at 100% power for two weeks when a substantial drop in power occurs (50% in one hour). How would the xenon concentration change over the next four hours?

A. increase sharply
B. decrease sharply
C. remain the same
D. decrease slowly

61. A reactor has been operating at 50% power for one week when power is quickly ramped (over four hours) to 100% power. How will the xenon concentration in the core respond?

A. decrease, then build up to a new equilibrium concentration in 40 to 50 hours

B. increase and build up to a new equilibrium concentration in 70 to 80 hours

C. decrease, then return to the same equilibrium concentration

D. increase, then return to the same equilibrium concentration

62. A reactor has been operating at 75% power for one week when power is decreased to 50% over a one hour period. Which one of the following statements explains how xenon concentration will initially change?

A. decreases, because the xenon production rate from fission has decreased

B. increases, because of the reduced rate of xenon burnout

C. decreases, because the rate of xenon decay exceeds the rate of production from fission

D. increases, because the concentration of iodine-135 increases

63. A reactor trips after operating at 100% power for two weeks. How long would it take for the xenon concentration to peak?

A. 2 to 3 hours
B. 8 to 10 hours
C. 20 to 30 hours
D. 40 to 50 hours

64. Explain how, why, and over what time frame xenon 135 concentration changes following a scram from equilibrium conditions.

65. A reactor scrams after operating at 100% power for two weeks. How would the xenon concentration change over the next eight hours?

    A. increase rapidly
    B. decrease rapidly
    C. decrease slowly
    D. remain the same

66. Two reactors with identical power ratings are operating at power. Reactor "A" is at 50% power and reactor "B" is at 100% power. Both reactors scram at the same time. In which reactor will the xenon level peak first?

    A. Xenon will peak first on Reactor "A."

    B. Xenon will peak first on Reactor "B."

    C. Xenon will peak on both reactors at the same time.

    D. Xenon level will not change on either unit.

67. Two reactors with identical power ratings are operating at power. Reactor "A" is at 50% power and Reactor "B" is at 100%. Both reactors scram at the same time. Which reactor will have the larger xenon concentration peak?

    A. Reactor "A" will have the larger peak.

    B. Reactor "B" will have the larger peak.

    C. The xenon peaks will be the same in magnitude, but at different times.

    D. Xenon level will not change in either reactor.

68. A reactor that has been operating at 100% power for two weeks scrams. How long will it take until the core is considered xenon-free again?

    A. 8 to 10 hours
    B. 10 to 20 hours
    C. 40 to 50 hours
    D. 70 to 80 hours

69. A reactor has been operating at 25% power for 5 days when a scram occurs. Xenon-135 will peak in approximately

    A. 2 hours
    B. 7 hours
    C. 10 hours
    D. 20 hours

70. Which one of the following statements best describes the difference in peak xenon concentration following a reactor scram after one week at 100% power and a scram after one week of 50% power?

    A. The peaks are equal because the decay rate of iodine remains constant.

    B. The time to reach the peak is shorter after 100% power than after 50% power, due to the higher iodine decay rate.

    C. The peak from 100% power is of a larger magnitude, due to the larger initial iodine concentration.

    D. The peak from 50% power is of a larger magnitude due to the lower initial rate of xenon burnout.

71. A power reactor has been operating at full power for over 10 days when a scram occurs. Which of the following describes the behavior of xenon following the reactor scram?

    A. A typical reactor cannot override peak xenon early in core life.

    B. The core will have approximately 0% ΔK/K from xenon approximately 41 hours after the scram.

    C. The time for xenon to peak is approximately 17 to 21 hours after the scram.

    D. The peak xenon reactivity worth is about -5% ΔK/K in a typical reactor.

72. Which of the following statements concerning fission product poison formation and removal is correct?

    A. It takes seven to 11 hours to reach the maximum xenon concentration after a reactor trip from rated power.

    B. The decay half-life of xenon-135 is approximately 2.5 hours.

    C. It takes about 20 hours to reach equilibrium xenon concentration after a step increase from zero to 50% power.

    D. The decay half-life of tellurium-149 to iodine-135 is approximately 10 hours.

73. What is the difference in peak xenon concentration following a reactor scram after 1 week at 100% power as compared to a scram after 1 week at 50% power?

    A. The time to reach the peak is shorter after 100% power than after 50% power, due to the higher iodine decay rate.

    B. The peak from 50% is of a smaller magnitude due to the lower xenon burnout rate.

    C. The peaks are equal because the decay rate of iodine remains constant.

    D. The peak from 100% power is of a larger magnitude, due to the larger initial iodine concentration.

74. Compare control rod worths during a reactor startup from 100% peak xenon and a reactor startup from xenon-free conditions.

    A. Center control rod worth will be higher during the peak xenon startup than during the xenon-free startup.

    B. Peripheral control rod worth will be higher during the peak xenon startup than during the xenon-free startup.

    C. Both control rod worths will be the same regardless of core xenon conditions.

    D. It is impossible to determine how xenon will affect the worth of center and peripheral control rods.

75. A reactor has been operating at full power for several weeks when a scram occurs. When the reactor is brought critical five hours later, Xe-135 concentration will be highest in the _______ of the core, which causes thermal flux to the highest in the _______ of the core.

A. periphery; center
B. periphery; periphery
C. center; center
D. center; periphery

76. A reactor is scrammed from 100% power and equilibrium xenon concentration. Later, when xenon concentration has just peaked, the reactor is pulled critical. Which of the following statements is true?

A. To maintain criticality, the control rods will have to be rapidly inserted as xenon is burned out.

B. The reactivity added by the peaked xenon concentration results in more control rods having been withdrawn to achieve criticality.

C. The control rod pattern to achieve criticality would be the same as that in a xenon-free reactor.

D. As criticality is achieved, xenon concentration will increase rapidly resulting in control rods having to be withdrawn to maintain criticality.

77. A reactor is scrammed from 50% power and equilibrium xenon concentration. When the reactor is brought critical five hours later, xenon distribution in the core will cause thermal flux to be

A. peaked as it was prior to the scram
B. peaked in the center of the core
C. peaked at the periphery of the core
D. evenly distributed throughout the core

78. A step change in reactor power from 100% power and equilibrium xenon concentration to 50% power is made using core flow. Control rod movement is then used to maintain reactor power at 50% as xenon concentration changes. Which of the following best describes control rod position five hours after the power change? Control rods will

A. have been withdrawn to overcome the xenon concentration increase

B. have been inserted to overcome the xenon concentration decrease

C. not have been moved since xenon concentration has not changed

D. have been inserted then withdrawn to about the same position as xenon concentration varies

79. A reactor is scrammed from 100% power and equilibrium xenon concentration. Five hours later, when the reactor is brought critical, which of the following statements is true?

A. Thermal flux will be peaked in the center of the core due to xenon concentration being so low.

B. Xenon concentration will be high throughout the core skewing thermal flux to the bottom of the core.

C. Xenon concentration will be highest in the center of the core due to thermal flux being low there prior to the scram.

D. Thermal flux will be highest at the periphery of the core due to xenon concentration being high in the center of the core.

80. A step change in reactor power is made using core flow to increase power from 50% to 75%. To maintain reactor power at 75% in the two hours following the step change using control rods to compensate for xenon concentration, the control rods would have been

A. inserted
B. withdrawn
C. inserted then withdrawn
D. withdrawn then inserted

81. Following a reactor startup from a long-term shutdown, the plant is taken to 100% power. How long must the operator compensate for xenon as it builds in?

A. 8 to 10 hours
B. 15 to 25 hours
C. 40 to 50 hours
D. 70 to 80 hours

82. Following a reactor startup from a long-term shutdown, the plant is taken to 100% power. After reaching 100% 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. none, power is already at maximum
D. none, xenon is not flux-dependent

83. The reactor is being started up and taken to rated power following an extended outage. (Assume a constant ramp rate.) To compensate for the effect of xenon 135 while increasing reactor power, it will be necessary to ______ rods and ______ recirculation flow.

A. withdraw; decrease
B. withdraw; increase
C. insert; increase
D. insert; decrease

84. Which one of the following statements best describes xenon buildup following a xenon-free reactor startup?

A. Xenon concentration will remain constant until the thermal neutron flux reaches 1×10^{10} neutrons/cm^2/sec.

B. Xenon concentration will immediately increase as the moderator temperature coefficient becomes positive.

C. Xenon concentration will remain constant until the iodine decay develops.

D. Xenon concentration will immediately increase due to fission yield production.

85. Following a 7 day shutdown, a reactor startup is performed and the plant is taken to 100% power over a 16-hour period. After reaching 100% 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

86. Four hours after a reactor trip from a long-term, steady-state, 100% power run, the reactor has been taken critical and is to be maintained at one to two% power. Which of the following will describe the operators' actions and what is happening?

A. Add positive reactivity because xenon is building in.

B. Add negative reactivity because xenon is building in.

C. Add negative reactivity because xenon is decaying away.

D. No actions required; xenon is at an equilibrium condition.

87. Four hours after a reactor trip from a long-term, steady-state, 100% power run, the reactor is to be taken critical. How will the xenon concentration be changing?

A. Xenon will be decaying away quickly.
B. Xenon will be building in quickly.
C. Xenon will be slowly decaying away.
D. There will be no effect from xenon.

88. Twenty-four hours after a reactor trip from a long-term, steady-state, 100% power run, the reactor is to be taken critical. What will be the xenon concentration compared to before the trip and how will it be changing?

A. The xenon concentration will be considerably higher and increasing.

B. The xenon concentration will be considerably lower and decreasing rapidly.

C. The xenon concentration will be slightly higher and increasing rapidly.

D. The xenon concentration will be about the same and decreasing slowly.

89. Twelve hours after a reactor trip from a long-term, steady-state, 100% power run, the reactor is to be taken critical and power is to be raised quickly to 100% power. As the power is raised, what is happening to the xenon concentration?

A. Xenon is building in quickly toward a new equilibrium.

B. Xenon is burning out and decaying away very quickly.

C. Xenon is not changing; it is independent of flux.

D. Xenon is building in faster than it is being removed.

90. Following a reactor trip from a long-term, steady-state, 100% power run, the reactor is to be taken critical. The calculated estimated critical conditions (position) are based on a xenon-free core. How soon 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

91. What is meant by the expression, "a xenon-precluded startup"? Under what conditions would such a situation be most likely to occur? Explain.

92. A reactor that has been operating at 100% power for about two weeks has power reduced to 50%. What is going to happen to the xenon-135 concentration in the core?

A. There will be no change because iodine concentration is constant.

B. Initially xenon will build in, then drop off to a new equilibrium value.

C. Initially xenon will drop off, then build in to a new equilibrium value.

D. Xenon will drop off to a new equilibrium value.

93. A reactor that has been operating at 100% power for about two weeks has power reduced to 50%. During the next four to six hours, what must the operator do to compensate for a change in xenon 135?

   A. The operator does not have to be concerned with xenon, only fuel depletion.

   B. The operator must add negative reactivity because xenon is rapidly decaying away.

   C. The operator must add positive reactivity to compensate for xenon building in.

   D. The operator must add negative reactivity because xenon is rapidly building in.

94. A reactor that has been operating at 100% power for about two weeks has power reduced to 50%. Xenon 135 will reach a new equilibrium condition in ______ hours.

   A. 8 to 10
   B. 10 to 20
   C. 40 to 50
   D. 70 to 80

95. A reactor has been operating at 50% power for about two weeks. Power is then ramped to 100% power in four hours. What must the operator do during the next two to three hours, after reaching 100% 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. Do nothing due to constant iodine concentration.

   D. Add positive reactivity because xenon production exceeds xenon decay.

96. A reactor has been operating at 25% power for two weeks. Power is then ramped to 100% power in four hours. What is going to happen to xenon 135 in the core?

   A. Xenon will ramp up with power.

   B. There will be no change; xenon is not flux-dependent.

   C. Xenon will drop off rapidly, then build in to a new higher equilibrium.

   D. Xenon will build in rapidly, then drop off to a new lower equilibrium.

97. A reactor has been operating at 50% for four days. Power is then increased to 100% over a one-hour period. Which of the following expresses the time range during which the minimum concentration of xenon is expected to occur after the power increase?

   A. 4 to 6 hours
   B. 10 to 12 hours
   C. 15 to 17 hours
   D. 19 to 21 hours

98. Two identical reactors have been operating at a constant power level for one week. Reactor A is at 50% power and Reactor B is at 100% 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

99. Which of the following describes the behavior of xenon following a reactor scram?

A. The core will be virtually xenon-free three days following the scram.

B. The peak xenon will be approximately 15 hours following the scram.

C. The gradual decrease in xenon concentration, after peak xenon, is due to xenon having a shorter half-life than iodine.

D. The xenon peak is caused by the elimination of xenon conversion to cesium.

100. A reactor has been operating at full power for several days when a trip occurs. Xenon concentration is expected to ______ because ______.

A. decrease; it is flux-dependent

B. increase rapidly; the burnout term has decreased significantly

C. not change; xenon is not flux-dependent

D. decrease slowly; xenon now is only removed by decay

101. A reactor has been operating at full power for several days when a scram occurs. How many hours after the trip will xenon peak?

A. 2 to 3 hours
B. 8 to 10 hours
C. 40 to 50 hours
D. > 72 hours

102. A reactor has been operating at 100% power for several weeks. Following a reactor scram/trip the reactor first will be considered xenon-free after

A. 40 to 50 hours
B. 70 to 80 hours
C. 100 to 110 hours
D. 130 to 140 hours

103. If a reactor that has operated at 100% power for ten days is shut down rapidly, xenon concentration will

A. slowly decay away to almost zero in three days

B. increase to a new equilibrium in three days

C. peak in about a half day, then decay to almost zero in three days

D. ramp down with reactor power

104. A reactor has been operating at full power for several days when a reactor trip occurs. Xenon will peak 8 to 10 hours after the trip at a value almost twice that of 100% equilibrium. If the reactor had been operating at 50% power, the time and size of the peak would have been

A. earlier and higher
B. earlier and lower
C. later and higher
D. later and lower

105. One reason that the xenon concentration initially increases when a reactor is shut down is that xenon

   A. is being produced from the decay of iodine 135

   B. is being produced from the spontaneous fission of uranium

   C. decay has dropped off significantly with flux

   D. is no longer being removed by ion exchange

106. In regard to xenon and samarium concentrations following a scram from extended operation at high power, which one of the following statements is correct?

   A. Xenon concentration increases for the first 5 hours, while samarium concentration decreases.

   B. Xenon and samarium concentrations increase for the first 5 hours.

   C. Xenon concentration increases, while samarium concentration remains at equilibrium.

   D. Xenon concentration decreases, while samarium concentration remains at equilibrium.

107. The plant has been operating at full power for 1 month when a scram occurs. During the first 3 hours after the scram, xenon concentration will __________ and samarium concentration will __________.

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

108. 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 slowly decay away to almost zero in three days.

   B. Xenon will increase to a new equilibrium in three days.

   C. Xenon will peak in about a half day, then decay to almost zero in three days.

   D. Xenon will ramp down with reactor power; xenon is flux-dependent.

109. Four hours after a reactor scram from full power, equilibrium xenon condition, the xenon concentration will be

   A. lower than 100% equilibrium xenon, and will have added negative reactivity since the scram

   B. higher than 100% equilibrium xenon, and will have added negative reactivity since the scram

   C. lower than 100% equilibrium xenon, and will have added positive reactivity since the scram

   D. higher than 100% equilibrium xenon and will have added positive reactivity since the scram

110. The reactor is initially at 100% power with equilibrium xenon concentration. Which of the following best describes the changes in xenon concentration if reactor power is suddenly dropped to 50%? Initially, xenon concentration ______; approximately four to six hours later it starts to ______, reaching a new ______ equilibrium level in approximately 40 to 50 hours.

A. decreases, increase, lower
B. decreases, increase, higher
C. increases, decrease, lower
D. increases, decrease, higher

111. The reactor is initially at 25% power with equilibrium xenon concentration. A step change of reactor power to 75% is made. Considering the effect on reactor power due to xenon concentration changes seven hours after the step change, and assuming no operator actions, which of the following statements is true? Reactor power will be

A. greater than 75% and decreasing slowly

B. greater than 75% and increasing slowly

C. lower than 75% and decreasing slowly

D. lower than 75% and increasing slowly

112. The reactor is initially shut down with no xenon in the core. The reactor is brought critical and four hours later is in the middle of the intermediate range monitor range 8. The maintenance department has asked that power be maintained constant at this level for approximately 12 hours. Which statement best describes the reactor operator's action required to compensate for xenon changes? Rods will have to be

A. pulled slowly for four to six hours, then inserted slowly

B. inserted slowly for four to six hours, then pulled slowly

C. inserted slowly for the duration of the 12 hours

D. pulled slowly for the duration of the 12 hours

113. Initially the reactor is at 100% power with equilibrium xenon conditions when a reactor scram occurs. Four hours later, the reactor is brought critical. Which of the following statements is true concerning xenon impact on reactor control?

A. High xenon concentration at the periphery of the core will cause periphery rods to exhibit high-worth characteristics.

B. Peak thermal flux at the periphery of the core will cause periphery rods to exhibit high-worth characteristics.

C. Peak thermal flux at the center of the core will cause center rods to exhibit high-worth characteristics.

D. Low xenon concentration at the center of the core will cause center control rods to exhibit high-worth characteristics.

114. A reactor has been operating at full power for 10 weeks when a scram occurs. Twenty-four hours later, the reactor is brought critical and power level is maintained on range 5 of the intermediate range monitors. To maintain a constant power level for the next several hours, control rods must be

A. inserted, because the critical reactor will cause a high rate of xenon burnout

B. maintained at the present height as xenon establishes its equilibrium value for this power level

C. inserted, because xenon will approximately follow its normal decay curve

D. withdrawn, because xenon concentration is increasing toward equilibrium

115. A reactor has been shut down for two weeks after six months of full power operation. A reactor startup is performed and reactor power is stabilized at 10%. What control rod movement is required to maintain 10% stable power over the next two hours?

A. small amounts of rod insertion to compensate for samarium depletion

B. small amounts of rod withdrawal to compensate for samarium buildup

C. small amounts of rod insertion to compensate for xenon burnout

D. small amounts of rod withdrawal to compensate for xenon buildup

116. A reactor that has been operating at 100% power for about two weeks has power reduced to 50% in one hour. To compensate for the change in xenon-135 during the next four hours, the operator must add

A. negative reactivity to compensate for xenon building in

B. negative reactivity because xenon is rapidly decaying away

C. positive reactivity to compensate for xenon building in

D. positive reactivity because xenon is rapidly decaying away

117. A correct statement regarding control-rod worth during a reactor startup under xenon-free conditions is that

A. central control-rod worth will be higher during the peak xenon startup than during the xenon-free startup

B. peripheral control-rod worth will be higher during the peak xenon startup than during the xenon-free startup

C. peripheral control-rod worth will be lower during peak xenon startup than during the xenon-free startup

D. both control-rod worths will be the same regardless of core xenon conditions

118. Four hours after a reactor trip from a long-term, steady-state, 100% power run, the reactor has been taken critical and is to be maintained at 1% to 2% power. Which one of the following operator actions is required?

A. Add positive reactivity because xenon is building in.

B. Add negative reactivity because xenon is building in.

C. Add negative reactivity because xenon is decaying away.

D. Add positive reactivity because xenon is decaying away.

119. Which of the following are the production mechanisms of Xe-135 in an operating power reactor?

A. primarily from fission, secondarily from iodine decay

B. primarily from fission, secondarily from promethium decay

C. primarily from iodine decay, secondarily from fission

D. primarily from promethium decay, secondarily from fission

120. Which of the following reactor pre-scram conditions require the greater amount of control rod withdrawal to perform a reactor startup during peak Xenon conditions after a reactor scram?

A. BOL and high power
B. EOL and high power
C. BOL and low power
D. EOL and low power

121. The reactor has been operating at full power for one month when power is decreased and stabilized at 25% over 2 hours. What will be the status of core xenon 24 hours after power reaches 25%?

A. Increasing toward a peak
B. Decreasing toward equilibrium
C. Decreasing toward a valley
D. At equilibrium

122. A reactor scram occurred from steady state 100% power and a startup is currently in progress. Which one of the following sets of initial startup conditions will require the most control rod withdrawal to achieve criticality? (BOC = beginning of fuel cycle; EOC = end of fuel cycle.)

	CORE AGE	TIME SINCE REACTOR SCRAM
A.	BOC	12 hours
B.	BOC	40 hours
C.	EOC	12 hours
D.	EOC	40 hours

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 that has a substantial neutron absorption cross section and does not fission.

Reference 45, page 467.

2. C

A fission product poison is a fission fragment or an isotope in its decay chain that has a substantial neutron absorption cross section and does not fission.

Reference 45, page 467.

3. A

A fission product poison is a fission product that has a substar [illegible] neutron absorption cross section and does not fission.

Reference 45, page 467.

4. D

Definition of fission product poison is a fission product with an appreciable neutron capture cross section.

Reference 01, page 50.

5. D

A fission product poison is a fission fragment or its progeny that has a substantial neutron absorption cross section and does not fission.

Reference 13, page 188.

6. C

Reference 01, page 50.

7. C

Because of its large and variable affect on reactivity, xenon-135 is the most significant fission product poison.

Reference 32, pages 250 and 251.

8. B

Reference 32, pages 250 and 251.

9. C

Reference 32, pages 782 and 785.

10. C

Reference 32, pages 250 and 251.

11. D

Reference 32

12. C

Xenon 135 has an extremely large microscopic cross section for thermal neutrons. Xenon 135 also has a relatively high fission yield (indirect and direct).

Reference 32, pages 250 and 251.

13. C

Xenon is removed both by radioactive decay and by neutron capture.

Reference 32, pages 250 and 251.

14. A

Xenon is produced directly from fission and indirectly from the decay of iodine 135.

Reference 32, pages 250 and 251.

15. D

Xenon is produced from the decay of iodine 135, not barium 135.

Reference 32, page 251.

16. B

Xenon 135 has a very large microscopic capture cross section for thermal neutrons.

Reference 32, page 251.

17.

Xenon 135 is a significant fission product poison because of its large microscopic capture cross section and its large and 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 designer and operator must contend with.

Because of its abundance, its macroscopic capture cross section can be large. Furthermore, xenon concentration is power-dependent, so that every change in reactor power produces a transient in which xenon concentration, and therefore reactivity, is changed.

Reference 77, pages 4-11 and 4-24.

18. B

Xenon is produced directly from fission and indirectly from the decay of iodine 135.

Reference 32, pages 250 and 251.

19. A

$$Te^{135} \xrightarrow{\beta-} I^{135} \xrightarrow{} Xe^{135} \xrightarrow{\beta-} Cs^{135}$$

Reference 32, pages 250 and 252.

20. C

Reference 32, pages 250 and 253.

21. B

Xenon concentration will increase following a trip because of the iodine concentration already in the core. The half-life for iodine is also shorter than for xenon. The flux-related production and removal terms are essentially nonexistent.

Reference 32, pages 251 and 252.

22. A

Xenon-135 is produced as a fission fragment in 0.3% of uranium-235 fissions; iodine-135 has a fission yield of 6.1% for uranium-235.

Reference 32, page 253.

23. C

Reference 32, page 253.

24. C

The ratio of the Xe-135 fission yield (0.3%) to that of I-135 (6.1%) is approximately five to 95.

Reference 32, page 253.

25. D

Reference 31, chapter 6.

26. D

Reference 32, pages 250 through 260.

27. D

As reactor power increases, the production of xenon will increase. The direct-from-fission term 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 radioactive decay.

Reference 45, pages 468 and 469.

28.

Xenon 135 is produced in an operating reactor by two mechanisms. Approximately 0.3% 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% 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 77, page 4-11.

29. A

Reference 32

30. B

Xenon 135 β^- decays to cesium 135.

Reference 45, page 468.

31. C

Reference 32, pages 250 through 252.

32. D

Reference 32

33.

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 microscopic 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 77, page 4-12.

34. A

Reference 32, pages 250 through 253.

35. 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 β- decay.

Reference 32, pages 256 and 257.

36. D

Xenon 135 is removed from an operating reactor by β- decay and neutron capture.

Reference 32, pages 256 and 257.

37. D

Reference 45, page 468.

38. C

39. B

Reference 77, pages 4-14 through 4-28.

40. C

Reference 32

41. C

Xenon equilibrium occurs after 40 to 50 hours of steady-state power operation.

Reference 77, chapter 4, page 15.

42. B

Xenon equilibrium value is dependent on the flux level of the reactor. This is not a linear function.

Reference 77, chapter 4, page 15.

43. 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% power to achieve an equilibrium condition; this can occur at any power level.

Reference 45, pages 469 through 473; and reference 32, page 253.

44. 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 77, chapter 4, page 15.

45. D

Xenon equilibrium is the condition in which the production of xenon equals the removal by neutron capture and radioactive decay.

Reference 32, pages 253 through 255.

46. A

Reference 32, pages 253 through 255.

47. D

Reference 77, page 4-25.

48. B

Reference 77

49. C

Reference 77

50. A

Reference 77, page 4-25.

51. A

Reference 25, page 2-11.

52. C

Reference 25, page 2-11.

53. B

Reference 25, page 2-11.

54.

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 77, pages 4-24 and 4-25.

55.

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 77, pages 4-26 and 4-27.

56. A

The increase in flux causes an initial drop in xenon concentration. Xenon then slowly builds up to a new equilibrium value in 40 to 50 hours.

Reference 77, chapter 4, page 25.

57. B

The new xenon equilibrium value will be approximately 25% greater than the 50% power value.

Reference 77, chapter 4, page 25.

58. C

Following a down-power transient, xenon concentration will increase quickly, then slowly decrease to a new equilibrium value in about 40 to 50 hours.

Reference 77, chapter 4, pages 26 and 27.

59. B

The 25% power xenon equilibrium value will be approximately 57% (50 to 60%) of the 100% power-level value.

Reference 77, chapter 4, pages 26 and 27.

60. A

Xenon concentration would increase rapidly for four to six hours following the transient.

Reference 77, chapter 4, pages 26 and 27.

61. A

Reference 77

62. B

Reference 77

63. B

Xenon peaks 8 to 10 hours following a reactor trip.

Reference 77, chapter 4, pages 20 through 22.

64.

When the reactor scrams, production of xenon directly from fission and production of iodine effectively cease. However, xenon burnout also immediately ceases, and decay of the existing iodine causes xenon concentration to rise. After approximately eight to 10 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 77, pages 4-21 and 4-22.

65. A

Following a reactor trip, xenon builds up rapidly for about 8 to 10 hours.

Reference 77, chapter 4, pages 20 through 22.

66. A

Reactor "A" would peak first with a smaller magnitude. Reactor "B" would peak sometime later with a larger magnitude.

Reference 77, chapter 4, pages 20 through 22.

67. B

Reactor "B" will have the larger peak following a trip.

Reference 77, chapter 4, pages 20 through 22.

68. D

A xenon-free condition would occur about 72 hours following the trip.

Reference 77, chapter 4, pages 20 through 22.

69. B

Reference 25, page 2-41.

70. C

Reference 25, page 2-11.

71. D

Reference 25, page 2-41.

72. A

Reference 25, page 2-11.

73. D

Reference 25

74. B

Rod worth depends on the relative magnitude of neutron flux at the tip of the rod. In a peak-xenon startup, more xenon will be in the core center (where power was concentrated) than at the periphery, suppressing flux in the center. Therefore, the peripheral rod worth will be higher.

75. D

Because the pre-scram power was higher in the center of the core, xenon concentration will be higher there. This will suppress the thermal flux near the center.

76. B

Peak xenon concentration at this point adds a large amount of negative reactivity that requires rods to be pulled further to get additional positive reactivity.

"A" could be a correct answer except for the underlined word "rapidly." Xenon does decrease faster with the renewed neutron flux and rods will have to be inserted, but not rapidly. The concern would be positive reactivity addition and not maintaining criticality.

77. C

High xenon concentration at the center of the core causes startup thermal flux to be peaked at the periphery.

Reference 31, chapter 6.

78. A

In the down-power transient, xenon burnout is decreased while production of xenon from Iodine decay is still high, resulting in a net increase in xenon and negative reactivity. The rods would have to be withdrawn to add positive reactivity to maintain power constant.

Reference 31, chapter 6.

79. D

High xenon concentration at the center of the core causes startup thermal flux to be peaked at the periphery.

Reference 31, chapter 6.

80. A

In the up-power transient, xenon is removed by increased burnout. The production increase lags because Iodine concentration increase lags, resulting in a net decrease in xenon, and positive reactivity is inserted. The control rods would be inserted to add negative reactivity to maintain power constant.

Reference 31, chapter 6.

81. C

Xenon equilibrium is reached approximately 40 to 50 hours after a startup.

Reference 77, chapter 4, page 16.

82. A

Xenon will be building in for about 40 to 50 hours, so the operator will have to add positive reactivity.

Reference 77, chapter 4, pages 14 through 23.

83. 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 methods being pulling rods or increasing recirculation flow.

Reference 32, page 262.

84. D

Reference 77, page 4-14.

85. D

Reference 77

86. A

Xenon is building in rapidly, which is adding negative reactivity. The operator must add positive reactivity to maintain power.

Reference 77, chapter 4, pages 14 through 28.

87. B

Xenon will be building in very quickly four hours after a trip.

Decay of iodine 135 is greater than the decay of xenon 135.

Reference 77, chapter 4, pages 14 through 28.

88. D

Following a reactor trip from 100% power, the xenon will peak and be back to about its pre-trip concentration 24 hours after the trip. The concentration will be decreasing at this time.

Reference 77, chapter 4, pages 14 through 28.

89. 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 77, chapter 4, pages 14 through 28.

90. D

The core is essentially xenon-free about 72 hours following a reactor trip.

Reference 77, chapter 4, pages 14 through 28.

91.

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 start up the reactor is precluded for the period of time that xenon reactivity exceeds reactivity. This situation is called a xenon-precluded startup.

92. B

Xenon concentration will increase for a few hours, then drop off slowly to a new, lower xenon equilibrium value.

Reference 77, chapter 4, pages 14 through 28.

93. C

Xenon concentration will be increasing for four to six hours. During this time the operator will have to be adding positive reactivity.

Reference 77, chapter 4, pages 14 through 28.

94. C

Xenon will reach a new equilibrium condition in 40 to 50 hours.

Reference 77, chapter 4, pages 14 through 28.

95. 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 77, chapter 4, pages 14 through 28.

96. C

Xenon concentration will drop off quickly because of burnout, then build in to a new higher equilibrium value.

Reference 77, chapter 4, pages 14 through 28.

97. A

Reference 77, page 4-25.

98. B

Reference 77

99. A

Reference 25, page 2-41.

100. B

Xenon concentration will build in significantly because the burnout term has essentially gone away.

Iodine 135 is at its 100% value initially and is decaying to xenon 135, yielding a net increase in xenon concentration.

Reference 77, chapter 4, pages 20 through 28.

101. B

Xenon will peak eight to 10 hours after a reactor trip mainly due to the decay time of iodine 135.

Reference 77, chapter 4, pages 20 through 28.

102. B

Reference 77

103. C

Reference 77

104. B

A lower power level will have an earlier and a smaller peak.

Reference 77, chapter 4, pages 20 through 28.

105. 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 77, chapter 4, pages 20 through 28.

FISSION PRODUCT POISONS
Answers

106. B

Reference 77

107. B

Reference 77

108. C

Xenon will peak in 8 to 10 hours and then decay away to essentially a xenon-free condition in about 72 hours.

Reference 77, chapter 4, pages 20 through 28.

109. B

Power reduction via scram from full power causes xenon to increase for seven hours, thus eliminating A and C. Xenon concentration increase adds more negative reactivity, eliminating answer D.

Reference 31, chapter 6.

110. C

Initially, xenon concentration increases, so answers A and B are eliminated.

The new equilibrium value is lower than the original equilibrium value, so answer D is eliminated.

Reference 31, chapter 6.

111. A

The power change is 50%. The xenon concentration reaches a minimum in four to six hours.

The xenon concentration will take another four to six hours to pass through the 25% equilibrium level while increasing. Total time to reattain the 25% equilibrium level will be eight to 12 hours.

In seven hours the xenon concentration will be less than the 25% equilibrium level.

With less negative reactivity than original steady state, power will be greater than 75%; with xenon concentration increasing, power will be decreasing.

Reference 31, chapter 6.

112. D

During startup from a xenon-free condition, xenon increases until 40 hours after the power increase has terminated. Rods will have to be withdrawn to counteract this negative reactivity increase. The fact that the heating range was reached (range 8) is coincidental and only gives more reason to withdraw rods to maintain power level.

Reference 31, chapter 6.

113. B

During fast restart, xenon concentration is peaked in the core center, where the flux had been peaked during operation. Therefore, A and D are eliminated. High xenon concentration in the center of the core reduces thermal flux and rod worth in the center of the core, so C is eliminated.

High center xenon concentration combined with low periphery xenon concentration pushes the thermal neutron flux to the periphery.

Therefore, answer B is correct.

Reference 31, chapter 6.

114. C

The thermal neutron flux under these conditions is not high enough to cause a significant rate of xenon burnout. Therefore, xenon decay will require rods to be gradually inserted.

Reference 31, chapter 6.

115. D

Reference 31

116. C

Reference 31.

117. B

Reference 31

118. A

Reference 31

119. C

120. B

121. B

122. C

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 7-17

State the characteristics of xenon 135 as a fission product poison.

K1.03 Questions 18-29, 119

Describe the production of xenon 135.

K1.04 Questions 30-40

Describe how xenon 135 is removed from a reactor.

K1.05 Questions 41-50, 121

Describe conditions necessary for establishing equilibrium xenon.

K1.06 Questions 51-62

Describe the effects of a change in reactor power on xenon.

K1.07 Questions 63-73, 120

Describe xenon behavior following a scram.

K1.08 Questions 74-80

Describe the effects that xenon concentration has on flux shape and control rod patterns.

K1.09 Questions 81-85

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 86-91, 122

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 92-98

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 99-108

Explain the reasoning for the reactivity insertion by xenon 135 versus time for the following: reactor scram or shutdown.

K1.14 Questions 109-118

Given a reactor's power history, explain the process and reasons for the reactor operator to compensate for the time-dependent behavior of xenon 135 concentration in the reactor.

1. _______ may be used to provide flux shaping and extend the fuel cycle without the addition of control rods.

   A. Fission product poisons
   B. Control rods with hafnium tips
   C. Operating in an undermoderated condition
   D. Burnable poisons

2. Using a burnable poison in an operating reactor will allow all of the following to be accomplished except

   A. increase margins to fuel limitations

   B. increase amount of fuel initially loaded

   C. counteract the effects of control rod boron depletion

   D. provide flux shaping

3. Burnable poisons are placed in a reactor core to

   A. accommodate control rod depletion that occurs over core life

   B. increase the amount of fuel that can be loaded into the core

   C. balance the production of xenon 135 that occurs in the core

   D. ensure that the reactor will always operate in an undermoderated condition

4. Burnable poisons are loaded into the core to

   A. allow the initial core to have excess reactivity to extend core life

   B. allow shallow rods to compensate for core burnout

   C. reduce the amount of time required for xenon to peak following a scram

   D. provide for flux shaping in areas of deep rods

5. Burnable poisons are loaded into the core to

   A. increase the excess reactivity that can be loaded into the core during each refueling

   B. reduce the rod shadowing effect between shallow rods early in core life

   C. ensure the moderator coefficient of reactivity remains negative throughout core life

   D. provide for flux shaping in areas of deep rods during high power operation

6. Which of the following lists the 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

7. Which of the following does not accurately describe burnable poisons?

    A. purposely loaded into the core

    B. gradually burns up with neutron irradiation

    C. fast neutron absorber

    D. compensates for high K-excess added at beginning of life

8. Which of the following statements best describes burnable poisons?

    A. thermal neutron absorber, compensates for high K-excess at beginning of life

    B. fast neutron absorber, compensates for high K-excess at beginning of life

    C. thermal neutron absorber, compensates for low K-excess at beginning of life

    D. fast neutron absorber, compensates for low K-excess at beginning of life

9. What is the definition of the term burnable poison?

    A. isotopes manufactured into the fuel with large-scatter macroscopic cross sections

    B. thermal neutron-absorbing material added to the fuel, during the manufacturing process

    C. neutron-absorber materials produced in the fuel by fast neutron absorption

    D. fast neutron-absorbing material loaded into the upper third of the core to aid in slowing down neutrons

10. Refer to Figure 2.7-1: The decrease in K_{eff} from point 1 to point 2 is caused by

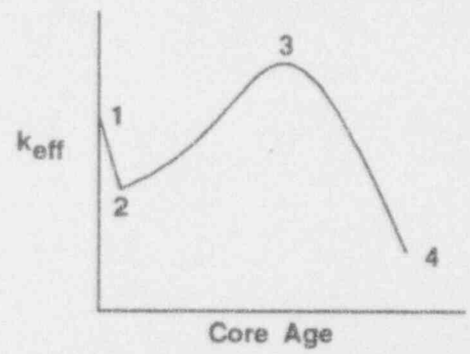
    A. buildup of fission product poisons

    B. burnout of burnable poisons

    C. initial heat-up of the reactor

    D. burnout of fuel during startup physics testing

FIGURE 2.7-1



K_{eff} Versus Core Age

11. Refer to Figure 2.7-1: The change in K_{eff} from point 2 to point 3 is caused by

    A. burnout of fission product poisons
    B. burnout of burnable poisons
    C. depletion of fuel
    D. depletion of control rods

12. Refer to Figure 2.7-1: The change in K_{eff} from point 3 to point 4 is caused by

    A. burnout of fission product poisons
    B. burnout of burnable poisons
    C. depletion of fuel
    D. depletion of control rods

13. Refer to Figure 2.7-1: Explain the change in K_{eff} between point 1 and point 2.

14. Refer to Figure 2.7-1: Explain the change in K_{eff} between point 2 and point 3.

15. Refer to Figure 2.7-1: Explain the change in K_{eff} between point 3 and point 4.

16. Just prior to refueling, control rods are nearly fully withdrawn at 100 percent power. After refueling, the control rods are inserted much farther into the core at 100 percent power.

    Which one of the following is the reason for the change in full power control rod position: (BOL = beginning of core life. EOL = end of core life.)

    A. Reactivity from power defect at BOL is much greater than at EOL.

    B. Reactivity from void coefficient at EOL is much greater than at BOL.

    C. The excess reactivity in the core at BOL is much greater than at EOL.

    D. The integral control rod worth at EOL is much greater than at BOL.

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. D

The explanation of why the distracters are unacceptable is:

A. Fission product poisons, removed by neutron absorption, maintain a fairly constant equilibrium value over core life and do not accomplish the extension of the fuel cycle.

B. Control rods, with or without hafnium tips, are designed for use through many operating cycles, and therefore don't accomplish extension of the fuel cycle.

C. Operation in an undermoderated condition does not significantly affect fuel depletion and does not extend the fuel cycle.

Reference 21, chapter 6, page 16.

2. C

Burnable poisons have no relation to depletion of control rod poisons.

Reference 21, chapter 6, page 16.

3. B

Burnable poisons insert negative reactivity at a rate that decreases with bundle exposure. Therefore, excess fuel can be initially loaded, and as the fuel depletes, the burnable poison also depletes, allowing core reactivity to remain a more constant value.

Reference 21, chapter 6, page 16.

4. A

Reference 31, app ndix G, page 4.

5. A

Reference 31, Appendix G.

6. C

Reference 31, Appendix G.

7. C

Reference 31, appendix G, page 4.

8. A

Reference 31, appendix G, page 4.

9. B

Reference 21, chapter 6, page 16.

10. A

The buildup of long-lived fission product poisons inserts negative reactivity until they reach an equilibrium concentration.

Reference 27, volume II, page 4-123.

11. B

The burnout of gadolinia inserts positive reactivity faster than fuel burnup inserts negative reactivity. As a result, K_{eff} increases until the gadolinia has largely burned out.

Reference 25, page 11-10.

12. C

After most gadolinia has burned out, K_{eff} decreases as fuel depletion inserts negative reactivity.

Reference 27, volume II, page 4-123.

13.

When a new core is initially operated, fission products begin to build up. Some of these fission products have a significant capture cross-section for neutrons. Therefore, the buildup of these fission product poisons inserts negative reactivity, causing K_{eff} to decrease. Once the fission product poisons reach an equilibrium concentration, they no longer cause a change in K_{eff} because their poisoning effect, while still present, is no longer changing.

Reference 27, volume II, page 4-123.

14.

BWR cores include a burnable poison, gadolinia. As the reactor operates, the depletion of gadolinia inserts positive reactivity at a rate greater than fuel depletion inserts negative reactivity. Therefore, K_{eff} increases until most of the burnable poison has been burned out.

Reference 25, page 11-10.

15.

Once the long-lived fission product concentration reaches equilibrium, and after most burnable poison is burned out, the value of K_{eff} is controlled by fuel depletion. Depletion of fuel inserts negative reactivity, causing K_{eff} to decrease.

Reference 27, volume II, page 4-123.

16. C

Reference 27, volume II.

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 1-6

Define the term "burnable poison" and state its use in the reactor.

K1.01 Questions 7-9

Define the term "burnable poison."

K1.03 Questions 10-16

Explain the shape of a curve of K_{eff} versus core age.

1. Which of the following parameters should be specifically monitored and controlled during the approach to criticality?

   A. source range count rate, reactor period and rod position

   B. source range count rate, reactor pressure, and steam demand

   C. axial peaking factor, reactor period, and source range count rate

   D. axial peaching factor, steam demand, and reactor pressure

2. Which of the following parameters should be closely monitored and controlled specifically during the approach to criticality?

   A. steam demand
   B. reactor period
   C. reactor pressure
   D. axial peaking factor

3. Which of the parameters should be closely monitored and controlled specifically during the approach to criticality?

   A. reactor pressure
   B. core exit thermocouple indications
   C. source range count rate
   D. axial peaking factor

4. Which of the following parameters should be closely monitored and controlled particularly during the approach to criticality?

   A. turbine bypass value position
   B. reactor pressure
   C. turbine speed
   D. rod position

5. List three parameters that should be monitored and controlled during an approach to criticality. Explain why each is monitored.

6. List four parameters or mechanisms that can affect reactivity during an approach to criticality and explain the effect of each.

7. Which of the following is the reactivity control mechanism used in a BWR as the reactor approaches criticality?

   A. recirculation pump flow
   B. turbine load control
   C. control rod movement
   D. steaming rate

8. For equal positive reactivity additions as a subcritical reactor approaches criticality, the neutron population

   A. increase is greater when K_{eff} is closer to 1.0

   B. increase is smaller when K_{eff} is closer to 1.0

   C. decreases linearly as K_{eff} approaches 1.0

   D. decreases exponentially as K_{eff} approaches 1.0

9. Control rods are withdrawn to a density of 95% with the reactor still subcritical. A control rod is notched out and the initial prompt jump is observed. Assuming the reactor stays subcritical the neutron population will

   A. increase exponentially
   B. stabilize at a new higher level
   C. decrease to the original value
   D. stay constant

10. During a reactor startup, for equal reactivity changes as K_{eff} approaches 1.0, steady-state neutron population will be reached

    A. in a longer time
    B. in a shorter time
    C. in the same amount of time
    D. instantaneously

11. 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).

12. While withdrawing control rods during a reactor startup, the count rate doubles. If the same amount of reactivity that caused the first doubling is added again, the count rate will __________ and the reactor will be __________.

    A. double; subcritical
    B. double; critical
    C. more than double; supercritical
    D. more than double; critical

13. After a rod notch withdrawal during the approach to criticality, the neutron count rate will settle at a new, higher level and reactor period indication will (assume reactor remains subcritical)

    A. not change
    B. return to infinity
    C. remain at a constant positive value
    D. remain at a constant negative value

14. Assume a reactor startup is in progress. Which of the following best describes control-rod withdrawal and startup instrument response as K_{eff} approaches unity.

    A. It requires a longer time for the neutron level to level out at the equilibrium level for each rod withdrawal.

    B. Reactor neutron level will continue to increase slightly even though the reactor period as returned to infinity.

    C. Successively smaller changes in neutron level will result for identical changes in K_{eff}.

    D. For each control-rod withdrawal, the reactor will become supercritical momentarily, due to a prompt jump.

15. Assume your reactor is being taken critical by periodically withdrawing equal reactivity control-rod increments. Which of the following statements is correct as K_{eff} approaches unity?

    A. The neutron level change for successive rod increments pulls becomes smaller.

    B. A longer period of time is required to reach the equilibrium neutron level after each rod withdrawal.

    C. A rod withdrawal will result in the reactor becoming slightly supercritical, due to a prompt jump, and then return to a subcritical level.

    D. If the rod withdrawal is stopped for several hours, the neutron level will decrease to source level.

16. Assume a reactor has a K_{eff} greater than unity and is several decades below the point of adding heat. Which of the following describes the reactor response during this period time?

    A. As power increases, the reactor period will increase due to moderator temperature increase.

    B. K_{eff} will return to unity shortly after control-rod withdrawal is terminated.

    C. [illegible] the heating range, a change in moderator temperature will have no effect on reactor period.

    D. A constant positive period, with increasing neutron level, will occur only if the net reactivity is not changing.

17. During a reactor startup, as K_{eff} approaches unity, which one of the following statements is correct for equal positive reactivity additions.

    A. The changes in neutron population are larger.

    B. As the neutron population increases, the number of neutrons lost per generation decreases.

    C. The number of fast neutrons gained per generation increases more slowly.

    D. A step increase in K_{eff} increases the neutron population and therefore decreases the number of neutrons lost per generation.

18. A reactor startup is being performed by adding equal amounts of positive reactivity and waiting for the neutron level to stabilize. Successive stable levels ________ critical will ______________________.

    A. near; nearly be the same
    B. far from; be large
    C. near; be twice the previous level
    D. far from; be small

19. During reactor startup, crit[illegible]d position is affected by

    A. core flow rate
    B. source range initial count rate
    C. recirculation ratio
    D. core age

20. Select the equation used to determine the subcritical multiplication factor of a reactor.

    A. $M = (K_{eff} - 1) / K_{eff}$

    B. $M = \dfrac{1}{1 - K_{eff}}$

    C. $M = \dfrac{\text{initial counts}}{\text{final counts}}$

    D. $M = \dfrac{\text{final counts - initial counts}}{\text{final counts}}$

21. Explain the effect of subcritical multiplication on reactor power (neutron count rate) for a control rod withdrawal in a subcritical reactor

22. Prior to withdrawing a control rod, the source range count rate is 220 cps. If the reactivity addition produces a subcritical multiplication factor of 2.0, what is the final steady-state count rate following this evolution?

    A. 110 cps
    B. 320 cps
    C. 440 cps
    D. 520 cps

23. Prior to withdrawing a control rod, the source range count rate is 210 cps. Following the withdrawal, the final steady-state count rate is 420 cps. What is the subcritical multiplication factor?

    A. 0.5
    B. 1.0
    C. 1.5
    D. 2.0

24. At one point during a reactor plant startup and approach to criticality, count rate is noted to be 780 counts, and K_{eff} is calculated to be .92. Later in the same startup, K_{eff} is calculated to be .985; what should the new indicated count rate be?

    A. 835
    B. 894
    C. 1461
    D. 4160

25. During a reactor startup, source range monitors (SRMs) indicate 100 CPS, and K_{eff} is 0.95. After a number of rods have been withdrawn, SRMs indicate 270 CPS. Which one of the following is closest to the new K_{eff}? (Assume reactor period is infinity before and after the rod withdrawal.)

    A. 0.936
    B. 0.971
    C. 0.982
    D. 0.990

26. 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

27. In a reactor with an installed source, a non-changing neutron flux is indicative of criticality at high flux levels or

    A. the point of adding heat at high levels

    B. supercriticality at low levels

    C. subcriticality at high levels

    D. equilibrium subcritical count rate at low levels

28. 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 to a stable value.

    B. The count rate will rapidly increase (prompt jump) then gradually decrease to the previous value.

    C. The count rate will rapidly increase (prompt jump) to a stable value.

    D. There will be no change in count rate until criticality is achieved.

29. 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.

30. 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 the same each time.

    B. The time required to reach equilibrium is shorter each time.

    C. The change in equilibrium count rate is greater each time.

    D. The change in equilibrium count rate is the same each time.

31. During a reactor startup, as K_{eff} approaches 1.0, it takes longer to reach an equilibrium neutron count rate due to the increased effect of

    A. prompt neutrons
    B. delayed neutrons
    C. fast neutrons
    D. slow neutrons

32. A reactor startup is in progress with K_{eff} at 0.995 and stable source range indication. If K_{eff} is increased to 0.997 by control rod withdrawal, reactor period will initially become __________ and then __________.

    A. shorter; approach infinity
    B. shorter; continue to gradually shorten
    C. longer; approach infinity
    D. longer; continue to gradually lengthen

33. 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. greater, longer
    B. greater, shorter
    C. smaller, longer
    D. smaller, shorter

34. As the reactor approaches criticality, for a given reactivity addition, the time required to reach a constant neutron population will be (shorter/longer) and the time required for period to reach infinity will be (shorter/longer).

    A. shorter, shorter
    B. shorter, longer
    C. longer, shorter
    D. longer, longer

35. As the reactor approaches criticality during a reactor startup it takes longer to reach an equilibrium neutron count rate after each control rod withdrawal due to the increased

    A. fraction of fission neutrons leaking from the core

    B. number of neutron generations required to reach a stable level

    C. length of time from neutron generation to absorption

    D. fraction of delayed neutrons appearing as criticality is approached

36. Which of the following parameters should be closely monitored and controlled upon reaching criticality

    A. axial peaking factor, pressure, and control rod position

    B. reactor pressure, vessel skin temperature, and source range counts

    C. reactor period, source range counts, and radial peaking factor

    D. reactor period, control rod position, and source range counts

37. Which parameter has the most significant effect on reactivity upon reaching criticality during a post-refueling reactor startup and prior to reaching the point of adding heat?

A. coolant temperature
B. coolant pressure
C. rod position
D. reactor power

38. When the reactor is exactly critical, core reactivity is

A. greater than zero
B. equal to zero
C. less than zero
D. undefined

39. When the reactor is exactly critical, reactivity is

A. greater than 1.0 Δk/k
B. equal to 1.0 Δk/k
C. less than 1.0 Δk/k
D. undefined

40. For a reactor that is exactly critical, and in which source neutrons are negligible, complete the following statement to best describe the change in neutron population in the core from one generation to the next generation. The neutron population _________ the neutron population in the previous generation.

A. fluctuates above and below
B. is less than
C. is greater than
D. is equal to

41. In a reactor that is just critical, K_{eff} is

A. equal to one
B. greater than one
C. less than one
D. fluctuates above and below one

42. With K_{eff} = 0.985, how much reactivity must be added to make the reactor critical?

A. 1.47% Δk/k
B. 1.50% Δk/k
C. 1.52% Δk/k
D. 1.61% Δk/k

43. With Keff = 0.985, how much reactivity must be added to make the reactor critical?

A. 0.0148 Δk/k
B. 0.0150 Δk/k
C. 0.0152 Δk/k
D. 0.0154 Δk/k

44. A reactor startup is in progress at your plant. The reactor operator entered in his log that the initial source range count rate prior to control rod withdrawal was 10 cps on each source range instrument. Rods are pulled for criticality, pausing per the startup procedure to monitor the count rate. The reactor operator notices that counts have now stabilized at 20 cps. Complete the following statement that best describes the size of the reactivity addition. The reactivity addition was approximately

A. twice the total amount required to reach criticality

B. half the total amount required to reach criticality

C. equal to the total amount required to reach criticality

D. a quarter of the total amount required to reach criticality

45. The reactor is critical and critical data has been recorded. Which of the following best describes reactor response to a subsequent withdrawal of control rods?

    A. Reactor power increases to or slightly above the point of adding heat and then levels off.

    B. Reactor power doesn't change, but reactor coolant temperature increases.

    C. Reactor power increases until the operator drives rods back in to level off power.

    D. Reactor power doesn't change, but fuel temperature increases.

46. During a reactor plant startup, with the reactor supercritical slightly below the point of adding heat, the reactor operator withdraws a control rod one additional notch. This rod motion should initially cause reactor power to

    A. take a step increase
    B. slowly ramp upward
    C. take a step decrease
    D. ramp upward at a diminished rate

47. During a reactor startup and after taking critical data, the operator withdraws a control rod one notch and stops. The rod withdrawal <u>initially</u> causes reactor power to take a

    A. step increase
    B. ramp increase
    C. step decrease
    D. ramp decrease

48. Assume a reactor is critical at a power level below the point of adding heat. For a 0.01% $\Delta k/k$ positive reactivity addition, the reactor period will be

    A. shorter at a higher reactor coolant temperature

    B. longer at a higher reactor coolant temperature

    C. shorter at EOL than at BOL

    D. longer at EOL than at BOL

49. A ________ with no further reactivity addition is an indication that a reactor has achieved criticality.

    A. constant positive period
    B. slightly increasing period
    C. constant negative period
    D. positive, slightly decreasing period

50. During a reactor startup, a positive 30-se[illegible]d reactor period is achieved with no [illegible]er reactivity addition. The reactor is

    A. exactly critical
    B. supercritical
    C. subcritical
    D. prompt critical

51. If a reactor is <u>exactly</u> 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

52. During a normal startup, the first indication observable by the operator that criticality has been achieved occurs when the reactor is

    A. subcritical
    B. prompt critical
    C. critical
    D. supercritical

53. If a reactor is exactly critical, and source neutrons are negligible, the reactor period is

    A. infinity
    B. -80 seconds
    C. +80 seconds
    D. zero

54. If a reactor is exactly critical, and source neutrons are negligible, the neutron flux is

    A. increasing
    B. constant
    C. decreasing
    D. fluctuating

55. Assume a reactor is critical at a power level below the point of adding heat. For an equal positive reactivity insertion, the reactor period would be:

    A. shorter if the core were xenon-free
    B. longer at EOL than at BOL
    C. shorter at EOL than at BOL
    D. longer at higher moderator temperature

56. Given a reactor that is critical below the point of adding heat, explain how the following parameter changes will affect reactor power.

    a. coolant temperatures decreases 3°F
    b. xenon concentration decreases
    c. a single control rod moves in one notch

57. Describe indications used by the operator to determine that a reactor has reached criticality.

58. During a reactor startup, the operator must make the reactor slightly supercritical to be able to determine that criticality has been attained. Why?

59. A reactor that has been shut down for one week is being started up. Control rods have been withdrawn to make K_{eff} equal to exactly one. If no further reactivity insertions are made over the next several minutes, describe how reactor power will change.

60. During a reactor startup, an exponential increase in neutron flux is observed while reactivity is not changing. The condition of the reactor is

    A. subcritical
    B. prompt critical
    C. critical
    D. supercritical

61. Which of the following parameters should be closely monitored and controlled during a startup after reaching criticality and before reaching the point of adding heat?

    A. reactor pressure, reactor heatup rate, and reactor level

    B. control rod position, reactor power, and reactor period

    C. feedwater flow rate, offgas radiation monitor, and reactor pressure

    D. reactor recirculation flow, reactor feedwater flow, and reactor level

62. The reactor is started up from cold, xenon-free conditions and is now at rated temperature and pressure with IRMs on range 9. Which of the following statements concerning reactor control is true?

    A. Feedwater injection at this point may cause the reactor to cool below the point of adding heat, requiring further rod withdrawal.

    B. Xenon will have to be compensated for by inserting control rods.

    C. The primary source of reactivity control available to the operator is control rods.

    D. Rod movement at this point is more difficult because rate of power change cannot be monitored.

63. A reactor is being started up with a stable 100-second period and power entering the intermediate range. Assuming no operator action, which of the following is true?

    A. Reactor period will remain constant through all ranges of intermediate range indication.

    B. As heat production in the reactor exceeds ambient losses, the temperature of the moderator increases, adding negative reactivity, and reactor period goes to infinity.

    C. As heat production in the reactor exceeds ambient losses, the resulting fuel temperature increase adds positive reactivity to counteract the negative reactivity added by increased moderator temperature.

    D. Prior to reaching the point of adding heat, fuel temperature increases, adding positive reactivity, which causes period to become shorter and shorter until a scram occurs on short period.

64. Which of the following represents the correct sequence in which reactivity mechanisms cause an observable effect in a reactor startup from cold, xenon-free conditions?

    A. α_D, α_M, α_V, xenon

    B. xenon, α_M, α_D, α_V

    C. xenon, α_M, α_V, α_D

    D. α_D, xenon, α_M, α_V

65. With the reactor critical at rated temperature and pressure, and with no steam loads, an injection of feedwater is required to raise reactor water level 20 inches. Which of the following is the primary concern for cold feedwater injection under these conditions?

    A. Positive reactivity will be inserted, increasing reactor power.

    B. The temperature in the reactor may drop below the point of adding heat, requiring rod withdrawal.

    C. Feedwater should not be injected since the reactor is uncontrollable.

    D. Excessive reactor cooldown may occur, causing thermal stress.

66. A reactor is being started up with a stable positive 100 second period and power is entering the intermediate range (below the point of adding heat). Assuming no operator action, which one of the following describes the response of reactor period?

   A. The heat produced by the reactor through all ranges of the intermediate range indication, is insufficient to raise the fuel or moderator temperatures, and reactor period remains constant throughout the intermediate range.

   B. As heat production in the reactor exceeds ambient losses, the temperature of the fuel and moderator will increase, adding negative reactivity, and reactor period will become infinite.

   C. As heat production in the reactor exceeds ambient losses, positive reactivity added by the fuel temperature increase counteracts the negative reactivity added by the moderator temperature increase, and reactor period remains constant throughout the intermediate range.

   D. Prior to reaching the point of adding heat, the fuel temperature increase will add negative reactivity and reactor period will approach infinity.

67. A reactor is being started up from cold shutdown conditions with a stable positive 100-second period and power is entering the intermediate range. Assuming no operator action is taken that affects reactivity, which one of the following will occur?

   A. Reactor period remains constant until saturation conditions are reached.

   B. Reactor period decreases to infinity as heat production in the reactor exceeds ambient losses.

   C. Reactor period remains constant until void production begins in the core.

   D. Reactor period decreases to zero as the fuel temperature increase adds negative reactivity to the core.

68. The point of adding heat 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 positive reactivity feedback

   C. to cause a temperature increase in fuel and coolant

   D. to produce superheated steam

69. After recording critical data during a reactor startup, the control operator withdraws the control rods to continue the startup. Along with reactor temperature, which of the following two parameters will provide the first indication of when the reactor reaches the point of adding heat?

   A. reactor pressure and reactor level
   B. reactor power and reactor period
   C. steam pressure and turbine load
   D. reactor flow and reactor level

70. During a reactor startup, reactor power response to reaching the point of adding heat is best described as increasing at

    A. an increasing rate due to increasing turbine load

    B. an increasing rate due to the development of two-phase flow resistance

    C. a diminishing rate due to the onset of reactor vessel pressurization

    D. a diminishing rate due to moderator density decreasing

71. After taking critical data during a reactor startup, the control operator begins increasing reactor power. At the point of adding heat, the doppler coefficient is one of the reactivity effects that will cause power to

    A. turn and level off
    B. decrease
    C. increase more rapidly
    D. fluctuate

72. Explain the significance of the point of adding heat on reactor stability.

73. Define the point of adding heat.

74. The point of adding heat is that power level where

    A. fuel temperature equals coolant temperature

    B. nuclear heat is sufficient to make up for ambient losses

    C. fuel centerline temperature approaches design limits

    D. nuclear heat is sufficient to cause clad creep

75. Which of the following is a factor that directly affects core reactivity at the point of adding heat?

    A. specific heat capacity
    B. thermal conductivity
    C. heat transfer coefficient
    D. moderator temperature

76. Which of the following parameters most significantly affects reactivity in a critical reactor below the point of adding heat?

    A. percent voids
    B. control rod position
    C. reactor pressure
    D. flux level

77. Prior to reaching the point of adding heat in a critical reactor, withdrawing control rods will cause

    A. reactor vessel temperature to increase
    B. a positive period
    C. reactor vessel temperature to decrease
    D. a negative period

78. 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

79. 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 added to the core approximately one minute later, reactor power will stabilize at

A. somewhat higher than the initial power level

B. somewhat lower than the initial power level

C. the initial power level

D. the subcritical multiplication equilibrium level

80. A reactor is critical at the point of adding heat when a small amount of negative reactivity is added to the core. If the same amount of positive reactivity is added to the core approximately five minutes later, reactor power will

A. stabilize at the initial power level.

B. level off at a subcritical multiplication equilibrium level.

C. continue to decrease on a negative 80 second period rate.

D. stabilize at a level lower than the initial power level.

81. Upon reaching criticality during a reactor startup, the operator establishes a positive reactor period. When the point of adding heat is reached, the period will become ________ due to the ________ reactivity feedback of moderator and fuel temperature.

A. shorter; negative
B. shorter; positive
C. longer; negative
D. longer; positive

82. During a reactor startup after recording critical data, the operator inserts enough positive reactivity into the core to cause power to increase at a steady rate. 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. MCPR safety limits

C. design limits for fuel centerline temperature

D. point of adding heat

83. What are the operator's indications that reactor power has reached the point of adding heat during a startup? Explain.

84. Which of the following parameters is not an indication of reactor power reaching the point of adding heat?

A. increase in reactor vessel temperature
B. decrease in reactor vessel level
C. lengthening of period
D. decrease in rate of power change

85. After taking critical data during a reactor startup, the operator establishes a 26 second reactor period 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:
$\beta = 0.00579$
$l = 1x10^{-5}$ sec
$\lambda_{eff} = 0.1$ sec^{-1}

A. 0.16% Δk/k
B. 0.19% Δk/k
C. 0.23% Δk/k
D. 0.29% Δk/k

86. During a reactor startup above the point of adding heat, the first factor to begin inserting negative reactivity into the core is the

A. Doppler coefficient
B. void coefficient
C. moderator temperature coefficient
D. pressure coefficient

87. A reactor heatup is in progress. A sudden rise in reactor power with a positive period is observed. The reactor operator has not moved rods. Which of the following could have caused this reaction?

A. reactor recirculation flow decreased
B. service water flow increased
C. reactor cleanup flow decreased
D. feedwater flow increased

88. During a reactor heatup, a center control rod is notched outward. The heatup rate is expected to

A. increase initially, then diminish

B. increase to a new higher value and remain there

C. decrease to a new lower value and remain there

D. decrease initially, then return to zero

89. During a reactor heatup in the intermediate range, a control rod is notched outward several notches with no subsequent operator action. The heatup rate is expected to

A increase initially, then steadily decrease to an equilibrium value

B. decrease initially, then steadily increase to an equilibrium value

C. increase and stabilize at a new higher value

D. decrease and stabilize at a new lower value

90. Heatup rate increase is seen on the nuclear instruments as a ___________ in power level followed by a ___________.

A. rise, slow decay
B. rise, step decrease
C. step increase, slow decay
D. step increase, step decrease

91. During a reactor heatup, as reactor period

    A. becomes shorter, heatup rate decreases

    B. increases to infinity, heatup rate decreases

    C. increases to infinity, heatup rate increases

    D. becomes stabilized, the point of adding heat decreases

92. The following are indications of a normal heatup <u>except</u>

    A. reactor temperature increasing
    B. reactor period fluctuating
    C. reactor level fluctuating
    D. reactor pressure increasing

93. During a reactor heat-up from 180°F to 500°F, in order to maintain a constant heat-up rate, reactor power will have to

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

94. If the moderator temperature coefficient is negative, once reactor power has reached the point of adding heat, a __________ reactivity insertion(s) is required to maintain a constant positive heatup rate.

    A. single negative
    B. single positive
    C. series of small negative
    D. series of small positive

95. Given a critical reactor operating below the point of adding heat, select from the list below the best answer to describe the reactivity effects associated with reaching the point of adding heat. At the point of adding heat,

    A. there are no reactivity effects since the reactor is critical

    B. the increase in moderator temperature will begin to create a positive reactivity effect

    C. the decrease in fuel temperature will begin to create a positive reactivity effect

    D. the increase in moderator temperature will begin to create a negative reactivity effect

96. After taking the reactor critical below the point of adding heat (POAH), the reactor operator establishes a positive 50-second period. Assuming no operator action and a constant xenon concentration, which of the following best describes the long-term power level of the reactor?

    A. slowly cycling between a level below POAH and a level above POAH

    B. at the POAH

    C. slightly above the POAH and stable

    D. slightly below the POAH and stable

97. Given a reactor with the following parameters:

    reactor power = 30 on IRM range 4
    period = +100 seconds
    coolant temperature = 160°F and stable

    If the operator took no further action, how will the parameters change before stabilizing?

98. A reactor is below but near the point of adding heat with a positive 50-second period. With no operator action, if this condition were allowed to continue, what would reactor power be 10 minutes later?

A. stable at the point of adding heat

B. stable above the point of adding heat

C. stable below the point of adding heat

D. slowly cycling above and below the point of adding heat

99. The reactor is stable at the point of adding heat (POAH) with the reactor coolant at 160°F during the reactor heatup in the intermediate range. Control rods are withdrawn a few notches to raise reactor power and establish a heatup rate. If no further control rod withdrawal occurs, reactor power will (Assume no voiding occurs.)

A. remain stable until voiding begins to occur

B. increase until the control rods are reinserted

C. decrease and stabilize at a subcritical power level

D. increase and begin to stabilize

100. Reactor vessel heatup and cooldown rates are closely controlled during plant startups and shutdowns to prevent

A. stresses on the reactor vessel
B. reactor power oscillations
C. stresses on fuel cladding
D. turbine loading or unloading

101. Reactor vessel heatup and cooldown rates are limited by technical specifications to a maximum of __________°F per hour.

A. 50
B. 100
C. 150
D. 200

102. During a plant shutdown, how is the reactor vessel cooldown rate typically controlled?

A. inserting control rods
B. reducing reactor core flow
C. reducing reactor pressure
D. lowering reactor water level

103. A reactor heatup in the intermediate range is in progress with a constant heatup rate. To maintain this constant heatup rate, reactor power will have to

A. remain constant with an essentially infinite period

B. increase with an increasingly positive period

C. remain constant with a constant positive period

D. increase with a constant positive period

104. During a reactor plant startup, the reactor pressure is increased from 26.2 psig to 262.0 psig in a two-hour period. Which of the following statements is true? Heatup rate is

A. negative and below the technical specification limit

B. positive and below the technical specification limit

C. above the technical specification limit

D. exactly at the technical specification limit

105. During a plant startup, the heatup rate is mainly controlled by

A. varying reactor core flow
B. withdrawing control rods
C. varying reactor pressure
D. adjusting reactor feedwater temperature

106. Which of the following has the least effect on reactivity while increasing power from 50% to 100%?

A. fuel temperature change
B. moderator temperature change
C. fission product poison change
D. void content change

107. Control rods are normally pulled until the desired load line is achieved to increase reactor power. Further increases to rated reactor power are accomplished by increasing

A. feedwater subcooling
B. recirculation flow
C. pressure setpoint
D. steam demand

108. When in the power range and increasing reactor power towards rated power, power changes are normally made by _________ and _____________.

A. increasing recirculation flow, increasing steam demand

B. decreasing pressure setpoint, withdrawing control rods

C. increasing steam demand, decreasing pressure setpoint

D. withdrawing control rods, increasing recirculation flow

109. While in the power range and increasing to rated power, power is increased by withdrawing control rods and increasing recirculation flow in accordance with the

A. temperature-to-pressure map
B. pressure-to-flow map
C. power-to-flow map
D. power-to-steam map

110. During a normal power increase from 20 percent to 100 percent, the <u>smallest</u> negative reactivity addition is caused by the change in

A. fuel temperature
B. moderator temperature
C. xenon concentration
D. void content

111. The reactor is operating at 90 percent power late in core life when an operator withdraws a shallow rod. The power level is observed to have decreased. This can be attributed to rod worth being _________ with ________ void content.

A. high, decreased
B. high, increased
C. low, increased
D. low, decreased

112. The reactivity addition associated with a rod withdrawal causes reactor power to ________ and void fraction to __________.

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

113. With the reactor plant operating at 90% power, ____________ in core flow rate will cause the core "boiling boundary" to move lower into the fuel zone and reactor power level to ______________.

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

114. Following a rod withdrawal, reactor power would ________ and void fraction would ________.

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

115. Given a 10 percent load increase from 20 percent power by control-rod withdrawal, which one of the following statements describes the change in void fraction?

   A. Void fraction initially decreases, then linearly increases with rod worth increase.

   B. Void fraction increases.

   C. Void fraction decreases.

   D. Void fraction remains the same.

116. In response to which one of the following events will the Doppler coefficient act first to change the reactivity addition to the core?

   A. a control-rod drop during reactor power operation

   B. the loss of one feedwater heater (extraction steam isolated) during reactor power operation

   C. tripping of the main turbine at 45 percent reactor power

   D. a safety relief valve opening during reactor power operation

117. A reactor is operating at 100 percent power and flow. Reactor power is reduced by driving control rods in. (recirculating pump speed remains constant.) What is the effect on core flow?

   A. Core flow will increase, due to the decrease in two-phase flow resistance.

   B. Core flow will remain constant, since reactor power does not affect core flow.

   C. Core flow will decrease, due to an increase in two-phase flow resistance.

   D. Core flow will increase, due to the decrease in recirculation ratio.

118. During a 10% load increase from 20% power by control rod withdrawal, which one of the following statements best describes the change in void fraction?

   A. Void fraction increases.

   B. Void fraction decreases.

   C. Void fraction initially increases, then decreases back to the original value.

   D. Void fraction initially decreases, then increases back to the original value.

119. Reactor power is increased from 70 percent to 90 percent with recirculating flow. Which one of the following statements describes the power plant response?

   A. The final feedwater temperature decreases.

   B. The pressure difference between the reactor and the turbine steam chest increases.

   C. The core void fraction increases.

   D. Condensate depression at the exit of the condenser increases.

120. At power, a core flow increase causes reactor power to ________ and the percent core voids ________.

A. increase, decrease then return to a slightly lower than initial value

B. increase, increase then return to initial value

C. decrease, decrease then return to a slightly lower than initial valve

D. decrease, increase then return to initial value

121. A core flow increase causes reactor power to increase because of

A. the Doppler coefficient of reactivity

B. the void coefficient of raactivity

C the moderator temperature coefficient of reactivity

D. improved heat transfer rate caused by increased flow turbulence

122. With the reactor at power, a core flow increase causes reactor power to ________ because initially percent core voids ________.

A. increase, remains constant
B. decrease, decreases
C. increase, decreases
D. remain constant, increases

123. A power increase is initiated by an increase in recirculation flow, causing voids to be swept away and adding positive reactivity. Which of the following statements best describes the response of the reactivity coefficients?

A. Increasing fuel temperature implies more heat transfer to the coolant. Increased moderator temperature causes more void formation, and power stabilizes at a new higher level.

B. Increasing fuel temperature implies more heat transfer to the coolant, thus increasing steam generation. The increased void fraction and fuel temperature add negative $\Delta k/k$, and power stabilizes at a new higher level.

C. Increasing fuel temperature implies more heat transfer to the coolant, thus increasing steam generation. The increased steam generation raises reactor pressure and moderator temperature, offsetting the decreasing voids, and power stabilizes at a new higher level.

D. Increased moderator and fuel temperature stabilize power at a new higher level.

124. A steady-state to steady-state core flow ________ causes reactor power to ________ and percent core voids to ________.

A. decrease, increase, increase to a new higher value

B. increase, decrease, decrease to a new lower value

C. decrease, increase, increase initially and then return to about its initial value

D. increase, increase, decrease initially and then return to about its initial value

125. During an increase in core flow, _________ initially decreases to cause ___________ to increase.

A. latent heat of vaporization, decay heat
B. decay heat, latent heat of vaporization
C. reactor power, core void fraction
D. percent core voids, reactor power

126. Which one of the following statements best describes the effects of isolating extraction steam to a high-pressure feedwater heater while at 90% power?

A. The core inlet subcooling remains the same while turbine generator MWe output decreases.

B. The core inlet subcooling and the reactor power (MWt) decrease.

C. The turbine generator MWe output and the reactor power (MWt) remain the same.

D. The turbine generator MWe output increases and the core inlet subcooling increases.

127. Which of the following statements best explains why steam production increases as power increases?

A. Latent heat of vaporization increases.

B. Decay heat becomes essential.

C. More heat energy is transferred to the coolant.

D. The thermal utilization factor decreases.

128. Following a reactor scram late in core life, steam production rate is primarily based on which of the following?

A. decay heat
B. thermal utilization factor
C. entropy of the reactor
D. moderator temperature coefficient

129. Following a middle-of-cycle reactor scram, the post-scram steam production rate is largely dependent upon ______ and _____.

A. thermal utilization factor, xenon production

B. previous power history, time since scram

C. moderator temperature coefficient, doppler effect

D. reactor period, subcritical multiplication

130. Following a normal reactor shutdown, steam production may continue for some period of time, with the rate of steam production dependent upon

A. the previous power history of the plant and the time elapsed since shutdown

B. the amount of time required for the reactor power level to drop below the point of adding heat

C. the reactor power level at the time of shutdown and initial reactor pressure vessel water level

D. the recirculation flow rate and the pressure being maintained in the RCS

131. During a normal reactor startup, steam production begins when the

A. point of adding heat is reached
B. reactor is declared critical
C. subcritical multiplication takes place
D. coolant reaches saturation temperature

132. With the reactor operating at 90 percent power, reactor pressure decreased. Which of the following could have caused this?

A. Steam flow rate increased.
B. Steam flow rate decreased.
C. Core flow rate increased.
D. Core inlet subcooling increased.

133. With no operator action or pressure control, how would reactor power respond to an increased steam demand above the steam rate currently being supplied?

   A. increase continually

   B. increase briefly, then level off

   C. decrease continually

   D. decrease for a period of time, then level off

134. Initially, reactor power would ______ if steam demand is _______ with no subsequent operator action or pressure control.

   A. remain the same, increased
   B. remain the same, decreased
   C. decrease, decreased
   D. decrease, increased

135. An increased steam demand with no operator action or pressure control results in a

   A. pressure increase
   B. pressure decrease
   C. recirculation flow decrease
   D. recirculation flow increase

136. The plant is operating normally at 50% power when a steam break occurs that releases 5% of rated steam flow. Assume no operator or protective actions occur, automatic pressure control returns reactor pressure to its value prior to the break, and feedwater injection temperature remains the same.

   How will reactor power respond?

   A. Decrease and stabilize at a lower power level.

   B. Increase and stabilize at a higher power level.

   C. Decrease, then increase and stabilize at the previous power level.

   D. Increase, then decrease and stabilize at the previous power level.

137. Following a reactor scram from rated power level, a few minutes after the initial "prompt drop" in power level, reactor power will diminish on a

   A. rate dependent upon core age

   B. rate dependent upon time spent at rated power

   C. stable negative 56 second period

   D. stable negative 80 second period

138. Regarding reactor plant scram response, as the control rod are completing their full scram stroke, reactor power level will _______________, prior to continuing to diminish on a stable negative 80 second period.

A. rapidly diminish to the "point of adding heat"

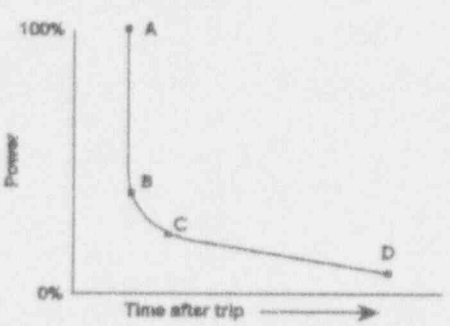
B. undergo a large "prompt drop"

C. experience a short increase, then rapidly diminish

D. drop to approximately twenty percent

139. Figure 2.8-1 shows the response of reactor power to a scram (trip) from 100 percent power. Explain the shape of the curve between points A and B, B and C, and C and D.

FIGURE 2.8-1



Response of Reactor Power to a Scram

140. Which equation below best describes the decrease in neutron flux in the core during a stable negative period?

A. $T = (\bar{\beta}_{eff} - \rho) / \bar{\lambda} \rho$

B. $P = P_o e^{t/T}$

C. $P = P_o \, \beta / (\beta - \rho)$

D. $P = P_o (.07)/T^{-2}$

141. Shortly after a reactor trip, reactor power indicates 0.5 percent when a stable negative period is attained. Reactor power indication will decrease to 0.05 percent in approximately ________ seconds.

A. 380
B. 280
C. 180
D. 80

142. A reactor plant that has been operating at rated power for two months experiences a reactor scram. A week after the reactor scram, with all control rods still fully inserted, indications are still visible on the nuclear instruments, with a stable count rate of 200 cps indicated on the source range nuclear instruments. This stable count rate in a subcritical reactor is due to the presence of

A. decay heat

B. shutdown margin

C. intrinsic source neutrons

D. the delayed neutron precursor decay constant

143. Which of the following is responsible for the negative 80-second stable reactor period experienced shortly after a reactor scram/trip?

A. the worth of the inserted control rods

B. the shutdown margin just prior to the scram

C. the longest-lived delayed neutron precursors

D. the shortest-lived delayed neutron precursors

144. The reactor is operating at 100 percent power when one of the recirculation pumps trips off. Reactor power decreases and levels off at a lower power level. Which reactivity coefficient caused reactor power to decrease?

   A. voids
   B. fuel temperature (Doppler)
   C. moderator temperature
   D. pressure

145. The reactor is operating at 100 percent power. Core flow rate suddenly decreases by 25 percent. Reactor power decreases and levels off at a lower power level. Which reactivity coefficient(s) caused the power to level off at a lower power level?

   A. void

   B. fuel temperature (Doppler) and moderator temperature

   C. moderator temperature and void

   D. void and fuel temperature (Doppler)

146. Given the following reactor conditions, when will the percent core voids be the <u>greatest</u>?

   A. at a 50 percent rod pattern with minimum recirculation pump speed

   B. at a 50 percent rod pattern with 100 percent core flow

   C. at a 100 percent rod pattern with minimum recirculation pump speed

   D. at a 100 percent rod pattern with 100 percent core flow

147. There are two primary methods of controlling reactor power in a BWR. One method is moving control rods. The other method is to vary

   A. reactor pressure
   B. reactor water level
   C. feedwater temperature
   D. core flow

148. A decrease in reactor core flow, when at 100 percent power, will result in a change in percent core voids and reactor power. How will these parameters be affected? Percent core voids will _______ and power will _________.

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

149. The reactor is operating at 70% power when one recirculation pump trips. Reactor power will __________ because of the effects of the __________ coefficient.

   A. decrease; void
   B. increase; moderator temperature
   C. decrease; moderator temperature
   D. increase; void

150. The reactor is operating at 100 percent power when one recirculation pump trips. Reactor power decreases and stabilizes at a lower power level. Which reactivity coefficient caused reactor power to decrease?

   A. fuel temperature (Doppler)
   B. pressure
   C. moderator temperature
   D. void

151. The reactor is exactly critical below the point of adding heat. A single rod is inserted into the core. Assume no operator or automatic action. The count rate as indicated by the source range instruments would slowly decrease to

A. zero

B. the value of the source neutron strength

C. a value above the source neutron strength

D. some value, then slowly increase to the initial value

152. During a normal shutdown it is important to insert control rods in a predetermined sequence to

A. ensure uniform burnup of fuel
B. minimize axial xenon oscillations
C. minimize radial xenon oscillations
D. prevent excessive control rod worth

153. Which of the following is the primary source of decay heat?

A. The heat produced in the reactor core by fission.

B. The heat produced in the reactor core by fuel cladding.

C. The heat produced in the reactor core by the reactor recirculation pumps.

D. The heat produced in the reactor core by emission of radiation from fission products.

154. After a long run at full power, approximately __________ of the thermal power produced by the reactor comes from the decay of fission products.

A. 7 percent
B. 5 percent
C. 3 percent
D. 1 percent

155. Which of the following does not contribute to decay heat?

A. fuel cladding
B. fuel
C. control rods
D. reactor recirculation pumps

156. The heat generated by the core after shutdown is referred to as _________ heat.

A. latent
B. pump
C. condenser
D. decay

157. The most significant amount of decay heat is produced by

A. prompt neutrons
B. delayed neutrons
C. beta and gamma decay
D. alpha and neutrino emission

158. A special test is being performed on the reactor plant. Coolant temperature is being maintained at 250°F with all recirculation pumps at full flow, one week following a normal shutdown from several months of operation at 100% power. The primary source of heat input to the reactor coolant is

A. reactor recirculation pumps
B. fission of activated U-235 and Pu-239
C. spontaneous fission
D. fission product decay

159. The largest source of decay heat 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

160. The major reason decay heat increases over core life is

A. increased fission product activity
B. increase in spontaneous fissions
C. increased production of plutonium
D. increased neutron flux

161. 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

162. The greatest amount of decay heat is generated from

A. spontaneous fission

B. beta and gamma decay of fission products

C. alpha emission from delayed neutron precursors

D. Sm-149 decay

163. The majority of power generated by a reactor at the beginning of core life comes from fission of U-235 and U-238. At the end of core life, the majority of power is generated by fission of which of the following two nuclides.

A. U-233 and U-234
B. Pu-241 and U-238
C. Pu-239 and U-235
D. Xe-135 and U-235

164. At the end of core life, the majority of power is generated by fission of which of the following two isotopes?

A. Pu-239 and U-235
B. Pu-239 and U-238
C. Pu-241 and U-238
D. U-235 and U-238

165. Which of the following percentages most closely approximates the decay heat produced in the reactor at one second and at one hour, respectively, following a scram from extended operation at 100% power?

A. 3% and 0.1%
B. 5% and 0.5%
C. 7% and 1.0%
D. 9% and 1.5%

166. Contrast the response of nuclear fission power and thermal power to a reactor scram from 100% equilibrium conditions.

167. After one month of operation at 100% reactor power, the fraction of thermal power being produced from the decay of fission products in the operating reactor is

A. greater than 10%
B. greater than 5% but less than 10%
C. greater than 1% but less than 5%
D. less than 1%

168. During a reactor plant startup, the reactor pressure is increased from 5.0 psig to 50.0 psig in a two-hour period. What was the average heatup rate?

A. 35°F/hr
B. 60°F/hr
C. 70°F/hr
D. 120°F/hr

169. The plant is operating at 85% power when a failure of the steam pressure control system opens the turbine control valves to admit 10% more steam flow to the main turbine. No operator actions occur and no protective system actuations occur.

How will reactor power respond? (Assume the valves remain in the failed position.)

A. Increase until reactor power matches the new steam demand.

B. Increase continuously until fuel damage occurs.

C. Decrease and stabilize at a lower power level and steaming rate.

D. Decrease and stabilize at a critical power level below the POAH.

170. At one point during a reactor plant startup and approach to criticality, count rate is noted to be 780 cps, and K_{eff} is calculated to be 0.92. Later in the same startup, count rate is 4160 cps.

What is the new K_{eff}?

A. 0.945
B. 0.950
C. 0.975
D. 0.985

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 specific parameters that must be monitored and controlled during the approach to criticality.

2. B

Reactor period indication monitors the rate of change of the neutron flux which is a measure of the fission rate or power.

3. C

Source range count rate is a direct indication of core neutron flux.

4. D

Rod position must be monitored to ensure that the withdrawal sequence is properly followed.

5.

Three parameters to be monitored during an approach to criticality are:

1. control rod position - 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 sequence must be verified.
2. source range neutron count rate - This measure of neutron flux reflects the effects of reactivity insertions, provides a means of predicting criticality (through count rate doubling and 1/M plots), and serves as indicator of having reached criticality.
3. reactor period - A constant positive period with no rod motion indicates that criticality has been reached and the reactor is supercritical.

6.

Factors affecting reactivity are:

1. control rod position - Rod withdrawal reduces neutron absorption in poisons, inserting positive reactivity. Rods are used as the operators' reactivity control mechanism during startups.
2. reactor pressure - If the reactor is producing sufficient decay heat to generate steam bubbles, an increase in pressure will collapse the bubbles and insert positive reactivity by improving neutron moderation.
3. coolant temperature - Because of the negative temperature coefficient, an increase in coolant temperature decreases coolant density and inserts negative reactivity by reducing neutron moderation.
4. fuel temperature - Due to the Doppler effect, when the fuel temperature increases, negative reactivity is inserted because more neutrons are absorbed in the fuel (uranium-238) while slowing down.
5. xenon concentration - Xenon-135 is a fission product poison that increases shortly after shutdown, then decreases, inserting negative, then positive, reactivity.

7. C

For plant condition given, recirculation flow is not used yet. Rod movement is used for startup.

Reference 32, page 304.

8. A

More generations are produced as K_{eff} approaches 1.0.

Reference 73, chapter 8, page 54.

9. B

Subcritical multiplication results in a higher stable power.

Reference 73, chapter 8, page 54.

10. A

More time is required for increased number of generations.

Reference 73, chapter 8, page 54.

11.

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 a value determined by K_{eff} 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 73, page 8-27.

12. C

13. B

Once a new equilibrium subcritical count rate is reached, period will be infinity.

Reference 22, page 67.

14. A

More time is required for the greater number of neutron generations to occur.

Reference 73, chapter 8, page 54.

15. B

More time is required for the greater number of neutron generations to occur.

Reference 73, chapter 8, page 54.

16. D

Reference 32, pages 242 through 245.

17. A

Reference 73, chapter 8, page 54.

18. D

Reference 73, chapter 8.

19. D

Of the factors listed, only core age affects reactivity of a shutdown reactor.

20. B

Reference 73, chapter 8, page 27.

21.

Assuming equilibrium initial conditions, count rate will be constant at a level determined by K_{eff} 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 withdraw, 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 exists at this higher count rate.

Reference 73, pages 8-12 to 8-20.

22. C

$$M = \frac{Ci}{Co}$$

$M \times Co = Ci = 2 \times 220 = 440$

Reference 73, chapter 8, page 16.

23. D

$$M = \frac{Ci}{Co} = \frac{420}{210} = 2.0$$

Reference 73, chapter 8, page 16.

24. D

$CR_1\ (1\text{-}K_{eff1}) = CR_2\ (1\text{-}K_{eff2})$

$780\ (1\text{-}.92) = CR_2\ (1\text{-}.985)$

$CR_2 = 4160$

25. C

$CR_1(1 - K_{eff1}) = CR_2(1 - K_{eff2})$

$$K_{eff2} = \frac{CR_2 - CR_1 + CR_1 K_{eff1}}{CR_2}$$

$$= \frac{265}{270} = 0.9814$$

26. B

$$M = \frac{1}{1\text{-}K}$$

$K = 1 - 1/M$

$= 1 - 1/2$

$= 0.5$

Reference 73, chapter 8, page 20.

27. D

Either criticality at high neutron flux levels or an equilibrium multiplication rate at low levels result in a non-changing population.

Reference 73, chapter 8, pages 12 through 16.

28. A

Reference 73, chapter 8.

29. A

With each added increase, more generations are produced. Therefore, it takes longer to reach equilibrium.

Reference 73, chapter 8, page 54.

30. C

Each increment adds additional reactivity, resulting in more neutron generations. Therefore, for each increment, the change in equilibrium count rate is greater.

Reference 73, chapter 8, page 54.

31. B

Delayed neutrons have an increased effect as more generations are being produced.

Reference 73, chapter 8, page 49.

32. A

Reference 73, chapter 8.

33. A

Each subsequent insertion of reactivity produces more neutron generations, requiring a longer time to reach equilibrium. The additional generations also cause the change in equilibrium count rate to become greater.

Reference 73, chapter 8, page 49.

34. D

Each subsequent insertion of reactivity produces more neutron generations, requiring a longer time to reach equilibrium. The additional generations also cause the change in equilibrium count rate to become greater

Reference 21, chapter 7.

35. B

Reference 21, chapter 7.

36. D

Peaking factors are not significant during reactor startup. Pressure and temperature will not change significantly until power is increased beyond the point of adding heat.

37. C

Below the point of adding heat, power changes will not affect temperature or voids so reactivity effects will not occur. Control rods will have a much larger affect on reactivity than pressure since there are few if any voids below the point of adding heat.

38. B

The reactor is critical when $K_{eff} = 1$.

$\rho = (K - 1) / K$

$\rho = (1-1) / 1 = 0$

Reference 73, chapter 5, page 21.

39. C

Reference 73, chapter 5.

40. D

Reference 73, chapter 5, page 21.

41. A

Reference 73, chapter 5, page 21.

42. C

$\Delta\rho = (K_2 - K_1) / (K_2K_1)$

$\Delta\rho$ = = (1.-.985) / (1) (.985)

$\Delta\rho$ = 1.523% $\Delta k / k$

Reference 73, chapter 5, page 22.

43. C

Reference 73, chapter 5.

44. B

Reference 73, chapter 8, page 29.

45. A

Reactor power increases until either the operator or natural feedback inserts negative reactivity.

Reference 54, page 13.5-3.

46. A

A step increase will occur unt' ,ne eftects of the delayed neutrons are seen, then a ramp increase will exist until either the operator or natural feedback inserts negative reactivity.

Reference 54, page 13.5-3

47. A

A step increase will occur until the effects of the delayed neutrons are seen, then a ramp increase will exist until either the operator or natural feedback inserts negative reactivity.

Reference 54, page 13.5-3.

48. C

Reference 54

49. A

Even though a constant positive period is related to supercritical conditions, it is the operator's indication that criticality has been achieved.

Reference 73, chapter 8, pages 57 through 60.

50. B

A constant, positive period without reactivity being added is indicative of supercritical conditions.

Reference 73, chapter 8, pages 57 through 60.

51. C

In a critical reactor, the chain reaction is exactly self-sustaining; hence, the fission rate is constant.

Reference 73, chapter 8, pages 57 through 60.

52. D

Supercritical conditions must be observed due to critical neutron population and subcritical neutron population increase being so similar in response.

Reference 73, chapter 8, pages 57 through 60.

53. A

By definition, power is not changing and the period is infinite.

Reference 73, chapter 8, pages 57 through 60.

54. B

The correct answer is constant and assumes that the source does not impact power (neutron level) indication.

Reference 73, chapter 8, pages 57 through 60.

55. C

As the core ages, U-235 depletes while Pu-239, which has a smaller delayed neutron fraction, builds up. As a result, the average delayed neutron fraction is decreased. This causes a more rapid power c[illegible] given reactivity insertion.

56.

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 coolant temperature inserts positive reactivity due to the negative temperature coefficient. Power will increase.

b. A decrease in xenon concentration removes poison from the core, inserting positive reactivity. Power will increase.

c. A rod insertion inserts negative reactivity. Power will decrease.

Reference 73, chapter 6 and 7.

57.

The response of neutron count rate and period 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 period and exponentially increasing count rate with no positive reactivity addition in progress.

Reference 73, pages 8-57 through 8-60.

58.

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 period) to know that criticality has been attained.

Reference 73, pages 8-57 through 8-59.

59.

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 73, page 8-54.

60. D

In a supercritical reactor, power rises exponentially.

Reference 73, chapter 8, pages 57 through 60.

61. B

Before reaching the point of adding heat, there should be no feedwater flow, and changes in reactor power will not affect heatup rate or pressure.

62. C

Cold water injection increases reactivity, necessitating control rod insertion, so "A" is wrong. Xenon buildup will require control rod withdrawal, so "B" is wrong.

Reference 31, chapter 7.

63. B

As heat production exceeds ambient losses, fuel and moderator temperature increase. Both changes insert negative reactivity. When the positive reactivity from rod withdrawal equals the negative reactivity from heatup, period will go to infinity.

Reference 31, chapter 7.

64. A

The Doppler coefficient provides the first observable effect as fuel is heated. The moderator is heated by the addition of heat from the fuel. Voids are formed when the moderator is heated to saturation temperature. Xenon is not produced in significant amounts until in the power range.

Reference 31, chapter 7.

65. A

"B" and "C" are false statements. Temporary metal cooling will occur, but positive reactivity insertion due to cold water injection will be the primary concern.

Reference 31, chapter 7.

66. B

Reference 31, chapter 7.

67. B

Reference 31, chapter 7.

68. 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 make up for ambient losses, and therefore, cause a temperature increase in the coolant, is termed "point of adding heat." Doppler and voids provide negative reactivity feedback.

Reference 54, pages 13.5-3 and 13.5-4.

69. B

Negative reactivity due to temperature increase must be offset to maintain period.

Reference 54, page 13.5-4.

70. D

Negative reactivity due to temperature increase must be offset to maintain period.

Reference 54, page 13.5-4.

71. A

Negative reactivity due to temperature increase must be offset to maintain period.

Reference 54, pages 13.5-2 through 13.5-4.

72.

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 is an "inherent stability" of the reactor.

Reference 77, pages 9-17 and 8-18.

73.

The point of adding heat (POAH) is the reactor power level at which the generation of heat by fission becomes noticeable.

Reference 77, page 9-17.

74. B

Reference 54, page 13.5-3.

75. D

Reference 54, page 13.5-2.

76. B

77. B

78. 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 initial power response.

Reference 78, chapter 12, pages 32 and 33.

79. A

The reactor will be critical somewhat above initial power level.

Reference 78, chapter 12, pages 32 and 33.

80. D

Reference 78, chapter 12.

81. C

Reference 54, pages 13.5-2 through 13.5-4.

82. D

Reference 54, pages 13.5-2 through 13.5-4.

83.

When power reaches the point of adding heat, the fission rate is high enough to produce observable heating of the fuel and coolant. A temperature increase in the fuel and coolant inserts negative reactivity.

As reactor power rises to the POAH, the operator will observe the power leveling off and period approaching infinity.

Reference 77, page 9-17.

84. B

Reactor vessel level will ultimately increase due to expansion of coolant as temperature increases.

Reference 54, pages 13.5-2 through 13.5-4.

85. A

$$\rho = (\bar{\beta}_{eff}) \;/\; (1 + \bar{\lambda} T)$$

$$= \frac{0.00579}{1 + (0.1)\,(26)} = 0.0016 \;\Delta k / k$$

Reference 73, chapter 7, pages 40 through 45; and reference 54, pages 13.5-2 through 13.5-4.

86. A

Due to heat transfer time through fuel/clad to moderator, Doppler will affect reactivity before moderator temperature.

Reference 54, pages 13.5-2 through 13.5-4.

87. D

An increase in the flow of relatively cold, feedwater, causes moderator temperature to decrease, inserting positive reactivity.

Reference 31, chapter 7, page 11.

88. A

Reference 31, chapter 7, page 10.

89. A

Reference 31, chapter 7.

90. A

Reference 31, chapter 7, page 10.

91. B

Reference 31, chapter 7, page 10.

92. C

Reference 31, chapter 7, page 11.

93. C

It takes more power to make steam and increase temperature at a high temperature than it takes at a low temperature because ambient losses are greater at higher temperatures. Also, the specific heat of water increases with increased temperature and the combination of the two effects are greater than the effect of the reduction in the heat of vaporization of water with increased temperature.

94. D

Negative reactivity due to temperature increase must be offset to maintain heatup rate.

Reference 54, page 13.5-4.

95. D

Reference 54, page 13.5-3.

96. A

Reference 77, page 41.

97.

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. Temperature will continue to rise until the reactor is critical and will actually overshoot, rendering the reactor subcritical. The power level will now start down, ultimately cycling slowly between a level below and above POAH. The coolant temperature will also cycle above and below the just critical temperature. The reactor period will move from positive to negative.

Reference 77, page 9-17.

98. D

99. D

Reference 77

100. A

Rapid reactor vessel heatup and cooldown rates exert excessive stresses on the reactor vessel metal. Vessel metal is relatively thick.

Reference 20.

101. B

Rapid reactor vessel heatup and cooldown rates exert excessive stresses on the reactor vessel metal.

Reference 20.

102. C

Reference 20.

103. A

Reference 77

104. B

Using steam tables with saturated conditions given pressure increase will show less than 100°F/hr heatup. It is below the technical specification limit.

Reference 20.

105. B

Reference 20.

106. B

Moderator temperature changes very little from 1 percent to 100 percent power, so there is no significant effect from the moderator temperature coefficient.

Reference 22, pages 69 and 70.

107. B

To increase reactor power to rated power, control rods are pulled until the 100 percent load line is reached. Power is then increased to rated power by increasing recirculation flow.

Reference 22, page 70.

108. D

In the power range, power increases are normally made by withdrawing control rods and increasing recirculation flow according to an operational envelope called the power-to-flow map.

Reference 22, page 69.

109. C

Power increases in the power range are made by withdrawing control rods and increasing recirculation flow according to an operational envelope called the power-to-flow map.

Reference 22, page 69.

110. B

Reactor pressure, and therefore moderator temperature, does not change as much from 20 to 100 percent power as the other parameters listed.

111. C

Reference 31, chapter 5, page 25.

112. A

Reference 31, chapter 5, page 25.

113. D

114. C

Reference 31, chapter 7, page 16.

115. B

Reference 31, chapter 5, page 25.

116. A

The rod drop inserts positive reactivity, causing a power transient. This results in a fuel temperature increase, allowing the Doppler effect to insert negative reactivity.

The other answer choices only affect reactivity (and therefore power) through void and/or moderator temperature changes. Thus, Doppler would not be the first coefficient whose effect is seen.

117. A

The power reduction will decrease boiling, which will reduce the two-phase flow resistance in the core.

118. A

Reference 31, chapter 5.

119. B

The increase in steam flow will cause a greater head loss between the reactor and the turbine.

120. A

As core flow rate is increased, the core "boiling boundary" will initially move to a point higher in the fuel zone, thus decreasing the percent core voids and adding positive reactivity. This positive reactivity addition causes power level of the reactor to increase. As the reactor power level increases, both the fuel pellets and the cladding begin to heat up. The reactor power level will stabilize when the positive reactivity addition from the void coefficient of reactivity is offset by an equal negative reactivity addition for the doppler coefficient. At the new stable power level, the "core boiling boundary" will now be slightly higher in the fuel region than it initially was, and the percent core voids will be slightly less than it initially was.

121. B

Increased recirculation flow causes a reduction in voids, which causes power to increase.

Reference 31, chapter 7, page 18.

122. C

As core flow rate is increased, the core "boiling boundary" will initially move to a point higher in the fuel zone, thus decreasing the percent core voids and adding positive reactivity. This positive reactivity addition causes power level of the reactor to increase. As the reactor power level increases, both the fuel pellets and the cladding begin to heat up. The reactor power level will stabilize when the positive reactivity addition from the void coefficient of reactivity is offset by an equal negative reactivity addition for the doppler coefficient. At the new stable power level, the "core boiling boundary" will now be slightly higher in the fuel region than it initially was, and the percent core voids will be slightly less than it initially was.

123. B

Reference 31, chapter 7.

124. D

As core flow rate is increased, the core "boiling boundary" will initially move to a point higher in the fuel zone, thus decreasing the percent core voids and adding positive reactivity. This positive reactivity addition causes power level of the reactor to increase. As the reactor power level increases, both the fuel pellets and the cladding begin to heat up. The reactor power level will stabilize when the positive reactivity addition from the void coefficient of reactivity is offset by an equal negative reactivity addition for the doppler coefficient. At the new stable power level, the "core boiling boundary" will now be slightly higher in the fuel region than it initially was, and the percent core voids will be slightly less than it initially was.

125. D

As core flow rate is increased, the core "boiling boundary" will initially move to a point higher in the fuel zone, thus decreasing the percent core voids and adding positive reactivity. This positive reactivity addition causes power level of the reactor to increase. As the reactor power level increases, both the fuel pellets and the cladding begin to heat up. The reactor power level will stabilize when the positive reactivity addition from the void coefficient of reactivity is offset by an equal negative reactivity addition for the doppler coefficient. At the new stable power level, the "core boiling boundary" will now be slightly higher in the fuel region than it initially was, and the percent core voids will be slightly less than it initially was.

126. D

127. C

Reference 31, chapter 7, page 17.

128. A

Decay heat is the major contributor to steam production after shutdown.

Reference 31, chapter 7, page 22.

129. B

Steam production comes from decay heat associated with radioactive fission products and fission product daughters.

Reference 31, chapter 7, page 22.

130. A

Reference 31, chapter 7, page 23.

131. D

Reference 31, chapter 7, page 12.

132. A

As steam demand increases, voids increase causing power to drop.

133. C

As steam demand increases voids increase causing power to drop. Consider only heat source and load with no pressure control system and no operator action.

134. D

As steam demand increases, voids increase causing power to drop. Consider only a heat source and load, no pressure control system and no operator action.

135. B

136. C

137. D

After the prompt drop, the short lived delayed neutron precursors will quickly decay, leaving the longest lived precursors to have a dominant effect on reactor period. The stable period resulting from the decay of the longest lived precursors is -80 sec.

Reference 32, page 246.

138. B

Reference 32, page 246.

139.

A-B: The rapid insertion of a large amount of negativity 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 -80 second period until neutron population is low enough for the effect of source neutrons to be seen and a subcritical equilibrium is reached.

Reference 73, page 7-70.

140. B

The delayed neutrons are decaying on a -80-second period. The formula for a change in neutron power when the period is given is

$P = P_o e^{t/T}$

Reference 32, page 234.

141. C

Since the neutron power is decreasing on a -80-second period, then the time to go from 5 percent neutron power to 0.5 percent neutron power is given by the equation $P = P_o e^{t/T}$

$.5 = (5)\, e^{t/T}$

$\ln .5 / 5 = t / T$

$-2.3 = t/-80$

$t = 184$ sec

Reference 32, page 246.

142. C

The stable count rate is the result of subcritical multiplication of source neutrons.

143. C

Reference 32

144. A

Less core flow results in less voids being swept away. Void fraction increases, which adds negative reactivity to the core.

Reference 29, chapter 5, pages 15 through 19.

145. D

Less core flow results in less voids being swept away. Void fraction increases, which adds negative reactivity to the core.

Fuel temperature decreases due to the power decrease. The fuel temperature coefficient is negative, resulting in a positive reactivity insertion that eventually balances out the void coefficient effects.

Reference 29, chapter 5, pages 15 through 19.

146. C

The condition with maximum power and least flow results in maximum void fraction.

Reference 29, chapter 5, pages 15 through 19.

147. D

Reactor power changes with a corresponding change in core flow due to an associated change in void fraction. Voids have a negative reactivity coefficient.

Reference 29, chapter 5, pages 15 through 19.

148. A

A change in reactor core flow will result in a change in reactor power due to an associated change in void fraction. Voids have a negative coefficient.

Reference 29, chapter 5, pages 15 through 19.

149. A

Reference 29, chapter 5.

150. D

Reference 29, chapter 5.

151. C

The count rate will decrease and level out above the source neutron strength as stated by the equation:

$$\text{Stable Count Rate} = \frac{S}{1 - K_{eff}}$$

Reference 32, page 240.

152. D

Below about 20 percent power, a control rod drop accident could cause fuel damage if rod worth is excessive. By following a predetermined rod insertion sequence, rod worths are kept small enough to avoid damage in a rod drop accident.

153. D

The greatest amount of decay heat results from the decay of fission products.

Reference 32, page 122.

154. A

After the reactor has operated for an extended period of time, the rate of energy released from decay products will be approaching the equilibrium value of approximately 7 percent power.

Reference 32, page 122.

155. D

The cladding, fuel, and control rods are radioactive and produce heat as they decay. The pumps do not contribute to decay heat.

Reference 32, page 122.

156. D

The generic term for heat generation after shutdown is decay heat.

Reference 32, page 122.

157. C

While other types of decay produce decay heat, they are insignificant compared to the heat produced by gamma and beta decay.

Reference 32, page 122.

158. A

Reference 32, page 122.

159. B

Very little decay heat results from fission because the fission rate is very low in a shutdown reactor. Fission product decay provides the most significant amount of the decay heat.

Reference 32, page 122.

160. A

Over core life, fission products that produce decay heat are increasing as the fuel is depleted. Activation products are also increasing. Thus, the decay heat load increases.

Reference 32, page 124.

161. B

From Figure 2.33 of the reference.

Reference 32, page 123.

162. B

Reference 32, page 122.

163. C

Reference 29, page 3-20.

164. A

Reference 29

165. C

Reference 32, page 122.

166.

When the scram occurs, the neutron-induced fission power level will fall quickly to below the point of adding heat. After a few minutes neutron power will decrease on a stable -80 second period 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 scram, decreasing to about 1% after an hour and about 0.5% after a day and diminishing gradually over weeks and years.

Reference 73, page 7-70, and reference 18, Figure 2.33.

167. B

168. A

169. C

170. D

$Keff_2 = 1 - C_1/C_2 \times (1 - Keff_1)$

$Keff_2 = 1 - 780/4160 \times (1 - 0.92)$

$Keff_2 = 1 - 0.1875 \times 0.08$

$Keff_2 = 0.985$

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

List the parameters that should be monitored and controlled specifically during the approach to criticality.

K1.02 Question 6

Explain four parameters that can affect reactivity during an approach to criticality.

K1.02 Question 7

State the reactivity control mechanism used during the approach to criticality.

K1.03 Questions 8-18

Describe count rate and period response that should be observed for rod withdrawal during the approach to criticality.

K1.04 Questions 19-27, 170

Relate the concept of subcritical multiplication to predicted count rate and period response for control rod withdrawal during the approach to criticality.

K1.05 Questions 28-35

Describe reactor response when the reactor is very close to criticality.

K1.06 Questions 36, 37

List the parameters that should be monitored and controlled upon reaching criticality.

K1.07 Questions 38, 39

Define criticality as related to reactor startup.

K1.07 Question 40

Define criticality in terms of the change in neutron population from one neutron generation to the next generation.

K1.07 Question 41

Define criticality in terms of the effective multiplication factor (K_{eff}).

K1.07 Question 42, 43

Given initial conditions, determine the change in reactivity required to make the reactor critical.

K1.07 Question 44

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.

K1.08 Questions 45-48, 60

Describe reactor power and period response once criticality is reached.

K1.08 Questions 49-53

Describe how to determine if a reactor is critical.

K1.08 Questions 54-59

Describe reactor power response when critical below the point of adding heat.

K1.09 Question 61

List the parameters that should be monitored and controlled between criticality and the point of adding heat.

K1.10 Questions 62-67

Given plant conditions, explain methods to control reactor power while in the intermediate range during reactor startup.

K1.11 Questions 68, 73, 74

Define the term "point of adding heat (POAH)."

K1.11 Questions 69-72

Describe the impact on reactor power of reaching the point of adding heat (POAH).

K1.11 Question 75

Discuss the concept of the point of adding heat and its impact on reactor power.

K1.12 Question 76

Describe parameters significantly affecting reactivity in a critical reactor below the point of adding heat.

K1.12 Questions 77, 78

Describe reactor power response to changing plant parameters after reaching criticality and below the point of adding heat.

K1.12 Question 79, 80

Describe reactor power response below the point of adding heat when equal amounts of positive and negative reactivity are added sequentially.

K1.13 Questions 81-84

Describe indications that the point of adding heat has been reached.

K1.13 Question 85

Determine the amount of negative reactivity required to level off power at the point of adding heat.

K1.13 Question 86

Explain the causes for reactor response when the point of adding heat is reached.

K1.14 Questions 87-93

Describe parameters that could affect the heatup rate during a reactor heatup.

K1.15 Questions 94-99

Describe reactor power response after reaching the point of adding heat.

K1.16 Questions 100-105, 168

Explain reasons for controlling reactor vessel heatup and cooldown rates.

K1.17 No questions

It was determined that there are many more than three parameters to be monitored and controlled during power operation.

K1.18 Questions 106, 110

Describe factors affecting reactivity during power increases in the power range.

K1.18 Questions 107, 109

Describe mechanisms for increasing reactor power from the point of adding heat to rated power.

K1.19 Questions 111, 112, 114-118

Explain transient effects of a control rod withdrawal on reactor power and void fraction content (during power operation).

K1.20 Questions 119-123

Explain the transient effects of an increase in core flow on reactor power and void fraction (during power operation).

K1.20 Questions 113, 124, 125

Explain the steady-state effects of a change in core flow on reactor power and void fraction (during power operation).

K1.21 Questions 126, 127

Explain the relationship between steam production and reactor power during power operations.

K1.21 Questions 113, 114

Explain the relationship between steam production and reactor power following a reactor scram.

K1.21 Question 130

Explain the relationship between steam production and reactor power following a normal reactor shutdown.

K1.21 Question 131

Explain the relationship between steam production and reactor power during a normal reactor startup.

K1.22 Questions 132-136, 169

At a given power, explain the effect an increased steam demand will have on reactor power during power operation.

K1.23, 1.24 No questions

Rod pattern exchanges are not generic to BWRs using "control cell" cores.

K1.25 Questions 137-143

Explain the shape of a curve of reactor power versus time after a trip.

K1.26 Questions 144-150

Explain reactor power responses to a change in core flow.

K1.27 Question 151

Explain the reactor response to a control rod insertion.

K1.28 Question 152

Explain why control rods must be inserted in a predetermined sequence during a reactor shutdown.

K1.29 Questions 153-158

Define the term decay heat.

K1.30 Questions 159-167

Explain the relationship between decay heat generation and power level history, power production, and time after reactor shutdown.

No topics in this subject area warranted development of questions. The operation of level and pressure sensing instruments (K1.03) is addressed in the Sensors and Detectors section of Components.

STEAM
Questions

1. Liquid that exists at its boiling point is said to be

   A. subcooled
   B. saturated
   C. compressed
   D. superheated

2. Which of the following best defines the condition of a saturated liquid?

   A. below the boiling point
   B. above the boiling point
   C. at the critical point
   D. at the boiling point

3. If a liquid is saturated and pressure remains constant

   A. the addition of heat will raise the liquid to the boiling point
   B. the removal of heat will result in no change to the liquid temperature
   C. the addition of heat will result in vaporization of the liquid
   D. the removal of heat will cause the liquid to become superheated

4. Which of the following is <u>not</u> a characteristic of a saturated liquid?

   A. The addition of heat will cause the liquid to boil with no temperature change.

   B. The removal of heat will result in a decrease in the liquid temperature.

   C. The liquid 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 it is

   A. at the boiling temperature and the next addition of heat causes vaporization

   B. hotter after an increase in heat

   C. converted to 100 percent vapor

   D. held constant at a temperature below boiling

6. Which one of the following is the best definition of the term saturated liquid?

   A. a liquid at a temperature and pressure condition such that any addition of heat will create vapor

   B. a liquid mixture such that the quotient of the mass of vapor divided by the mass of liquid-vapor mixture is greater than one

   C. a liquid at a temperature and pressure condition such that the liquid contains a large percentage of steam

   D. a liquid at a temperature and pressure condition such that any addition of heat will increase the mass of the liquid

7. Water is initially saturated with a quality of 50 percent, when a small amount of heat is added. Assuming the water pressure remains constant and the water remains saturated, water quality will __________ and water temperature will __________.

   A. increase; increase
   B. increase; remain the same
   C. remain the same; increase
   D. remain the same; remain the same

8. Which one of the following is the best definition of the term saturated vapor?

   A. a vapor with 100 percent liquid content

   B. a vapor containing less than 10 percent liquid by weight

   C. a vapor existing at the boiling point

   D. a vapor with a quality of zero percent

9. If the addition of heat to a vapor results in a temperature increase, the vapor is called

   A. wet vapor
   B. saturated vapor
   C. hot vapor
   D. expanded vapor

10. At a constant pressure, heat removed from a _______causes its quality to decrease.

    A. saturated liquid
    B. superheated vapor
    C. subcooled liquid
    D. saturated vapor

11. Saturated steam, with a quality of 100 percent, reacts at a constant pressure as follows: When heat is

    A. added, more vapor is produced

    B. removed, the vapor temperature drops, and its quality is decreased

    C. removed, the vapor temperature remains constant, and more liquid is formed

    D. removed, the vapor temperature drops, but the vapor volume remains constant

12. Given a constant pressure, any further addition of heat will result in an increase in the temperature of

    A. saturated vapors and subcooled liquids
    B. wet vapors and saturated vapors
    C. saturated liquids and saturated vapors
    D. subcooled liquids and wet vapors

13. If heat is removed from a saturated vapor at a constant pressure

    A. the temperature decreases
    B. the density decreases
    C. the specific volume decreases
    D. the enthalpy increases

14. If heat is added to a saturated vapor at a constant pressure

    A. the specific volume decreases
    B. the temperature increases
    C. the density remains constant
    D. the moisture content increases

15. The addition of a small amount of heat to a steam vapor results in a temperature increase. The steam is presently a __________ vapor.

    A. wet
    B. saturated
    C. superheated
    D. subcooled

16. The mass of steam divided by the mass of the steam and water mixture is defined as

    A. steam moisture content
    B. steam quality
    C. void fraction
    D. specific volume

17. Steam quality is defined as

    A. mass of the steam/mass of the water plus steam in the mixture

    B. mass of the water/mass of the water plus steam in the mixture

    C. mass of the water plus steam in the mixture/mass of the steam

    D. mass of the steam/mass of the water

18. ____________ is defined as the mass of the steam divided by the mass of the steam and water mixture.

    A. void fraction
    B. saturation ratio
    C. moisture content
    D. steam quality

19. Which of the following is a definition of steam quality?

    A. volume of the steam divided by the volume of the steam and water mixture

    B. volume of the water divided by the volume of the steam and water mixture

    C. mass of the steam divided by the mass of the steam and water mixture

    D. mass of the water divided by the mass of the steam and water mixture

20. The ratio "mass of the steam / mass of the steam plus water mixture" is the definition of

    A. moisture content
    B. steam quality
    C. saturated water ratio
    D. saturated steam ratio

21. What is the quality of wet steam leaving the reactor at 476 °F with an enthalpy of 928.9 BTU/lbm?

    A. 37%
    B. 54%
    C. 63%
    D. 75%

22. Given a steam/water mixture leaving the reactor core at a temperature of 550 °F, a pressure of 1035 psig, and a quality of 14.5 percent, which one of the following most closely approximates the enthalpy of the steam-water mixture?

    A. 610 BTU/lbm
    B. 643 BTU/lbm
    C. 720 BTU/lbm
    D. 860 BTU/lbm

23. Which one of the following sets of water parameters will result in the highest fluid quality?

    A. 160°F; 960 BTU/lbm
    B. 200°F; 1040 BTU/lbm
    C. 320°F; 1070 BTU/lbm
    D. 500°F; 1100 BTU/lbm

24. Which one of the following has the lowest quality?

    A. superheated steam
    B. wet vapor
    C. saturated steam
    D. saturated liquid

25. Which one of the following is the best description of a subcooled liquid?

    A. a liquid at a temperature above its critical temperature

    B. a liquid at a pressure below the saturation pressure for a specific temperature

    C. a liquid at a saturation temperature for the liquid's pressure (system pressure)

    D. a liquid at a temperature lower than the saturation temperature for the liquid's pressure (system pressure)

26. If the enthalpy of the water in a bucket is 60 BTU/lbm, which of the following is the number of degrees of subcooling of the water?

    A. 120 °F
    B. 122 °F
    C. 124 °F
    D. 126 °F

27. Given an operating reactor at 985 psig and a feedwater inlet temperature of 400 °F, what is feedwater subcooling?

    A. 136.6 °F
    B. 140.6 °F
    C. 144.6 °F
    D. 148.6 °F

28. When a liquid exists at a temperature below saturation for its pressure, it is said to be

    A. sublimated
    B. super saturated
    C. subcooled
    D. condensed

29. A subcooled liquid has all of the following properties, <u>except</u>

    A. its enthalpy is lower than saturation enthalpy

    B. its density is greater than saturation density

    C. its temperature is lower than saturation temperature

    D. its pressure is lower than saturation pressure

30. When heat is added to a subcooled liquid,

    A. vapor is formed
    B. temperature increases
    C. pressure decreases
    D. specific volume decreases

31. If the enthalpy of a liquid is less than saturation enthalpy for a given pressure, the liquid is said to be

    A. saturated
    B. superheated
    C. supercooled
    D. subcooled

32. A subcooled liquid has which of the following properties?

    A. temperature and enthalpy less than saturation

    B. temperature less than saturation, but enthalpy greater than saturation

    C. enthalpy less than saturation, but temperature greater than saturation

    D. temperature and enthalpy equal to saturation

33. What effect will occur if heat is removed from water that is in a subcooled condition?

    A. Temperature of the water will increase.
    B. Enthalpy of the water will decrease.
    C. Quality of the water will increase.
    D. Density of the water will decrease

34. Determine the amount of inlet subcooling present in feedwater at a temperature of 400 °F and a reactor pressure of 1,000 psia.

    A. 75 °F
    B. 100 °F
    C. 125 °F
    D. 145 °F

35. A saturated liquid at 1,100 psia has an enthalpy of

    A. 557.5 BTU/lbm
    B. 631.5 BTU/lbm
    C. 1189.1 BTU/lbm
    D. 1192.9 BTU/lbm

36. Condensate temperature in the hotwell is 112 °F and is 6 °F subcooled. What is the condenser pressure?

A. 1.9 psia
B. 1.6 psia
C. 1.3 psia
D. 1.1 psia

37. For a wet vapor at 130 °F with a quality of 90 percent, the 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

38. 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

39. The saturation pressure for water at 328 °F is

A. 85 psig
B. 100 psig
C. 115 psig
D. 130 psig

40. What is the saturation temperature for steam at a pressure of 785 psig?

A. 513 °F
B. 518 °F
C. 522 °F
D. 532 °F

41. What is the quality of a 540 °F vapor-liquid mixture with a specific enthalpy of 1175 BTU/lbm?

A. 0.964
B. 0.971
C. 0.984
D. 1.016

42. What is the saturation pressure for a boiling water reactor operating at 546 °F?

A. 990 psig
B. 997 psig
C. 1012 psig
D. 1027 psig

43. A calibrated pressure gauge is measuring 350 psig in a saturated system. A temperature gauge in the same system would read

A. 420 °F
B. 425 °F
C. 430 °F
D. 435 °F

44. What is the temperature of a water-steam mixture that has an enthalpy of 1150 BTU/lbm and a quality of 95%?

A. 210 °F
B. 270 °F
C. 360 °F
D. 420 °F

45. The saturation pressure corresponding to 440 °F is

A. 366.8 psia
B. 247.3 psig
C. 381.5 psia
D. 444.6 psig

46. Which one of the following is the correct value for a reactor cooldown rate, assuming an initial reactor pressure of 985 psig and a reactor pressure of 385 psig one hour later?

A. 80 °F/hour
B. 100 °F/hour
C. 120 °F/hour
D. 125 °F/hour

47. Given the following steam parameters:

    Pressure = 485.3 psig
    Specific volume = 0.06297 ft^3/lb

    Which of the following set of values represents the entropy (s), enthalpy (h), and quality (x), respectively, of the steam?

    A. s = 0.6878 BTU/lbm,
       h = 485.4 BTU/lbm,
       x = 4.76 percent

    B. s = 0.6878 BTU/lbm,
       h = 485.4 BTU/lbm,
       x = 5.3 percent

    C. s = 0.7187 BTU/lbm,
       h = 506.8 BTU/lbm,
       x = 4.76 percent

    D. s = 0.7187 BTU/lbm,
       h = 506.8 BTU/lbm,
       x = 5.3 percent

48. Which of the following represents the values of entropy (s), enthalpy (h), and specific volume (v), respectively, for steam at 235.3 psig and 550 °F?

    A. s = 1.6239 BTU/lbm, h = 1291.8 BTU/lbm, v = 2.2909 ft^3/lbm

    B. s = 1.6301 BTU/lbm, h = 1299.6 BTU/lbm, v = 2.3243 ft^3/lbm

    C. s = 1.63705 BTU/lbm, h = 1305.4 BTU/lbm, v = 2.3586 ft^3/lbm

    D. s = 1.6502 BTU/lbm, h = 1319.0 BTU/lbm, v = 2.4262 ft^3/lbm

49. Given a reactor pressure decrease from 1000 psig to 250 psig in one hour and 45 minutes, which one of the following values most closely approximates the reactor cooldown rate?

    A. 41 °F/hour
    B. 81 °F/hour
    C. 98 °F/hour
    D. 144 °F/hour

50. The saturation temperature for steam at a pressure of 785 psig is

    A. 510 °F
    B. 513 °F
    C. 515 °F
    D. 518 °F

51. Saturated steam at 250 psia enters turbine "X". Superheated steam at 250 psia and 500°F enters turbine "Y". Both turbines are 100 percent efficient and exhaust to a condenser at 1.0 psia.

    Which one of the following lists the percentage of moisture at the exhaust of turbines X and Y?

    A. turbine X = 24.5%; turbine Y = 20.8%
    B. turbine X = 26.3%; turbine Y = 13.0%
    C. turbine X = 24.5%; turbine Y = 13.0%
    D. turbine X = 26.3%; turbine Y = 20.8%

52. An operator suspects that a steam line temperature instrument reading is not correct. A recently calibrated pressure gauge sensing steam pressure for the same steam line indicates 351 psig. Assuming the system is operating at saturation pressure, what should the temperature instrument indicate?

    A. 424°F
    B. 428°F
    C. 432°F
    D. 436°F

53. Which of the following values most accurately represents the quality of steam leaving a cyclone separator at 985 psig and 1183 Btu/lbm?

    A. 95%
    B. 96%
    C. 97%
    D. 99%

54. Cooling water exits a fuel channel with an enthalpy of 1195 BTU/lbm at a reactor pressure of 1050 psig. What is the state of the fluid at the exit of the fuel channel?

    A. saturated
    B. superheated
    C. compressed
    D. subcooled

55. Consider a water/steam mixture with a current quality of 99%. 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

STEAM
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

Reference 68, pages 113 through 115; and reference 78, page 2-47.

2. D

Reference 68, pages 113 through 115, and reference 78, page 2-47.

3. C

Reference 78, page 2-47, and reference 68, pages 113 through 115.

4. C

Reference 78, page 2-47.

5. A

Reference 78, page 2-47.

6. A

Reference 68, pages 113 through 115.

7. B

Reference 68.

8. C

Reference 57, page 4-12.

9. B

Reference 57, page 4-12.

10. D

A saturated vapor is a substance whose temperature increases if heat is added at a constant pressure. If heat is removed the vapor's temperature remains the same, but its quality decreases (liquid forms).

Reference 57, page 4-12.

11. C

Saturated steam's temperature will increase if heat is added at a constant pressure; if heat is removed, the temperature remains the same, but the quality decreases (liquid forms).

Reference 57, page 4-12.

12. A

Answer choices B, C, and D are incorrect because an addition of heat to wet vapors and saturated liquids causes (increased) vaporization rather than a temperature increase.

Reference 57, page 4-12.

13. C

When heat is removed from a saturated vapor, its temperature remains the same, but its quality decreases (liquid forms) and if liquid is formed from the vapor, specific volume decreases.

Reference 57, page 4-12.

14. B

A saturated vapor cannot undergo further vaporization. Therefore, if heat is added, its temperature goes up.

Reference 57, page 4-12.

15. C

Reference 57.

16. B

Steam quality is defined as:

$$\frac{\text{mass of the steam}}{\text{mass of steam and water mixture}}$$

Reference 59, page 87; and reference 68, page 116.

17. A

Steam quality (X) is defined as:

$$\frac{\text{mass of the steam}}{\text{mass of the steam-water mixture}}$$

Reference 59, page 87; and reference 68, page 116.

18. D

Steam quality is defined as:

$$\frac{\text{mass of the steam}}{\text{mass of the steam-water mixture}}$$

Reference 59, page 87; and reference 68, page 116.

19. C

Steam quality (X) is defined as:

$$\frac{\text{mass of the steam}}{\text{mass of the steam and water mixture}}$$

Reference 59, page 87; and reference 68, page 116.

20. B

Steam quality (X) is defined as:

$$\frac{\text{mass of the steam}}{\text{mass of the steam-water mixture}}$$

Reference 59, page 87; and reference 68, page 116.

21. C

From saturated steam table for 476 °F:

h_f = 459.9 BTU/lbm

h_{fg} = 744.5 BTU/lbm

Quality = (actual enthalpy - h_f)/h_{fg}

= (928.9 - 459.9)/744.5

= 63%

Reference 10.

22. B

From saturated steam table for 1050 psia:

h_f = 550.1 BTU/lbm

h_{fg} = 640.9 BTU/lbm

Enthalpy = h_f + (quality) (h_{fg})

= 550.1 + (14.5%) (640.9)

= 643 BTU/lbm

Reference 10.

23. B

Reference 10.

24. D

Reference 57, chapter 4, pages 13 through 17.

25. D

Reference 57, chapter 4, page 21.

26. A

From the saturated steam temperature table, T_{sat} for enthalpy of 60 BTU/lbm is 92 °F. Therefore, the liquid is 212 °F - 92 °F = 120 °F subcooled.

Reference 10.

27. C

From the saturated steam pressure table, T_{sat} for pressure of 1,000 psia is 544.58 °F. Therefore, the feedwater is 544.58 - 400 = 144.58 °F subcooled.

Reference 10.

28. C

Subcooling - The difference between the actual temperature of a liquid and its saturation temperature at a given pressure.
or The difference in the liquid's enthalpy and its saturation enthalpy.

Reference 57, page 4-21.

29. D

Reference 57, page 4-21.

30. B

Reference 57, page 4-21

31. D

Subcooling - The difference between the actual temperature of a liquid and its saturation temperature at a given pressure.
or The difference in the liquid's enthalpy and its saturation enthalpy.

Reference 57, page 4-21

32. A

Subcooling - The difference between the actual temperature of a liquid and its saturation temperature at a given pressure.
or The difference in the liquid's enthalpy and its saturation enthalpy.

Reference 57, page 4-21

33. B

Reference 57, page 4-21.

34. D

Saturation temperature for 1,000 psia = 544.58 °F

544.58 - 400 °F = 144.58 °F (approximately 145 °F)

Reference 10, page 13.

STEAM
Answers

35. A

Saturated Liquid (h_f) at 1,100 psia is 557.5 BTU/lbm.

Reference 10, page 13.

36. B

112 °F + 6 °F = 118 °F
Saturation pressure of 118 °F = 1.6 psia

Reference 10, page 7.

37. A

$h_x = h_f + (X)h_{fg}$
$h_x = 97.96 + (.9)(1{,}019.8)$
$h_x = 1{,}015.78$ BTU/lbm

Reference 10, page 13.

38. C

Reference 10, page 12.

39. A

From the saturated steam temperature table, saturation pressure for 328 °F is 100 psia, or 85 psig.

Reference 10.

40. B

From the saturated steam pressure table, saturation temperature for 785 psig (800 psia) is 518.21 °F.

Reference 10.

41. B

From the saturated steam temperature table:

h_f = 536.8 BTU/lbm

h_{fg} = 657.5 BTU/lbm

Quality = (actual enthalpy - h_f)/h_{fg}

= (1175 - 536.8)/657.5

= .971

Reference 10.

42. B

From the saturated steam temperature table, P_{sat} for 544 °F is 995.22 psia, and P_{sat} for 548 °F is 1028.49 psia. Interpolating to find the pressure for 546 °F yields 1011.86 psia, or approximately 997 psig.

Reference 10.

43. D

From the saturated steam pressure table, find T_{sat} for a pressure of 350 psig (365 psia):

365 psia is 30% of the difference between 350 and 400. Therefore, T_{sat} will be 30% of the difference between 431.73 °F and 444.60 °F, or 435.59 °F.

Reference 10.

44. C

45. C

From the saturated steam temperature table, saturation pressure for 440 °F is 381.54 psia, or 366.8 psig. (Note: psig = psia - 14.7 psi)

Reference 10.

STEAM
Answers

46. B

From the saturated steam pressure table, saturation temperature for 1000 psia (985 psig) is 544.58 °F, and for 400 psia (385 psig) is 444.60 °F. Thus, in one hour, the temperature was decreased by 100 °F.

Reference 10.

47. A

From the saturated steam pressure table for 500 psia (485 psig):

$v_f = 0.01975$
$v_{fg} = 0.90787$

Quality $= (v_{actual} - v_f)/v_{fg}$
$= (0.06297 - 0.01975)/0.90787$
$= 4.76\%$

With this value of quality known, enthalpy and entropy can be calculated:

$h_{actual} = h_f + x\, h_{fg}$
$= 449.5 + (4.76$[illegible]$5.1)$
$= 485.4$ BTU/lbm

$s_{actual} = s_f + x\, s_{fg}$
$= 0.6490 + (4.76\%)\,(0.8148)$
$= 0.6878$ BTU/lbm

Reference 10.

48. A

From the superheated steam table for 250 psia (235 psig) and 550 °F.

Reference 10.

49. B

From the saturated steam pressure table, saturation temperature is approximately 546 °F for 1015 psia and 405 °F for 265 psia. The cooldown rate is therefore:

(546 °F - 405 °F)/1.75 hr = 81 °F/hr

Reference 10.

50. D

From the saturated steam pressure table.

Reference 10.

51. A

From the mollier diagram

Reference 10.

52. D

From the saturated steam temperature table

Reference 10.

53. D

Steam tables

Reference 10.

54. B

Reference 10.

55. D

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.

K1.07 Questions 1-7

Define "saturated liquid."

K1.09 Questions 8-12

Define "saturated vapor."

K1.09 Questions 1[illegible] 15, 55

Describe the characteristics of saturated vapor.

K1.12 Questions 16-20, 24

Define "steam quality."

K1.12 Questions 21-23

Perform calculations involving steam quality.

K1.[illegible] [illegible]estions 26, 27

Perform calculations of subcooling.

K1.16 Questions 28, 29

Define "subcooling."

K1.16 Questions 25, 30-33

Describe subcooling.

K1.22, 1.23 Questions 34-54

Given a set of steam tables, perform calculations to determine enthalpies, temperatures or pressures.

THERMODYNAMIC PROCESSES
Questions

1. The function of a convergent-divergent nozzle in an air ejector is to

   A. decrease flow velocity, increase pressure

   B. increase flow velocity, decrease pressure

   C. increase flow velocity, increase pressure

   D. decrease flow velocity, decrease pressure

2. An ideal convergent-divergent nozzle process is essentially adiabatic. However, the real nozzle process increases the entropy of the fluid because

   A. the flow through the nozzle is too rapid for heat exchange

   B. the pressure change in the nozzle, due to velocity changes, increases entropy

   C. turbulence and friction losses occur

   D. some heat is lost to atmosphere, as no insulation is 100% efficient

3. The basic function of the nozzle in air ejectors is to

   A. change potential energy to enthalpy

   B. change enthalpy to heat in the air ejector

   C. change heat to work in the air ejector

   D. change fluid energy from one form to another

4. The point in a steam jet air ejector (SJAE) where the lowest pressure exists is located at the

   A. throat of the nozzle

   B. inlet to the nozzle

   C. outlet of the nozzle

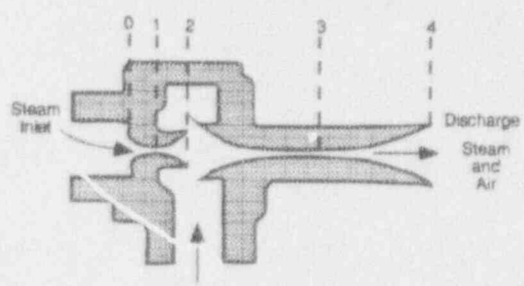
   D. suction piping from the condenser to the SJAE

5. Refer to the drawing of an operating steam-jet air ejector (see Figure 3.4-1).

   At which of the following locations is the lowest pressure experienced?

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

FIGURE 3.4-1



Steam-Jet Air Ejector

6. Refer to the drawing of a steam-jet air ejector (see Figure 3.4-1).

   In the figure of an operating steam jet air ejector, steam flowing from 3 to 4 undergoes a pressure ____________ and a velocity ____________.

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

7. Refer to the drawing of a steam-jet air ejector (see Figure 3.4-1).

   The section of an air ejector that converts steam pressure into kinetic energy is called the:

   A. diffuser
   B. nozzle
   C. intercondenser
   D. riser

8. Which of the following statements correctly describes the operation of a steam jet air ejector (SJAE)?

   A. The highest velocity of the steam-and-air mixture occurs at the throat of the air ejector.

   B. The steam jet entering the suction chamber entrains the non-condensible condenser gases.

   C. The highest steam pressure occurs at the throat of the steam jet during normal operations.

   D. The velocity of the steam flow entering the suction chamber is independent of the pressure (vacuum) in the main condenser.

9. [For reactors with jet pumps only] During jet pump operation, a high pressure, low velocity fluid flow is supplied through a _______ where the pressure drops and the velocity increases, creating a low pressure area in the _______ section.

   A. nozzle; throat
   B. nozzle; diffuser
   C. diffuser; throat
   D. diffuser; nozzle

10. Explain how a steam jet air ejector works.

11. [For reactors with jet pumps only] "A high pressure, low velocity driving flow is supplied through a nozzle. The pressure drops and the velocity increases, creating a low pressure area in the throat section. This low pressure area draws the fluid to be pumped into the throat area. As the flow continues into the diffuser section the velocity drops and the pressure rises." This statement describes the principle of operation of a

    A. centrifugal pump
    B. jet pump
    C. centripetal pump
    D. reciprocating pump

12. [For reactors with jet pumps only] Select the arrangement in the following statement that best explains the principle of jet pump operation. A high pressure, low velocity driving flow is supplied through a __1__ where the pressure drops and the velocity increases creating a low pressure area in the __2__ section. This low pressure area draws the fluid to be pumped into the __3__ section. As flow continues into the __4__ section, the velocity drops and the pressure rises.

	1	2	3	4
A.	nozzle	throat	throat	diffuser
B.	diffuser	throat	nozzle	throat
C.	nozzle	diffuser	throat	throat
D.	throat	nozzle	throat	diffuser

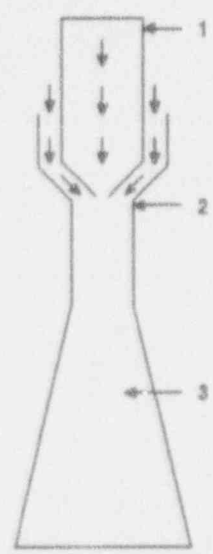
13. [For reactors with jet pumps only] In a jet pump, a low pressure area is created in the

    A. impeller section
    B. rams head
    C. throat
    D. diffuser

14. [For reactors with jet pumps only] Which of the following sets represents a correct arrangement of numbered components on the jet pump diagram in Figure 3.4-2?

	1	2	3
A.	nozzle	diffuser	throat
B.	diffuser	throat	nozzle
C.	throat	nozzle	diffuser
D.	nozzle	throat	diffuser

FIGURE 3.4-2



Jet Pump

15. [For reactors with jet pumps only] In a jet pump, _______ is supplied to a nozzle where the pressure drops and the velocity increases, creating a low pressure area in the throat section. This low pressure area draws the fluid to be pumped into the throat area. As the flow continues into the diffuser section, the velocity drops and the pressure rises.

    A. low-pressure, high-velocity driving flow
    B. low-pressure, low-velocity driving flow
    C. high-pressure, low-velocity driving flow
    D. high-pressure, high-velocity driving flow

16. Explain how a jet pump operates.

17. Steam exhausts from the low pressure turbine at 1.0 psia. Hotwell temperature reads 98°F. The fluid in the hotwell is a

    A. saturated liquid
    B. saturated vapor
    C. subcooled liquid
    D. superheated vapor

18. Subcooling in the condenser is increased by 3°F. This will result in

    A. increased overall plant efficiency
    B. no change in overall plant efficiency
    C. decreased condensate depression
    D. decreased overall plant efficiency

19. Referring to the diagram in Figure 3.4-3, choose the best explanation for the decrease in temperature of the P_1 line after it crosses the saturated liquid line to point 2.

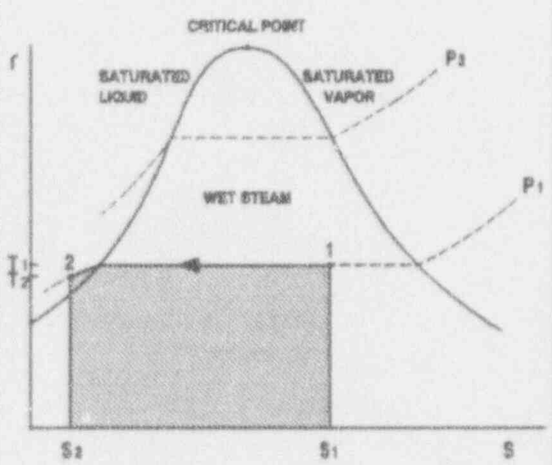
   A. the removal of the latent heat of vaporization

   B. subcooling in the condenser

   C. inlet subcooling in the reactor

   D. extracting the latent heat of fusion

FIGURE 3.4-3



T-s Diagram for Steam

20. The thermodynamic cycle efficiency of a power plant is increased by

   A. decreasing the amount of condensate depression (subcooling)

   B. removing a high-pressure feedwater heater from service

   C. lowering condenser vacuum from 29 inches to 25 inches

   D. decreasing power from 100% to 25%

21. Which of the following effects will an increase in main condenser vacuum (lower absolute pressure) have on the plant? (Assume reactor power, main steam flow, and condenser circulating water flow rate are unchanged.)

   A. increase in condensate temperature

   B. increase in the amount of noncondensable gas in the condenser

   C. increase in main turbine efficiency

   D. increase in condensate subcooling

22. Explain how condensate depression affects plant operation. Describe one benefit and one harmful effect.

23. Given that condensate depression lowers Rankine cycle efficiency, why do plants operate with some condensate depression?

24. The difference between the saturation temperature and actual temperature of condensate in the hotwell is referred to as

   A. super saturation
   B. latent heat of vaporization
   C. sublimation
   D. subcooling

25. Condensate depression (subcooling) is increased by increasing

   A. main turbine load

   B. the circulating water temperature

   C. circulating water flow through the condenser

   D. air leakage into the condenser

26. Condenser pressure is 1.0 psia. During the cooling process in the condenser, the LP turbine exhaust reaches a temperature of 101°F, at which time it is

    A. saturated liquid
    B. saturated vapor
    C. subcooled liquid
    D. superheated vapor

27. Given a power plant at 50% rated power, with condenser vacuum at 28 in Hg, which of the following will increase main condenser vacuum most?

    A. increasing main circulating flow through the condenser

    B. increasing main circulating water inlet temperature

    C. increasing main turbine load (kW)

    D. decreasing seal steam pressure

28. Which of the following correctly explains why the condensation of the steam entering the main condenser creates a vacuum?

    A. The specific volume of the steam decreases.

    B. The specific volume of the steam increases.

    C. The entropy of the steam decreases.

    D. The temperature of the steam decreases.

29. All of the following are methods utilized to draw and/or maintain condenser vacuum except

    A. removing non-condensible gases by air ejectors

    B. operating the circulating water system to condense steam

    C. minimizing air in-leakage

    D. injection of oxygen scavengers into feedwater

30. The on-shift reactor operator, while monitoring circulating waterbox inlet temperatures, notices the temperature steadily decreasing. Condenser vacuum can be expected to

    A. increase (lower absolute pressure)

    B. decrease (higher absolute pressure)

    C. stay the same (constant absolute pressure)

    D. oscillate (oscillating absolute pressure)

31. The on-shift reactor operator receives an annunciator that the in-service air ejector(s) has/have failed. He immediately checks and verifies circulating water system parameters haven't changed. If no action is taken, the operator should observe, over the next hour, vacuum to

    A. increase (lower absolute pressure)

    B. decrease (higher absolute pressure)

    C. remain the same (constant absolute pressure)

    D. vary with turbine load (variable absolute pressure)

32. Cooling water to the main condenser is stopped. Choose the best explanation as to why vacuum decreases (absolute pressure increases).

    A. The ΔT between the tube and shell side of the condenser is insufficient to remove the latent heat of vaporization from the exhaust steam.

    B. The loss of cooling water increases the enthalpy change (top to bottom) of the steam/condensate across the condenser.

    C. The ΔT across the steam side of the condenser (inlet to outlet) is insufficient to subcool the condensate.

    D. The condenser tube outer surfaces are blanketed by air and the air ejector capacity is insufficient to remove that air, causing a loss of vacuum.

33. The plant is operating at 100% power when the only in-service steam jet air ejector is inadvertently isolated from main condenser. The operator verifies circulating water system parameters have not changed. If no operator action is taken over the next 60 minutes, condenser vacuum will

    A. slowly increae (lower absolute pressure)

    B. slowly decrease and stabilize at a slightly lower vacuum (higher absolute pressure)

    C. slowly and continuously decrease (higher absolute pressure towards atmospheric pressure

    D. remain essentially the same (constant absolute pressure)

34. Besides producing a vacuum and increasing plant efficiency, another important function of the condensing process is to _________ the condensate.

    A. deaerate
    B. thoroughly mix
    C. heat
    D. sublimate

35. Condensate depression is defined as the amount

    A. hotwell level is lowered by condenser backpressure

    B. condensate is cooled below saturation temperature

    C. condensate is reheated prior to returning to the reactor

    D. of latent heat of vaporization that must be removed to condense the exhaust vapor

36. It is desirable for the condensing process to take place in a vacuum because

    A. steam will not condense at a pressure above atmospheric

    B. plant efficiency is increased

    C. outlet entropy is increased by exhausting to a vacuum

    D. increased vacuum raises condensate pump net positive suction head

37. If the circulating water flow rate through the main condenser is increased, which of the following statements correctly describes the response of the condensing process?

   A. The energy transferred from the steam to the circulating water decreases.

   B. The entropy of the condensate leaving the condenser increases.

   C. The circulating water temperature leaving the condenser increases.

   D. The entropy of the condensate leaving the condenser decreases.

38. Explain the condensing process.

39. During normal plant power operations, the operating pressure in the main condenser is directly affected by the

   A. amount of condensate subcooling

   B. level of the condensate in the hotwell

   C. temperature of the circulating water

   D. quality of the steam entering the high pressure turbine

40. What effect will an increase of noncondensible gases in a main condenser have on condenser operations in a plant operating at full power?

   A. decreased steam pressure in the condenser

   B. increased amount of condensate depression

   C. decreased condensate temperature

   D. increased cooling water outlet temperature

41. The plant is operating at 90% of rated power. Which one of the following describes the effect of an increase in circulating water flow rate on main condenser operation?

   A. The heat transfer required to condense 1 lbm of steam increases.

   B. The total rate of heat transfer in the main condenser decreases.

   C. The circulating water temperature leaving the main condenser increases.

   D. The enthalpy of the condensate leaving the main condenser increases.

42. The plant is operating at 100% power. Which one of the following describes how and why main condenser pressure changes when condenser cooling water flow rate significantly decreases?

   A. Decreases because main condenser vapor (shell) temperature increases.

   B. Decreases because main condenser condensate subcooling decreases.

   C. Increases because main condenser vapor (shell) temperature increases.

   D. Increases because main condenser condensate subcooling decreases.

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

For an incompressible fluid, the velocity of the fluid must increase if the cross-sectional flow area decreases and vice versa.

$$\dot{m} = (A_1V_1) / v_1 = (A_2V_2) / v_2$$

Reference 57, page 5-19.

2. C

The real process is essentially adiabatic because the flow through the nozzle is too rapid for heat exchange. However, turbulence and friction losses do occur and increase the entropy of the fluid.

Reference 57, page 5-20.

3. D

Reference 57, page 5-19.

4. C

Reference 57, page 5-65.

5. B

Reference 57.

6. D

Reference 57

7. B

Reference 57.

8. B

Reference 78, pages 9-26 and 9-27.

9. A

Reference 40, chapter 4, page 2.

10.

An air ejector removes non-condensible gases low pressure into which steam and gas from from the condenser by creating a region of the condenser are drawn. The air ejector includes a steam nozzle through which steam (reduced in pressure from the main steam header) flows, creating a low pressure. The condenser is tapped into this low pressure region, and steam and gases are drawn into it. The gases are entrained in the steam and thus are removed from the condenser.

Reference 78, pages 9-25 through 9-27.

11. B

Reference 40, chapter 4, page 2.

12. A

Reference 40, chapter 4, page 2; and reference 55, page 6.3-1.

13. C

In a jet pump, as velocity through the nozzle increases, a pressure drop develops. A low pressure area is created in the throat section of the jet pump.

Reference 40, chapter 4, page 2.

14. D

Reference 55, page 6.3-2.

15. C

Reference 40, chapter 4, page 2.

16.

Water is pumped at high pressure to a nozzle in the jet pump. The nozzle converts the high water pressure into a high-velocity, low-pressure "driving" flow. The low pressure draws surrounding water into the jet pump throat area, where this water is entrained in the flow. As the mixture of driving and driven water flows into the diffuser section, its velocity is reduced and its pressure increased.

Reference 57, page 38.

17. C

At 1.0 psia, saturation temperature is 101.74°F. A temperature of 98°F in the hotwell implies 3.74°F subcooling.

Reference 57, page 5-52, and reference 10.

18. D

Excessive subcooling of the condensate means that heat is being unnecessarily rejected in the condenser, lowering cycle efficiency.

Reference 57, page 6-62.

19. B

Most condensers are designed to achieve a certain amount of subcooling by the time the condensed liquid reaches the outlet. Therefore, point 2 occurs in the subcooled liquid region rather than on the saturated liquid line and $T_2 < T_1$. The difference between T_2 and T_1 is the amount of subcooling of the liquid.

Reference 57, page 5-52.

20. A

Reference 57.

21. D

Reference 57.

22.

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 78, page 9-22.

23.

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 78, page 9-22.

24. D

Subcooling is the amount by which the temperature of a substance is below the saturation temperature for the existing pressure.

Reference 57, page 5-52.

25. C

Increased circulating water flow increases the rate of heat removal from the condensate, thereby increasing condensate depression.

Reference 78, page 9-22.

26. C

From the saturated steam pressure table, saturation temperature for 1.0 psia is 101.74°F. Therefore, condensate with a temperature of 101°F is subcooled.

Reference 10.

27. A

The other answer choices would all decrease condenser vacuum.

Reference 78, page 9-22.

28. A

Reference 78, page 9-3.

29. D

Reference 55, pages 5.2-2 and 5.3-2.

30. A

Condenser subcooling will increase, causing condenser efficiency to increase with an increase in the heat transfer process; this will cause vacuum to increase.

Reference 30, chapter 17, pages 17 and 18.

31. B

The air ejector removes non-condensible gases from the condenser. When the air ejector fails, non-condensibles will build up and vacuum will decrease over time.

Reference 30, chapter 17, page 9.

32. A

Loss of cooling <u>decreases</u> enthalpy change across the condenser (top to bottom), so "B" is eliminated. Degree of subcooling has nothing to do with the condensing process, so "C" is eliminated. The condenser tubes do become air-blanketed on loss of cooling water, but the air ejectors can easily remove the <u>normal</u> gas that enters the condenser. But without cooling and condensing, the gas won't move toward the air ejector off-take. Therefore, "A" is the only correct statement.

Reference 57, pages 8-48 and 8-49.

33. C

Reference 57.

34. A

Vacuum is important to deaerate the condensate. Changing the temperature of the condensate is not a function of the <u>condensing</u> process. Sublimation (change of state from solid to gas) does not occur in the condenser.

Reference 57, page 8-45.

35. B

Reference 57, page 8-47.

36. B

Approximately 1/3 of turbine output is produced at pressures between atmospheric and the condenser vacuum in the LP turbines. Vacuum increases overall plant efficiency. A, C, and D are false statements in themselves.

Reference 30, chapter 17, page 3.

37. D

Additional heat removal from the condensate lowers its entropy.

38.

The condensing process involves removal of latent heat of vaporization from a vapor so that it condenses into a liquid. The latent heat is transferred to a substance at a lower temperature. The specific volume of the fluid is significantly reduced when it condenses, creating a vacuum if the process occurs in an enclosed space.

Reference 78, chapter 9.

39. C

Reference 78, Chapter 9.

40. D

Reference 78, Chapter 9.

41. A

An increase in circulating water flow rate results in increased heat removal, lower condenser temperatures, and greater vacuum. At greater vacuums, it is necessary to remove more enthalpy per lbm of steam in order to condense it.

42. C

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 functions of nozzles in air ejectors.

K1.04 Question 2

Describe the nozzle process in air ejectors.

K1.04 Questions 4, 5-7, 10

Explain the principles of operation of a steam jet air ejector.

K1.05 Questions 9, 11-16 [For reactors with jet pumps only]

Describe the principles of operation of a jet pump.

K1.12 Questions 17, 26

Given steam tables, discuss subcooling in condensers.

K1.12 Questions 18, 20-25

Discuss subcooling in condensers.

K1.12 Question 19

Given a T-S diagram of the condensing process, discuss subcooling in condensers.

K1.13 Questions 27-33, 41-42

Explain vacuum formation in condenser processes.

K1.14 Questions 34-40

Explain the condensing process.

1. Moisture affects turbine integrity and efficiency. It ______ turbine blade erosion and ______ turbine efficiency.

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

2. Moisture in the steam supplied to a turbine has what long-term effect on turbine efficiency?

   A. increases efficiency
   B. decreases efficiency
   C. causes efficiency to fluctuate
   D. has no effect on efficiency

3. Moisture has what effect on turbine efficiency?

   A. increases efficiency

   B. has no effect

   C. decreases efficiency

   D. causes efficiency to fluctuate depending on turbine load

4. Moisture has what effect on turbine blade integrity?

   A. improves integrity at all turbine loads

   B. degrades integrity at all turbine loads

   C. has no effect on integrity

   D. improves integrity only at high turbine loads

5. Moisture has what effect on turbine nozzle erosion?

   A. increases erosion

   B. has no effect on erosion

   C. decreases erosion

   D. eliminates erosion by lubricating the nozzle

6. The location in a main turbine that experiences the greatest amount of blade erosion is in the __________ stage of the __________ pressure turbine.

   A. first; low
   B. last; low
   C. first; high
   D. last; high

7. If the moisture content of the steam supplied to a turbine increases, turbine efficiency will immediately decrease because the

   A. enthalpy of the steam being supplied to the turbine has decreased

   B. steam flow rate through the turbine has decreased

   C. excessive moisture causes erosion of the turbine blades

   D. water droplets clinging to the turbine blades have increased windage losses

8. A loss of feedwater heating will have what effect on cycle efficiency?

   A. increases efficiency

   B. decreases efficiency

   C. has no effect on efficiency

   D. causes efficiency to fluctuate depending on feedwater flow

9. An advantage of feedwater heaters in a typical steam cycle is that heaters

   A. increase turbine kW output

   B. increase turbine efficiency

   C. increase cycle efficiency

   D. prevent thermal shock to the reactor vessel

10. A loss of the moisture separators'/reheaters' moisture removal ability will have what effect on plant efficiency?

    A. increases efficiency

    B. has no effect on efficiency

    C. decreases efficiency

    D. causes efficiency to fluctuate depending on turbine load

11. A loss of the moisture separators'/reheaters' moisture removal ability will have what effect on turbine blade erosion?

    A. causes erosion to fluctuate depending on turbine load

    B. has no effect on erosion

    C. decreases erosion rate

    D. increases erosion rate

12. What is the primary purpose of the feedwater heaters?

    A. increase the MW output of the reactor

    B. decrease the amount of corrosion products in the condensate

    C. increase plant efficiency

    D. prevent thermal shock to the reactor vessel

13. A direct advantage of using feedwater heaters in a typical steam cycle is that heaters increase

    A. cycle efficiency
    B. turbine efficiency
    C. turbine KW output
    D. feedwater pump NPSH

14. Which of the following is the most probable steam plant location for superheated steam?

    A. the outlet of the high pressure turbine

    B. the outlet of the moisture separators/ reheaters

    C. the inlet of the high pressure turbine

    D. the outlet of the low pressure turbine

15. Which one of the following is the most probable location for superheated steam in a BWR steam cycle that uses moisture separator reheaters?

    A. the outlet of the high pressure turbine
    B. the inlet of the low pressure turbines
    C. the inlet of the high pressure turbine
    D. the outlet of the low pressure turbine

16. Which of the following is not one of the advantages of having feedwater heating in a BWR cycle?

    A. less energy demand on the cycle by returning the feedwater heating drains to the condenser

    B. less exhaust flow to the condenser resulting in less energy released to the environment

    C. high feedwater inlet temperatures resulting in less heat output by the reactor in order to generate the required steam

    D. smaller volume steam flow after extraction, thereby allowing reduction in size of low-pressure turbine

17. Which of the following conditions is <u>not</u> a result of the addition of feedwater heaters into steam turbine/generating cycle?

    A. For a given steam flow out of the reactor, the main condenser heat load is reduced.

    B. For a given steam flow out of the reactor, the turbine power output will increase.

    C. For any given turbine power output, reactor thermal power required to generate the correct amount of steam is decreased.

    D. For any given turbine power output, overall plant efficiency increases.

18. List and explain three plant parameter changes that would increase plant thermodynamic efficiency.

19. 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

20. The extraction steam to a high-pressure feedwater heater is isolated with the plant operating at 85% power. Which one of the following describes the effect on main turbine generator output (MWe)?

    A. MWe decreases because the total steam flow through the turbine decreases.

    B. MWe decreases because plant efficiency decreases.

    C. MWe increases because the total steam flow through the turbine increases.

    D. MWe increases because plant efficiency increases.

21. A loss of the heating steam to the moisture separator/reheaters for a main turbine will result in __________ turbine blade erosion and __________ steam cycle efficiency.

    A. increased; unchanged
    B. increased; decreased
    C. unchanged; unchanged
    D. unchanged; decreased

22. The plant is operating at 80% power. A loss of the heating steam to the moisture separators/reheaters will __________ steam cycle efficiency and __________ turbine blade erosion.

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

THERMODYNAMIC CYCLES
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

Water droplets in the steam will cause blade erosion and a decrease in turbine efficiency.

Reference 24.

2. B

Increased moisture concentration can lead to blade erosion, which will decrease turbine efficiency.

Reference 24.

3. C

Moisture entrained in the steam passing through a turbine will decrease its efficiency.

Reference 24.

4. B

Water in the steam will cause blade erosion.

Reference 24.

5. A

Moisture entrained in the steam will cause nozzle erosion.

Reference 24.

6. B

Reference 24.

7. A

Reference 24

8. B

Killowatt output will increase. This occurs because the steam that was formerly extracted now passes through the turbine to the condenser. However, the colder feedwater temperature drives reactor power up and the new plant efficiency is lower than the original plant efficiency.

Reference 23.

9. C

Loss of feedwater heating will cause a loss of plant efficiency.

Reference 23.

10. C

Moisture separators increase plant efficiency by increasing inlet enthalpy to the low pressure turbine. If low quality steam is supplied to the LP turbines, the turbine efficiencies will be decreased.

Reference 33, page 7.5.

11. D

Moisture entrained in the steam will cause turbine blade erosion.

Reference 24.

12. C

Feedwater heaters increase plant efficiency.

Reference 33, page 7.5

13. A

Reference 33, page 7.5.

14. B

A moisture separator/reheater not only removes moisture from the steam (increasing its quality toward 100 percent) it also transfers heat into the steam, allowing the steam to become superheated.

Reference 78, pages 7-69 through 7-72.

15. B

Reference 78.

16. A

Reference 78, pages 7-80 through 7-82.

17. B

Reference 78, pages 7-80 through 7-82.

18.

Plant 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 T_{sat} for reactor 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 78, pages 7-66 through 7-82.

19.

a. Isolating a feedwater heater would decrease plant thermodynamic efficiency by decreasing the temperature of the feedwater. Efficiency is maximized when the heat input 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 78, pages 7-68, 7-80, 9-25, and 9-34.

20. C

21. B

22. C

THERMODYNAMIC CYCLES
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 1-7

Describe moisture effects on turbine integrity and efficiency.

K1.05 Questions 8-22

State the advantages of moisture separators/ reheaters and feedwater heaters for a typical steam cycle.

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. "Head loss" is

   A. the reduction in discharge pressure experienced by a real pump due to slippage

   B. the reduction in thermal efficiency caused by core bypass flow in the upper portions of the reactor vessel

   C. the conversion of fluid pressure and velocity to heat energy due to friction

   D. the decrease in static pressure in a piping system resulting from decreases in elevation

2. The conversion of fluid pressure and velocity to heat energy through friction is called

   A. capillary action
   B. head loss
   C. convection
   D. fluid hammer

3. Define "head loss" and explain its cause.

4. Which one of the following statements describes the head loss in a section of horizontal pipe of uniform diameter containing flowing water?

   A. a constant multiplied by the volumetric flow rate

   B. a constant multiplied by the velocity of the fluid

   C. the difference between the hydrostatic head at the beginning of the pipe section and the hydrostatic head at the end of the pipe section

   D. the difference between the pressure head at the beginning of the pipe section and the pressure head at the end of the pipe section

5. Given a sudden stop in a fluid flow in a piping system due to rapid closure of an outlet valve, which one of the following terms best describes the pressure change in the system?

   A. cavitation
   B. shutoff head
   C. water hammer
   D. pipe whip

6. If a valve closure suddenly stops fluid flow, the resulting piping system pressure change is referred to as

   A. cavitation
   B. shutoff head
   C. water hammer
   D. valve chatter

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. Which of the following operating practices <u>minimizes</u> the possibility of water hammer?

   A. changing valve positions as rapidly as possible

   B. starting centrifugal pumps with the discharge valve closed

   C. starting positive displacement pumps with the discharge valve closed

   D. venting systems after initiating system flow

9. Which one of the following methods would increase the possibility of water hammer?

   A. ensure fluid systems are fully vented prior to admitting flow

   B. start centrifugal pumps with the discharge path closed

   C. after centrifugul pump start, rapidly open discharge valve

   D. open and close system valves slowly

10. The possibility of a water hammer would be increased by

    A. maintaining the discharge line filled with fluid on an automatically starting pump

    B. condensation in a steam line

    C. warming system steam lines prior to initiating flow

    D. slowly closing the discharge valve on an operating pump

11. The main reason for keeping condensate out of steam lines is to

    A. prevent corrosion buildup
    B. reduce heat losses
    C. eliminate steam traps
    D. prevent water/steam hammers

12. The proper method of initiating flow in a system to minimize the possibility of 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 the pump is running

13. Starting a centrifugal pump in a system that has not been adequately vented could result in

    A. large fluctuations of pressure in the piping

    B. pump impeller erosion

    C. high radial pump thrusts

    D. high system flow rates

14. Water hammer can be caused by

    A. throttling the suction valve to a pump

    B. starting a pump without proper system venting

    C. starting a pump without proper priming

    D. restarting a pump without letting it coast to a stop

15. Explain water hammer, including possible causes and consequences.

16. After starting a large pump, a pipe hanger is observed to have been pulled out of the wall. The most likely cause for this event would be:

    A. thermal transient
    B. high system flow rate
    C. water hammer
    D. high pump vibration

17. Which of the following is most likely to cause water hammer?

    A. starting a pump without proper priming

    B. throttling a suction valve on a pump

    C. throttling a discharge valve on a pump

    D. starting a pump without proper system filling

18. "Keep fill" systems are used to prevent

    A. water hammer
    B. thermal transients
    C. pump vibration
    D. high system flow rates

19. 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

20. The purpose of a pump is to

    A. compress a fluid to reduce its specific volume

    B. transfer fluid from one point to another at the same or higher pressure

    C. convert a fluid's heat energy to pressure energy

    D. convert a fluid's pressure energy to velocity energy

21. If a centrifugal pump's discharge valve is throttled partially closed, the pump head will:

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

22. Which of the following best defines pump head?

    A. the energy added to each pound of fluid to maintain or reduce its pressure or velocity

    B. the energy removed from each pound of fluid to maintain or reduce its pressure or velocity

    C. the energy added to each pound of fluid to maintain or increase its pressure or velocity

    D. the energy added to or removed from each pound of fluid to maintain or increase its volume or velocity

23. Which of the following best describes a centrifugal pump's response to the partial closing of a discharge valve?

    A. Pump head decreases and flow rate increases to establish a new operating point.

    B. Pump head increases and flow rate decreases to establish a new operating point.

    C. Pump head and flow rate decrease to establish a new operating point.

    D. Pump head and flow rate increase to establish a new operating point.

24. State the effect on pump head and flow rate (or capacity) of a positive displacement pump due to an increase in flow line friction. (Disregard pump slip.)

    A. Pump head increases; flow rate increases.

    B. Pump head decreases; flow rate decreases.

    C. Pump head remains constant; flow rate increases.

    D. Pump head increases; flow rate remains constant.

25. If the discharge valve of an operating positive displacement pump is repositioned from full open to 75 percent open, pump head will __________ and pump flow rate will __________.

    A. increase; remain approximately the same

    B. increase; decrease

    C. remain approximately the same; remain approximately the same

    D. remain approximately the same; decrease

26. The energy added by a pump to each pound of fluid to maintain or increase its pressure or velocity is termed pump

    A. runout
    B. head
    C. cavitation
    D. displacement

27. The head added by a centrifugal pump in a closed system is directly proportional to

    A. the pump speed
    B. twice the pump speed
    C. the square of the pump speed
    D. the cube of the pump speed

28. In a closed system, the power required by a centrifugal pump's motor is directly proportional to

    A. the pump speed
    B. twice the pump speed
    C. the square of the pump speed
    D. the cube of the pump speed

29. The flow rate of a centrifugal pump in a closed system is directly proportional to

    A. the pump speed
    B. twice the pump speed
    C. the square of the pump speed
    D. the cube of the pump speed

30. As the speed of a centrifugal pump in a closed system is increased

    A. the flow rate will remain constant and discharge pressure will increase directly proportionally to the pump speed

    B. the flow rate will increase directly proportionally to the pump speed and discharge pressure will increase directly proportionally to the square of the pump speed

    C. the flow rate will increase directly proportionally to the square of the pump speed and discharge pressure will increase directly proportionally to the pump speed

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)

1.0 2.8 2.5
3.2 2.2
3.6 2.0
4.0
1.1 1.8
1.25 1.4 1.6

150mm

6"

D. the flow rate and discharge pressure will increase directly proportionally to the square of the pump speed

31. For an ideal, multi-speed, centrifugal pump, explain the relationship between pump speed, flow, head, and power.

32. As the speed of a centrifugal pump in a closed system is increased

A. the discharge pressure and the power required by the pump motor will increase directly proportionally to the pump speed

B. the discharge pressure will increase directly proportionally to the pump speed and the power required by the pump motor will increase directly proportionally to the square of the pump speed

C. the discharge pressure and the power required by the pump motor will increase directly proportionally to the square of the pump speed

D. the discharge pressure will increase directly proportionally to the square of the pump speed and the power required by the pump motor will increase directly proportionally to the cube of the pump speed

33. Regarding centrifugal pump laws, the pump head varies with the

A. inverse of the driving speed
B. square root of the driving speed
C. square of the driving speed
D. cube of the driving speed

34. If two identical centrifugal pumps are operating in parallel, then

A. The total brake horsepower for the system is more than twice the horsepower of an individual pump.

B. The total head for the system is the sum of the two individual pump capacities.

C. The total capacity of the system is the sum of the two individual pump capacities.

D. The total brake horsepower for the system is the sum of the individual pump brake horsepowers.

35. Which one of the following statements concerning the pump laws, as applied to centrifugal pumps, is correct?

A. pump head is directly proportional to speed

B. power varies as the square of the speed

C. pump head varies as the square of the speed

D. capacity varies as the cube of the speed

36. 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

37. Cavitation is the formation of vapor bubbles in the _______ pressure area of a pump followed by the ________ of these bubbles within the pump casing.

    A. low, expansion
    B. low; collapse
    C. high; expansion
    D. high; collapse

38. 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. vapor binding
    D. nucleate boiling

39. Cavitation is best described as

    A. the process of subcooling the condensate below the saturation condition, normally done 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 a higher pressure area 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

40. The condition that would most likely cause cavitation of an operating pump is

    A. lowering the suction temperature
    B. throttling the pump suction valve
    C. throttling the pump discharge valve
    D. decreasing the pump speed

41. Which of the following is not an indication of pump cavitation?

    A. fluctuation in discharge pressure
    B. pump vibration
    C. pump overheating
    D. high pump discharge pressure

42. While on surveillance rounds, an operator notices a cooling water pump is making a great deal of noise and discharge pressure is fluctuating. This set of conditions is indicative of

    A. excessive net positive suction head
    B. excessive shut-off head
    C. pump cavitation
    D. pump head

43. Explain cavitation in a centrifugal pump.

44. Which of the following best defines net positive suction head?

    A. the difference between pump inlet pressure and the saturation pressure of the fluid being pumped

    B. the difference between pump inlet temperature and saturation temperature of the fluid being pumped

    C. the difference between pump discharge pressure and saturation pressure of the fluid being pumped

    D. the difference between the pump inlet pressure and the pump discharge pressure

45. The available net position suction head (NPSH) of a centrifugal pump

    A. decreases with increased subcooling to the pump

    B. decreases with an increase in pump flow rate

    C. increases as the suction temperature increases

    D. decreases as pump discharge pressure increases

46. Total available net positive suction head (NPSH) is

    A. the difference between pump suction pressure and the saturation pressure of the fluid being pumped

    B. the difference between the total suction head and the pressure at the eye of the pump

    C. the amount of suction pressure required to prevent cavitation

    D. the difference between the pump suction pressure and the pump discharge pressure

47. Which one of the following best describes available net positive suction head (NPSH)?

    A. the difference between the pump suction pressure and saturation pressure

    B. the difference between saturation pressure at the pump discharge and the actual pump discharge pressure

    C. the difference between the pump suction pressure and the pump discharge pressure

    D. the pressure above which the pump can no longer provide flow

48. Which one of the following events will increase the available net positive suction head (NPSH) for the reactor recirculation pump?

    A. Recirculation pump speed decreases.
    B. Feedwater inlet temperature increases.
    C. Reactor pressure decreases.
    D. Reactor water level decreases.

49. Which of the following parameters directly affect available net positive suction head for recirculation pumps?

    A. feedwater temperature, reactor power, and reactor water level

    B. feedwater temperature, reactor pressure, and reactor water level

    C. reactor water level, feedwater flow rate, and reactor power,

    D. reactor pressure, reactor power, and feedwater flow rate

50. Increasing reactor water level will cause recirculation pump net positive suction head to

    A. decrease to a new, lower value

    B. decrease during the transient, then return to the original value

    C. increase to a new, higher value

    D. increase during the transient, then return to the original value

51. Define net positive suction head (NPSH), and describe the consequences of operating a pump with inadequate NPSH.

52. List and explain four parameters that can cause net positive suction head to be inadequate.

53. Operating a pump with less than the required net positive suction head will cause pump vibration to

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

54. A boiling water reactor is operating at a pressure of 1025 psia. It has a temperature of 530°F in the suction of the recirculating pump and an elevation head of 25 psi. Neglecting line losses, which one of the following values is the net positive suction head?

    A. 143 psi
    B. 154 psi
    C. 165 psi
    D. 177 psi

55. Explain what causes axial thrust in a centrifugal pump.

56. Unbalanced forces are exerted on a single-suction radial-flow impeller in a centrifugal pump. Which of the following is the unbalanced force caused by subjecting one side of the impeller to suction pressure while the opposite side is subjected to a pressure near that of the discharge?

    A. axial thrust
    B. radial thrust
    C. kingsbury thrust
    D. journal thrust

57. An acceptable method to reduce water hammer in emergency core cooling systems is to

    A. maintain the system full of liquid (vented)

    B. ensure minimum flow paths are maintained

    C. maintain minimum NPSH requirements

    D. start pumps with discharge paths open

58. 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 sees ______ capacity and _______ discharge head.

    A. lower, lower
    B. lower, higher
    C. higher, lower
    D. higher, higher

59. Fluid being pumped provides cooling, lubricating, and sealing functions for normal operation of pump internals. To ensure that these functions are fulfilled for the protection of pump internals, an operator should verify, during initial check-out of a pump prior to starting it, that the

    A. packing gland is removed
    B. pump is properly vented
    C. packing gland leak-off is adequate
    D. bearing oil level is adequate

60. Why are high-point casing vents important for pump operation?

    A. They allow solids in the fluid to be flushed from the pump casing.

    B. They prevent pump casing leak-off during operation.

    C. They allow removal of non-condensible gases trapped in the casing.

    D. They allow pump head to be adjusted for normal operation.

61. An operator places a centrifugal pump in service for post-maintenance check-out. His instrumentation indicates that pump capacity and discharge head are lower than normal. What is the most probable cause for these indications?

    A. The flow and pressure instrumentation are out of calibration.

    B. The pump suction valve was left closed.

    C. The pump discharge valve was left closed.

    D. The pump was not properly vented.

62. Improper system venting for pump operation could result in

    A. water hammer
    B. excessive system pressure
    C. pump runout
    D. excessive system flow

63. The primary reason for operating a set of centrifugal pumps in <u>series</u> is to

    A. increase system pressure
    B. increase system flow rate
    C. decrease system pressure
    D. decrease system flow rate

64. The major effect of operating a set of centrifugal pumps in <u>parallel</u> is

    A. increased system pressure
    B. increased system flow rate
    C. decreased system pressure
    D. decreased system flow rate

65. Given a closed system with two identical centrifugal pumps in parallel, one of which is running. Describe the effect on <u>system flow</u> and <u>pump head</u> when the second pump is started. Contrast the final, steady-state conditions to the initial conditions.

66. Which one of the following items is not a characteristic of centrifugal pumps operating in series?

    A. The available net positive suction head (NPSH) of the second pump in the series is greater than the NPSH in a single-pump system.

    B. The capacity for two pumps operating in series is limited by the capacity of the first pump in the series.

    C. The total head for two pumps operating in series is approximately twice the head for a single pump supplying the same capacity.

    D. The power required to supply two centrifugal pumps operating in series is less than twice the power required for each of the individual pumps.

67. Operating a centrifugal pump at shutoff head may cause all of the following <u>except</u>

    A. overheating
    B. excessive vibration
    C. cavitation
    D. excessive system flow rates

68. Overheating and damage to a centrifugal pump will occur if the pump is operated ______ over long periods of time.

    A. at maximum system load
    B. at shutoff head
    C. with varying flows
    D. at rated flow

69. An operator is sent to make an inspection of a service water pump after starting. He notices the pump casing is extremely hot and vibrating excessively. The discharge valve is

still closed and there is no recirculation line on the pump. The hot casing and vibration are most likely due to

A. low pump bearing oil level
B. lack of cooling water to the pump seals
C. running at shutoff head
D. the pump not being vented

70. 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

71. Explain the possible consequences of running a centrifugal pump at shutoff head for extended periods.

72. A reactor feed pump is placed in service at minimum speed prior to injecting feedwater into the reactor vessel. To prevent running the pump for an extended period at shutoff head and to minimize overheating of the pump, the operator should

    A. ensure the discharge valve is cracked open to allow a minimum flow through the pump

    B. ensure the recirculation line valve is open to allow minimum flow through the pump

    C. shutdown the pump until it is ready to inject into the reactor vessel

    D. close the suction and discharge valve of the pump until it is ready to inject into the reactor vessel

73. Explain what is meant by the term "two-phase" flow," and describe three types or regions of two-phase flow.

74. The term "two-phase flow" refers to flow of fluid in which

    A. there is a mixture of liquid and vapor

    B. there are suspended solids in the liquid flow stream

    C. there are dissolved solids in the liquid flow stream

    D. subcooled nucleate boiling is occurring

75. A mixture of steam and water flowing through a channel is referred to as

    A. boiling flow
    B. mixed flow
    C. two-phase flow
    D. boiling crisis

76. Which one of the following valves is the best flow-controlling device?

    A. gate valve
    B. globe valve
    C. check valve
    D. plug valve

77. A common method used in emergency cooling water systems to reduce the flow rate lost from a pipe rupture, thereby ensuring design cooling flow capability, is the installation of

    A. venturis
    B. orifices
    C. redundant pumps
    D. pipe hangers

78. To increase total system 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

79. Placing two identical pumps in parallel alignment versus a single pump will result in

    A. a large increase in system head and the same flow rate

    B. the same system head and a small increase in flow rate

    C. a small increase in system head and a large increase in flow rate

    D. the same system head and flow rate

80. During operation of a positive displacement pump, one acceptable 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

81. Which of following is <u>not</u> a method normally used for flow regulation?

    A. pump discharge valve throttling
    B. pump suction valve throttling
    C. speed regulation
    D. bypass regulation

82. Low pressure emergency fluid systems sometimes use ________ to prevent pump runout.

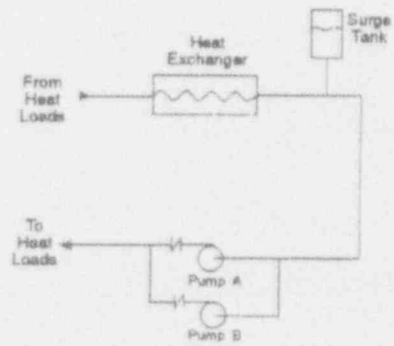
    A. orifices
    B. low suction pressure trip circuits
    C. overload trip circuits
    D. bypass regulation

83. Refer to the drawing of a cooling water system and the associated centrifugal pump operating curve (see figure 3.6-1) in which pumps A and B are identical single-speed centrifugal pumps and only pump A is operating.

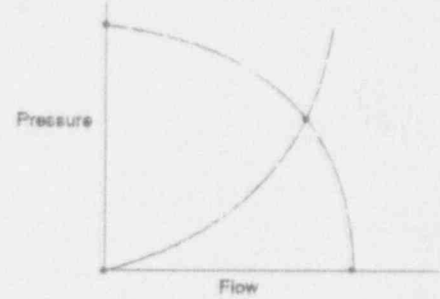
    If pump B is started, system flow rate will be ________ and common pump discharge pressure will be ________.

    A. the same; higher
    B. higher; the same
    C. the same; the same
    D. higher; higher

FIGURE 3.6-1



Cooling Water System



Centrifugal Pump and System Characteristic 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

Reference 57, chapter 7, page 27.

2. B

Reference 57, chapter 7, page 27.

3.

Head loss is the conversion of useful forms of fluid energy, especially pressure and velocity, into heat. It is caused by friction resulting from collisions of fluid molecules and piping system surfaces.

Reference 57, chapter 7, page 27.

4. D

Reference 57, chapter 7, page 27.

5. C

Reference 40, section 9.4.

6. C

Reference 40, section 9.4.

7. C

Reference 40, section 9.4

8. B

Starting a centrifugal pump with its discharge valve open will tend to increase the possibility of a system pressure surge and thus water hammer.

Reference 14, pages 3-185 through 3-193.

9. C

Rapid opening of a pump discharge valve increases the possibility of a system pressure surge and thus water hammer.

Reference 14, pages 3-185 through 3-193.

10. B

Steam admittance to a pipe containing water will result in water/steam hammer.

Reference 14, pages 3-185 through 3-193.

11. D

Condensate in steam lines will result in water/steam hammer when flow is initiated.

Reference 14, pages 3-185 through 3-193.

12. 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, pages 3-185 through 3-193.

13. A

Water hammer can cause large fluctuating pressures.

Reference 40, page 8.85.

14. B

Lac‹ of system venting can cause water hammer.

Reference 40, page 8.85.

15.

Water hammer results from the sudden conversion of kinetic energy to pressure energy in the flow of fluid in a piping system. It can be caused by any suddent perturbation in system flow, such as rapidly closing a valve, initiating liquid flow into a gas-or vapor-filled volume, or initiating steam flow through pipes containing liquid condensate.

Because of the large pressure transient involved in water hammer, damage can result. This damage could occur to valves, pipes, and pipe hangers.

Reference 57, chapter 7, pages 67 through 70.

16. C

Water hammer can cause large stresses on pipe hangers.

Reference 40, page 8.85.

17. D

Lack of system fill and venting can cause water hammer.

Reference 40, pa[illegible] 8 85.

18. A

"Keep fill" systems are used to keep piping full for correct system response time and to prevent water hammer.

Reference 40, page 8.85.

19. B

Reference 40, page 8.85.

20. B.

Reference 57, chapter 7, page 85.

21. A

Reference 28, part B, section III, pages 328 through 331.

22. C

Reference 28, part B, section III, pages 328 through 331.

23. B

Reference 28, part B, section III, pages 328 through 331.

24. D

Reference 28, part B, section III, pages 328 through 331.

25. A

Reference 28, part B, section III, pages 328 through 331.

26. B

Reference 28, part B, section III, pages 328 through 331.

27. C

Reference 28, part B, section III, page 322.

28. D

Reference 28, part B, section III, page 322.

29. A

Reference 28, part B, section III, page 322.

30. B

Reference 28, part B, section III, page 322.

31.

The relationship between ideal centrifugal pump speed, flow, head, and power is as follows:

Flow is directly proportional to speed .

Head is directly proportional to speed squared.

Power is directly proportional to speed cubed.

Reference 57, chapter 7, page 111.

32. D

Reference 28, part B, section III, page 322.

33. C

Reference 28, part B, section III, page 322.

34. C

Reference 28.

35. C

Reference 28.

36. B

Reference 28.

37. B

Reference 78, page 10-53.

38. A

Cavitation is defined as the formation and subsequent collapse of vapor bubbles in a pump.

Reference 78, page 10-53.

39. B

The definition of cavitation is the formation and subsequent collapse of vapor bubbles in a pump.

Reference 78, page 10-53.

40. B

Throttling the suction valve will increase the pressure drop between the pump suction and the eye of the impeller. This may drop the pressure at the eye to the vapor pressure.

Reference 78, page 10-53.

41. D

Reference 78, page 10-53.

42. C

Fluctuating discharge pressure and excessive pump noise are indications of cavitation.

Reference 78, page 10-53.

43.

Cavitation is the formation and collapse of vapor bubbles in a pump due to local variations in pressure. Where the local pressure is less than saturation pressure for the liquid temperature, steam bubbles will form. As these bubbles then flow into a higher pressure area, they condense and collapse. A result of the sudden decrease in specific volume when a bubble collapses is a brief but powerful pressure pulse or shock wave. Such shock waves can exert sufficient force to erode pump components, severely damaging the pump.

Reference 78, pages 10-53 and 10-54.

44. A

Reference 40, page 2.215.

45. B

Reference 57, chapter 7, page 97.

46. A

Reference 57, chapter 7, page 92.

47. A

Reference 57, chapter 7, page 92.

48. A

Reference 57, chapter 7, page 97.

49. B

NPSH depends on the saturation pressure and the actual pressure at the pump suction. Feed-water temperature affects saturation pressure, and reactor pressure and level affect actual pressure.

Reference 40, page 2.215.

50. C

An increase in the height of water above the pump suction will increase the NPSH.

Reference 40, page 2.215.

51.

Net positive suction heat (NPSH) is the difference between actual pump suction pressure and saturation pressure for suction fluid temperature. The pump manufacturer specifies a minimium required NPSH. If NPSH falls below the minimum required value, cavitation can occur in the lowest-pressure regions of the pump, resulting in pump damage.

Reference 78, pages 10-54 to 10-61.

52.

NPSH is affected by parameters that affect the actual suction pressure and the saturation pressure at the pump suction. These parameters include:

a. suction fluid temperature - An increase in temperature increases the corresponding saturation pressure, reducing NPSH.

b. system pressure - A decrease in overall pressure in a closed system reduces suction pressure and NPSH.

c. flow rate - a higher flow rate increases head losses as the fluid approaches the pump suction. This reduces suction pressure and NPSH.

d. pump speed - A higher pump speed requires a greater value of NPSH to avoid cavitation.

e. static pressure at the pump suction - A decrease in surge tank level, a reduction in booster pump output, or a throttling of the pump suction valve would decrease suction pressure and NPSH.

Reference 78, pages 10-60 to 10-61.

53. A

Operating a pump at less than the required NPSH will cause the pump to cavitate which could lead to excessive vibration.

54. C

NPSH = (actual pressure) - (saturation pressure)

actual pressure = 1025 + 25 = 1050 psia

saturation pressure for 530°F is 885 psia (from interpolation of saturated steam temperature table)

Therefore, NPSH = 1050-885 = 165 psi

Reference 10, and reference 57, chapter 7, page 93.

55.

Axial thrust results from unbalanced forces acting in the axial direction on a pump impeller. These unbalanced forces are caused by the difference between the suction pressure, experienced on one side of the impeller, and the discharge pressure on the other side. Additionally, differences in the surface area exposed to these pressures contributes to axial thrust.

Reference 40, pages 2-59 through 2-61.

56. A

Reference 40, pages 2-59 through 2-61.

57. A

58. A

As the pump is not fully vented (filled), it will generally not develop full discharge head. When this occurs, capacity (flow) and discharge head (pressure) will decrease due to gas being compressed.

Reference 26, chapter 6, page 109.

59. B

Pump internals are specified. If the pump is not properly vented and is air bound, internal components will be degraded.

Reference 26, chapter 6, page 109.

60. C

Venting removes non-condensible gases and primes the pump casing.

Reference 26, chapter 6, page 109.

61. D

If pump was not properly vented, it will generally not develop full discharge head. When this occurs, capacity (flow) and discharge head will decrease due to air being compressed.

Reference 26, chapter 6, page 109.

62. A

Water column separation can cause water hammer when the two columns come rapidly together.

Reference 40, page 8.85.

63. A

Operating centrifugal pumps in series increases system pressure.

Operating centrifugal pumps in parallel increases system flow.

Reference 40, pages 2.239 and 2.240.

64. B

Operating centrifugal pumps in series increases system pressure.

Operating centrifugal pumps in parallel increases system flow.

Reference 40, pages 2.239 and 2.240.

65.

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 less than four times initial.

Reference 78, pages 10-45 and 10-46.

66. D

Reference 78

67. D

Operation at shutoff head implies zero system flow, whereas overheating, cavitation and excessive vibration may occur noticeably when operating at shutoff head.

Reference 40, page 243.

68. B

Reference 26, chapter 6, page 108.

69. C

Reference 26, chapter 6, page 108.

70. D

Reference 26, chapter 6, page 108.

71.

A pump running at shutoff head does not produce a net flow of fluid. It does, however, impart energy to the fluid in the pump casing, causing the fluid (and pump) temperature to rise. Eventually, fluid temperature will reach the saturation temperature for the pump suction pressure, causing cavitation and possible damage to the pump. Additionally, the increased temperature of the pump could lead to bearing damage or inadequate clearances between moving parts, thus damaging the pump.

Reference 57, chapter 7, page 123.

72. B

Prior to injection of water into the reactor vessel, placing a reactor feed pump in service to ensure reliability is a prudent action. Placing the pump in service with minimum flow through the recirculation line is the recommended method to prevent pump overheating.

Reference 26, chapter 6, page 108.

73.

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. Several "types," "forms," or "regions" of two-phase flow have been identified:

a. bubble or bubbly flow - Individual vapor bubbles are formed and might or might not collapse as they flow with the fluid stream.

b. slug flow - Vaporization reaches an extent where the individual bubbles form into slugs of vapor that flow along the center of the stream.

c. annular flow - A continuous flow of vapor is in the channel center, with liquid left on the channel walls.

Reference 17, pages 325 and 326; reference 78, pages 6-14 through 6-17.

74. A

Reference 57, chapter 9, pages 45 through 48.

75. C

Reference 27, chapter 9, pages 45 through 48.

76. B

Reference 65, chapter 6.

77. B

Reference 78, page 10-45.

78. B

Two pumps in parallel will increase system flow rate.

79. C

Placing two pumps in parallel is used to primarily increase system flow but will also result in a small increase in pump head due to the increased flow rate causing higher head loss in system.

80. D

Increasing the speed of a positive displacement pump will increase flow rate out of the pump, thus increasing total flow.

81. B

Throttling the pump suction valve could reduce NPSH to the point where pump cavitation would occur.

Reference 40, page 2.238.

82. A

Orifices are used on some systems to prevent pump runout.

Reference 40, page 2.238.

83. D

FLUID STATICS AND DYNAMICS
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 1-4

Define head loss.

K1.05 Questions 5-19

Explain the operational implications of water hammer.

K1.06 Question 20

State the purpose of a pump.

K1.07 Questions 21, 23-25

State the effect on the pump head and flow rate (or capacity) of a centrifugal pump due to a change in flow line friction.

K1.07 Questions 22, 26

State the definition of pump head.

K1.08 Questions 27-36

State the relationship between an ideal centrifugal pump's speed, flow, head, and power.

K1.09 Questions 37-39

Define cavitation.

K1.09 Questions 40-43

Define or explain cavitation.

K1.10 Questions 44-50

Define net positive suction head (NPSH).

K1.10 Questions 51-53

Describe causes and effects of a net decrease in net positive suction head.

K1.10 Question 54

Determine net positive suction head from pressure and temperature data.

K1.11 Question 55, 56

Explain axial thrust.

K1.12 Questions 57-62

Explain the importance of proper system venting for pump operations.

K1.13 Questions 63-66, 83

State the effects on system flow and pressure that result from operating centrifugal pumps in series and parallel.

K1.17,1.19 Questions 67-72

State how operating a centrifugal pump at shut-off head can cause overheating of the pump and identify methods used to avoid overheating.

K1.21 Questions 73-75

Define and describe two-phase flow.

K1.29 Questions 76-82

State the methods of controlling system flow rates.

HEAT TRANSFER
Questions

1. The transfer of heat by interaction between adjacent molecules of a material is best described as

   A. conduction heat transfer
   B. convection heat transfer
   C. radiation heat transfer
   D. laminar heat transfer

2. The transfer of heat by motion and mixing of macroscopic portions of a fluid is best described as

   A. conduction heat transfer
   B. convection heat transfer
   C. radiation heat transfer
   D. molecular heat transfer

3. The transfer of heat due to the difference in temperature between two separated bodies in a vacuum is best described as

   A. conduction heat transfer
   B. convection heat transfer
   C. radiation heat transfer
   D. molecular heat transfer

4. The transfer of heat through a solid piece of material can best be described as

   A. conductive heat transfer
   B. convective heat transfer
   C. radiant heat transfer
   D. laminar heat transfer

5. Convection heat transfer can best be described as the transfer of heat by

   A. interaction and mixing of molecules of a solid or fluid

   B. electromagnetic radiation which arises due to the temperature of a body

   C. interaction between adjacent molecules of the material through which the heat is being transferred

   D. motion and mixing of macroscopic portions of a fluid

6. List and describe three mechanisms of heat transfer.

7. If an accident causes a portion of the reactor core to become steam-blanketed, which form of heat transfer will predominate? Explain.

8. The three basic modes of heat transfer are

   A. conduction, convection, and radiation

   B. conduction, induction, and radiation

   C. conduction, convection, and condensation

   D. conduction, convection, and evaporation

9. The transfer of heat by electromagnetic waves is called

   A. induction
   B. conduction
   C. convection
   D. radiation

10. Which of the following best describes the conduction mode of heat transfer?

    A. the transfer of heat by the interaction between adjacent molecules of the material through which heat is being transferred

    B. the transfer of heat by motion and mixing of macroscopic portions of a fluid

    C. the transfer of heat by electromagnetic waves

    D. the transfer of heat through a vacuum

11. The heat-transfer mechanism using direct contact transfer of kinetic energy from molecular motion is

    A. convection
    B. conduction
    C. radiation
    D. transmission

12. Which of the following methods of heat transfer is defined by "the exchange of energy between bodies by electromagnetic waves through an intervening space"?

    A. conduction
    B. convection
    C. electrokinetics
    D. radiation

13. Which of the following heat-transfer methods transfers the heat of fission through the fuel cladding?

    A. convection
    B. transition
    C. conduction
    D. radiation

14. During normal operations at the end of a fuel cycle, by which one of the following is heat transferred from the fuel to the cladding?

    A. conduction
    B. radiation
    C. convection
    D. friction

15. The predominant mode of heat transfer from the fuel-clad surface to the coolant during film boiling conditions is

    A. radiation
    B. convection
    C. photoelectric
    D. conduction

16. Which of the following heat-transfer mechanisms is defined as the direct contact transfer of kinetic energy from molecular motion?

    A. convection
    B. conduction
    C. radiation
    D. electrokinetics

17. The heat transfer mechanism that accounts for the majority of core heat removal during a LOCA after total core voiding is

    A. conduction
    B. convection
    C. radiolysis
    D. radiation

18. Thermal conductivity is a measure of a material's ability to

    A. generate heat when exposed to radiation

    B. retain heat within itself

    C. transfer heat through itself

    D. impede heat transfer to an adjacent material

19. The ability of a substance to transfer heat is quantitatively expressed by its

    A. thermal conductivity
    B. thermoreluctance
    C. temperature
    D. temperature gradient

20. A material whose thermal conductivity is large would be well suited for which of the following applications?

    A. fuel cladding in the reactor
    B. thermal barrier in a pump
    C. insulation on piping
    D. insulation on electrical cables

21. How does a stagnant fluid film affect heat transfer equipment?

    A. impedes heat transfer

    B. enhances the transfer of heat

    C. has no effect on heat transfer

    D. will cause corrosion, reducing heat transfer

22. Which of the following indicates how stagnant fluid films affect the heat transfer process?

    A. The overall heat transfer coefficient will decrease as the fluid film thickness for the cooling medium decreases.

    B. Fluid films increase the rate of heat transfer.

    C. Fluid films have no effect on the heat transfer coefficient of equipment.

    D. Fluid films degrade heat transfer.

23. The relationship between stagnant fluid films and heat transfer is <u>best</u> described by which of the following?

    A. As fluid film thickness increases, heat transfer decreases.

    B. As fluid film thickness decreases, heat transfer decreases.

    C. As fluid film thickness increases, heat transfer increases.

    D. There is no relationship between fluid films and heat transfer.

24. Given all other parameters remaining the same, as the thickness of the stagnant fluid film on a heat exchanger surface increases, the heat transfer rate across the surface

    A. increases
    B. decreases
    C. stays the same
    D. cannot be predicted

25. List and describe three factors that affect the heat transfer coefficient for a fluid film.

26. 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

27. Which of the following is the most effective method of heat transfer?

    A. film boiling
    B. nucleate boiling
    C. forced convection
    D. departure from nucleate boiling

28. The order of reactor coolant heat transfer mechanisms from the most desirable to the least desirable, is

    A. stable film boiling, transition boiling, nucleate boiling

    B. nucleate boiling, stable film boiling, transition boiling

    C. stable film boiling, nucleate boiling, transition boiling

    D. nucleate boiling, transition boiling, stable film boiling

29. Which one of the following formulas is most representative of the heat-transfer rate across the tubes of a heat exchanger?

    A. $\dot{m}\ \Delta h$
    B. $\dot{m}\ \Delta T$
    C. $\dot{m} c_p\ \Delta T$
    D. $UA\ \Delta T$

30. Which of the following is a correct statement concerning parallel-and counter-flow heat exchangers?

    A. Counter-flow heat exchangers are more efficient than parallel-flow heat exchangers due to the high initial ΔT.

    B. Counter-flow heat exchangers allow the exiting cooled fluid temperature to be below the exiting cooling fluid temperature.

    C. Parallel-flow heat exchangers are more efficient than counter-flow heat exchangers, due to the high initial ΔT.

    D. Parallel-flow heat exchangers allow the exiting cooled fluid temperature to be below the exiting cooling fluid temperature.

31. The heat transfer rate ($\dot{Q}$) of a heat exchanger is dependent on all of the following <u>except</u> the

    A. ΔT of fluids
    B. area of the surface
    C. coefficient of thermal conductivity
    D. fluid pressure

32. Define and explain each term in the equation used to describe the heat transfer rate in a heat exchanger:

    $\dot{Q} = UA\Delta T$.

33. Which one of the following does <u>not directly</u> affect the thermodynamic performance of a heat exchanger?

    A. surface area available for heat transfer

    B. mass flow rate of fluid through the heat exchanger

    C. inlet and outlet temperatures of hot and cold fluids

    D. pressure drop (ΔP) through the heat exchanger

34. The heat transfer rate (BTU/hr) in a heat exchanger is <u>most</u> dependent upon the

    A. pressure drop (ΔP) across heat exchanger

    B. pumping power supplying heat exchanger flow

    C. surface area available for heat transfer

    D. difference in pressure (ΔP) between the two fluids

35. A counterflow lubricating oil heat exchanger is in operation when the cooling water flow rate is reduced to 1/2 of its former value. Which of the following will decrease as a result?

    A. lube oil outlet temperature
    B. heat transfer rate
    C. cooling water outlet temperature
    D. lube oil inlet temperature

36. Which one of the following formulas is representative of the heat-transfer rate across the tubes of a heat exchanger?

    Where:

    h_t = fluid enthalpy inside tubes
    h_{ss} = fluid enthalpy on heat exchanger shell side
    T_t = fluid temperature inside tubes
    T_{ss} = fluid temperature on heat exchanger shell side

    A. $\dot{Q} = \dot{m}c_p (h_t - h_{ss})$

    B. $\dot{Q} = UA (h_t - h_{ss})$

    C. $\dot{Q} = \dot{m}c_p (T_t - T_{ss})$

    D. $\dot{Q} = UA (T_t - T_{ss})$

37. Given a sheet of equations, constants, and conversion factors and using the following data for a typical steam condenser (i.e., a cross-flow heat exchanger), calculate the heat load in megawatts thermal (MWth).

    Total tube area = 500,000 ft^2
    Cooling water flow rate = 200,000 gpm
    Condenser pressure = 1 psia
    Specific heat of cooling water (Cp) = 1.0 BTU/lbm-°F
    Cooling water inlet temperature = 60°F
    Cooling water outlet temperature = 85°F
    Steam condensing rate = 3×10^6 lbm/hr
    1 gallon water = 8.34 lbm

    A. 703 MW
    B. 733 MW
    C. 783 MW
    D. 833 MW

38. In the reactor, nucleate boiling is desirable to increase the amount of heat transfer from the core to the coolant. Why is boiling undesirable in a single-phase heat exchanger?

    A. The bubble formation will break up the laminar layer in the heat exchanger.

    B. Steam formation could block fluid flow.

    C. The ΔT across the tubes will decrease across the heat exchanger.

    D. The heat transfer coefficient will increase in the heat exchanger.

39. In a single-phase heat exchanger, heat transfer can be affected by several factors, one of which is gases entrained in the fluid. Excessive amounts of gases passing through the heat exchanger is undesirable because

    A. air binding can occur in the heat exchanger

    B. gases will break up the laminar layer in the heat exchanger

    C. the heat transfer coefficient will increase in the heat exchanger

    D. the ΔT will decrease across the tubes in the heat exchanger

40. How and why does the presence of air affect heat transfer in a condenser?

41. State and explain two mechanisms by which the presence of gas affects the performance of a single-phase (liquid) heat exchanger.

42. The reason for venting a heat exchanger on the steam heating side during a plant start-up is to

    A. vent off excess steam to prevent overpressurization

    B. prevent non-condensible gases from blanketing heat exchanger tubes

    C. allow for better pressure control of steam in heat exchanger

    D. maintain constant pressure in heat exchanger for better level control

43. Which one of the following statements best describes the result of an increase in noncondensable gases in a steam turbine/condenser?

    A. Condenser pressure decreases (vacuum increases).

    B. Condenser circulating water outlet temperature increases.

    C. Steam cycle efficiency decreases.

    D. Condensate depression increases.

44. Excessive amounts of entrained 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 temperature difference across the tubes will decrease through the heat exchanger

45. Which one of the following statements most accurately explains why condensate subcooling is necessary in the steam turbine/condenser phase of a plant cycle?

    A. to increase overall plant efficiency

    B. to provide a better condenser vacuum

    C. to allow use of a higher circulating water temperature

    D. to provide net positive suction heat (NPSH) to the condensate pumps

46. Which of the following statements concerning condensate depression in the main condenser is correct?

    A. Decreasing condenser vacuum increases condensate depression.

    B. Increasing condensate depression improves the NPSH for the condensate pumps.

    C. Decreasing condensate depression decreases plant efficiency.

    D. Increasing circulating water temperature increases condensate depression.

47. A condenser is operating at a vacuum of 28 inches of Hg vacuum and a condensate outlet temperature of 88°F. Which one of the following values most closely approximates the value for the condensate depression?

    A. 8°F
    B. 10°F
    C. 14°F
    D. 17°F

48. Describe one benefit and one disadvantage of condensate depression.

49. Core thermal power can be 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

50. The measure 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

51. When the reactor is at power, one of the limits placed on the operator is core thermal power. In what unit is core thermal power normally expressed?

    A. MWe
    B. MWt
    C. BTU/hr - °F
    D. BTU/lbm - °F

52. Which one of the following best defines the term core thermal power?

    A. heat from the fission process

    B. heat from the fission process plus total of other heat inputs and outputs

    C. heat from the fission process plus heat from recirculation pumps

    D. heat from the fission process minus reactor water cleanup losses

53. Which of the following expressions correctly defines core thermal power?

    A. $\dot{Q}_{Feedwater} - \dot{Q}_{Steam} - \dot{Q}_{CRD} - \dot{Q}_{Recirc} + \dot{Q}_{Ambient} + \dot{Q}_{RWCU}$

    B. $\dot{Q}_{Steam} - \dot{Q}_{Feedwater} + \dot{Q}_{CRD} + \dot{Q}_{Recirc} - \dot{Q}_{Ambient} - \dot{Q}_{RWCU}$

    C. $\dot{Q}_{Steam} - \dot{Q}_{Feedwater} - \dot{Q}_{CRD} - \dot{Q}_{Recirc} + \dot{Q}_{Ambient} + \dot{Q}_{RWCU}$

    D. $\dot{Q}_{Steam} - \dot{Q}_{Feedwater} - \dot{Q}_{CRD} - \dot{Q}_{Recirc} - \dot{Q}_{Ambient} - \dot{Q}_{RWCU}$

54. List the heat sources and losses used in determining core thermal power, and explain why each is added or subtracted to calculate core thermal power.

55. Describe the effect on calculated core thermal power (assuming actual core thermal power is constant) if the effect of each of the following factors is omitted from the calculation:

    a. reactor water cleanup system
    b. control rod drive system
    c. recirculation pump power
    d. ambient heat losses

56. Percent reactor power is referenced to 100 percent being

    A. rated core thermal power
    B. rated electrical output
    C. rated neutron flux level
    D. total megawatts electric of the system

57. In the definition of percent reactor power, percent power refers to percent

    A. full power core delta flow
    B. neutron count level
    C. megawatt thermal
    D. megawatt electric

58. The term "measured percent rated thermal power" refers to percent

    A. electrical power
    B. reactor power
    C. turbine load
    D. generator power

59. Nuclear power plants are limited by the amount of reactor power they may generate. When referring to percent reactor power, this means percent

    A. turbine load
    B. generator output
    C. net electrical output
    D. rated thermal output

60. Percent reactor power refers to percent

A. electrical power output
B. rated thermal power
C. turbine load
D. BTUs per pound mass

61. Given the following data for a typical steam condenser, select the heat load rejected in megawatts thermal.

Total tube area:	500,000 square feet
Cooling water flow rate:	200,000 gpm
Condenser pressure:	1 psia
Specific heat of cooling water (cp):	1.0 BTU/lbm-°F
Cooling water inlet temperature:	60°F
Cooling water outlet temperature:	85°F
Steam condensing rate:	3,000,000 lbm/hr
Mass of cooling water:	8.34 lbm/gal

A. 703 MWt
B. 733 MWt
C. 783 MWt
D. 833 MWt

62. The power range nuclear instruments have been adjusted to 100 percent based on a calculated heat balance. Which one of the following will result in indicated reactor power being greater than actual reactor power?

A. The feedwater temperature used in teh heat balance calculation was higher than actual feedwater temperature.

B. The reactor recirc pump heat input term was omitted from the heat balance calculation.

C. The feed flow rate used in the heat balance calculation was lower than actual feed flow rate.

D. The steam pressure used in the Heat Balance calculation is lower than actual steam pressure.

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 28, part A, chapter 3, page 99.

2. B

Definition of convection: The transfer of heat by motion and mixing of macroscopic portions of a fluid.

Reference 28, part A, chapter 3, page 99; and reference 55, page 3.1-2.

3. C

Definition of radiation or radiant heat transfer: The transfer of heat by electromagnetic radiation which arises due to the temperature of a body.

Reference 28, part A, chapter 3, page 99; and reference 55, page 3.1-2.

4. A

Definition of conduction: The transfer of heat by interaction between adjacent molecules of the material through which the heat is being transferred.

Reference 28, part A, chapter 3, page 99; and reference 55, page 3.1-2.

5. D

Definition of convection: The transfer of heat by motion and mixing of macroscopic portions of a fluid.

Reference 28, part A, chapter 3, page 99; and reference 55, page 3.1-2.

6.

Three mechanisms of heat transfer are:

conduction - transfer of heat by interaction between adjacent molecules 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 78, pages 3-10, 3-66, and 3-82.

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 78, page 3-92.

8. A

Reference 28, part A, chapter 3, pages 99 and 100.

9. D

Reference 28, part A, chapter 3, pages 99 and 100.

10. A

Reference 28, part A, chapter 3, pages 99 and 100.

11. B

Reference 28, part A, chapter 3, pages 99 and 100.

12. D

Reference 28, part A, chapter 3, pages 99 and 100.

13. C

Reference 28, part A, chapter 3, pages 99 and 100.

14. A

Reference 28, part A, chapter 3, pages 99 and 100.

15. A

Reference 57, chapter 9, page 12.

16. B

Reference 28, part A, chapter 3, pages 99 and 100.

17. D

Reference 57, chapter 9, page 12.

18. C

Reference 78, page 3-13.

19. A

Reference 78, page 3-13.

20. A

Reference 78, page 3-13.

21. A

Fluid films provide resistance to heat flow from one body to the next. The overall heat transfer coefficient, which is a measure of good heat transfer, is inversely related to fluid film thickness.

Reference 57, page 8-15; and reference 46, chapter 4, page 92.

22. D

Reference 57, page 8-15.

23. A

Reference 57, page 8-15.

24. B

Reference 57, page 8-15.

25.

There are several possible factors affecting the heat transfer coefficient for a fluid film. Most of these affect the film thickness, which, in conjunction with the thermal conductivity of the film, determines the heat transfer coefficient.

(1) fluid velocity - The greater the velocity of the fluid steam, the thinner the fluid film will be, increasing the heat transfer coefficient.

(2) fluid viscosity - The greater the viscosity, the thicker the film and the smaller the heat transfer coefficient.

(3) heat flux/nucleate boiling - If the heat flux is sufficient to cause nucleate boiling, the film thickness will effectively decrease (due to the turbulence caused by the bubbles), reducing the heat transfer coefficient.

(4) fluid thermal conductivity - An increase results in an increased heat transfer coefficient.

Reference 57, pages 8-15 through 8-18; reference 78, pages 3-67 through 3-72.

26. C

Reference 57, page 8-15.

27. B

Reference 57, page 9-8.

28. D

Reference 57, pages 9-8 through 9-13.

29. D

Reference 57, pages 8-19 through 8-23.

30. B

Reference 57, page 8-30.

31. D

Reference 57, pages 8-19 through 8-23.

32.

$\dot{Q}$ is the heat transfer rate, or power, expressed in BTU/hr or other units of energy per time.

U is the overall heat transfer coefficient. It includes the effects of three heat transfer media: The stagnant fluid films on each side of the tube wall and the tube wall itself. While the value of U varies with parameters such as temperature, pressure, flow rate, and fluid density, it is considered constant over the range of conditions specified for a particular heat exchanger.

A is the surface area of the heat transfer surfaces, usually measured at the outer surface of the tubes.

ΔT is the temperature difference between the two fluids.

Reference 57, pages 8-19 through 8-23; reference 78, pages 5-16 through 5-22.

33. D

Pressure drop does <u>not</u> affect heat transfer rate directly.

Reference 41, page 486; and reference 57, page 8-15.

34. C

Reference 41, page 486; and reference 57, page 8-15.

35. B

Reference 57, page 8-15.

36. D

Reference 57, page 8-30.

37. B

From equation sheet:

$$\dot{Q}_c = \dot{m}_c C_p (T_{out} - T_{in})$$

$$1 \text{ Mw} = 3.413 \times 10^6 \ \frac{BTU}{hr}$$

$$\dot{m}_c = (200{,}000)(8.34)(60) = 1.001 \times 10^8 \text{ lbm/hr}$$

$$\dot{Q}_c = (1.001 \times 10^8)(1.0)(85 - 60) = 2.503 \times 10^9 \text{ BTU/hr}$$

$$= 733 \text{ MW}$$

Reference 57, page 8-15.

38. B

Boiling in a heat exchanger could generate excessive steam, which could block the water and cause the heat transfer coefficient to decrease.

Reference 52, page 1.1-6.

39. A

Excessive gases in a heat exchanger can block the water.

Reference 52, page 1.1-6.

40.

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 78, pages 9-24 and 9-25.

41.

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 78, pages 9-24 and 9-25; and reference 55, page 1.1-6.

42. B

Steam pressure is at saturation. Venting will not affect pressure or level control. Removing non-condensible gases will ensure maximum heat transfer.

Reference 30, chapter 17, page 60.

43. C

Reference 78, page 9-25.

44. A

Reference 78, page 9-22.

45. D

The only benefit resulting from condensate subcooling is the NPSH it provides.

Reference 78, page 9-22.

46. B

Reference 78, page 9-22.

47. C

A 28-inch vacuum equates to a 1 psia pressure. Saturation temperature for 1 psia is 101.74 °F. Therefore, the condensate is subcooled by 101.74 - 88 = 13.74 °F or approximately 14 °F.

48.

Condensate depression is subcooling of the condensate in the condenser. With subcooled condensate, the net positive suction head for the condensate pumps is increased, reducing the chance for cavitation.

A disadvantage of condensate depression is that it is created by rejecting heat to the circulating water that might otherwise have been retained in the system. This decreases overall plant efficiency.

Reference 78, page 9-22.

49. A

Reference 53, page 15.5-3.

50. D

Reference 28, part A, chapter 3, page 101.

51. B

Reference 55, chapter 7.

52. A

Reference 57, page 8-51.

53. C

Reference 49, chapter 7, page 49.

54.

Core thermal power (CTP) can be calculated from the following heat inputs and outflows:

steam outflow - This is the major heat removal term from the reactor, so it is added in calculating CTP.

feedwater inflow - The feedwater carries energy into the reactor, so it is subtracted to calculate CTP.

control rod drive inflow - As with feedwater, CRD flow is subtracted because it carries energy into the reactor.

recirculation pump power - The pumps transfer energy into the system, so this factor must be subtracted in calculating CTP.

ambient heat losses - Some reactor power is lost to ambient, and is accounted for by adding it in the CTP calculation.

reactor water cleanup system - The RWCU system removes heat from the system, and therefore is added to calculate CTP.

Reference 57, pages 8-50 through 8-53.

55.

Core thermal power (CTP) can be calculated from a balance of heat inputs and outputs:

CTP + Feedwater + CRD + pumps
= steam + ambient + RWCU

a. If the heat lost through the RWCU system is not considered, calculated CTP will be lower than actual. The reactor will not be given "credit" for generating this heat.

b. If the energy added to the system by the CRD flow is not considered, calculated CTP will exceed actual. The reactor will be "credited" with generating this energy.

c. As with CRD input, if the energy added through the recirculation pumps is omitted, calculated CTP will exceed actual.

d. If ambient losses are not considered, calculated CTP will be less than actual. The reactor will not be "credited" with producing this heat.

Reference 57, pages 8-50 and 8-51.

56. A

Percent reactor powe' .. based on the cor' '- rated thermal power.

Reference 67, page 1-1; and referenc. page 13.

57. C

Percent reactor power is based on the core's rated thermal power.

Reference 67, page 1-1; and reference 60, page 13.

58. B

Reference 67, page 1-1, and reference 60, page 13.

59. D

Reference 67, page 1-1; and reference 60, page 13.

60. B

Reference 67, page 1-1; and reference 60, page 13.

61. B

Reference 67.

62. B

Reference 57, pages 8-50 and 8-51.

HEAT TRANSFER
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 1-17

Describe three mechanisms of heat transfer.

K1.02 Questions 18-20

Define thermal conductivity.

K1.03 Questions 21-26

Describe how fluid films affect heat transfer.

K1.03 Questions 27, 28

Determine the relative efficiency of various methods of heat transfer.

K1.06 Questions 29-35

Discuss the factors that affect heat transfer rate in a heat exchanger.

K1.06, 1.13 Question 36

Given necessary data, calculate the heat transfer rate in a heat exchanger.

K1.07 Questions 37-42

Describe how the presence of non-condensible gases or steam can affect heat transfer and fluid flow in heat exchangers.

K1.08 No questions

Condenser functions are addressed in the Thermodynamic Processes section.

K1.09 Questions 43, 44, 46

Discuss an advantage of condensate depression.

K1.09 Question 45

Calculate condensate depression.

K1.10 Questions 47-50

Define core thermal power.

K1.11 Questions 51, 52

Explain how core power is calculated.

K1.12 Questions 54-58

Define percent reactor power.

K1.12 Questions 61-62

Explain or calculate reactor core performance problems.

1. Using the diagram shown in Figure 3.8-1, identify the region(s) of the curve which most closely approximate(s) where your reactor operates to transfer heat from the cladding to the coolant at 100 percent power.

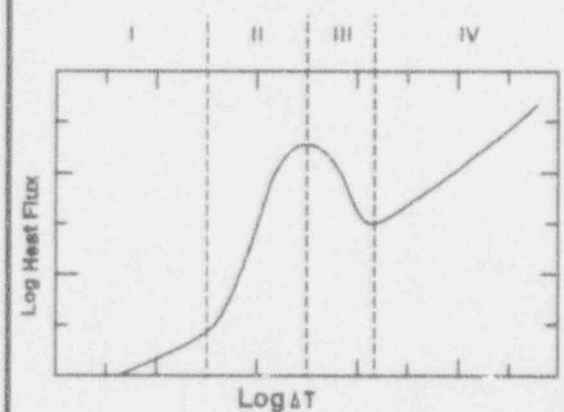
   A. Region I only - single-phase convection

   B. Regions I and II - single-phase convection and nucleate boiling

   C. Region II only - nucleate boiling

   D. Regions II and III - nucleate boiling and partial film boiling

FIGURE 3.8-1



Pool Boiling Curve

2. For boiling to occur, the liquid adjacent to the heating surface must have sufficient heat flux for vapor bubble formation. Select the characteristic below which will <u>not</u> aid in bubble formation.

   A. gas or vapor present in the liquid

   B. surface scratches or cavities in the heating surface

   C. particles suspended in the bulk of the liquid

   D. favorable wetting characteristics of the heating surface and liquid

3. For boiling to occur, the liquid adjacent to the heating surface must have sufficient heat flux for vapor bubble formation to occur. Select the characteristic below which will aid in bubble formation.

   A. surface scratches or cavities in the heating surface

   B. particles suspended in the bulk of the liquid

   C. the absence of dissolved gases in the liquid

   D. the absence of ionizing radiation exposure to the liquid

4. For boiling to occur, the liquid adjacent to the heating surface must have sufficient heat flux for bubble formation to occur. Select the characteristic below which will aid in bubble formation.

   A. chemicals dissolved in the bulk of the liquid

   B. the absence of ionizing radiation exposure to the liquid

   C. a highly polished heat transfer surface with minimal scratches or cavities

   D. gas or vapor present in the liquid

5. The dominant heat transfer mechanism that occurs when film boiling is present is

   A. convection
   B. radiation
   C. conduction
   D. induction

6. The highest rate of heat transfer from the fuel-cladding surface to the coolant channel is provided by

   A. forced convection with subcooled coolant (no boiling)

   B. natural convection with subcooled coolant (no boiling)

   C. natural convection with bulk boiling of coolant

   D. forced convection with nucleate boiling

7. The order of the heat-transfer mechanisms in the boiling water reactor (BWR) core (consider inlet-to-outlet flow) is

   A. subcooled nucleate boiling, single-phase convection, slug flow, annular flow

   B. single-phase convection, subcooled nucleate boiling, annular flow, slug flow

   C. single-phase convection, subcooled nucleate boiling, slug flow, annular flow

   D. single-phase convection, subcooled nucleate boiling, annular flow, slug flow

8. Boiling improves heat transfer because

   A. it increases the effective thickness of the fluid film surrounding the heat transfer surface

   B. it increases the fluid velocity past the heated surface, which offsets the reduction in fluid film thickness at the heated surface

   C. it increases the heat transfer from the heated surface due to latent heat of condensation, as the steam bubbles collapse at the heated surface

   D. it produces agitation, which reduces the thickness of the fluid film and results in the latent heat of vaporization being removed, as the bubbles move away from the heated surface

9. Which one of the following statements indicates why nucleate boiling is a better heat-transfer mechanism than single-phase convection?

   A. A boundary layer is formed.

   B. Steam has a lower specific heat (Cp) then water.

   C. The movement of bubbles from the surface enhances the heat transfer.

   D. The specific heat (Cp) of steam increases more rapidly than the specific heat (Cp) of water.

10. Nucleate boiling occurring at the surface of the fuel rod

    A. increases the convective heat transfer from the fuel rod to the coolant

    B. decreases the convective heat transfer from the fuel rod to the coolant

    C. has no effect on convective heat transfer because it is boiling heat transfer

    D. causes damage to the fuel rod because it agitates the laminar flow of coolant next to the fuel rod

11. Explain how onset of nucleate boiling affects convection heat transfer in a reactor core.

12. Nucleate boiling in the core improves heat transfer from the fuel pin 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. carry the latent heat of condensation directly to the coolant

13. Which of the following best describes why nucleate boiling improves heat transfer in the core?

    A. Heat is removed from the fuel rod as sensible heat and transferred directly to the coolant by the steam bubbles.

    B. Heat is removed from the fuel rod as both sensible heat and latent heat of vaporization, and the motion of the steam bubbles causes rapid mixing of the coolant.

    C. Heat is removed from the fuel as both sensible heat and latent heat of condensation, and the heat is transferred directly to the coolant by the steam bubbles.

    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.

14. Convection heat transfer improves for two reasons when nucleate boiling begins on the surface of the fuel rod. The first reason is because heat is removed as both sensible heat and latent heat of vaporization. The other reason is because

    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

15. 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

16. Which of the following best describes convection heat transfer?

    A. the flow of heat through a body or between bodies in direct contact

    B. the flow of heat between two different fluids not in direct contact

    C. the flow of heat from a body by electromagnetic waves across an intervening space

    D. the flow of heat between a fluid and surface by circulation of the fluid

17. Which of the following conditions is not characteristic of natural convection heat transfer?

    A. The surface of an object is in contact with a fluid at a different temperature.

    B. A fluid is set in motion by contact with an object at a different temperature.

    C. Heat transfer occurs between two solid bodies in direct contact.

    D. Molecules in a fluid move away from the surface of an object and into the fluid where energy is given up in collision with other fluid molecules.

18. Explain the process of heat transfer by natural convection flow.

19. Which of the following is not an example of convection heat transfer?

    A. the cooling of water in a counterflow heat exchanger

    B. the flow of water vapor from the cooling tower to atmosphere

    C. the changing of steam to water in a main circulating water condenser

    D. the flow of heat from inside of fuel rods to the zirconium cladding

20. Which of the following statements concerning convection heat transfer is true?

    A. In natural convection, heat flows from hot to cold, while forced convection heat flows from cold to hot.

    B. Increasing the velocity of water flow in a condenser affects the convective heat transfer in the condenser.

    C. Convective heat transfer occurs when there is a flow of heat between solid bodies in direct contact.

    D. Fluid viscosity and fluid film thicknesses have no effect on convective heat transfer.

21. All of the following are examples of convective heat transfer except

    A. heat transfer from the boundary layer adjacent to the cladding to the bulk coolant stream

    B. heat transfer from the fuel pellet center to the fuel pellet edge

    C. heat transfer resulting in a change in density of water causing less dense water to flow upward and more dense water to flow downward

    D. heat transfer from a circulating water pump motor to the surrounding air

22. Which of the following terms most accurately identifies the type of heat transfer occurring when a heated surface is submerged in a fluid and the warmer fluid rises from the heated surface while the cooler fluid flows downward toward the heated surface?

    A. natural convection
    B. natural recirculation
    C. natural conduction
    D. natural radiation

23. Which of the following is not necessary to sustain natural convection?

    A. condensate depression
    B. density difference
    C. energy storage
    D. conduction

24. Which one of the following conditions must occur to sustain natural convection?

    A. condensate subcooling of the fluid
    B. a phase change in the fluid
    C. an enthalpy change in the fluid
    D. radiative heat transfer to the fluid

25. Which of the following terms most accurately refers to the boiling that results when the steam bubbles moving away from a heated surface collapse in the bulk fluid?

    A. subcooled nucleate boiling
    B. saturated convection
    C. subcooled convection
    D. saturated nucleate boiling

26. Which one of the following statements best applies to nucleate boiling?

    A. Nucleate boiling consists of both conduction and radiation heat transfer.

    B. The existence of nucleate boiling effectively increases the heat-transfer coefficient.

    C. Nucleate boiling occurs about the heated surface after the onset of transition boiling.

    D. Nucleate boiling consists of forming a steam blanket around the heated surface, thus allowing the heat transfer coefficient to increase.

27. Which of the following most accurately defines the term nucleate boiling?

    A. boiling that results in the bulk fluid temperature reaching saturated conditions

    B. boiling that results in a thin layer of steam at the heated surface

    C. boiling that occurs when small bubbles are formed at the heated surface and move off into the liquid

    D. boiling that occurs when the critical heat flux is reached

28. Which of the following statements defines the term "bulk boiling"?

    A. The bubbles move away from the heated surface and collapse in the bulk fluid.

    B. Bulk fluid temperature is at saturation temperature and the steam bubbles do not collapse as they enter the flow.

    C. It is boiling that occurs before the critical heat flux is reached.

    D. The bubbles move away from the heated surface and are separated in the bulk flow.

29. Explain the difference between subcooled and saturated nucleate boiling, and state whether either or both exists in a BWR during normal operation.

30. Which of the following best describes the term nucleate boiling?

    A. Vapor bubbles form at different sites and break from the surface where they may or may not collapse as they move upward in the channel flow.

    B. Bubbles on the heated surface combine to form vapor barriers between liquid and heated surface.

    C. An unstable vapor film is formed and, as it moves, the surface becomes rewetted.

    D. The entire heated surface is blanketed by a stable vapor blanket characterized by a substantial radiation heat transfer.

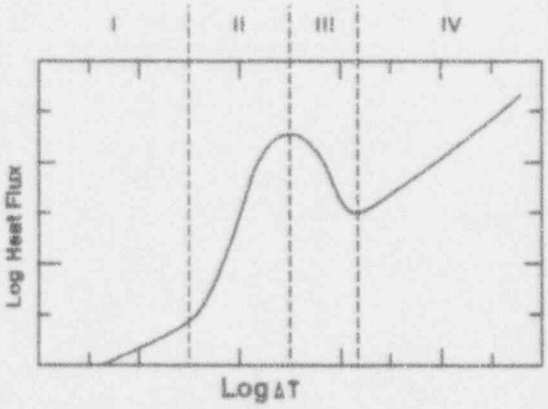
31. In the definition of subcooled nucleate boiling, the relationship of bulk fluid temperature to saturation temperature is best described by which of the following?

A. $T_{Bulk\ Fluid} > T_{Sat}$
B. $T_{Bulk\ Fluid} > T_{Rewetting}$
C. $T_{Sat} > T_{Bulk\ Fluid}$
D. $T_{Sat} > T_{Rewetting}$

32. Identify, on the diagram shown in Figure 3.8-2, the region in which nucleate boiling occurs.

A. Region I
B. Region II
C. Region III
D. Region IV

FIGURE 3.8-2



Pool Boiling Curve

33. Which one of the following is a definition for bulk boiling?

A. The hotter water is less dense than the cooler bulk liquid and it rises, while the cooler, denser bulk liquid flows down the sides.

B. Bubbles in the heated surface combine to form vapor barriers between the bulk liquid and heated surface.

C. The bulk liquid temperature is at the saturation temperature so that bubbles do not collapse and vapor is generated at liquid surface.

D. At very high temperatures of bulk fluid temperature above saturation temperature, the entire heated surface is blanketed by a stable vapor.

34. What type of boiling is 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. transition boiling
D. partial film boiling

35. 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

36. The term departure from nucleate boiling (DNB) is best described by which of the following?

    A. Bubbles on the heated surface combine to form vapor barriers between the liquid and heated surface. A change in mode of heat transfer then begins.

    B. Nucleate boiling is changing under a condition where bulk liquid temperature is below saturation temperature resulting in a collapse of vapor bubbles.

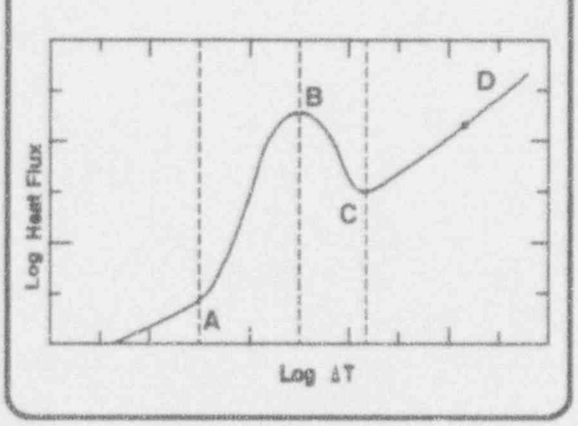
    C. Nucleate boiling is occurring when the temperature of the bulk liquid is at saturation temperature and bubbles don't collapse. Vapor is then generated.

    D. At very high values of bulk liquid temperature above saturation temperature, the entire heated surface is blanketed by an unstable vapor blanket. This is characterized by substantial film boiling.

37. Which point on the curve shown in Figure 3.8-3 is the point of departure from nucleate boiling?

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

FIGURE 3.8-3



Pool Boiling Curve

38. Which of the following best describes departure from nucleate boiling (DNB)?

    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 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.

39. Describe the process and effects of departure from nucleate boiling.

40. A rapid increase in the ΔT between the fuel clad and the coolant with a decrease in heat flux indicates

    A. bulk boiling is occurring

    B. departure from nucleate boiling (DNB) has been reached

    C. critical heat flux (CHF) is increasing

    D. nucleate boiling is occurring

41. Departure from the 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 rapid increase in heat flux may cause fuel melting

42. 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. remain the same

43. Departure from nucleate boiling (DNB) occurs when steam bubbles begin to blanket the fuel rod, resulting in a rapid __________ in heat transfer rate and a rapid __________ in delta-T (fuel rod clad minus coolant temperature).

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

44. Which of the following describes onset of transitional 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.

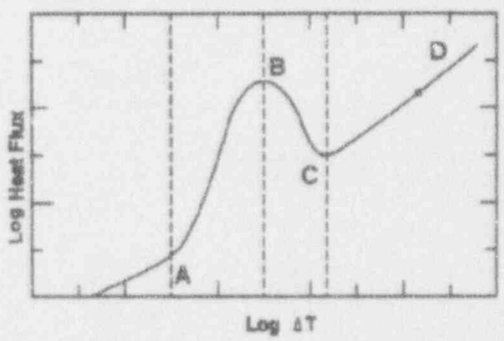
    C. Steam bubbles begin to blanket the fuel rod, causing a rapid decrease in ΔT between the fuel rod and the coolant.

    D. Steam bubbles begin to form on the surface of the fuel rod, causing an increase in the heat flux from the fuel rod.

45. Which of the following points on the pool-boiling curve shown in Figure 3.8-4 represents the onset of transition boiling (OTB)?

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

FIGURE 3.8-4



Pool Boiling Curve

46. What is significant about the heat flux at the onset of transition boiling (OTB)?

    A. Heat flux becomes proportional to $(T_s - T_{Sat})^{5/4}$.

    B. Heat flux begins to decrease due to a change in heat transfer mechanisms.

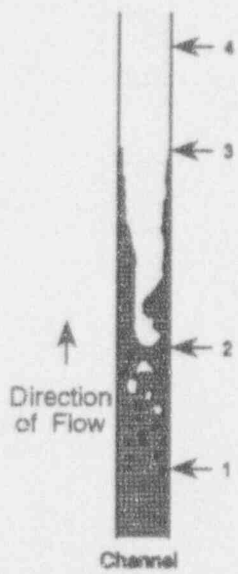
    C. Heat flux decreases due to a failure of the heated surface under poor heat transfer conditions.

    D. Heat flux increases as vapor bubbles combine on the heated surface forming an unstable vapor film.

47. For the hypothetical BWR channel shown in Figure 3.8-5, identify along its length where the onset of transition boiling (OTB) begins during two-phase flow.

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

FIGURE 3.8-5



Hypothetical BWR Channel

48. Describe the process and effects of reaching the onset of transition boiling.

49. In a hypothetical BWR channel, there is a point where annular flow stops, mist flow starts, and heat flux begins to decrease due to a change in heat transfer mechanisms. This point is known as the point of

A. onset of transition boiling
B. dryup
C. nucleate boiling
D. rewetting

50. At the onset of transition boiling (OTB), the BWR fuel channel heat flux reacts in which of the following ways? Heat flux

A. does not change appreciably because heat transfer mechanisms do not change

B. increases because the heat transfer mechanism shifts to a more efficient mode

C. decreases drastically because the entire heated surface is steam blanketed

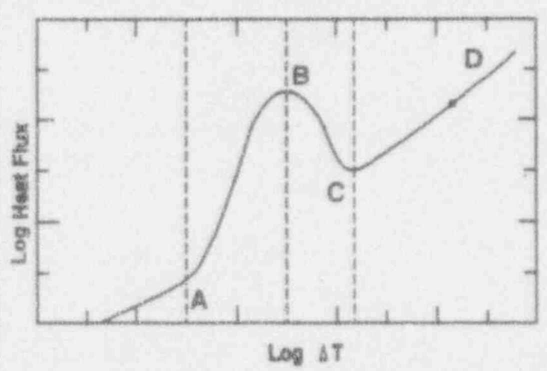
D. begins to decrease because heat transfer mechanisms change

51. Refer to Figure 3.8-6 for the following question.

On the figure of a pool-boiling curve, the point at which heat flux is increasing and the critical heat flux has been reached (point B), marks the onset of

A. single-phase convection
B. film boiling
C. nucleate boiling
D. partial film boiling

FIGURE 3.8-6



Pool Boiling Curve

52. The magnitude of the local fuel pin heat flux that is necessary to cause the onset of transition boiling (OTB) is

A. largest at the top of the core and smallest at the bottom

B. largest at the bottom of the core and smallest at the top

C. largest at the midplane and smallest at the top and bottom

D. smallest at the core midplane and largest at the top bottom

53. Referring to the diagram shown in Figure 27, choose the region of the curve where transition (partial film) boiling occurs.

A. region A to B
B. region B to C
C. region C to D
D. region B to D

54. Which type of boiling exhibits the following characteristics:

A small increase in ΔT (at the heat transfer and coolant interface) causes increased steam blanketing and a reduction in heat flux.

A. subcooled
B. nucleate
C. partial film
D. film

55. Select the statement that best describes transition (partial film) boiling.

A. A small increase in ΔT (at the heat transfer 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 radiative 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 which may collapse when they enter into the bulk of the fluid.

56. Transition (partial film) boiling employs both convective and thermal radiative heat transfer mechanisms. Which statement best describes transition (partial film) boiling?

    A. Both heat transfer mechanisms are significant, and heat flux increases with an increasing ΔT.

    B. Only the convective mechanism is significant, and heat flux decreases with an increasing ΔT due to vapor blanketing.

    C. Only the radiative mechanism is significant, and heat flux does not increase significantly with an increasing ΔT.

    D. Both mechanisms are significant, but the heat flux does not increase significantly with an increasing ΔT.

57. In commercial nuclear reactors, it would be difficult to maintain transition (partial film) boiling. Why is this statement true?

    A. The heat flux increasing beyond the onset of transition boiling causes a shift directly to the film boiling region, effectively bypassing the transition boiling region.

    B. Reactor pressure could not be regulated to maintain transition boiling without redesigning the reactor pressure control system.

    C. The reactor is incapable of producing the heat flux necessary under any operating conditions.

    D. The negative moderator temperature coefficient would not allow critical heat flux to be exceeded under any condition.

58. Describe the process and effects of transition boiling.

59. 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

60. Select the statement that best describes film boiling.

    A. A small increase in ΔT (at the heat transfer and coolant interface) causes increased steam blanketing and a reduction in heat flux.

    B. The ΔT at the heat transfer interface is so high that thermal radiation heat transfer becomes significant and heat flux increases as ΔT 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, few vapor bubbles are formed which may collapse when they enter into the bulk of the fluid.

61. When the ΔT at the heat transfer interface reaches a high value, the contribution from thermal radiation becomes significant and the heat flux increases. This best describes which boiling regime?

    A. local nucleate
    B. bulk nucleate
    C. partial film
    D. full film

62. The film boiling regime utilizes both convective and thermal radiative heat transfer mechanisms. Which statement best describes film boiling?

    A. Both heat transfer mechanisms are significant and heat flux increases with an increasing ΔT.

    B. Only the convective mechanism is significant; heat flux decreases with an increasing ΔT due to vapor blanketing.

    C. Only the radiative mechanism is significant and heat flux does not increase significantly with an increasing ΔT.

    D. Both heat transfer mechanisms are significant and heat flux decreases with an increasing ΔT.

63. In commercial nuclear reactors, if the critical heat flux is reached, the boiling regime will quickly shift from nucleate to full film boiling. Why does this shift occur?

    A. The reactor is designed to shift from nucleate to film boiling because partial film boiling is unstable.

    B. Film boiling is very stable and can be tolerated for short periods without endangering fuel cladding integrity.

    C. The heat flux is controlled by the operator and the ΔT is the result of the heat flux or power level; therefore, this shift occurs quickly beyond the onset of transition boiling.

    D. The reactor is designed to shift from nucleate to film boiling because the operator can easily control reactor pressure during film boiling but not during partial film boiling.

64. Describe the process and effects of stable film boiling.

65. Which one of the following describes the relative contributions of the convective and radiative heat transfer mechanisms during stable film boiling heat transfer?

    A. Only the radiative heat transfer mechanism is significant and heat flux increases in direct proportion to delta-T squared.

    B. Both heat transfer mechanisms are significant and heat flux increases in direct proportion to delta-T squared.

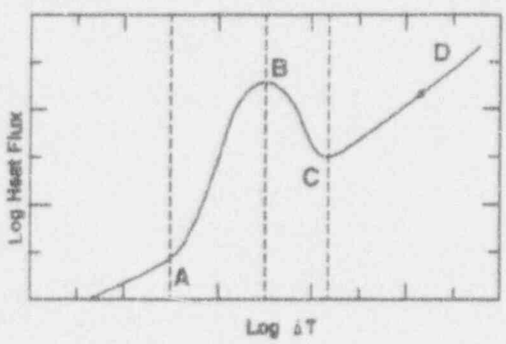
    C. Only the radiative heat transfer mechanism is significant and a significant increase in heat flux requires a large delta-T increase.

    D. Both heat transfer mechanisms are significant and significant increase in heat flux requires a large delta-T increase.

66. Referring to the diagram shown in Figure 3.8-7, choose the region of the curve where film boiling occurs.

A. region I
B. region II
C. region III
D. region IV

FIGURE 3.8-7



Pool Boiling Curve

67. The onset of transition boiling (OTB) is

A. the area of a heat transfer curve where the most energy is added to the coolant

B. the period when clad temperature fluctuates at the heat transfer coefficient alternates between a high value and a much lower value

C. the most effective means of heat transfer

D. the period when clad temperature significantly increases as the heat transfer coefficient becomes negative

68. If transition boiling is occurring in a fuel assembly coolant channel, then coolant flow is characterized as

A. slug flow
B. vapor flow
C. annular flow
D. bubble flow

69. Core inlet subcooling is best defined as the difference between the enthalpy of fluid

A. in the core inlet plenum and the saturation enthalpy of the fluid at that pressure

B. at the feedwater pump discharge and the enthalpy of fluid in core inlet plenum

C. in the downcomer area and the saturation enthalpy of fluid in the core inlet plenum

D. in the lower fuel channel area and the enthalpy of fluid in the core inlet plenum

70. Core inlet subcooling is defined as the difference between the enthalpy of fluid in the ____ ____ and the saturation enthalpy of the _______.

A. core inlet plenum, fluid in the downcomer

B. lower end of reactor core fuel channels, fluid at that pressure

C. core inlet plenum, fluid at that pressure

D. downcomer, fluid at that pressure

71. Calculate the value of core inlet subcooling in BTU/lbm for the following data:

Core inlet plenum temperature = 521°F
Reactor core inlet pressure = 1,020 psia

A. 20.3 BTU/lbm
B. 23.2 BTU/lbm
C. 32.3 BTU/lbm
D. 33.5 BTU/lbm

72. Performing a mass and energy balance on the downcomer region of the reactor vessel gives the amount of

A. carryunder
B. core inlet subcooling
C. core thermal power
D. fuel channel quality

73. List and explain the factors that must be considered in determining core inlet subcooling.

74. As the reactor feedwater system discharge temperature decreases due to loss of feedwater heating, the value of core inlet subcooling for a given core inlet pressure

A. increases
B. decreases
C. stays the same
D. decreases briefly, then returns to initial value

75. The term core inlet subcooling is most accurately defined as the difference between the fluid enthalpy

A. at the jet pump nozzles and the saturation enthalpy of the fluid from feedwater pumps

B. at the discharge of the condensate pumps and the fluid enthalpy at the discharge of the steam dryers

C. in the steam dome and the saturation fluid enthalpy in the bottom head

D. in the bottom head region and the saturation enthalpy of fluid in the bottom head region

76. Inadequate subcooling is an example of the adverse effect caused by

A. carryunder

B. carryover

C. excessive main condenser circulating flow

D. positive moderator temperature coefficient

77. Define "carryunder."

78. Void fraction is defined as the ratio of the

A. density of steam to the density of the steam/water mixture

B. mass of steam to the mass of steam/water mixture

C. volume of steam to the volume of steam/water mixture

D. viscosity of the steam to the viscosity of the steam/water mixture

79. Void fraction is related to the ______ of steam and steam/water mixture.

A. density
B. mass
C. volume
D. viscosity

80. In a boiling water reactor, void fraction is

A. the amount of nucleate boiling taking place in the reactor core

B. related to neutron moderation, resulting in power changes as void percentage changes

C. necessary to provide an accurate ratio of mass of steam/water mixture present in the reactor core

D. directly related to reactor power such that as voids increase then reactor power increases dramatically

81. Void fraction is the ratio of the _________ of steam to the _________ of steam/water mixture at a given elevation in the fuel channel.

A. volume, mass
B. mass, mass
C. volume, volume
D. mass, volume

82. Explain the difference between the static quality of the coolant at a point in a fuel channel and the void fraction at that point.

83. Calculate the void fraction in percent for the following conditions:

10 lbm mixture of vapor and liquid
steam quality = 10 percent
pressure = 1,000 psia

A. 41.8 percent
B. 69.6 percent
C. 90.3 percent
D. 95.4 percent

84. As applied to operations of the reactor core, voids are defined as

A. the amount of reactor core free of inserted control rods

B. gaps between inserted control rods adjacent to the fuel channels

C. the amount of saturated steam contained in saturated liquid returning to the downcomer after leaving the reactor core

D. steam bubbles in the fuel channels caused by flow boiling

85. As voids increase during reactor power operations, neutron moderation in the core

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

86. As voids change in the core during power operations, _______ changes causing a change in _______.

A. steam production, steam quality
B. neutron moderation, core power
C. core power, thermal limits
D. steam quality, cladding thickness

87. Because a BWR undergoes flow boiling, ___________ are always present in fuel channels during __________.

A. steam voids, power operations
B. thermal limits, transient operations
C. xenon levels, coolant enthalpy changes
D. dryout effects, heat flux changes

88. During a reactor power increase initiated by changing flow, steam voids will initially __(1)__ and neutron moderation __(2)__ causing __(3)__ thermal neutrons to be available for fission.

	(1)	(2)	(3)
A.	increase	increases	fewer
B.	decrease	increases	fewer
C.	decrease	increases	more
D.	increase	decreases	more

89. A reactor is operating at 100 percent power. Recirculation flow is decreased from 100 percent to 80 percent.

Which of the following statements describes the initial response of the boiling boundary within the core?

A. It physically moves up the fuel rods, because fewer BTUs per pound mass of water are now being transferred.

B. It physically moves up the fuel rods, because more BTUs per pound mass of water are now being transferred.

C. It physically moves down the fuel rods, because more BTUs per pound mass of water are now being transferred.

D. It physically moves down the fuel rods, because fewer BTUs per pound mass of water are now being transferred.

90. Which of the following values most accurately represents steam quality leaving a cyclone separator at 985 psig and 1183 BTU/lbm?

A. 95 percent
B. 96 percent
C. 97 percent
D. 98 percent

91. Which of the following best defines the term "steam quality"?

A. mass of liquid divided by mass of liquid-vapor mixture

B. mass of liquid-vapor mixture divided by mass of liquid

C. mass of vapor divided by mass of liquid

D. mass of vapor divided by mass of liquid-vapor mixture

92. Draw and label a sketch of the temperature profile from the fuel pellet centerline to the centerline of the channel for a BWR operating normally at power.

93. 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-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 gap
B. zircalloy cladding
C. cladding corrosion film
D. flow channel boundary layer

94. [This question is not applicable to Big Rock Point Nuclear Plant.]

The primary function of BWR forced core recirculation is to

A. control neutron population in the core such that control rods can change reactor power output

B. drive coolant through the core and control reactor power output

C. circulate water through the core to minimize core voiding

D. ensure that core thermal limits are maintained within specification

95. Which of the following best describes the heat transfer characteristic of forced circulation in the reactor core during power operations?

A. Heat transfer is based upon a density difference where the hotter, less dense water is displaced by the cooler, more-dense water.

B. Heat transfer is inefficient due to establishment of a relatively thick fluid film which promotes convection.

C. Heat transfer mechanism shifts to film boiling with the cladding surface blanketed by steam.

D. Heat transfer mechanism is mainly nucleate boiling and the fuel clad surface does not become blanketed by steam.

96. The reactor core is at 100 percent power when a trip of the recirculation pumps occurs. What is the resulting effect on void fraction percentage? Void fraction percentage will

    A. stay the same due to minimal change in reactor pressure

    B. decrease because the reactor power decrease reduces the steam bubbles being generated

    C. increase because steam bubbles are no longer being swept away

    D. decrease initially due to reactor pressure increase, then return to initial value

97. Forced circulation is required at all times during power operations in a BWR to prevent

    A. the reactor core from becoming prompt critical due to high temperatures which would be allowed to exist

    B. jet pump cavitation

    C. high fuel clad surface temperatures that result in a crack or leak in the clad

    D. excessive zirconium-water reaction which would result with minimum flow and high power levels

98. State and explain three reasons for using forced core recirculation.

99. [This question is not applicable to Big Rock Point Nuclear Plant.]

    By changing the amount of forced recirculation flow through the reactor core, the operator is able to

    A. uniformly control reactor power output throughout the core

    B. control reactor power output in the bottom of the core such that flux profile is more linear

    C. locally control reactor power output similar to controlling reactor power with control rods

    D. maintain steam quality within acceptable levels to prevent turbine blade impingement

100. Describe how a jet pump works.

101. Which of the following statements most accurately describes the principle of jet pump operation?

    A. High-velocity jet flow draws downcomer fluid into the jet pump throat, as a result of friction between the driving flow and the driven flow.

    B. Low static pressure created by the increasing area in the diffuser draws downcomer fluid into the jet pump throat.

    C. The high driving-to-driven flow ratio creates a low static pressure in the diffuser, which draws downcomer fluid into the jet pump throat.

    D. Low static pressure created by the high-velocity jet draws downcomer fluid into the jet pump throat.

102. It is important to be able to determine core coolant flow because

    A. insufficient flow can allow buildup of crud on the fuel clad, degrading heat transfer to the coolant

    B. excessive flow can result in jet pump cavitation

    C. improper flow can reduce jet pump efficiency, thereby reducing overall cycle efficiency

    D. improper flow can result in violation of technical specification thermal limits

103. Why is it necessary to be able to determine core coolant flow?

104. Single-phase flow resistance can be calculated by adding the resistance values due to

    A. friction, acceleration, and local restrictions

    B. viscosity, acceleration, and turbulence

    C. crud layer, stagment fluid film layer, and laminar flow layer

    D. crud layer, local restrictions, and coolant channel width

105. List and briefly discuss the three contributors to single-phase flow resistance.

106. Compared to single-phase flow, the resistance of two-phase flow due to its quality exiting a fuel bundle at rated power is approximately

    A. half as great
    B. the same
    C. four times as great
    D. twelve times as great

107. Describe the effects of coolant quality and boiling on the resistance to two-phase flow compared to liquid-only flow.

108. Given a power increase in a boiling water reactor (BWR) core, as the fuel bundle power increases, resistance to flow will

    A. increase

    B. remain the same

    C. decrease

    D. increase until departure from nuclear boiling (DNB) occurs, then decrease

109. The reactor is operating at 100 percent power. Recirculation flow is decreased from 100 percent to 80 percent. The boiling boundary will move __________ in the core because each pound-mass (lbm) of water flowing through the core is required to remove __________ heat from the fuel rods.

    A. upward; less
    B. upward; more
    C. downward; less
    D. downward; more

110. Which of the following describes the relationship between bundle power and bundle flow resistance characteristics?

    A. Flow resistance decreases as the quality and two-phase flow increase.

    B. Prior to boiling, as bundle power increases, bundle flow decreases.

    C. Flow resistance increases as the quality and void fraction increase.

    D. After boiling has begun, as bundle power increases, bundle flow is constant.

111. Which one of the following statements describes the effect of an increase in bundle power on bundle flow in a centrally located fuel bundle? (Assume total recirculation flow remains constant.)

   A. Bundle flow increases because the increased boiling causes average coolant density to decrease, thereby reducing flow resistance.

   B. Bundle flow decreases because the increased boiling increases backpressure due to increased reactor steam dome pressure, thereby increasing flow resistance.

   C. Bundle flow increases because the increased boiling causes acceleration of coolant due to rapid expansion, thereby reducing flow resistance.

   D. Bundle flow decreases because the increased boiling increases backpressure due to increased turbulence, thereby increasing flow resistance.

112. Describe the effects of an increase in fuel bundle power on that bundle's flow resistance.

113. For two-phase flow through a channel, as bundle power continuously increases, the large <u>increase</u> in flow resistance up the flow channels is primarily due to the effects of increased

   A. density due to hotter water present in channels

   B. friction of fuel channel surfaces

   C. fluid film thickness on sides of fuel channel surfaces

   D. two-phase flow resistance

114. With core orificing and single-phase flow in the reactor, the flow distribution across the core is

   A. highest in the low-powered bundles
   B. highest in the high-powered bundles
   C. constant for all bundles
   D. lowest in the high-powered bundles

115. At high power, the highest resistance to flow occurs in the highest powered bundles due to

   A. single-phase flow
   B. increased density of coolant
   C. two-phase flow
   D. decrease in specific volume of coolant

116. With <u>no</u> core orificing in the reactor, the flow characteristic in the reactor at rated power would be that the

   A. highest flow occurs in the highest-powered bundle

   B. flow is constant through each bundle regardless of power

   C. lowest flow occurs in the lowest-powered bundles

   D. highest flow occurs in the lowest-powered bundles

117. Which of the following would <u>not</u> be used to compare flow resistance in different powered fuel bundles?

   A. plenum ΔP
   B. orifice size
   C. quality
   D. void fraction

118. With single-phase flow alone, the highest flow occurs in the highest powered bundles because

   A. density change of the coolant is greater
   B. quality of the coolant is greater
   C. void fraction is higher
   D. quality plenum ΔP is decreased

119. Without core orificing, the coolant flow through a high-power bundle with be less than the flow through a low-power bundle because the

   A. two-phase flow-friction multiplier would be greater in the low-power bundle

   B. channel quality would be greater in the high-power bundle

   C. bypass flow would be greater in the high-power bundle

   D. thermal expansion of the fuel rods would be greater in the high-power bundle

120. Flow in a BWR bundle has different characteristics with and without fuel bundle orifices. With regard to this statement, which of the following is correct?

   A. The inlet orifice provides a larger flow resistance so that any additional flow resistance is acceptably small.

   B. With inlet orifices and zero power and minimum recirculation flow, the flow through each bundle is equal.

   C. In a non-orificed core, flow resistance would be lower in high-powered bundles compared to lower-powered bundles.

   D. Low-power bundles, in a non-orificed core, would have a higher flow resistance than overall core flow resistance.

121. Neglecting any effects of core orificing, explain how and why the flow rate of coolant would differ between high- and low-power bundles during a startup.

122. Where and why is core orificing is used in the reactor core?

   A. Large orifices are used in the peripheral bundles to assure adequate quality in these lower-powered bundles.

   B. Large orifices are used in the core interior to increase the resistance of two-phase flow.

   C. Large orifices are used in the peripheral bundles since these are the higher-powered bundles requiring the most flow.

   D. Large orifices are used in the core interior, effectively reducing flow in the peripheral bundles where the power is normally low.

123. Core orificing is used in the reactor core because the orifices

   A. counteract the buoyant force of the bubbles accelerating flow in the high-powered bundles

   B. improve the distribution of core flow to offset the effect of increasing quality on bundle flow

   C. increase core ΔP so that minor crud buildup on fuel bundles will not adversely affect flow

   D. decrease flow during periods of natural circulation to increase the void coefficient

124. In the reactor core, a flow restriction is created using orifices to

   A. provide a large resistance to flow so that any additional flow resistance caused by two-phase flow is acceptably small

   B. create a large pressure drop from the inlet to outlet plenum to ensure that flow through all channels is equal at all times

   C. restrict flow in the lower-powered center bundles so that flow is highest in peripheral bundles at all times

   D. maintain a constant flow during any single flow changes due to density as the coolant temperature is increased from cold to operating temperature

125. With regard to two-phase flow without reactor core orificing, core flow would

   A. be highest in the high-powered bundles
   B. be highest in the low-powered bundles
   C. be essentially constant across the core
   D. decrease at low power

126. Reactor core orifices ensure

   A. highest flow in low-powered bundles

   B. total core flow is divided equally through all fuel channels

   C. highest flow supplied to highest powered bundles

   D. core flow remains same at all power levels

127. Why do BWRs have flow orifices installed in the core?

128. What is the purpose of core bypass flow?

   A. cooling reactor internal components

   B. controlling the amount of feedwater subcooling

   C. providing control rod drive temperature indication

   D. preventing onset of transition boiling along the fuel assembly

129. Describe core bypass flow and its sources.

130. The reactor coolant that bypasses the core and is used for cooling reactor vessel internal components is ________ bypass flow.

   A. fuel
   B. core
   C. reactor
   D. internal

131. Core bypass flow is the reactor coolant flow which bypasses the core, thereby

   A. limiting core exit temperature within specifications

   B. aiding natural circulation capability on loss of recirculation flow

   C. providing cooling to internal components

   D. limiting the power-to-flow ratio

132. Core bypass flow is the reactor coolant flow that bypasses the core, thereby

   A. providing natural circulation capability on loss of recirculation flow

   B. providing minimum amount of reactor water removal by cleanup system

   C. providing recirculation flow in the core

   D. providing cooling to internal components

133. Core bypass flow is provided to bypass the core to

   A. limit the amount of core cooling during accident conditions

   B. provide cooling to internal components

   C. provide even flow distribution through the fuel

   D. enhance natural circulation

134. Core bypass flow is

   A. undesirable but cannot be prevented due to machined clearances within the reactor vessel

   B. desirable because it provides cooling for low-power areas of the core

   C. undesirable because it makes actual core flow hard to measure

   D. desirable because it provides cooling for incore instrumentation

135. Explain why an adequate amount of core bypass flow is important.

136. It is important that an adequate amount of coolant bypass the fuel because this bypass flow

   A. provides a source of water to the incore thermocouples to ensure they measure a representative coolant temperature

   B. acts as a neutron reflector to minimize fast neutron leakage

   C. assures that recirculation pump flow is adequate to prevent pump overheating

   D. provides cooling to prevent excessive boiling in the bypass region

137. What is the purpose of the coolant flow that bypasses the fuel assemblies and enters the core interstitial region?

   A. removes the heat that is generated in the control rods and the LPRMs

   B. equalizes core differential pressure between the inlet and outlet plenums

   C. offsets the decrease in heat removal from the fuel bundle due to decreased flow as two phase flow resistance increases

   D. lubricates the interfacing surfaces of control rods and fuel channels to reduce sliding friction and wear

138. Natural circulation through a reactor core requires a

   A. high convective heat transfer coefficient
   B. heat source
   C. phase change
   D. previously established flow

139. Natural circulation through a reactor core is the result of

A. the siphon effect after forced flow is stopped

B. equalized pressure throughout the system

C. a difference in downcomer and riser pressure

D. density being equalized throughout the system

140. For natural circulation to occur in a reactor, a ΔP must be developed. A ΔP is developed by

A. the difference in the height of water between the recirculation loop and reactor

B. opening a high point vent, and a low point drain

C. starting and then stopping a pump to start flow and create a siphon effect

D. reactor adding heat and changing coolant density

141. Natural circulation will continue until the

A. coolant is cooled below saturation temperature

B. coolant temperature is less than 212°F

C. reactor stops producing heat

D. reactor vessel temperature is less than 212°F

142. List three conditions that must exist for natural circulation flow to occur.

143. Natural circulation is inherent in a boiling water reactor (BWR). Which one of the following statements best describes natural circulation after a loss of offsite power?

A. Liquid density in the downcomer and reduction of density in the core region support the cycle.

B. Two-phase flow in the separators allows steam to be removed and liquid to return to the downcomer region.

C. Relief and safety valves provides a heat sink for decay heat. In spite of leakage, control rod drives are adequate to maintain inventory.

D. Density of liquid in the core region increases, thereby allowing liquid in the downcomer to enter the core.

144. Which one of the following statements describes natural circulation in a shutdown reactor? (Assume no isolation condenser.)

A. The moisture separators return the liquid portion of the coolant mixture exiting the core to the downcomer where it cools and increases in density.

B. The jet pump diffusers establish a thermal driving head by increasing the velocity of the coolant as it flows downward through the diffuser.

C. At least one reactor recirculation loop must be unisolated to provide a hat sink to ambient for cooling the coolant entering the core.

D. At least one source of coolant injection must be available to establish the thermal driving head by providing cold coolant to the downcomer or the bottom head region.

145. At what temperature does thermal stratification become a concern?

A. 112°F
B. 162°F
C. 212°F
D. 272°F

146. Which of the following is least effective in delaying thermal stratification?

A. natural circulation

B. forced circulation

C. normal shutdown/residual heat removal system flows

D. main steam line drain flow

147. With the reactor shutdown and the reactor recirculating pumps isolated, it is important to monitor vessel skin temperatures because

A. cooldown rates are easily exceeded with the recirculation pumps isolated

B. these temperatures will provide one of the first indications of thermal stratification

C. these temperatures are the only reliable source of reactor recirculation loop temperature

D. these temperatures must be maintained constant with no flow in the core

148. Explain two problems that could result from thermal stratification in the reactor vessel.

149. The reactor is shut down with recirculation loops isolated, and cooling from the decay heat removal system is throttled. Recirculation loop temperatures and clean up inlet temperature from the reactor read 190°F. Given these conditions, what is the most likely cause of reactor pressure increasing?

A. The reactor pressure indicator is faulty.

B. The increased density of the coolant causes the pressure gauges to show an increasing pressure.

C. Thermal stratification has occurred, producing steam.

D. The temperature increase causes density to decrease, resulting in a pressure increase.

150. Describe two methods that can be used to determine if natural circulation flow exists.

151. Which of the following is necessary for natural circulation flow to exist?

A. RHR running in the shutdown cooling mode

B. reactor water temperature less than 212°F

C. reactor recirculation pumps running

D. reactor water level above the bottom of the pre-dryers of the steam separators

152. Which of the following is the best indication that natural circulation flow in a shutdown reactor has been lost?

A. Reactor coolant temperature is increasing.

B. Shutdown cooling flow from RHR has been secured.

C. Reactor water level has decreased below the bottom of the steam separators.

D. Safety relief valves are open.

153. While shutdown, what effect will decreasing reactor water level below the steam separators have on natural circulation flow?

   A. Flow will increase to a new stable value.

   B. Flow will increase temporarily until a new thermal equilibrium is established, returning flow to the original value.

   C. There will be no effect on flow.

   D. Flow will decrease.

154. Which action will have the most effect on increasing natural circulation flow?

   A. opening safety relief valves

   B. increasing shutdown cooling flow

   C. increasing reactor water recirculation flow

   D. raising reactor water level to above the steam separators

155. Describe two methods an operator could use to enhance natural circulation flow.

156. Which one of the following is a characteristic of subcooled nucleate boiling but not saturated nucleate boiling?

   A. T_{Clad} equals T_{Sat}

   B T_{Clad} is greater than T_{Sat}

   C. $T_{Bulk\ Coolant}$ equals T_{Sat}

   D. $T_{Bulk\ Coolant}$ is less than T_{Sat}

157. Which one of the following describes the conditions in a fuel channel that is experiencing transition boiling?

   A. complete steam blanketing of the fuel rod surface

   B. alternate wetting and drying of the fuel rod surface

   C. subcooled nucleate boiling

   D. saturated nucleate boiling

158. Two reactors, A and B, are operating at rated power with neutron flux radially peaked in the center of each core. Reactors A and B are identical except that Reactor A has core orificing and Reactor B does not.

   Compared to Reactor B, Reactor A will have the __________ critical power and the __________ core differential pressure.

   A. highest; lowest
   B. lowest; lowest
   C. highest; highest
   D. lowest; highest

159. The reactor is shutdown at 400 psia during a maintenance outage when all forced decay heat removal is lost. Which one of the following will enhance natural circulation within the reactor vessel?

   A. Increasing reactor vessel water level above the steam separators.

   B. Increasing reactor vessel pressure to 500 psia.

   C. Decreasing reactor vessel water level to just above the top of the core.

   D. Decreasing reactor vessel pressure to 300 psia.

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 32, page 380.

2. C

In the nucleate boiling range, the formation of bubbles occurs upon nuclei, such as solid particles or gas absorbed on the surface, or gas dissolved in the liquid.

Reference 32, page 380.

3. A

In the nucleate boiling range, the formation of bubbles occurs upon nuclei, such as solid particles or gas absorbed on the surface, or gas dissolved in the liquid.

Reference 32, page 380.

4. D

In the nucleate boiling range, the formation of bubbles occurs upon nuclei, such as solid particles or gas absorbed on the surface, or gas dissolved in the liquid.

Reference 32, page 380.

5. B

In film boiling, liquid does not contact the hot surface. Heat transfer is poor, and the temperature of the hot surface increases to a level at which radiation becomes the dominant heat transfer mechanism.

Reference 57, chapter 8, page 12.

6. D

Forced convection provides a greater coolant flow rate, increasing the rate of heat transfer for a given temperature difference. Nucleate boiling increases heat transfer by removing heat of vaporization from the hot surface and by agitating the stagnant fluid film.

Reference 57, chapter 9, page 15.

7. C

Reference 57, chapter 9, page 15.

8. D

Reference 57, chapter 9, page 8.

9. C

Reference 57, chapter 9, page 8.

10. A

Reference 17, pages 198 through 301.

11.

The onset of nucleate boiling improves heat transfer through three mechanisms:

a. When the liquid 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, reducing its thickness. A thinner laminar layer means better heat transfer.

Reference 73, page 3-75.

12. 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 push into area vacated by bubbles.

Reference 17, pages 198 through 301.

13. B

Reference 17, pages 198 through 301.

14. D

Nucleate boiling improves heat transfer by removing latent heat of vaporization, sensible heat and by the rapid mixing of coolant by steam bubbles.

Reference 17, pages 198 through 301.

15. D

Reference 17, pages 198 through 301

16. D

Reference 49, pages 7-5 and 7-6.

17. C

Reference 49, pages 7-5 and 7-6.

18.

Natural convection flow occurs in a system when heating takes place in one part of the system. When the fluid is heated, its density decreases, causing it to tend to rise. If a flow path exists, the hotter fluid will rise while colder, denser fluid flows down. The fluid flowing up and away from the heat source carries that heat away.

Reference 57, page 9-116.

19. D

Reference 41, pages 3 through 12.

20. B

Reference 16, chapter 7.

21. B

Reference 09, pages 7-5 and 7-6.

22. A

Reference 57, chapter 9, page 116.

23. A

Reference 57, chapter 9, pages 116 and 117.

24. A

Reference 57, chapter 9.

25. A

Reference 57, chapter 9, page 8.

26. B

Reference 57, chapter 9, pages 8 and 9.

27. C

Reference 57, chapter 9, pages 8 and 9.

28. B

Reference 57, chapter 9, pages 9 and 10.

29.

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 called subcooled nucleate boiling, and it occurs low in the coolant channels during operation.

If the bulk fluid as at saturation temperature, steam bubbles will not condense, but rather will remain as steam in the bulk fluid. This condition is called saturated nucleate boiling or bulk boiling, and it takes place higher in the coolant channels.

During normal operation both conditions exist in a BWR.

Reference 57, chapter 9, pages 8 through 19.

30. A

Reference 49, pages 8-10 through 8-14.

31. C

Reference 49, pages 8-10 through 8-14.

32. B

In Region II, boiling occurs as the heated surface exceeds saturation temperature by a small amount; bubbles then form at nucleation sites. These bubbles may break free of the site and rise. Since bulk fluid temperature (Ts) is less than T_{sat}, the bubbles collapse before they reach the surface.

Reference 49, pages 8-10 through 8-14.

33. C

Reference 49, pages 8-10 through 8-14.

34. B

Reference 49.

35. D

Reference 49.

36. A

Reference 49, pages 8-10 through 8-14.

37. B

Reference 44, page 344.

38. A

Reference 32, pages 380 through 385; and reference 57, chapter 9.

39.

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 78, page 3-77.

40. B

Reference 32, pages 380 through 385; and reference 57, chapter 9.

41. C

Basis of safety limit to protect the clad.

Reference 32, pages 380 through 385; and reference 57, chapter 9.

42. A

Clad surface temperature increases rapidly due to steam blanket insulation effects.

Reference 32, pages 380 through 385; and reference 57, chapter 9.

43. A

Reference 57, chapter 9, pages 10 and 11.

44. A

Reference 57, chapter 9, pages 10 and 11.

45. B

The peak of the curve is where there is a maximum Q/A for (Ts-Tsat) . This point is referred to as the onset of transition boiling (OTB), and is the point where heat flux begins to decrease due to a change in heat transfer mechanisms and transition boiling begins.

Reference 49, page 8-12.

46. B

Reference 49, page 8-12.

47. C

The point of OTB exists at the dividing point between annular flow and mist flow when the fluid film inside the walls of the fuel channel cease to exist. The surface of the fuel is then cooled by the impingement of moisture droplets entrained in the vapor flow.

Reference 49, page 8-12.

48.

When the onset of transition boiling is reached, the liquid that is in contact with the heated surface drys up. The heated surface is then alternately in contact with steam (carrying some moisture droplets that impinge on the surface) and liquid. This alternate drying and re-wetting of the surfaces causes oscillations of the surface temperature, the heat transfer coefficient, and the rate of heat transfer.

Reference 57, page 9-18.

49. A

Reference 49, page 8-12.

50. D

Reference 49, page 8-12.

51. D

Reference 57, chapter 9, page 13.

52. B

Reference 57, chapter 9.

53. B

Reference 17, pages 300 and 301.

54. C

Reference 57, chapter 9.

55. A

Reference 57, chapter 9.

56. B

Reference 57, chapter 9.

57. A

Reference 57, chapter 9.

58.

When transition boiling occurs, the liquid that is in contact with the heated surface drys up. The heated surface is then alternately in contact with steam (carrying some moisture droplets that impinge on the surface) and liquid. This alternate drying and re-wetting of the surfaces causes oscillations of the surface temperature, the heat transfer coefficient, and the rate of heat transfer.

Reference 57, page 9-18.

59. A

Reference 57, chapter 9.

60. B

Reference 17, pages 300 and 301.

61. D

Reference 49, pages 8-8 through 8-14.

62. C

Reference 49, pages 8-8 through 8-14.

63. C

Reference 49, pages 8-8 through 8-14.

64.

When the difference in temperature between the heated surface and the adjacent fluid is very large, a stable film of vapor will blanket the surface. Because the heat transfer coefficient during stable film boiling is very small, the surface temperature will increase to the point that radiation heat transfer will become significant. However, to maintain the same rate of heat transfer as was possible with liquid convection or nucleate boiling requires the surface temperature to be high enough that damage would result.

Reference 57, page 9-12.

65. C

Reference 49, chapter 8.

66. D

Reference 49, pages 8-8 through 8-14.

67. B

Reference 57, chapter 9, page 11.

68. B

Reference 57, chapter 9.

69. A

Reference 49, pages 8-20 through 8-24.

70. C

Reference 49, pages 8-20 through 8-24.

71. C

h_f = saturation enthalpy of fluid at core inlet pressure

= 545.6 BTU/lbm @ 1,020 psia (by interpolation)

h_o = core inlet (jet pump discharge) pressure
= 513.3 BTU/lbm @ 520°F (by interpoation)

core inlet subcooling = $h_f - h_o$
= 545.6 - 513.3 = 32.3 BTU/lbm

Reference 49, pages 8-20 through 8-24.

72. B

Reference 49, pages 8-20 through 8-24.

73.

Core inlet subcooling is defined as the difference between the saturated liquid enthalpy for the core inlet pressure and the enthalpy of the fluid entering the core. Because the actual fluid enthalpy cannot be directly measured, it is calculated using a mass and energy balance of fluid entering and leaving the reactor downcomer. Therefore, factors considered in calculating core inlet subcooling are:

- flow rate and enthalpy of feedwater
- carryunder flow rate and latent heat of vaporization
- flow rate and enthalpy of control rod drive cooling flow
- recirculation pump power
- rate of energy removal by the RWCU system

Reference 57, pages 9-20 through 9-25.

74. A

h_o = actual fluid enthalpy in core inlet plenum (jet pump discharge)

h_f = saturation enthalpy for core inlet pressure

As reactor temperature decreases, h_o decreases.

Assuming h_f does not change:

= core inlet subcooling = $h_f - h_o$
As h_o decreases without h_f changing, core inlet subcooling increases.

Reference 49, pages 8-20 through 8-24.

75. D

Reference 49, pages 8-20 through 8-24.

76. A

Reference 57, chapter 9, pages 20 through 25.

77.

"Carryunder" is defined as saturated steam entrained in the saturated liquid that returns to the reactor vessel downcomer from the steam separator and steam dryers.

Reference 57, chapter 9, page 22.

78. C

Reference 49, page 8-26.

79. C

Reference 49, page 8-26.

80. B

Reference 49, page 8-26.

81. C

Reference 49, page 8-26.

82.

The static quality of a steam-water mixture is defined as the mass of the steam divided by the total mass of the steam and water. The void fraction, however, depends on the relative volume of the steam and liquid; it is defined as the volume of steam divided by the total volume of the steam-water mixture.

Reference 57, page 9-28.

83. B

$V_g = 0.44596\ ft^3/lbm$

$V_f = 0.02159\ ft^3/lbm$

Total Volume =

$(0.44596)(1) + (0.02159)(9) = 0.6403\ ft^3$

$$\text{Void Fraction} = \frac{0.44596}{0.6403} \times 100\% = 69.6\%$$

Reference 49, pages 8-8 through 8-14.

84. D

Reference 49, page 8-26.

85.

Reference 49, page 8-26.

86.

Reference 49, page 8-26.

87. A

Reference 49, page 8-26.

88. C

Reference 49, page 8-32.

89. C

Reference 49, chapter 8.

90. D

985 psig + 15 psi = 1,000 psia

From steam tables, for 1,000 psia saturated steam:

h_f = 542.6 BTU/lbm

h_g = 1192.9 BTU/lbm

h_{fg} = 1192.9 - 542.6
= 650.3 BTU/lbm

To find the quality of fluid with h = 1183 BTU/lbm:

1183 - 542.6 = 640.4

$\frac{640.4}{650.3}$ = .985 or approximately 98 percent

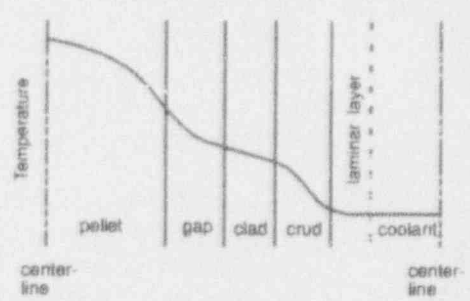
91. D

Reference 57, chapter 9, page 26.

92.

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 3.8-8.

FIGURE 3.8-8



Reference 57, chapter 9, pages 33 and 34.

93. C

Reference 57, chapter 9.

94. B

Reference 49, page 8-25

95. D

Reference 49, pages 8-8 through 8-14.

96. C

Reference 49, page 8-32.

97. C

To prevent fuel rod surface temperatures that may cause the clad material to lose its strength and may buckle or crack, forced circulation is required at all times during BWR power operation.

Reference 49, page 8-32.

98.

Forced reactor recirculation provides the following functions and benefits:

1. Allows higher reactor power levels than with natural circulation alone - The higher flow rates allow for a greater heat transfer rate and thus higher power.
2. Provides a means of controlling reactor power - By varying recirculation flow rate, the operator can move the boiling boundary in the core, affecting reactivity and thus power.
3. Provides a greater margin of safety to the MCPR thermal limit - The greater mass flow rate afforded by forced recirculation means a higher power can be tolerated without experience transition boiling.

Reference 22.1, page 1; and reference 57, page 9-86.

99. A

Reference 49, page 8-32.

100.

Jet pumps are supplied with high-pressure water from the recirculation pumps. A nozzle in the jet pump converts the pressure head into a high-velocity, low-pressure flow. The low pressure developed at the nozzle discharge draws water from the downcomer region into the jet pump, where it mixes with the high-velocity stream. As the mixture of driving and driven water flows through the jet pump diffuser, the velocity head is converted back to a pressure head, creating the driving force for coolant flow up into the core.

Reference 57, page 9-38.

101. D

Reference 57, chapter 9, pages 38 and 39.

102. D

Reference 57, chapter 9, page 34.

103.

Core coolant flow is important to determine because it affects core power and power distribution. In addition, core flow must be known to allow evaluation of technical specification thermal limits.

Reference 57, chapter 9, page 34.

104. A

Reference 57, chapter 9, page 44.

105.

The total single-phase flow resistance is the sum of the following factors:

1. resistance due to friction - This factor depends on the effects of the fuel rod spacers, the surface roughness of the fuel rods and bundle channel, and the flow-to-surface-area ratio. Crud buildup on the surfaces will affect both the roughness and the area ratio.

2. resistance due to acceleration - This factor considers the resistance resulting from a change in fluid velocity (such as occurs when coolant passes from the lower plenum into a fuel bundle).

3. resistance due to local restrictions - This factor considers both turbulence caused by the restriction and its effect on acceleration.

Reference 57, chapter 9, pages 44 and 45.

106. C

Two-phase flow resistance exceeds single-phase resistance by a factor related to the steam quality. For the typical quality of steam exiting a bundle at rated power, this factor is on the order of three to five.

Reference 57, chapter 9, page 46.

107.

Both quality and boiling serve to increase two-phase flow resistance over comparable single-phase flow. The effect of quality is empirically derived and is applied as a coefficient that is multiplied by the single-phase resistance. This coefficient reflects the increased resistance in the two-phase flow.

The boiling process greatly increases the specific volume of the water. Therefore, for the mass flow rate of the fluid exiting a bundle to equal the liquid-only flow entering that bundle, the two-phase mixture must accelerate to a higher velocity. This acceleration produces an additional resistance to flow, which is added to the quality-related resistance described above to determine the total resistance to the two-phase flow.

Reference 57, chapter 9, pages 45 through 48.

108. A.

An increase in bundle power causes quality to increase, which increases flow resistance.

Reference 57, chapter 9, page 51.

109. D

Reference 57, chapter 9.

110. C

Reference 57, chapter 9, page 51.

111. D

Reference 57, chapter 9.

112.

An increase in bundle power causes increased boiling, generating more voids. This increase in voids causes an increase in the bundle's resistance to flow for two reasons:

- Experiments have shown that a bundle's resistance to two-phase flow is greater than with single-phase flow. The resistance increases with increased quality. Therefore, the power increase causes quality to increase, which causes flow resistance to increase.

- The process of creating voids causes the specific volume of the fluid to increase significantly. In order for the mass flow rate to remain relatively constant, the steam-liquid mixture must be accelerated. This acceleration of the mixture up and out of the bundle causes an increased resistance to flow trying to enter the bottom of the bundle.

The overall effect of an increase in bundle power, therefore, is an increase in flow resistance.

Reference 57, pages 9-45 through 9-51.

113. D

Reference 49, pages 8-46.

114. B

Highest flow occurs where the most power is produced, due to orifices giving an artificially high ΔP.

Reference 57, page 9-53.

115. C

Reference 57, page 9-48.

116. D

Least resistance to flow in lower powered bundles.

Reference 57, page 9-48.

117. A

ΔP same from common inlet to common outlet.

Reference 57, page 9-50.

118. A

Density change between downcomer and outlet of bundle creating greatest ΔP.

Reference 57, page 9-51.

119. B

Reference 57, page 9-51.

120. A

Reference 57, page 9-51.

121.

Without orifices, the zero-power pressure drop across the bundles will be identical. However, as power is increased, the high-power bundle will heat the coolant flowing through it more than the low-power bundle. This hotter coolant will exert a greater buoyant force, especially once steam bubbles begin to form. Therefore, the high-power bundle flow will increase more than the low-power bundle.

As power continues to be increased, however, the high-power bundle's quality increases, causing increased flow resistance. This two-phase flow resistance will exceed that in the low-power bundle, causing reduced flow in the high-power bundle.

Reference 57, pages 9-50 and 9-51.

122. D

Reference 57, page 9-51.

123. B

Increased quality increases two phase flow which increases the two phase friction multiplier. Orifices give an artificially high ΔP so the effect of two phase resistance is negligible.

Reference 57, page 9-51.

124. A

Reference 57, page 9-51.

125. B

Less resistance to flow, due to low quality steam in low powered bundles.

Reference 57, page 9-51.

126. C

Large orifices in high powered bundles.

Reference 57, page 9-51.

127.

Without flow orifices, a BWR Aat power would experience the greatest two-phase flow resistance in the bundles with the highest power. This would cause the flow rate in those bundles to be lowest. This combination of high bundle power and low bundle flow would place strict limits on overall core power.

Core orifices are designed to minimize this effect. The orifices are sized to create a large flow resistance, so that the resistance created by two-phase flow will be small in comparison. Therefore, the adverse impact on bundle flow caused by high bundle power is minimized.

Reference 57, page 9-50 through 9-55.

128. A

Core bypass flow cools neutron instrumentation.

Reference 57, chapter 9.

129.

Core bypass flow is that flow of coolant that does not pass along the fuel rods. This coolant instead flows outside the fuel regions and along other core components such as control rods and local power range monitor strings. A major portion of core bypass flow comes through holes cast into the lower tie plate. Other flow paths include: leakage through the channel-lower tie plate joint; the lower tie plate - fuel support joint; the joints between the control rod guide tube and the fuel support, CRD housing, and core support plate; the joints between the core support plate and the shroud and incore drive tubes; and the CRD cooling flow.

Reference 57, pages 9-56 and 9-57.

130. B

Core bypass flow cools neutron instrumentation.

Reference 57, chapter 9.

131. C

Core bypass flow cools neutron instrumentation.

Reference 57, chapter 9.

132. D

Core bypass flow cools neutron instrumentation.

Reference 57, chapter 9.

133. B

Core bypass flow cools neutron instrumentation.

Reference 57, chapter 9.

134. D

Reference 57, chapter 9.

135.

Core bypass flow provides cooling to the control rods, local power range monitor strings, and other core components. This flow must be adequate to prevent excessive voiding in these regions.

Reference 57, chapter 9, page 56.

136. D

Reference 57, chapter 9, page 56.

137. A

Reference 57, chapter 9.

138. B

To create a ΔP due to density change.

Reference 57, page 9-117.

139. C

Reference 57, page 9-116.

140. D

Reference 57, page 9-117.

141. C

Reference 57, page 9-116.

142.

The following conditions must be met for natural circulation to occur:

1. There must be a heat source.

2. There must be a heat sink at an elevation higher than the heat source.

3. There must be a flow path between the heat source and sink.

Reference 78, pages 14-16 and 14-17.

143. A

Reference 57, chapter 9.

144. A

Reference 57, chapter 9.

145. C

At 212 °F pressurization or steam generation begins.

Reference 57, page 9-118.

146. D

In order to get steam out of the drain, stratification would have occurred.

Reference 57, page 9-118.

147. B

Monitoring vessel skin temperature when decay heat is being removed in the normal mode will indicate the approximate vessel water temperature.

Reference 57, page 9-119.

148.

The following problems could result from thermal stratification:

1. Temperature indications (reactor vessel skin, reactor water cleanup system, and reactor recirculation system loop temperatures) will no longer be representative of coolant temperatures in the hottest regions.

2. Inadvertent boiling and vessel pressurization could occur, violating technical specifications and possibly resulting in isolation of low pressure systems for cooling the shutdown reactor.

Reference 57, pages 9-118 and 9-119.

149. C

When thermal stratification occurs, the lower region of the core indicates cooler temperatures, while the surface temperature increases above 212°F causing steam to be produced and pressurizing the system.

Reference 57, pages 9-118 and 9-119.

150.

The following provide indication of natural circulation flow:

1. core plate ΔP greater than zero

2. reactor water level above the bottom of the steam separator pre-dryers

3. no excessive temperature difference between the head flange and the bottom drain line of the reactor vessel

4. positive jet pump flow indications

151. D

The flowpath for natural circulation is created by raising reactor water level above the steam separator pre-dryers.

Reference 57, pages 9-119 and 9-120.

152. C

If water level falls below the level of the steam separators, the flowpath for natural circulation will be interrupted.

Reference 57, page 9-119.

153. D

Reactor water level must be above the steam separators to provide a natural circulation liquid flowpath.

Reference 57, page 9-119.

154. D

A liquid flowpath for natural circulation will only exist after water is raised to above the steam separators.

Reference 57, page 9-119.

155.

Methods for enhancing natural circulation flow include the following:

1. Increase reactor vessel water level to establish a natural circulation flowpath and to increase the static driving head.

2. Increase the thermal driving head by raising the temperature of the heat source (increase reactor power) or reducing the temperature of the heat sink (increasing shutdown cooling flow).

156. D

157. B

158. C

159. 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

Distinguish between boiling processes and other heat transfer mechanisms.

K1.04 Questions 10, 11

Explain the effect of nucleate boiling on convective heat transfer.

K1.04 Questions 8, 9, 12-15

Describe means by which boiling improves convection heat transfer.

K1.06 Questions 16-24

Describe and identify characteristics of convection heat transfer.

K1.07 Questions 25-31, 33-35, 156

Define and discuss nucleate boiling, subcooled nucleate boiling, and bulk boiling.

K1.07 Question 32

Given a pool boiling curve, identify nucleate boiling, subcooled nucleate boiling, and bulk boiling.

K1.08 Question 37

Given a pool boiling curve, identify the point of departure from nucleate boiling.

K1.08 Questions 36, 38, 39

Describe departure from nucleate boiling (DNB).

K1.08 Questions 40-43

Describe the effects of reaching DNB.

K1.09 Question 45

Given a pool curve, determine OTB (onset of transition boiling).

K1.09, 1.17 Questions 44, 46-50, 157

Describe OTB (onset of transition boiling).

K1.10 Questions 51, 52

Identify the phenomenon that occurs when the critical heat flux is reached.

K1.11 Question 53

Given a pool-boiling curve, identify the region where transition (partial film) boiling occurs.

K1.11 Questions 54-59

Describe transition (partial film) boiling.

K1.12 Questions 60-65

Describe film boiling.

K1.12 Question 66

Given a pool-boiling curve, identify the region where film boiling occurs.

K1.17 Question 67, 68

Describe the onset of transition boiling effects on clad temperature and the heat transfer coefficient.

K1.19 Questions 69, 70, 75

Define core inlet subcooling.

K1.19 Question 71

Calculate core inlet subcooling given the appropriate data and steam tables.

K1.19 Questions 72, 73

Describe how core inlet subcooling is calculated.

K1.19 Question 74

Describe the change in core inlet subcooling based on changes in plant parameters.

K1.20 Questions 76, 77

Define and state an effect of carryunder.

K1.21 Questions 78-81

Define void fraction.

K1.21, 1.23 Question 82

Contrast void fraction and static quality.

K1.21 Question 83

Calculate void fraction given the appropriate data and steam tables.

K1.22 Questions 84-89

Explain the term void as applied to core operations.

K1.23 Question 90

Calculate the quality of a steam-liquid mixture.

K1.23 Question 91

Define steam quality.

K1.24 Questions 92, 93

Explain or sketch the temperature profile from the centerline of the fuel pell ˇ to that of the coolant channel.

K1.25 Questions 94-99

Explain the reason for forced core recirculation.

K1.26 Questions 100, 101

Describe the principle of jet pump operation.

K1.27 Questions 102, 103

Explain the necessity for determining core coolant flow.

K1.28 Questions 104, 105

Describe factors affecting single-phase flow resistance.

K1.28 Questions 106, 107

Describe how two-phase flow resistance differs from single-phase flow.

K1.29 Questions 108-113

Describe the effects of increasing bundle power on bundle flow resistance.

K1.30 Questions 114-121, 158

Compare the flow resistance through high-powered bundles to that of low-powered bundles.

K1.31 Questions 122-127

Explain the necessity of core orificing.

K1.32 Questions 128-134

Describe core bypass flow.

K1.33 Questions 135, 137

Explain the importance of adequate core bypass flow.

K1.34 Questions 138-144

Identify the causes for natural circulation in BWRs.

K1.35 Questions 145, 147-149

Describe the effect of thermal stratification.

K1.35 Question 146

Identify the factors affecting thermal stratification.

K1.36 Question 150

Describe indications of natural circulation flow.

K1.36 Questions 151, 152, 159

Identify conditions necessary for natural circulation flow to exist.

K1.37 Questions 153-155

Identify the impact of operator actions on natural circulation flow.

NOTE: Some of the questions that follow deal with concepts and acronyms that might not apply to all BWRs. Plants have modified their thermal limit bases due to the use of barrier fuel or plants that do not use MAPRAT, FLCPR, MFLPD, or K_f should selectively delete or modify questions that do not apply.

1. The radial peaking factor of a fuel bundle is defined as

   A. $\frac{\text{core average bundle power}}{\text{individual bundle power}}$

   B. $\frac{\text{individual bundle power}}{\text{core average bundle power}}$

   C. $\frac{\text{core average bundle power}}{\text{peak nodal power}}$

   D. $\frac{\text{peak nodal power}}{\text{core average bundle power}}$

2. The ratio of individual bundle power to core average bundle power is called the

   A. radial peaking factor
   B. axial peaking factor
   C. critical power ratio
   D. thermal margin ratio

3. Define "radial peaking factor" and explain where in the core it tends be largest.

4. In a reactor operating at full power, the fuel bundle with the highest power has the

   A. largest critical power ratio
   B. largest radial peaking factor
   C. smallest MAPLHGR
   D. smallest LHGR

5. The axial peaking factor depends on the values of __________ power and ________ power.

   A. a particular node's; the core average node's

   B. the peak bundle; the core average bundle

   C. the peak bundle; a particular bundle's

   D. a particular node's; that bundle's

6. The axial peaking factor for a node of a fuel bundle is defined as

   A. $\frac{\text{core average bundle power}}{\text{peak nodal power}}$

   B. $\frac{\text{peak nodal power}}{\text{core average bundle power}}$

   C. $\frac{\text{bundle average nodal power}}{\text{nodal power}}$

   D. $\frac{\text{nodal power}}{\text{bundle average nodal power}}$

7. The ratio of a fuel bundle's peak nodal power to its average nodal power is that bundle's maximum

   A. critical power ratio
   B. thermal margin ratio
   C. axial peaking factor
   D. radial peaking factor

8. Define "axial peaking factor" and explain where in the core it tends to be largest.

9. The local peaking factor is defined as the ratio of the

   A. highest heat flux in a fuel pin node to the nodal average heat flux

   B. average heat flux in a bundle to the highest fluel pin heat flux

   C. lowest heat flux in a fuel pin to the bundle average heat flux

   D. average heat flux in a bundle to the lowest fuel pin heat flux

10. The ratio of the highest heat flux in a fuel pin node to the nodal average heat flux is called the

   A. radial peaking factor
   B. axial peaking factor
   C. local peaking factor
   D. total peaking factor

11. Which fuel rods in a typical fuel bundle tend to have the largest local peaking factor? Why?

12. If the actual and average nodal power, radial factor (RPF), axial peaking factor (APF), and local peaking factor (LPF) for a node are known, the total peaking factor (TPF) can be calculated from which of the following equations?

   A. TPF = RPF + APF + LPF

   B. TPF = RPF x APF x LPF

   C. $TPF = \frac{RPF + APF + LPF}{\text{average nodal power}}$

   D. $TPF = \frac{RPF \times APF \times LPF}{\text{actual nodal power}}$

13. The total peaking factor can be defined as

   A. $\frac{\text{highest pin power in a node}}{\text{average pin power in that node}}$

   B. $\frac{\text{highest pin power in a node}}{\text{average pin power in the core}}$

   C. $\frac{\text{highest pin power in the core}}{\text{average pin power in the highest powered node}}$

   D. $\frac{\text{highest pin power in the core}}{\text{average pin power in the core}}$

14. Define and describe the significance of the total peaking factor.

15. Reactor thermal limits are established to

   A. predict core thermal performance during normal operation

   B. prevent fuel cladding damage

   C. establish the thermal efficiency of the plant

   D. predict the coolant temperature rise across the core

16. 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 the "spent" fuel assemblies

   D. use of zirconium as the clad material

17. Reactor thermal limits are established to

   A. establish 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

18. For each of the three thermal limits, identify whether it is associated with normal operations and transient events or postulated accidents. Explain the objectives for the thermal limits.

19. During normal operation, fuel clad integrity is ensured by

   A. the vessel safety relief valves
   B. control rod drive speed limitations
   C. the use of burnable poisons
   D. not exceeding core thermal limits

20. During normal operation, fuel clad integrity is ensured by

   A. reactor safety systems
   B. not exceeding core thermal limits
   C. the vent stack monitor
   D. the use of burnable poisons

21. The actual rate of heat generation per unit length of a specific fuel rod is a definition of

   A. APLHGR
   B. MCPR
   C. MAPRAT
   D. LHGR

22. Which of the following best describes LHGR?

   A. the specific power in a fuel assembly that could cause some point in the assembly to experience boiling transition

   B. the heat generation per unit length of fuel rod

   C. the total reactor core heat transferred to the reactor coolant

   D. the sum of the exposure of all the fuel rods in the specified bundle at the specific height divided by the number of fuel rods in the fuel bundle

23. Linear heat generation rate is the heat generated

   A. per unit length of fuel rod
   B. in each fuel bundle
   C. that will cause transition boiling
   D. after an accident

24. ________ is defined as the heat generated per unit length of a fuel rod.

   A. minimum critical power ratio

   B. average planar linear heat generation rate

   C. linear heat generation rate

   D. axial peaking factor

25. The linear heat generation rate is defined as

   A. the power level at which the point of adding heat is reached

   B. total heat generated in each fuel bundle

   C. heat generated per unit length of fuel rod

   D. heat generation that will cause transition boiling

26. Linear heat generation rate (LHGR) is the

    A. ratio of the power produced in a given fuel bundle divided by total core thermal power

    B. ratio of the average power per rod divided by the rod power at 100% power

    C. sum of the power produced by all fuel rods in a given fuel bundle at a specific planar cross section

    D. sum of the power per unit area for each unit area of the fuel cladding for a unit length of a fuel rod

27. Define linear heat generation rate (LHGR).

28. The linear heat generation rate (LHGR) is being maintained within the thermal limits of the reactor core if the ratio __________ is being maintained at ________.

    A. LHGR-limit/LHGR-actual; 0.95
    B. LHGR-actual/LHGR-limit; 1.05
    C. LHGR-limit/LHGR-actual; 1.10
    D. LHGR-actual/LHGR-limit; 1.15

29. Maintaining the linear heat generation rate (LHGR) below the technical specification limiting condition for operation (LCO) ensures that

    A. peak cladding temperature (PCT) after the design basis loss of coolant accident will not exceed 2200 °F

    B. during transients, more than 99.97% of the fuel rods are expected to avoid transition boiling

    C. plastic strain (deformation) of the cladding will not exceed 1%

    D. peaking factors will not exceed those assumed in the safety analysis

30. To ensure that fuel cladding plastic strain (deformation) is limited to 1%, which of the following must be maintained within the technical specification limit?

    A. average planar linear heat generation rate (APLHGR)

    B. linear heat generation rate (LHGR)

    C. minimum critical power ratio (MCPR)

    D. maximum fraction of limiting critical power ratio (MFLCPR)

31. The basis for ______ ensures that plastic strain (deformation) of the fuel cladding does <u>not</u> exceed 1%.

    A. linear heat generation rate (LHGR)

    B. average planar linear heat generation (APLHGR)

    C. minimum critical power ratio (MCPR)

    D. maximum fraction of limiting critical power ratio (MFLCPR)

32. Which of the following best explains the basis of the linear heat generation rate limit?

    A. During accident conditions, peak cladding temperature limit is not exceeded.

    B. Transition boiling does not occur.

    C. Axial variations in the linear heat generation rate are kept within limits.

    D. Plastic deformation of the cladding will not exceed 1% during power operation.

33. Describe the limiting condition upon which the linear heat generation rate thermal limit is based and the consequence of exceeding this limit.

34. What is the primary purpose of the linear heat generation rate limit?

    A. to ensure peak cladding temperature is not exceeded during accident conditions

    B. to ensure transition boiling does not occur during accident conditions

    C. to ensure plastic deformation of the cladding will not exceed 1% during power operation

    D. to ensure the maximum heat generated is kept below the licensed power limit

35. Which one of the following limits takes into consideration fuel-pellet swell effects?

    A. Average gain adjustment factor (AGAF)

    B. Maximum linear heat generation rate (MLHGR)

    C. Rated thermal power (RTP)

    D. Minimum critical power ratio (MCPR)

36. If the LHGR limiting condition for operation is exceeded, the most probable type of fuel failure is cladding

    A. gross failure due to a lack of cooling

    B. cracking due to inadequate cooling of the clad

    C. embrittlement due to excessive oxidation

    D. cracking due to high stress

37. Which of the following thermal limits protects the fuel clad from cracking or rupturing due to plastic strain (deformation)?

    A. maximum average planar linear heat generation rate (MAPLHGR)

    B. minimum critical power ratio (MCPR)

    C. linear heat generation rate (LHGR)

    D. maximum average planar ratio (MAPRAT)

38. Explain how and why fuel failure could occur if the linear heat generation rate thermal limit is exceeded.

39. The linear heat generation rate (LHGR) thermal limit is set primarily to prevent which of the following?

    A. onset of transition boiling

    B. clad cracking due to excessive stress

    C. exceeding the license power limit

    D. exceeding the minimum critical power ratio

40. Fuel clad cracking due to excessive stress (plastic deformation) is prevented by <u>not</u> exceeding which of the following thermal limits?

    A. linear heat generation rate (LHGR)

    B. maximum average planar linear heat generation rate (MAPLHGR)

    C. minimum critical power ratio (MCPR)

    D. maximum average planar ratio (MAPRAT)

41. Which of the following modes of fuel failure results from exceeding the linear heat generation rate thermal limit?

    A. 1% plastic strain is exceeded.

    B. Transition boiling occurs in the bundle.

    C. Peak cladding temperature exceeds 2200°F.

    D. Reactor power exceeds the license limits.

42. Operating the reactor below the linear heat generation rate (LHGR) thermal limit prevents

    A. cracking of the fuel cladding due to high stress from fuel pellet expansion

    B. melting of the fuel cladding due to a cladding temperature exceeding 2,200 °F during an anticipated transient without a scram (ATWAS)

    C. cracking of the fuel cladding due to the lack of cooling caused by departure from nucleate boiling

    D. gross fuel cladding failure due to a lack of cooling following a loss of coolant accident (LOCA)

43. The fraction of the limiting power density (FLPD) is equal to

    A. $\frac{\text{LHGR (actual)}}{\text{LHGR (limit)}}$

    B. $\frac{\text{LHGR (design)}}{\text{LHGR (actual)}}$

    C. $\frac{\text{LHGR (design) x TPF}}{\text{LHGR (actual)}}$

    D. $\frac{\text{LHGR actual}}{\text{LHGR (limit) x TPF}}$

44. Maximum fraction of limiting power density (MFLPD) is defined as ________ and must be maintained __________.

    [LHGR is the linear heat generation rate.]

    A. LHGR-actual/LHGR-limit; <1
    B. LHGR-actual/LHGR-limit; >1
    C. LHGR-limit/LHGR-actual; <1
    D. LHGR-limit/LHGR-actual; >1

45. Which of the following describes FLPD?

    A. $\frac{\text{APLHGR}}{\text{MAPLHGR}_{\text{limit}}}$

    B. $\frac{\text{MCPR x } K_f}{\text{bundle CPR}}$

    C. $\frac{\text{critical power}}{\text{actual bundle power}}$

    D. $\frac{\text{LHGR}}{\text{LHGR}_{\text{limit}}}$

46. Actual linear heat generation rate (LHGR) divided by the technical specification limit for LHGR is a description of

    A. APLHGR
    B. MAPRAT
    C. FLPD
    D. MCPR

47. Which of the following defines core maximum fraction of limiting power density (CM-FLPD)?

    A. $\frac{\text{core maximum LHGR}}{\text{LHGR limit}}$

    B. $\frac{\text{LHGR limit}}{\text{core maximum LHGR}}$

    C. $\frac{\text{core maximum CPR}}{\text{bundle CPR}}$

    D. $\frac{\text{bundle CPR}}{\text{core maximum CPR}}$

48. Core maximum linear heat generation rate (LHGR) divided by the technical specification limit for LHGR is a description of

   A. APLHGR
   B. CMFLPD
   C. MCPR
   D. MAPRAT

49. Define the fraction of limiting power density (FLPD) and explain its relationship to the linear heat generation thermal limit.

50. ________ is defined as the ratio of linear heat generation rate (LHGR) in a node to the LHGR limit.

   A. Minimum critical power ratio
   B. Maximum critical generation ratio
   C. Fraction of limiting power density
   D. Fraction of linear heat generation rate

51. The amount of heat stored in the fuel as a result of the operating power history prior to a scram, describes the

   A. average planar linear heat generation rate (APLHGR)

   B. maximum average planar linear heat generation rate (MAPLHGR)

   C. preconditioning interim operating management recommendations (PCIOMR)

   D. maximum average planar linear heat generation rate limit (MAPRAT)

52. Which of the following thermal limits protects the fuel from reaching 2200°F following a loss-of-coolant accident (LOCA)?

   A. linear heat generation rate (LHGR)

   B. total peaking factor

   C. average planar linear heat generation rate (APLHGR)

   D. rated thermal power (RTP)

53. The sum of the linear heat generation rates for all the fuel rods in the specified bundle at the specified height divided by the number of fuel rods in the fuel bundle is a definition of

   A. APLHGR
   B. MAPRAT
   C. MCPR
   D. MFLPD

54. The average of the linear heat generation rates of the fuel rods in a bundle at a particular node is a description of

   A. MLFPD
   B. MAPRAT
   C. MCPR
   D. APLHGR

55. The ________ limit is used to ensure that the peak cladding temperature following a LOCA does not exceed 2200°F.

   A. fraction of limiting power density (FLPD)

   B. linear heat generation rate (LHGR)

   C. average planar linear heat generation rate (APLHGR)

   D. minimum critical power ratio (MCPR)

56. The best explanation of average planar linear heat generation rate (APLHGR) is

    A. actual heat flux for a fuel bundle
    B. average heat flux for a fuel bundle
    C. actual heat flux for an individual pin
    D. average heat flux for a node of fuel

57. Define average planar linear heat generation rate.

58. Maintaining the average planar linear heat generation rate (APLHGR) below the technical specification limiting condition for operation (LCO) ensures that

    A. peak clad temperature after the design basis loss of coolant accident will not exceed 2200°F

    B. during transients, more than 99.9% of the fuel rods are expected to avoid transition boiling

    C. plastic strain (deformation) of the cladding will not exceed 1%

    D. axial peaking factors will not exceed those assumed in the safety analyses

59. To ensure that peak cladding temperatures after the design basis loss of coolant accident will not exceed 2200°F, which of the following must be maintained below the technical specification limit?

    A. linear heat generation rate (LHGR)

    B. average planar linear heat generation rate (APLHGR)

    C. minimum critical power ratio (MCPR)

    D. maximum fraction of limiting critical power ratio (MFLCPR)

60. The basis for the _____ thermal limit ensures that peak cladding temperature after the design basis loss of coolant accident will not exceed 2200°F.

    A. minimum critical power ratio (MCPR)

    B. maximum fraction of limiting critical power ratio (MFLCPR)

    C. linear heat generation rate (LHGR)

    D. average planar linear heat generation rate (APLHGR)

61. Describe the limiting condition upon which the average planar linear heat generation rate thermal limit is based and explain the consequence of exceeding the limit.

62. The peak clad temperature limit of 2200°F after a design basis loss of coolant accident (LOCA) will be maintained by not exceeding the limit on

    A. minimum critical power ratio (MCPR)

    B. linear heat generation rate (LHGR)

    C. average planar linear heat generation rate (APLHGR)

    D. maximum fraction of limiting critical power ratio (MFLCPR)

63. If the average planar linear heat generation rate (APLHGR) limit were exceeded and the design basis loss of coolant accident (LOCA) occurred, what would be the failure mechanism of the fuel?

    A. fuel pellet expansion beyond design

    B. gross cladding failure due to lack of cooling

    C. fuel clad cracking due to transition boiling

    D. fuel clad cracking due to high stress

64. If the average planar linear heat generation rate (AP' HGR) limiting condition for operation is exceeded, the most probable type of fuel clad failure during a design basis loss of cooling accident is

   A. gross failure due to exceeding 2200°F peak clad temperature

   B. cracking due to excessive cooling of the clad

   C. embrittlement due to excessive oxidation

   D. cracking due to high stress

65. Which of the thermal limits protects the fuel clad from gross failure due to a lack of cooling (exceeding 2200°F)?

   A. minimum critical power ratio (MCPR)

   B. average planar linear heat generation rate (APLHGR)

   C. maximum fraction of limiting critical power ratio (MFLCPR)

   D. linear heat generation rate (LHGR)

66. The thermal limit for average planar linear heat generation rate is set to prevent which of the following?

   A. onset of transition boiling

   B. exceeding the license power limit

   C. gross clad failure during a loss of coolant accident

   D. operating outside the bounds set by the General Electric critical quality boiling length correlation (GEXL)

67. Gross fuel clad failure due to a lack of cooling (exceeding 2200°F peak cladding temperature) is prevented by not exceeding which of the following thermal limits?

   A. minimum critical power ratio (MCPR)

   B. linear heat generation rate (LHGR)

   C. maximum fraction of limiting critical power ratio (MFLCPR)

   D. average planar linear heat generation rate (APLHGR)

68. The most probable cause of a gross fuel failure due to a lack of cooling during a design basis loss of coolant accident would be a result of exceeding

   A. MFLCPR
   B. APLHGR
   C. LHGR
   D. MCPR

69. Operating the reactor within limits defined by the maximum average planar linear heat generation rate (MAPLHGR) prevents

   A. exceeding 1% plastic strain in the cladding

   B. exceeding peak fuel temperature of 2200 °F

   C. the onset of transition boiling in the upper core

   D. exceeding a peak clad temperature of 2200 °F

70. Explain how and why fuel failure could occur if the average planar linear heat generation rate thermal limit is violated.

71. Explain what is represented by MAPLHGR (maximum average planar linear heat generation rate).

72. Which of the following defines MAPRAT?

    A. $\frac{APLHGR}{MAPLHGR_{limit}}$

    B. $\frac{MCPR}{\text{bundle CPR}}$

    C. $\frac{MAPLHGR_{limit}}{APLHGR}$

    D. $\frac{\text{bundle CPR}}{MCPR}$

73. Average planar linear heat generation rate divided by the maximum planar linear heat generation rate limit is a description of which of the following?

    A. MFLCPR
    B. MCPR
    C. MFLPD
    D. MAPRAT

74. The ratio $\frac{APLHGR}{MAPLHGR_{limit}}$ is a definition for which of the following?

    A. maximum fraction of limiting critical power ratio (MFLCPR)

    B. maximum average planar ratio (MAPRAT)

    C. maximum fraction of limiting power density (MFLPD)

    D. minimum critical power ratio (MCPR)

75. When the plant process computer indicates a MAPRAT less than 1.0, you

    A. have <u>not</u> exceeded your LHGR limit
    B. <u>have</u> exceeded your LHGR limit
    C. have <u>not</u> exceeded your APLHGR limit
    D. <u>have</u> exceeded your APLHGR limit

76. A MAPRAT greater than 1.0 is indicative of exceeding

    A. average nodal power (kw/ft) limit
    B. linear heat generation rate limit
    C. maximum power density in a bundle
    D. maximum total bundle power

77. As the core ages, the MAPLHGR limit

    A. decreases continually

    B. increases continually

    C. decreases initially, then increases with exposure

    D. increases initially, then decreases with exposure

78. Explain how and why the MAPLHGR limit changes as a core ages.

79. At low core exposures, the MAPLHGR limit increases with increasing exposure. What is the reason for this increase?

    A. Fuel pellet cracking brings the fuel pellets into contact with the fuel cladding, thereby increasing the fuel-to-clad heat transfer coefficient.

    B. Fission product gases that are building up in the fuel pin have a lower heat transfer coefficient than the helium fill gas, thereby decreasing the fuel cladding temperature.

    C. Fissionable elements in the fuel pellet are being depleted, thereby reducing the heat that is transferred to the fuel cladding.

    D. Fission product gases that are building up in the fuel pin have lower specific volume than the helium fill gas, thereby resulting in lower cladding stresses.

80. At high core exposures, the MAPLHGR limit decreases with increasing core exposure. What is the reason for this decrease?

    A. Buildup of krypton and xenon gas reduces stress on cladding, thereby reducing MAPLHGR limit.

    B. Zirconium-steam chemical reaction in cladding becomes less reactive with increased core age.

    C. Fission product gases leak out of control rods, thereby reducing heat transfer coefficient.

    D. Fission product gases have a lower heat transfer coefficient than the helium fill gas.

81. In which of the following conditions would radiative heat transfer be the significant method of heat transfer in a fuel bundle?

    A. just prior to a reactor scram on high power

    B. following a loss of "forced" flow through the bundle

    C. just prior to a reactor scram on high pressure

    D. following a loss of coolant accident

82. During a design basis loss of coolant accident (LOCA), the fuel bundles in the core are completely uncovered. During this time, which heat transfer mechanism in the fuel bundle is the most significant?

    A. steam cooling
    B. radiative
    C. convective
    D. conductive

83. 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

84. Describe the condition that could cause radiation heat transfer to become the most significant method of heat transfer in a fuel bundle. What thermal limit is based on this condition.

85. Explain how fuel centerline temperature varies with different values of thermal conductivity of the fuel pellet. Assume the heat generation rate and pellet surface temperature remain constant.

86. If the thermal conductivity of a fuel pellet decreases, the fuel centerline temperature for a given power output

    A. increases due to increased resistance to heat flow

    B. decreases due to decreased resistance to heat flow

    C. decreases due to the reduced heat transfer coefficient

    D. does not change

87. If the fuel pellet thermal conductivity and pellet surface temperature remain constant, a linear increase in heat generation rate (power) causes __________ in fuel centerline temperature.

    A. an exponential increase
    B. an exponential decrease
    C. a linear increase
    D. a linear decrease

88. Refer to the drawing of a fuel rod and coolant flow channel at beginning of core life (see figure 3.9-1).

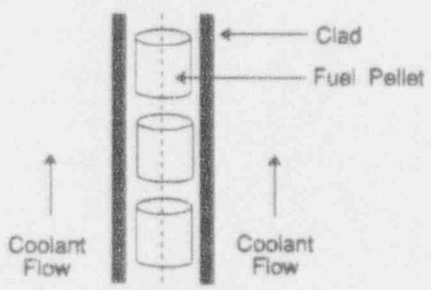
Given the following initial core parameters;

Reactor power	=	100%
$T_{coolant}$	=	500°F
$T_{fuel\ centerline}$	=	3000°F

What would the fuel centerline temperature be if, [illegible] 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 3.9-1



Fuel Rod and Coolant Flow Channel

89. That bundle power that could cause onset of transition boiling to occur at some point in that bundle is the

A. critical power
B. rated thermal power
C. linear heat generation rate
D. limiting control rod pattern

90. Which of the following describes critical power?

A. the highest value of linear heat generation that exists in the core for any one bundle

B. the highest power fuel bundle in the core

C. the power level when the reactor becomes critical

D. the bundle power that could cause onset of transition boiling to occur at some point in that bundle

91. ______ power is defined as the bundle power at which onset of transition boiling occurs somewhere in the bundle.

A. transition
B. critical
C. boiling transition
D. safety bundle

92. In the definition of critical power, "transition boiling" refers to

A. when the point of adding heat is reached

B. when bulk coolant temperature reaches saturation temperature

C. oscillating heat transfer between vapor blanketing and nucleate boiling

D. the transition from single-phase convective heat transfer to nucleate boiling

93. Define the term "critical power."

CORE THERMAL LIMITS
Questions

94. Critical power is defined as the bundle power at which

    A. onset of transition boiling occurs somewhere in the bundle

    B. 1% plastic strain is achieved

    C. the threshold of the pellet/cladding interaction is reached

    D. 2200°F peak cladding temperature is reached

95. Which of the following is defined as the fuel bundle power level at which onset of transition boiling occurs?

    A. critical power
    B. MCPR
    C. MFLPD
    D. LHGR

96. The fuel bundle power that would cause the onset of transition boiling at some point in the fuel bundle is the best definition of which of the following terms?

    A. maximum core power

    B. critical power

    C. maximum fraction of limiting power density

    D. maximum power density

97. The fuel bundle power that would cause the onset of transition boiling at some point in the fuel bundle is the

    A. technical specification limit

    B. critical power

    C. maximum fraction of limiting power density

    D. maximum power density

98. Define the term "critical power ratio."

99. The formula $\frac{\text{bundle critical power}}{\text{actual bundle power}}$ defines which of the following terms?

    A. LHGR
    B. CPR
    C. MFLCPR
    D. APLHGR

100. The power in a fuel assembly necessary to cause some point to experience boiling transition, divided by the actual assembly operating power, is a definition of

    A. MFLCPR
    B. LHGR
    C. CPR
    D. APLHGR

101. Which one of the following expressions best describes the critical power ratio?

    A. $\frac{\text{critical power}}{\text{actual bundle power}}$

    B. $\frac{\text{actual bundle power}}{\text{critical power}}$

    C. $\frac{\text{average bundle power}}{\text{critical power}}$

    D. $\frac{\text{critical power}}{\text{average bundle power}}$

102. Which of the following best describes critical power ratio?

A. individual bundle power divided by core average bundle power

B. individual nodal power divided by average nodal power

C. average critical power divided by average bundle power

D. critical power divided by actual bundle power

103. The ratio of the bundle power required to produce onset of transition boiling somewhere in the bundle to the actual bundle power describes

A. linear heat generation ratio
B. total peaking factor ratio
C. transition boiling ratio
D. critical power ratio

104. "Transients caused by a single operator error or equipment malfunction shall be limited so that, considering uncertainties in monitoring the core operating state, more than 99.9% of the fuel rods are expected to avoid boiling transition." This is the basis for which of the following limits?

A. minimum critical power ratio (MCPR)

B. linear heat generation rate (LHGR)

C. average planar linear heat generation rate (APLHGR)

D. fraction of limiting power density (FLPR)

105. Explain the basis for the critical power ratio thermal limit.

106. The basis for minimum critical power ratio (MCPR) is to

A. not exceed a 1% plastic strain (deformation) which could lead to clad cracking

B. maintain peak clad temperature below 2200°F after the design basis loss of coolant accident

C. prevent exceeding the license power limit which could lead to fuel failure and/or loss of core cooling geometry

D. ensure more than 99.9% of the fuel rods are expected to avoid boiling transition during anticipated transients

107. Maintaining the minimum critical power ratio (MCPR) above the technical specification limit ensures that

A. more than 99.9% of the fuel rods are expected to avoid boiling transition during anticipated transients

B. plastic strain (deformation) will not exceed a total of 1%

C. peak cladding temperature (PCT) will remain below 2200°F after the design basis loss of coolant accident

D. total peaking factors will not exceed those assumed in the safety analysis report

108. The primary purpose of establishing a limiting condition for operation for the critical power ratio is to

A. maintain adequate margin to prevent fuel clad cracking due to stress

B. maintain adequate margin to the onset of transition boiling

C. limit the rate of power change during critical operation

D. limit the critical bundle power variation across the core

109. In order to maintain an adequate margin to the onset of transition boiling, limiting conditions for operating are placed upon which one of the following?

A. linear heat generation rate
B. total peaking factors
C. critical power ratio
D. fraction cf limiting power density

110. Which thermal limit is maintained to ensure the core does not experience transition boiling?

   A. minimum critical power ratio (MCPR)

   B. maximum average planar linear heat generation ratio (MAPLHGR)

   C. maximum fraction of limiting power density (MFLPD)

   D. APLHGR-to-MAPLHGR ratio (MAPRAT)

111. Which one of the following adverse conditions is avoided by maintaining the minimum critical power ratio (MCPR) within specified values (limits)?

   A. excessive plastic strain on cladding
   B. excessive cladding creep
   C. excessive decay heat in the fuel
   D. excessive cladding temperatures

112. If the MCPR limiting condition for operation is exceeded, the most probable type of fuel failure is

   A. gross failure due to clad melting

   B. cracking due to excessive thermal stress

   C. embrittlement due to excessive oxidation

   D. cracking due to pellet/clad differential expansion

113. Which of the following thermal limits protects the fuel clad from cracking due to excessive thermal stress (lack of cooling)?

   A. maximum average planar linear heat generation rate (MAPLHGR)

   B. maximum average planar ratio (MAPRAT)

   C. minimum core flow rate (MCFR)

   D. minimum critical power ratio (MCPR)

114. The thermal limit for minimum critical power ratio is set primarily to prevent which of the following?

   A. exceeding the license power limit

   B. exceeding the maximum planar ratio

   C. clad cracking due to excessive thermal stress

   D. clad cracking due to excessive embrittlement

115. Explain how and why fuel damage could occur if the critical power ratio thermal limit is violated.

116. Fuel clad cracking due to excessive thermal stress (lack of cooling) is prevented by <u>not</u> exceeding which of the following thermal limits?

   A. minimum core flow rate (MCFR)

   B. minimum critical power ratio (MCPR)

   C. maximum average planar linear heat generation rate (MAPLHGR)

   D. maximum fraction of limiting power density (MFLPD)

117. Which of the following best describes the mode of fuel failure when the critical power ratio is exceeded?

   A. cracking due to excessive thermal stress on cladding

   B. differential pellet/clad thermal expansion

   C. embrittlement due to excessive oxidation

   D. tramp uranium release due to high clad temperatures

118. Which of the following best describes the purpose for limiting the minimum critical power ratio (MCPR)?

   A. protects the fuel from clad rupture due to plastic deformation

   B. limits peak cladding temperature under accident conditions

   C. maintains adequate margin to avoid transition boiling

   D. smallest value in the core for total power in a bundle

119. Which of the following limits must not be exceeded to avoid onset of transition boiling?

   A. maximum fraction limiting power density
   B. minimum critical power ratio
   C. maximum total peaking factor
   D. minimum pre-conditioning power level

120. In the definition of minimum critical power ratio (MCPR), the critical power ratio refers to

   A. actual bundle power
   B. local pin power
   C. average nodal power
   D. total core power

121. Which of the following best describes the ratio on which the minimum critical power ratio (MCPR) sets a limit?

   A. $\frac{\text{critical power}}{\text{actual nodal power}}$

   B. $\frac{\text{critical power}}{\text{average nodal power}}$

   C. $\frac{\text{critical power}}{\text{average bundle power}}$

   D. $\frac{\text{critical power}}{\text{actual bundle power}}$

122. Minimum critical power ratio is monitored and evaluated to

   A. maintain nucleate boiling and avoid the onset of transition boiling

   B. limit the amount of heat that must be removed following a loss of coolant accident

   C. prevent fuel clad cracking due to high stress from pellet expansion

   D. decrease the effects of pellet/cladding interaction during power operation

123. Define the term "minimum critical power ratio."

124. Which of the following limits or conditions is avoided by maintaining the minimum critical power ratio (MCPR) within specified values?

    A. 1% plastic strain on cladding

    B. 99.9% of the fuel pins in the core not experiencing transition boiling during a transient

    C. gross cladding failure due to lack of cooling

    D. fuel cladding cracking due to high stress

125. Which one of the following parameter changes will cause a decrease in the critical power of a fuel bundle?

    A. the coolant temperature entering the bundle decreases

    B. the coolant pressure decreases

    C. the coolant flow through the bundle increases

    D. the local peaking factor decreases

126. Which of the following best describes the effect of core inlet subcooling on critical power?

    A. as inlet subcooling increases, critical power decreases

    B. as inlet subcooling increases, critical power increases

    C. as inlet subcooling increases, critical power initially increases, then decreases

    D. inlet subcooling changes have no effect on critical power

127. An increase in core inlet subcooling causes critical power to

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

128. When core inlet subcooling _____, critical power increases.

    A. remains constant
    B. decreases
    C. increases
    D. fluctuates

129. Which statement best describes how critical power is affected by core inlet subcooling?

    A. Changes in inlet subcooling do not affect critical power.

    B. An increase in inlet subcooling causes critical power to decrease.

    C. An increase in inlet subcooling causes critical power to fluctuate.

    D. An increase in inlet subcooling causes critical power to increase.

130. Explain how and why a change in inlet subcooling affects the critical power for a bundle.

131. A step increase in core inlet subcooling causes critical power to

    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

132. Which one of the following parameter changes will cause an increase in the critical power of a fuel bundle?

    A. The subcooling of the coolant entering the bundle decreases.

    B. The local peaking factor increases.

    C. The coolant flow through the bundle increases.

    D. The axial power peak shifts from the bottom to the top of the bundle.

133. Which of the following best describes the effect of core mass flow rate on critical power?

    A. Changes in mass flow rate have no effect on critical power.

    B. As the mass flow rate increases, critical power decreases.

    C. As the mass flow rate increases, critical power increases briefly, then decreases.

    D. As the mass flow rate increases, critical power increases.

134. A decrease in core mass flow rate causes critical power to

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

135. An increase in core mass flow rate causes critical power to

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

136. Explain how and why a change in coolant mass flow rate affects the critical power for a bundle.

137. A step increase in core mass flow rate causes critical power to

    A. decrease to a new, lower value

    B. remain constant

    C. increase to a new, higher value

    D. increase temporarily, then return to its initial value

138. How is critical power affected by a core mass flow rate increase?

    A. Changes in mass flow rate do not affect critical power.

    B. Critical power will increase temporarily, then return to its initial value.

    C. Critical power will increase.

    D. Critical power will decrease.

139. A step decrease in reactor pressure will cause critical power to

    A. increase temporarily, then return to its initial value

    B. decrease to a new lower value

    C. increase to a new higher value

    D. decrease temporarily, then return to its initial value

140. Which of the following best describes the effect of reactor pressure on critical power?

  A. Changes in pressure have no effect on critical power.

  B. As pressure decreases, critical power decreases.

  C. As pressure decreases, critical power increases briefly, then decreases.

  D. As pressure decreases, critical power increases.

141. Explain how and why a change in pressure affects a bundle's critical power.

142. A reactor pressure increase causes critical power to decrease because the latent heat of vaporization

  A. increases
  B. decreases
  C. remains constant
  D. is delayed

143. How is critical power affected by an increase in reactor pressure?

  A. critical power will decrease

  B. critical power will increase

  C. critical power will fluctuate

  D. changes in pressure do not affect critical power

144. A decrease in reactor pressure will cause critical power to

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

145. Critical power is expected to _____ as local power distribution (local peaking factors) _________.

  A. remain constant, decreases
  B. decrease, decreases
  C. increase, increases
  D. decrease, increases

146. Explain how and why a change in local peaking factors affects a bundle's critical power.

147. Which of the following best describes the effects of local power distribution (local peaking factors) on critical power?

  A. Changes in the local power distribution have no effect on critical power.

  B. As the local power decreases, critical power decreases.

  C. As the local power decreases critical power increases.

  D. As the local power decreases, critical power increases briefly, then decreases.

148. An increase in local power (local peaking factors) will cause critical power to

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

149. How is critical power affected by a decrease in local power (local peaking factors)?

  A. Critical power will increase.
  B. Critical power will decrease.
  C. Critical power will fluctuate.
  D. Critical power will remain constant.

150. As the local power (local peaking factors) increases, critical power is expected to

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

151. Explain how and why the axial power distribution affects a bundle's critical power.

152. Which of the following best describes the effects of axial power distribution on critical power?

    A. A top-peaked power distribution causes critical power to be lower.

    B. A bottom-peaked power distribution causes critical power to be lower.

    C. A change in axial power distribution causes critical power to fluctuate.

    D. Changes in axial power distribution do not affect critical power.

153. How is critical power affected when the axial power distribution in a fuel bundle shifts from bottom-peaked to top-peaked?

    A. Criti al power increases to a new, higher value.

    B. Critical power increases temporarily, then returns to its initial value.

    C. Critical power decreases to a new, lower value.

    D. Critical power decreases temporarily, then returns to its initial value.

154. Critical power _____ as the axial power distribution shifts from bottom-peaked to top-peaked.

    A. remains constant
    B. fluctuates
    C. increases
    D. decreases

155. As the axial power distribution becomes top-peaked, critical power

    A. becomes higher
    B. becomes lower
    C. remains constant
    D. fluctuates

156. If the axial power distribution shifts from bottom-peaked to top-peaked, how does this change affect critical power?

    A. It has no effect on critical power.
    B. Critical power will increase.
    C. Critical power will decrease.
    D. Critical power will fluctuate.

157. ________ is the factor that adjusts the minimum critical power ratio (MCPR) for operation at less than rated core flow.

    A. K_f
    B. K
    C. K^m
    D. K_r^p

158. For what operational condition does the flow biasing correction factor, K_f, adjust the minimum critical power ratio (MCPR)?

    A. operation at greater than rated steam flow

    B. operation at less than rated feedwater flow

    C. operation at less than rated core flow

    D. operation at greater than rated core flow

159. For what operational condition does the flow biasing correction factor (K_f) adjust the minimum critical power ratio (MCPR)?

   A. operation at less than rated steam flow

   B. operation at greater than rated steam flow

   C. operation at less than rated core flow

   D. operation at greater than rated core flow

160. Which of the following thermal limits is adjusted by the flow biasing correction factor K_f for less-than-rated core flow?

   A. MCPR
   B. FLPD
   C. LHGR
   D. APLHGR

161. What is the purpose for the flow biasing correction factor K_f (flow-biased MCPR operating limit for BWR-6 plants) as it relates to MCPR operating limits?

162. What factor is applied to adjust the minimum critical power ratio for operation at less than 100% reactor recirculation flow?

   A. K_r
   B. K_p
   C. K_m
   D. K_f

163. Operation at _______ is the condition for which the correction factor, K_f, is applied to the minimum critical power ratio (MCPR).

   A. less than rated steam flow
   B. less than rated core flow
   C. less than rated feedwater flow
   D. greater than rated feedwater flow

164. Fraction of limiting critical power ratio (FLCPR) is defined as

   A. $\dfrac{\text{critical power ratio limit}}{\text{bundle critical power ratio}}$

   B. $\dfrac{\text{bundle critical power ratio}}{\text{critical power ratio limit}}$

   C. $\dfrac{\text{critical power}}{\text{actual bundle power}}$

   D. $\dfrac{\text{actual bundle power}}{\text{critical power}}$

165. "The ratio of the flow adjusted, steady-state minimum critical power ratio to the actual bundle critical power ratio," is the definition of

   A. CMCPR
   B. MAPRAT
   C. FLCPR
   D. MFLPD

166. The purpose of maintaining the fraction of limiting critical power ratio less than one is to

   A. preclude fuel clad cracking due to excessive plastic strain on the clad

   B. maintain adequate margin to avoid the onset of transition boiling

   C. limit peak cladding temperatures to less than 2200°F during accidents

   D. limit actual pin power to node average power to limit fuel failure during transients

167. The purpose of maintaining the critical power ratio greater than 1.0 is to

A. prevent fuel clad cracking during analyzed accident conditions

B. avoid the onset of transition boiling during expected operating transients

C. limit peak cladding temperatures to less than 2200°F during analyzed accident conditions

D. melting at the fuel pellet centerline during expected operating transients

168. In order to avoid conditions that could lead to the onset of transition boiling, adequate margin from these conditions is maintained by a

A. FLPD greater than 1.0
B. FLPD less than 1.0
C. FLCPR greater than 1.0
D. FLCPR less than 1.0

169. $\frac{\text{critical power ratio limit}}{\text{bundle critical power ratio}}$ is the definition of

A. FLPD
B. FAPLHGR
C. CHFR
D. FLCPR

170. Define FLCPR.

171. Describe the fuel thermal time constant.

172. The fuel thermal time constant is defined as the amount of time required for

A. the fuel to change its rate of heat generation by 63%

B. the fuel centerline temperature to undergo 63% of its total change resulting from a given power change

C. the fuel cladding temperature to undergo 63% of its total change resulting from a given change in fuel temperature

D. reactor power to undergo 63% of its total change resulting from a given reactivity insertion

173. The fuel thermal time constant reflects the

A. thermal energy stored in the fuel at rated power

B. time required for power to be generated in the fuel for an instantaneous increase in fission rate

C. number of megawatt-days per ton of fuel a new fuel bundle can produce

D. time required for the cladding temperature to undergo 63% of its total change due to a change in fuel temperature

174. Given the following information for steady-state values before and after an instantaneous decrease in fuel temperature:

initial fuel centerline temperature = 630°F
final fuel centerline temperature = 580°F
initial cladding temperature = 558°F
final cladding temperature = 540°F
fuel thermal time constant = 6 seconds

Six seconds after the power decrease,

A. cladding temperature will be 551°F

B. cladding temperature will be 547°F

C. fuel centerline temperature will be 612°F

D. fuel centerline temperature will be 598°F

175. A step increase in reactor power results in a step increase in fuel centerline temperature from 1300 to 1350°F. Initial fuel cladding surface temperature is 550° F and the fuel heat transfer thermal time constant is 6 seconds.

After the power increase, how much time will be required for the fuel cladding surface temperature to increase to its new steady state value?

A. 5 to 7 seconds
B. 17 to 19 seconds
C, 28 to 30 seconds
D. 59 to 61 seconds

176. Explain what takes place in pellet-clad interaction.

177. Which of the following is <u>not</u> an initiating factor for pellet-clad-interaction (PCI)?

A. presence of embrittling species
B. stress
C. neutron embrittlement
D. susceptible material

178. One of the factors needed to cause pellet-clad-interaction (PCI) is

A. fission product gas buildup in fuel rods

B. fuel rod oxidation

C. differential expansion between fuel and fuel rod

D. hydrogen embrittlement of fuel rod

179. Stress is one of the factors that can cause pellet-clad-interaction (PCI). How is this stress generated?

A. fission product gas buildup in fuel, which swells the fuel

B. fuel rod oscillations caused by two-phase flow

C. fuel rod creep caused by fast flux

D. differential expansion between fuel and fuel rod

180. Chemical embrittlement of fuel cladding is one of the factors of pellet-clad-interaction (PCI). Which of the following chemicals can cause this to occur?

A. iodine and cesium
B. indium and cesium
C. iodine and cadmium
D. indium and cadmium

181. _______ of fuel rods is one of the major initiating factors that causes pellet-clad-interaction (PCI).

A. fast neutron embrittlement
B. chemical embrittlement
C. chemical oxidation
D. chemical corrosion

182. The presence of embrittling species/isotopes is one of the initiating factors of pellet-clad-interaction (PCI). Where do those embrittling species/isotopes come from?

   A. erosion products contained in coolant

   B. corrosion products on core components

   C. impurities remaining from manufacturing

   D. products generated during the fission process

183. The presence of embrittling isotopes is one of the initiating factors of pellet-clad-interaction (PCI). From where do these embrittling isotopes come?

   A. chemicals from reactor coolant migrate through cladding

   B. produced as corrosion products inside fuel rod

   C. introduced during manufacturing process

   D. generated during the fission process

184. Where do the embrittling isotopes that help initiate pellet-clad-interaction (PCI) come from?

   A. produced as corrosion products inside fuel rod

   B. migrate from reactor coolant into cladding

   C. introduced during the manufacturing process

   D. created during fission of the reactor fuel

185. Which of the following events best describes how pellet-clad-interaction (PCI) could occur during reactor operation?

   A. slow power increase
   B. rapid power increase
   C. slow power decrease
   D. rapid power decrease

186. With regard to pellet-clad-interaction (PCI), embrittling species/isotopes ________ the ________ of the cladding metal.

   A. reduce, ductility
   B. increase, ductility
   C. reduce, toughness
   D. increase, toughness

187. Which of the following is <u>not</u> a factor in initiating pellet-clad-interaction (PCI)?

   A. rapid power increases
   B. core age
   C. fuel ro hydrogen concentration
   D. fuel pellet cracking

188. Slowly increasing reactor power will help to minimize the ______ factor associated with pellet-clad-interaction (PCI).

   A. pressure
   B. stress
   C. chemical
   D. material

189. The threshold power for pellet clad interaction (PCI) decreases as fuel exposure increases because

   A. heat-transfer capability is reduced by buildup of fission products and crud layers

   B. the cladding suffers chemical embrittlement due to fission products

   C. pellet densification occurs due to fuel burnout

   D. zirconium hydride is reduced with fuel burnup

190. List four factors affecting the incidence of pellet-clad interaction.

191. The purpose of the gap between a fuel pellet and the surrounding cladding is to

A. aid in manufacturing the fuel rod

B. provide a collection volume for fission product gases

C. maintain the design fuel thermal conductivity throughout the fuel cycle

D. accommodate differential expansion of the pellet and cladding to preclude excessive cladding stress

192. The pellet-to-clad gap in fuel rod construction is designed to

A. decrease fuel pellet densification and elongation

B. reduce fission produce gas pressure buildup

C. increase heat transfer

D. reduce internal clad strain

193. Select the purpose of the gap between the fuel pellet and the clad.

A. prevent contact between the fuel pellets and the clad

B. reduce diffusion of fission product gases through the clad and into the RCS

C. increase heat transfer from the fuel pellet to the clad

D. accommodate differential expansion between the fuel pellets and the clad

194. The differential diametrical expansion of the fuel pellets and cladding is accommodated by

A. clad swelling
B. pellet densification
C. pellet-clad interaction
D. pellet-to-clad gap

195. What is the purpose of the pellet-to-clad gap?

196. What are three possible effects of fuel densification?

197. Fuel densification can result in

A. pellet-clad interaction
B. increased thermal conductivity
C. increased $U0_2$ melting point
D. increased linear heat generation rate

198. A combination of local power spikes, increased LHGR, and cladding creep collapse could result from

A. fuel densification
B. fuel melting
C. pellet-clad interaction
D. increased thermal conductivity

199. Select the cause for the reduction in the size of the gap between the fuel pellet and the clad over core life.

A. Contraction of the clad due to zirconium hydriding.

B. Expansion of the fuel pellets due to fission produce buildup.

C. Contraction of the clad due to fuel rod internal vacuum.

D. Expansion of the fuel pellets due to densification.

200. What are the effects of iodine and cadmium on pellet-clad interaction (PCI)?

A. They are used in the manufacture of barrier fuel to inhibit PCI.

B. They are embrittling agents that contribute to PCI.

C. They contribute to fuel densification, reducing PCI by reducing cladding stress.

D. They have no effect on PCI.

201. Identify two embrittling agents that contribute to pellet-clad interaction.

A. iodine and samarium
B. cadmium and iodine
C. copper and cadmium
D. xenon and copper

202. Studies of nuclear fuel rod damage revealed that two essential criteria for pellet-cladding interaction (PCI) fuel damage are cladding stress and a chemical embrittling fission product interaction between two chemical agents and the zircalloy cladding.

What are the two (2) chemical agents?

A. iodine and cadmium
B. cadmium and bromine
C. bromine and ruthenium
D. ruthenium and iodine

203. What are the effect of iodine and cadmium on pellet-clad interaction?

204. What is the purpose PCIOMR?

205. How does operation within the restrictions of PCIOMR minimize pellet-clad interaction?

206. What parameter is measured to ensure the core does not exceed the thermal limit associated with minimizing gross cladding failure due to heatup following a LOCA?

A. MCPR
B. LHGR
C. MAPLHGR
D. MFLPD

207. What parameter is measured to ensure the core does not exceed the thermal limit associated with avoiding the boiling transition?

A. MCPR
B. MAPLHGR
C. MFLPD
D. MAPRAT

208. What parameter is measured to ensure the core does not exceed the thermal limit associated with fuel clad cracking due to high stress?

A. FLCPR
B. LHGR
C. CMAPR
D. MAPRAT

209. The three thermal limits, MCPR, LHGR, and APLHGR, are each concerned with the power produced by the fuel, but each consider a different "subdivision" or "unit" of fuel in the core (e.g., core, bundle, pin, node, pellet, etc.). State what "unit" of fuel each of these limits is based on and whether the limit considers total, average, or localized power production in that unit.

210. What is the limiting condition for the thermal limit associated with fuel cladding cracking due to lack of cooling?

A. clad temperature in excess of 2200°F
B. 1% plastic strain on cladding
C. avoiding boiling transition
D. excessive fuel pin swelling

211. What is the limiting condition for the thermal limit associated with cladding failure due to temperature cycling?

A. clad temperature in excess of 2200°F
B. 1% plastic strain on cladding
C. avoiding boiling transition
D. excessive fuel pin swelling

212. During a design basis loss of coolant accident (LOCA), gross cladding failure is precluded by the ______ thermal limit.

A. PCIOMR
B. LHGR
C. CPR
D. APLHGR

213. The ______ limit provides protection during a loss of coolant accident.

A. critical heat flux

B. linear heat generation rate

C. average planar linear heat generation rate

D. minimum critical power ratio

214. Gross fuel cladding failure during a design basis loss of coolant accident is prevented by adhering to the _______ limit.

A. LHGR
B. APLHGR
C. MCPR
D. PCIOMR

215. The core thermal limit APLHGR protects the core during which of the following accidents

A. loss of coolant
B. continuous rod withdrawal
C. control rod drop
D. loss of reactor feedwater

216. Gross cladding failure during a design basis loss of coolant accident would be more likely to occur if

A. MAPRAT was greater than 1
B. MAPRAT was less than 1
C. MFLPD was greater than 1
D. MFLPD was less than 1

217. With the reactor at 60% power, the recirculation loop flow suddenly increases. The limiting thermal limit for these conditions is

A. MCPR
B. LHGR
C. APLHGR
D. PCIOMR

218. During a rapid increase in core flow , the most limiting thermal limit is

A. total peaking factor (TPF)

B. critical power ratio (CPR)

C. average planar linear heat generation rate (APLHGR)

D. linear heat generation rate (LHGR)

219. During a rapid increase in core flow, the thermal limit most limiting would be

A. PCIOMR
B. MCPR
C. APLHGR
D. LHGR

220. Which of the following would result in the greatest decrease in CPR?

   A. a step decrease in core flow from 100% to 50%

   B. a ramp decrease in core flow from 100% to 50%

   C. a step increase in core flow from 50% to 100%

   D. a ramp increase in core flow from 50% to 100%

221. If power is increased from 50% to 100% by increasing core flow, critical power ratio will

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

222. The flow biasing correction factor (K_f) is used to increase the _____ thermal limit as a function of _____.

   A. CPR, core flow
   B. CPR, reactor power
   C. LHGR, core flow
   D. LHGR, reactor power

223. For a turbine trip from 100% power without bypass valve actuation, CPR will initially

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

224. With the reactor at 100% power, reactor pressure suddenly increases. The limiting thermal limit for these conditions is

   A. LHGR
   B. APLHGR
   C. CPR
   D. PCIOMR

225. For a turbine trip without bypass valve actuation, the limiting thermal limit would be

   A. PCIOMR
   B. LHGR
   C. APLHGR
   D. CPR

226. For a decrease in feedwater temperature, CPR will

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

227. With the reactor at 100% power, an event that increases core inlet subcooling would have the greatest effect on which of the following thermal limits?

   A. LHGR
   B. MPKF
   C. APLHGR
   D. CPR

228. At low reactor power, a sudden increase in feedwater flow would _____ core inlet subcooling and decrease _____.

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

229. Which of the following statements is correct for an injection of cold water into the reactor at power?

   A. Critical power increases, bundle power increases and CPR increases.

   B. Critical power increases, bundle power increases and CPR decreases.

   C. Critical power decreases, bundle power decreases and CPR decreases.

   D. Critical power decreases, bundle power decreases and CPR increases.

230. For a loss of feedwater heating transient, the most limiting thermal limit would be

A. APLHGR
B. LHGR
C. CPR
D. core thermal power

231. If cold water is suddenly injected into the reactor vessel while operating at 50% power, critical power (critical heat flux) will ________ and bundle power will _______.

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

232. Which one of the following is responsible for the clad failure caused by operating the reactor above the limit for linear heat generation rate?

A. Fission product gas expansion causes clad internal design pressure to be exceeded.

B. The zirconium-water reaction causes accelerated oxidation of the clad at high temperatures.

C. Corrosion buildup on the fuel clad surface reduces heat transfer and promotes transition boiling.

D. The difference between thermal expansion rates of the fuel pellets and the clad causes severe clad stress.

233. The plant is operating at 60% reactor power. Which one of the following will result in the highest critical power ratio? (Assume neutron flux distribution does not change.)

A. 25% power increase using only recirculation flow

B. 25% power increase using only control rods

C. 25% power decrease using only recirculation flow

D. 25% power decrease using only control rods

234. Reactor power will be closer to critical power if the reactor is operating with a _________-peaked axial power distribution and a __________ recirc flow.

A. top; low
B. top; high
C. bottom; low
D. bottom; high

235. Bundle critical power ratio (CPR) must be maintained ________ 1.0 to prevent fuel damage caused by a rapid increase in the temperature of the ____________.

A. greater than; fuel pellets
B. less than; fuel pellets
C. greater than; fuel clad
D. less than; fuel clad

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 57, page 9-61.

2. A

Reference 57, page 9-61.

3.

The radial peaking factor is defined as

$$\frac{\text{individual bundle power}}{\text{core average bundle power}}$$

Because the thermal neutron flux tends to be greatest near the center of the core, the power of bundles near the center tends to be greatest. Therefore, the radial peaking factor tends to be largest in a center fuel bundle.

Reference 57, page 9-61.

4. B.

Radial peaking factor is the bundle power divided by core average bundle power. The bundle with the highest power therefore has the largest RPF.

Reference 57, page 9-61.

5. D

Reference 57, page 9-62.

6. D

Reference 57, page 9-62.

7. C

Reference 57, page 9-62.

8.

The axial peaking factor is defined as the power of a node of interest divided by the average nodal power of the fuel bundle. It reflects the power distribution along the axis of the core.

Even with control rods inserted to shape the axial flux and maximize burnout, the axial water density differences cause the peaking factors to be greatest in the lower part of the core.

Reference 57, page 9-62.

9. A

Reference 57, page 9-63.

10. C

Reference 57, page 9-63.

11.

The corner rods adjacent to the water gap left by a withdrawn control rod tend to have the largest local peaking factor. This is because of the peak in thermal neutron flux (and hence power) that occurs where moderator (water) has replaced poison (control rod). The corner fuel rods see the increased neutron flux from two water gaps resulting from withdrawal of the cruciform control rod.

Reference 57, page 9-63.

12. B

Reference 57, page 9-65.

13. B

Reference 57, page 9-66.

14.

The total peaking factor (TPF) for a node is defined as the highest pin power in that node divided by the core average pin power. If the core average pin power is known (and it can be calculated using a heat balance), multiplying it by the TPF yields the highest power produced in a pin in a given node. Multiplying the average pin power times the maximum TPF in the core yields the power produced in the highest powered pin in the core. If the core is operated to maintain this highest powered pin within safe limits, the entire core will be protected from exceeding limits.

Reference 57, page 9-66.

15. B

Reference 17, page 397.

16. A

Reference 17, page 397.

17. B

Reference 17, page 397.

18.

Two limits are established to ensure this objective is met: The linear heat generation rate limit is associated with normal operation and transient events and avoids excessive cladding stress by limiting expansion of fuel pellets. The minimum critical power ratio is also associated with normal operation and transient events and maintains adequate heat transfer by avoiding transition and film boiling.

The objective of the thermal limit set for postulated accidents (the MAPLHGR limit) is to maintain design core geometry by minimizing gross cladding failure following a loss of coolant accident.

Reference 57, pages 9-67 and 9-68.

19. D

Reference 17, page 397.

20. B

Reference 17, page 397.

21. D

The technical specification definition for LHGR (linear heat generation rate) is the heat generation per unit length of fuel rod.

Reference 66, section 1.0.

22. B

The definition of LHGR is the heat generation per unit length of fuel rod.

Reference 66, section 1.0; and reference 26, chapter 9.

23. A

24. C

25. C

Reference 66, section 1.0.

26. D

Reference 66, section 1.0.

27.

The linear heat generation rate is the heat generated per unit length of fuel rod, normally expressed in kw/ft. It can also be defined as the integral of the heat flux over the heat transfer area of a unit length of fuel rod.

Reference 66, page 1-3.

28. C

Reference 66

29. C

The LCO for LHGR is based upon not exceeding 1% plastic strain of the fuel cladding.

Reference 66, bases section; and reference 26, page 9-75.

30. B

MLHGR is calculated to prevent exceeding 1% plastic strain of the fuel cladding.

Reference 66, bases section; and reference 26, page 9-75.

31. A

The LCO for LHGR is based upon not exceeding 1% plastic strain of the fuel cladding.

Reference 66, bases section; and reference 26, page 9-75.

32. D

Imposing a limit on LHGR ensures that the 1% plastic strain is not exceeded during "normal" operation.

Reference 66, bases section; and reference 26, page 9-75.

33.

The LHGR limit is set to ensure that 1% plastic strain on the cladding is not exceeded to prevent cladding cracking caused by fuel pellet expansion. As power is increased, fuel pellet temperature increases, causing the pellet to expand. Because the cladding expands more slowly, the pellet could contact the cladding and put excessive stress on it, causing the cladding to crack.

Reference 57, page 9-75.

34. C

Imposing a limit on LHGR ensures that the 1% plastic strain is not exceeded during "normal" operation.

Reference 66, bases section; and reference 26, page 9-75.

35. B

Reference 66

36. D

Exceeding the LHGR limit could cause excessive plastic strain, which could cause clad cracking.

Reference 26, page 9-124.

37. C

Exceeding the LHGR limit could cause excessive plastic strain which could cause clad cracking or rupture.

Reference 26, page 9-124.

38.

The LHGR limit is set to prevent the clad from experiencing more than 1% plastic strain. If the LHGR limit is exceeded, the power produced in a length of fuel rod could be sufficient to increase fuel pellet temperature enough to cause excessive fuel pellet expansion. This expanded pellet could contact the cladding and exert pressure on it, causing excessive tensile stress in the cladding. If this stress is sufficient to cause plastic strain of the cladding to exceed 1%, the cladding could crack, allowing direct contact between the fuel pellets and the coolant and releasing fission product gases.

Reference 57, page 9-75.

39. B

The LHGR limit prevents excessive clad deterioration, which could lead to stress cracking.

Reference 26, chapter 9.

40. A

Exceeding the LHGR limit can cause clad cracking due to excessive stress.

Reference 26, chapter 9.

41. A

The mode of fuel failure when looking at LHGR is 1% plastic strain.

Reference 57, page 9-75.

42. A

Differential expansion between the fuel pellet and clad is the concern underlying the LHGR limit.

Reference 57, page 9-75.

43. A

Reference 57, pages 9-76 and 9-77.

44. A

Reference 57, page 9-76

45. D

FLPD is defined a $\frac{LHGR}{LHGR_{limit}}$

Reference 26, page 9-76.

46 . C

FLPD is defined as $\frac{LHGR}{LHGR_{limit}}$

Reference 26, page 9-76.

47. A

CMFLPD is defined as $\frac{\text{core maximum LHGR}}{LHGR_{limit}}$

Reference 26, page 9-76.

48. B

CMFLPD is defined as $\frac{\text{core maximum LHGR}}{LHGR_{limit}}$

Reference 26, page 9-76.

49.

The FLPD is defined as the actual highest LHGR of a fuel pin in a node divided by the LHGR limit. If the value of FLPD for every node in the core is less than one, the LHGR limit is not being violated.

Reference 57, pages 9-75 and 9-76.

50. C

$$FLPD = \frac{\text{LHGR actual}}{\text{LHGR limit}}$$

Reference 26, page 9-76.

51. A

Reference 57, page 9-70.

52. C

Reference 57, page 9-71.

53. A

Reference 26, page 9-70.

54. D

Reference 26, page 9-70; and reference 25, page 8-7.

55. C

The basis of the APLHGR limit is to maintain average planar heat flux low enough that post-LOCA peak cladding temperature does not exceed 2200°F.

56. D

A "node" is a quantified segment/section of a fuel bundle typically defined to be six inches in length.

Reference 26, page 9-70.

57.

The average planar linear heat generation rate (APLHGR) is defined as the sum of the linear heat generation rates of all fuel rods in a node divided by the number of fuel rods in the node. APLHGR represents the average power passing through a one-foot length of fuel rod in a particular node.

Reference 57, page 9-70; and reference 66, page 1-1.

58. A

Maintaining APLHGR below the LCO limit ensures that peak cladding temperature (PCT) after the design basis loss of coolant accident will not exceed 2200 °F.

Reference 26, page 9-70.

59. B

The APLHGR LCO ensures PCT would not exceed 2200 °F after a design basis LOCA.

Reference 66, section 3.0 bases; and reference 26, chapter 9.

60. D

Maintaining APLHGR below the LCO limit ensures that post-LOCA PCT will not exceed 2200°F.

Reference 66, section 3.0 bases; and reference 26, chapter 9.

61.

The APLHGR thermal limit is set such that cladding temperatures following the postulated design basis LOCA will not exceed 2,200°F. It is established to maintain acceptable core geometry following a loss of coolant accident (LOCA). This is accomplished by avoiding gross cladding failure that could result from excessive heat energy stored in the fuel due to operation at high power levels.

In a LOCA that uncovers the fuel, heat transfer from fuel will be largely by radiation to surrounding materials. Because this means of heat transfer is less efficient than convection, fuel and cladding temperatures will increase. Gross failure of the cladding could occur if cladding temperatures exceed 2,200°F.

Reference 57, pages 9-69 and 9-70; and reference 66, page B 3/4 2-1.

62. C

Peak cladding temperature following a LOCA is maintained less than 2200°F by keeping average nodal power during power operation less than the APLHGR limit.

Reference 26, chapter 9.

63. B

Peak cladding temperature following a LOCA is maintained less than 2200°F by keeping average nodal power during power operation less than the APLHGR limit.

Reference 26, chapter 9.

64. A

Exceeding APLHGR can lead to gross clad failure during a LOCA because PCT may exceed 2200°F.

Reference 26, chapter 9.

65. B

Exceeding APLHGR limit could cause gross clad failure during a LOCA by exceeding 2200°F PCT.

Reference 26, chapter 9.

66. C

Gross cladding failure could result during a LOCA if APLHGR limit is exceeded.

Reference 26, chapter 9.

67. D

Gross clad failure during a LOCA can be caused by exceeding the APLHGR LCO.

Reference 26, chapter 9.

68. B

Gross cladding failure is prevented by placing a limit on average pin power such that peak cladding temperature following a LOCA does not exceed 2200°F.

Reference 26, chapter 9.

69. D

Reference 26, page 9-70.

70.

The APLHGR thermal limit is established to limit the average power in each node sufficiently that a design basis LOCA would not result in gross cladding failure.

In a design basis LOCA, the core is quickly voided of liquid. As a result, convection heat transfer will be replaced by less efficient radiation heat transfer, and fuel and cladding temperatures will rise. The greater the pre-LOCA linear heat generation rate, the greater this temperature rise will be. If the cladding temperature reaches 2,200°F, gross cladding failure can occur.

The APLHGR limit is set prevent post-LOCA cladding temperature from exceeding 2,200°F.

Reference 57, pages 9-68 through 9-71.

71.

MAPLHGR stands for the maximum average planar linear heat generation rate. It is the largest value of the APLHGR of all nodes in the core. If the MAPLHGR is maintained below the APLHGR thermal limit, gross cladding failure will not occur as a result of the design basis loss of coolant accident.

Reference 57, pages 9-70 and 9-71.

72. A

MAPRAT is defined as $\frac{ALPHGR}{MAPLHGR_{limit}}$

Reference 26, page 9-74.

73. D

MAPRAT is definod as $\frac{ALPHGR}{MAPLHGR_{limit}}$

Reference 26, page 9-74.

74. B

MAPRAT is defined as $\frac{ALPHGR}{MAPLHGR_{limit}}$

Reference 26, page 9-74.

75. C

MAPRAT refers to APLHGR not LHGR. Exceeding a limit means MAPRAT exceeds 1.0.

Reference 26, page 9-74.

76. A

MAPRAT refers to APLHGR, not LHGR. MAPRAT refers to a node, not a bundle.

77. D

Initially, the MAPLHGR limit increases because less heat is stored in the fuel (due to the swelling of fuel pellets causing them to more closely contact the cladding). Eventually, however, the limit decreases due to the combined effects of the following:

1) Fission product gas buildup reduces the heat transfer coefficient of the pellet-to-clad gap.

2) Fission product gas buildup increases stress on the cladding, making clad cracking more likely in the event of dryout.

3) Crud buildup inhibits heat transfer, increasing energy stored in the fuel.

4) Decay energy from fission product buildup increases, increasing energy stored in the fuel.

5) The local peaking factor decreases, decreasing the disparity between highest powered and average pin powers and degrading the ability of the highest powered pin to radiate its energy.

Reference 57, page 9-73.

78.

Initially, the MAPLHGR limit increases because less heat is stored in the fuel (due to the swelling of fuel pellets causing them to more closely contact the cladding). Eventually, however, the limit decreases due to the combined effects of the following:

1) Fission product gas buildup reduces the heat transfer coefficient of the pellet-to-clad gap.

2) Fission product gas buildup increases stress on the cladding, making clad cracking more likely in the event of dryout.

3) Crud buildup inhibits heat transfer, increasing energy stored in the fuel.

4) Decay energy from fission product buildup increases, increasing energy stored in the fuel.

5) The local peaking factor decreases, decreasing the disparity between highest powered and average pin powers and degrading the ability of the highest powered pin to radiate its energy.

Reference 57, page 9-73.

79. A

Reference 57

80. D

Reference 57.

81. D

Reference 57, page 8-12.

82. B

Reference 57, page 8-12.

83. A

Reference 57, page 8-12.

84.

In a design basis loss of coolant accident (LOCA), water in and around the fuel bundles is quickly lost. As a result, the fuel is steam-blanketed, and metal-to-steam convection heat transfer takes place. However, the low thermal conductivity of steam compared to liquid water reduces the rate of heat transfer from the fuel. Fuel temperature therefore increases enough that radiation becomes the dominant mode of heat transfer.

The APLHGR thermal limit is established to limit cladding temperature in a LOCA to less than 2,200°F, thereby avoiding gross cladding failure.

Reference 78, page 3-92; and reference 57, page 9-68.

85.

The mathematical relationship between pellet centerline temperature, heat transfer rate, and thermal conductivity is a complex one due to the geometry (cylindrical) of the pellet and the fact that heat is generated throughout, as well as transferred through, the pellet. In simple terms, the relationship can be expressed:

$$\dot{Q} \propto K (T_{cl} - T_{ps})$$

where

$\dot{Q}$ = heat generation rate

K = pellet thermal conductivity

T_{cl} = pellet centerline temperature

T_{ps} = pellet surface temperature

If $\dot{Q}$ and T_{ps} are held constant, then centerline temperature increases when the thermal conductivity decreases and vice versa.

Reference 78, page 3-53.

86. A

Reference 57, page 8-5.

87. C

Reference 78, page 3-53.

88. D

Reference 57

89. A

Critical power is that bundle power that could cause onset of transition boiling to occur at some point in that bundle.

Reference 26, chapter 9.

90. D

Critical power is that bundle power that could cause onset of transition boiling to occur at some point in that bundle.

Reference 26, chapter 9.

91. B

Critical power is that bundle power that could cause onset of transition boiling to occur at some point in that bundle.

Reference 57, page 9-85.

92. C

Reference 57, page 9-85.

93.

Critical power is defined as the power of a fuel bundle that results in the onset of transition boiling at some point in the bundle.

Reference 57, page 9-85.

94. A

Critical power is that bundle power that could cause onset of transition boiler to occur at some point in that bundle.

Reference 57, page 9-85.

95. A

Reference 57, page 9-85.

96. B

Reference 57, page 9-85.

97. B

Reference 57, page 9-85.

98.

The critical power ratio is defined as the bundle power that will cause onset of transition boiling to occur somewhere in the bundle divided by the actual bundle power:

$$CPR = \frac{\text{critical power}}{\text{actual bundle power}}$$

Reference 57, page 9-92.

99. B

CPR is defined as $\frac{\text{bundle critical power}}{\text{actual bundle power}}$

Reference 66, section 1.0; and reference 26, pages 9-77 through 9-93.

100. C

CPR is defined as $\frac{\text{bundle critical power}}{\text{actual bundle power}}$

Reference 66, section 1.0; and reference 26, pages 9-77 through 9-93.

101. A

$\text{Critical power ratio} = \frac{\text{bundle critical power}}{\text{actual bundle power}}$

Reference 57, page 9-92.

102. D

$\text{Critical power ratio} = \frac{\text{bundle critical power}}{\text{actual bundle power}}$

Reference 57, page 9-92.

103. D

The wording describes the critical power ratio:

$$\frac{\text{bundle critical power}}{\text{actual bundle power}}$$

Critical power is the power required to produce onset of transmission boiling somewhere in the bundle.

Reference 57, page 9-92.

104. A

Reference 66, section 2.0 bases; and reference 26, chapter 9.

105.

The limits on minimum critical power ratio are established to avoid onset of transition boiling in 99.9% of the fuel rods during any predictable transient caused by a single operator error or equipment malfunction. The limits are selected recognizing the uncertainties involved in monitoring the core operating state.

Reference 57, page 9-93.

106. D

The basis for MCPR is to ensure more than 99.9% of the fuel rods are expected to avoid boiling transition during anticipated transients.

Reference 66, section 2.0 bases; and reference 26, chapter 9.

107. A

The basis for MCPR is to ensure that more than 99.9% of the fuel rods are expected to avoid boiling transition during anticipated transients.

Reference 66, section 2.0 bases; and reference 26, chapter 9.

108. B

Critical power ratio looks at maintaining adequate margin to the onset of transition boiling.

109. C

Critical power ratio looks at maintaining adequate margin to the onset of transition boiling.

110. A

Reference 66

111. D

Reference 66

112. B

Exceeding MCPR could cause clad cracking due to excessive thermal stress because of excessive clad temperature oscillations.

Reference 26, chapter 9.

113. D

Exceeding MCPR could cause clad cracking due to excessive thermal stress.

114. C

Exceeding MCPR could lead to clad cracking due to excessive thermal stress.

Reference 26, chapter 9.

115.

The critical power ratio thermal limit is established to prevent onset of transition boiling (OTB) anywhere in the core. Thus, a violation of the limit means OTB could occur. If OTB did occur at some location(s) in the core, the rate of heat transfer from the cladding to the coolant would decrease sharply, causing a rapid increase in fuel and cladding temperature. The result could be cracking of the cladding due to the lack of cooling.

Reference 57, pages 9-68, 9-69, and 9-93.

116. B

Exceeding MCPR could lead to clad cracking due to excessive thermal stress.

Reference 26, chapter 9.

117. A

When the critical power ratio is exceeded and fuel failure occurs, it is due to the excessive thermal stress on the cladding.

Reference 57, chapter 9.

118. C

MCPR is the limiting ratio of critical power to actual bundle power. The MCPR is specified to maintain adequate margin to the onset of transition boiling.

Reference 57, page 9-93.

119. B

Reference 57, page 9-93.

120. A

MCPR is the minimum critical power ration (CPR). CPR is the critical power divided by the actual bundle power.

Reference 57, pages 9-92 and 9-93.

121. D

Reference 57, pages 9-92 and 9-93.

122. A

Reference 57, page 9-93.

123.

Minimum critical power ratio is defined as the smallest value of critical power ratio existing in the core. That is, it is the smallest value in the core of the ratio of the bundle power that would cause onset of transition boiling to the actual bundle power.

Reference 57, pages 9-92 and 9-93; and reference 66, page 1-3.

124. B

Reference 57, page 9-93.

125. A

Reference 57, page 9-85.

126. B

As inlet subcooling increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-85.

127. A

As inlet subcooling increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-85.

128. C

As inlet subcooling increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-85.

129. D

As inlet subcooling increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-85.

130.

With greater inlet subcooling, the coolant is farther from saturation as it enters a fuel bundle. Therefore, a greater transfer of heat, resulting from a higher bundle power, is needed to bring the coolant temperature to saturation, and a correspondingly higher power would be required to induce transition boiling. Thus, an increase in subcooling causes an increase in the critical power.

Reference 57, page 9-85.

131. A

As inlet subcooling increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-85.

132. C

As the mass flow rate increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-86.

133. D

As the mass flow rate increases, a higher power can be attained without causing transition boiling.

Reference 57, page 9-86.

134. B

A decrease in mass flow rate causes the power at which transition boiling begins to decrease.

Reference 57, page 9-86.

135. A

An increase in mass flow rate causes critical power to increase.

Reference 57, page 9-86.

136.

As coolant mass flow rate increases, the coolant enthalpy rise for a given bundle power is reduced. This moves the conditions in the bundle further from the possibility of transition boiling. A greater bundle power would therefore be needed to cause OTB. Hence, the critical power increases with an increase in coolant mass flow rate.

Reference 57, page 9-86.

137. C

A step increase in mass flow rate causes critical power to increase to a new, higher value.

Reference 57, page 9-86.

138. C

Critical power will increase when mass flow rate increases.

Reference 57, page 9-86.

139. C

A decrease in pressure causes an increase in critical power. It is a linear relationship. The change is due to the change in the latent heat of vaporization (h_{fg}).

Reference 57, page 9-87.

140. D

A decrease in pressure causes an increase in critical power. It is a linear relationship. The change is due to the change in the latent heat of vaporization (h_{fg}).

Reference 57, page 9-87.

141.

The latent heat of vaporization decreases as pressure increases. Therefore, it takes less power to vaporize saturated water at higher pressure. As a result, the bundle power necessary to cause transition boiling is less, and the critical power is lower at high pressure than at lower pressure.

Reference 57, page 9-87.

142. B

An increase in pressure causes a decrease in critical power. It is a linear relationship. The change is due to the change in the latent heat of vaporization (h_{fg}).

Reference 57, page 9-87.

143. A

An increase in pressure causes a decrease in critical power. It is a linear relationship. The change is due to the change in the latent heat of vaporization (h_{fg}).

Reference 57, page 9-87.

144. A

A decrease in pressure causes an increase in critical power. It is a linear relationship. The change is due to the change in the latent heat of vaporization (h_{fg}).

Reference 57, page 9-87.

145. D

Local power distribution (local peaking factor) looks at the ratio of the hottest pin power compared to the average pin power. As this factor increases at a given power, that hot pin is closer to the onset of transition boiling. Therefore, critical power will decrease as the local power distribution increases.

Reference 57, page 9-88.

146.

Critical power refers to the bundle power that causes onset of transition boiling in a bundle. As the local heat flux increases, the margin to transition boiling decreases. For a given bundle power, the higher the largest local peaking factor is, the greater the heat flux at that location is. Therefore, an increase in local peaking factor causes a decrease in critical power.

Reference 57, page 9-88.

147. C

Local power distribution (local peaking factor) looks at the ratio of the hottest pin power compared to the average pin power. As this factor increases at a given power, that hot pin is closer to the onset of transition boiling. Therefore, critical power will decrease as the local power distribution increases.

Reference 57, page 9-88.

148. B

Local power distribution (local peaking factor) looks at the ratio of the hottest pin power compared to the average pin power. As this factor increases at a given power, that hot pin is closer to the onset of transition boiling. Therefore, critical power will decrease as the local power distribution increases.

Reference 57, page 9-88.

149. A

Local power distribution (local peaking factor) looks at the ratio of the hottest pin power compared to the average pin power. As this factor increases at a given power, that hot pin is closer to the onset of transition boiling. Therefore, critical power will decrease as the local power distribution increases.

Reference 57, page 9-88.

150. B

Local power distribution (local peaking factor) looks at the ratio of the hottest pin power compared to the average pin power. As this factor increases at a given power, that hot pin is closer to the onset of transition boiling. Therefore, critical power will decrease as the local power distribution increases.

Reference 57, page 9-88.

151.

The rate of enthalpy rise in the coolant depends on the local power. The enthalpy rise is greatest where the power peaks.

If the axial power peak occurs low in the core, the coolant experiencing this high enthalpy rise is of low quality or subcooled; there is a large margin to OTB. However, if the axial power peak shifts to higher in the core, the coolant undergoing the high enthalpy rise is already closer to OTB. Therefore, the critical power is lower when the axial power distribution shifts to a top-peaked distribution.

Reference 57, page 9-89.

152. A

Axial power distribution looks at where the highest power in a bundle is produced. A top-peaked bundle results in the largest coolant enthalpy rise occurring in a high quality region, which is closer to the onset of transition boiling. Therefore, the critical power is lower for a top-peaked power distribution. It is a linear relationship.

Reference 57, page 9-89.

153. C

Axial power distribution looks at where the highest power in a bundle is produced. A top-peaked bundle results in the largest coolant enthalpy rise occurring in a high quality region, which is closer to the onset of transition boiling. Therefore, the critical power is lower for a top-peaked power distribution. It is a linear relationship.

Reference 57, page 9-89.

154. D

Axial power distribution looks at where the highest power in a bundle is produced. A top-peaked bundle results in the largest coolant enthalpy rise occurring in a high quality region, which is closer to the onset of transition boiling. Therefore, the critical power is lower for a top-peaked power distribution. It is a linear relationship.

Reference 57, page 9-89.

155. B

Axial power distribution looks at where the highest power in a bundle is produced. A top-peaked bundle results in the largest coolant enthalpy rise occurring in a high quality region, which is closer to the onset of transition boiling. Therefore, the critical power is lower for a top-peaked power distribution. It is a linear relationship.

Reference 57, page 9-89.

156. C

Axial power distribution looks at where the highest power in a bundle is produced. A top-peaked bundle results in the largest coolant enthalpy rise occurring in a high quality region, which is closer to the onset of transition boiling. Therefore, the critical power is lower for a top-peaked power distribution. It is a linear relationship.

Reference 57, page 9-89.

157. A

The steady-state MCPR limit is multiplied by a flow-biasing correction factor (K_f), which increases the MCPR limit at flows less than rated core flow.

Reference 25, chapter 9.

158. C

The steady-state MCPR limit is multiplied by a flow-biasing correction factor (K_f), which increases the MCPR limit at flows less than rated core flow.

Reference 25, chapter 9.

159. C

Reference 25, Chapter 9

160. A

The steady-state MCPR limit is multiplied by a flow-biasing correction factor (K_f), which increases the MCPR limit at flows less than rated core flow.

Reference 25, chapter 9.

161.

With core flow less than rated (100 percent) flow, the flow biasing factor adjusts the critical power ratio limit to make it more conservative. This is necessary because the critical power is lower at lower reactor core flow rates.

Reference 57, pages 9-96 through 9-98.

162. D

The steady-state MCPR limit is multiplied by a flow-biasing correction factor (K_f), which increases the MCPR limit at flows less than rated core flow.

Reference 25, chapter 9.

163. B

The steady-state MCPR limit is multiplied by a flow-biasing correction factor (K_f), which increases the MCPR limit at flows less than rated core flow.

164. A

165. C

166. B

167. B

168. D

169. D

170.

FLCPR stands for fraction of limiting critical power ratio. It is defined as:

$$FLCPR = \frac{(CPR\ limit)\ (K_f)}{CPR\ actual}$$

FLCPR expresses how close the actual critical power ratio (CPR) is to the flow-biased limit for CPR.

For BWR-6 plants, FLCPR is defined as:

$$FLCPR = CPR_{limit}/CPR_{actual}$$

In this equation, CPR_{limit} is the maximum value of the following:

- the flow-biased MCPR limit,
- the power-biased MCPR operating limit, or
- the cycle-specific MCPR limit based on transient and ECCS performance analysis

Reference 25, pages 9-7 and 9-8.

171.

The fuel thermal time constant is the amount of time required for the cladding temperature to increase or decrease by 63% of the difference between its initial value and the final values resulting from an instantaneous change in fuel temperature. This factor becomes significant in transient and accident analysis because, while power may change rapidly, its effect on cladding temperature will not be seen as rapidly.

Reference 57, page 9-102.

172. C

Reference 57, page 9-102.

173. D

Reference 57, page 9-102.

174. B

The fuel thermal time constant is the time required for the cladding to reach 63.2% of the decrease resulting from an instantaneous change in fuel temperature. Since the total cladding temperature decrease is 558°F-540°F or 18°F, after six seconds, temperature will have decreased 18°F x 63.2% or 11.4°F. Therefore, temperature will be 558°F-11.4°F or approximately 547°F.

175. C

Reference 57

176.

Pellet-clad interaction refers to a phenomenon in which the fuel pellet and the cladding expand at different rates during a power increase. As a result, a high, localized stress is imposed on the cladding. If embrittling agents (such as iodine and cadmium) are present, stress corrosion cracking of the cladding can result.

Reference 57, page 9-107.

177. C

PCI effect is independent of core flux.

Reference 25, pages 25-1 and 25-2.

178. C

Reference 25, pages 25-1 and 25-2.

179. D

Reference 25, pages 25-1 and 25-2.

180. C

Reference 25, pages 25-1 and 25-2.

181. B

Reference 25, pages 25-1 and 25-2.

182. D

Reference 25, pages 25-1 and 25-2.

183. D.

Reference 25, pages 25-1 and 25-2

184. D

Reference 25

185. B

PCI only occurs during a rapid power increase due to differential thermal expansion between fuel pellet and cladding.

Reference 25, pages 25-1 and 25-2.

186. A

The presence of embrittling species reduces ductility or embrittles metal.

Reference 25, pages 25-1 and 25-2.

187. C

Fuel rod hydrogen concentration is irrelevant to PCI.

Reference 25, pages 25-1 and 25-2.

188. B

Reference 25, pages 25-1 and 25-2.

189. B

Reference 25, pages 25-1 and 25-2.

190.

Any four of the following factors affecting pellet-clad interaction satisfy this question:

- absolute power
- increase in power
- duration of the power increase
- previous power history
- fuel exposure

191. D

Reference 57, page 9-105.

192. D

Reference 57

193. D

Reference 57

194. D

Reference 57, page 9-105.

195.

The pellet-to-clad gap is designed to accommodate differential expansion of the fuel pellet and the cladding to prevent excessive cladding strain.

Reference 57, page 9-105.

196.

Any three of the following possible effects of fuel densification will satisfy the question:

- Local power spikes can occur due to axial gap formation.
- Linear heat generation rate (LHGR) can increase due to reduction of pellet length.
- The cladding can undergo creep collapse due to axial gap formation.
- The energy stored in the pellet can increase due to decreased pellet-clad thermal conductance.

Reference 57, page 9-107.

197. D

Reference 57, page 9-107.

198. A

Reference 57, page 9-107.

199. B

Reference 57, page 9-107

200. B

Reference 57, pages 9-107 through 9-110.

201. B

Reference 57, page 9-107.

202. A

Reference 57, page 9-107

203.

Iodine and cadmium are embrittling agents that can cause cladding under high stress to suffer stress-corrosion cracking.

Reference 57, page 9-107.

204.

Pre-conditioning interim operating management recommendations (PCIOMR) are intended to reduce cladding failures caused by pellet-clad interaction (PCI). PCIOMR limits the rate of power increase above certain powers and holds power at certain levels to "soak" the clad, allowing it time to expand elastically.

Reference 57, pages 9-110 through 9-113.

205.

By adhering to PCIOMR limitations on rates of power increase and fuel "soak" times, the operator reduces the stress imposed on the clad, thereby minimizing pellet-clad interaction effects.

Reference 57, pages 9-110 through 9-113.

206. C

Reference 25, chapter 9.

207. A

208. B

209.

The three thermal limits are based on power in the following units of fuel:

MCPR - total power in a fuel bundle

APLHGR - average fuel pin power in a node

LHGR - local fuel pin power in a node

Reference 57, pages 9-67 through 9-103.

210. C

Lack of cooling due to steam blanketing and subsequent rewetting could cause clad cracking. Such a condition could result from experiencing boiling transition. The MCPR limit is established to ensure that boiling transition is avoided.

211. C

Temperature swings of 25°F cause mechanical stress to the cladding. These swings are caused by departure from nucleate boiling and the alternating insulating steam blanketing of the clad. Therefore, "C" is the correct answer.

212. D

APLGHR is the only thermal limit designed and applied to provide protection during a LOCA.
PCIOMR is not a thermal limit.
LHGR is a steady-state limit.
CPR is a power-transient limit.

Reference 26, page 9-19.

213. C

214. B

215. A

216. A

APLHGR is established to prevent gross clad/fuel failure during a DBA LOCA. APLHGR is maintained within limits during operation by keeping MAPRAT<1.

$$MAPRAT = \frac{\text{APLHGR max. in core}}{\text{APLHGR limit}}$$

217. A

218. B

219. B

220. C

221. C

222. A

223. B

During a pressure increase event, critical power decreases due to a decrease in latent heat of vaporization. Additionally, bundle power increases. Therefore, CPR decreases. CPR is the limiting thermal limit for pressure increase transients.

Reference 26, pages 9-35 and 9-36.

224. C

During a pressure increase event, critical power decreases due to a decrease in latent heat of vaporization. Additionally, bundle power increases. Therefore, CPR decreases. CPR is the limiting thermal limit for pressure increase transients. LHGR and APLHGR approach their limits but not as fast as CPR approaches its limit.
PCIOMR is not a thermal limit. APLHGR and LHGR are not limiting for pressure increase events.

225. D

226. C

Loss of feedwater heating is a cold water injection and a CPR limiting transient that causes a decrease in CPR. Critical power increases, but actual bundle power increases more.

Reference 26, pages 9-35 through 9-37.

227. D

Increased core inlet subcooling would increase critical power and increase bundle power. Net affect would be to decrease CPR.

228. A

An overfeed event increases core inlet subcooling due to increased cooler water entering the reactor vessel.

229. B

230. C

231. A

232. D

233. D

234. A

235. C

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 Questions 1-5

Define and explain radial peaking factor.

K1.02 Questions 6-8

Define and explain axial peaking factor.

K1.03 Question 9-11

Define and explain local peaking factor.

K1.04 Questions 12-14

Define and explain total peaking factor.

K1.05 Questions 15-20

State the reason core thermal limits are necessary.

K1.06 Questions 21-28

Define "LHGR (linear heat generation rate)."

K1.07 Questions 29-35, 232

State the basis of the LHGR (linear heat generation rate) limit.

K1.08 Questions 36-42

Describe the mode of fuel failure for exceeding the LHGR (linear heat generation rate) thermal limit.

K1.09 Questions 43, 45, 46, 49, 50

Define "FLPD (fraction of limiting power density)."

K1.09 Questions 44, 47, 48

Define "MFLPD (maximum fraction of limiting power density)."

K1.10 Questions 51-57

Define "APLHGR (average planar linear heat generation rate) ."

K1.11 Questions 58-63

Explain the basis of the limiting condition for APLHGR (average planar linear heat generation rate).

K1.12 Questions 64-70

Describe the mode of fuel failure for violation of the APLHGR thermal limit.

K1.13 Question 71

Define "MAPLHGR (maximum average planar linear heat generation rate)."

K1.13 Questions 72-76

Define "MAPRAT (maximum average planar ratio)."

K1.14 Questions 77-80

Explain how and why the MAPLHGR limit curve changes over core life.

K1.15 Questions 80-84

Describe conditions under which radiative heat transfer becomes the significant method of heat transfer in a fuel bundle.

K1.16 Questions 85-88

Explain the relationship between fuel pellet centerline temperature and pellet thermal conductivity.

K1.17 Questions 89-97

Define "critical power."

K1.18 Questions 98-103

Define "critical power ratio."

K1.19 Questions 104-111

Explain the basis of the limiting condition for CPR (critical power ratio).

K1.20 Questions 112-117, 235

Describe the mode of fuel failure for CPR (critical power ratio).

K1.21 Questions 118-124

Define MCPR (minimum critical power ratio).

K1.22 Questions 125-131

Describe the effects of subcooling on critical power.

K1.23 Questions 132-138

Describe the effects of mass flow rate on critical power.

K1.24 Questions 139-144

Describe the effects of pressure on critical power.

K1.25 Questions 145-150

Describe the effects of local power distribution (local peaking factors) on critical power.

K1.26 Questions 151-156, 234

Describe the effects of axial power distribution on critical power.

K1.27 Questions 157-163

Describe the flow biasing correction factor, K_f, as it relates to MCPR limits.

K1.28 Questions 164-170

Define FLCPR (fraction of limiting critical power ratio).

K1.29 Questions 171-173

Define the fuel thermal time constant.

K1.30 Question 174, 175

Apply the fuel thermal time constant in transient calculations.

K1.31 Questions 176-181

Describe pellet-clad-interaction (PCI).

K1.32 Questions 182-190

State the causes of pellet-clad-interaction (PCI).

CORE THERMAL LIMITS
Learning Objectives

K1.33 Questions 191-195

Explain the purpose of the pellet-clad gap.

K1.34 Questions 196-198

Explain possible effects of fuel densification.

K1.35 Questions 199-203

Explain the effect of iodine and cadmium on pellet-clad interaction.

K136 Question 204

Explain the purpose of pre-conditioning interim operating management recommendations (PCIOMR).

K1.37 Question 205

State how operation within PCIOMR limitations minimizes PCI.

K1.38 Questions 206-209

State the parameter measured for each of the three core thermal limits.

K1.38 Questions 210,211

State the limiting condition associated with each of the three core thermal limits.

K1.40 Questions 212-216

Identify which of the three core thermal limits is most limiting for loss of reactor coolant.

K1.41 Questions 217-222, 233

Identify which of the three core thermal limits is most limiting for an increase in core flow.

K1.42 Questions 223-225

Identify which of the three core limits is most limiting for increase in reactor pressure.

K1.43 Questions 226-231

Identify which of the three core thermal limits is most limiting for cold water addition.

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 much lower than the material's yield stress

   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. 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

3. 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

4. Why is brittle fracture more of a concern in reactor operation than ductile fracture?

5. Describe the difference between the ductile and brittle modes of metal failure.

6. Which one 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. The probability of reactor vessel brittle fracture is increased by all of the following <u>except:</u>

   A. the presence of a pre-existing flaw in the vessel wall

   B. the presence of a tensile stress on the reactor vessel

   C. operation at low temperatures

   D. the presence of minimal copper in the reactor vessel

8. 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.

9. 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

10. 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

11. Define nil-ductility transition temperature.

12. 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

13. 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 vessel gamma flux exposure

14. Which of the following modes of reactor pressure vessel (RPV) failure is minimized by limiting the vessel cooldown rate to less than 100°F per hour?

    A. creep failure
    B. ductile fracture
    C. brittle fracture
    D. fatigue failure

15. Plant technical specifications typically include curves showing pressure-temperature limitations during plant heatup. Explain two factors that affect these curves.

16. List and state the cause of each of the stresses that combine to produce total reactor vessel stress.

17. Plant cooldown limitations (°F/hr) are imposed primarily to prevent

    A. excessive reactivity additions

    B. reactor vessel voiding

    C. impurities from precipitating out of solution

    D. brittle fracture

18. A compressive stress will be applied to the outside reactor vessel wall as a result of

    A. neutron embrittlement of the reactor vessel
    B. increasing reactor pressure
    C. performing a reactor cooldown
    D. performing a reactor heatup

19. The total stress on the reactor vessel inner wall is greater during cooldown than heatup because

    A. both pressure stress and cooldown stress are tensile on the inner wall

    B. heatup stress totally offset pressure stress on the inner wall

    C. thermal cooldown stresses and heatup stresses are both tensile on the inner wall, but cooldown stress are greater in magnitude

    D. the tensile cooldown stress on 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 on the inner wall, compressive on the outer wall

    D. compressive on the inner wall, tensile on the outer wall

21. The possibility of brittle fracture is minimized by placing limits on the cooldown rate to limit stress due to

    A. differential pressure stresses
    B. neutron embrittlement stresses
    C. residual stresses
    D. thermal gradient stresses

22. Brittle fracture of the reactor coolant pressure boundary is most likely to occure at

    A. 120°F, 10 psig
    B. 120°F, 400 psig
    C. 400°F, 10 psig
    D. 400°F, 400 psig

23. The probability of reactor vessel brittle fracture is decreased by minimizing

    A. oxygen content in the reactor coolant

    B. the time taken to cool down the reactor coolant system

    C. operation at high reactor coolant temperatures

    D. the amount of copper in the reactor vessel

24. The two factors that have the greatest effect on the RT^{NDT} of the reactor vessel over its life are

    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

25. Prolonged exposure to a fast neutron flux will cause the reference temperature for nil-ductility transition ______ to due to changes in the ______ properties of the vessel wall.

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

26. 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

27. Which of the following statements concerning the relationship of fast neutron radiation and the nil-ductility transition temperature is correct?

    A. The greater the amount of fast neutron radiation exposure, the lower the nil-ductility temperature.

    B. As fast neutron flux is decreased, the nil-ductility temperature will also decrease.

    C. The greater the amount of fast neutron radiation exposure, the greater the chance of ductile failure.

    D. The greater the amount of fast neutron radiation exposure, the higher the value of nil-ductility transition temperature.

28. Which of the following best represents the effects of long-term radiation exposure of the reactor vessel?

    A. High-energy fission fragments, reacting with the stainless steel vessel, are the principal cause of vessel embrittlement.

    B. During the vessel lifetime, the nil-ductility temperature (NDT) of the vessel decreases due to the annealing of the metal by high reactor temperature.

    C. High-energy gamma irradiation of the vessel wall is the major contributor to embrittlement of the vessel.

    D. High-energy neutron exposure increases the possibility of brittle fracture.

29. Which of the following describes the effect of fast neutron irradiation on a reactor pressure vessel (RPV)?

    A. increased fatigue crack growth rate

    B. decreased stress which must be applied to the RPV to cause plastic deformation

    C. increased ductility

    D. increased nil-ductility transition temperature

30. Which of the following types of 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

31. How and why does the nil-ductility transition temperature change as the plant ages?

32. A curve showing allowable plant pressure versus temperature undergoes changes over the life of the plant. Explain how and why.

33. 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 lower average power capacity

    B. reactor A due to the greater number of heatup/cooldown cycles

    C. reactor B due to the higher average power capacity

    D. reactor B due to the fewer number of heatup/cooldown cycles

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 failure
- C - definition of fracture only
- D - characteristic of ductile failure

A is correct because brittle fracture generally occurs at a very low yield stress with little or no deformation.

Reference 78, page 13-58.

2. B

A, C, and D are incorrect because the conditions decrease the probability of brittle fracture.

Reference 78, pages 13-58 through 13-60.

3. C

Reference 78, page 13-60.

4.

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 78, pages 13-58 through 13-60.

5.

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 78, pages 13-58 through 13-60.

6. A

A is correct because the probability of brittle fracture increases as temperature decreases.

Reference 78, page 13-60.

7. D

Reference 78, page 13-60.

8. C

Reference 78, page 13-60.

9. C

Reference 78, page 13-60.

10. A

Reference 78, page 13-60.

11.

Nil-ductility transition temperature is the temperature at and below which a material exhibits brittle behavior. When a metal is at its nil-ductility transition temperature, its failure stress and yield stress are equal.

Reference 78, page 13-60.

12. C

Reference 78.

13. B

A reduction in pressure reduces stress on the vessel, decreasing the chance of brittle failure. Brittle failure is more likely with increased age (due to increased neutron fluence) and lower temperature, and gamma flux does not affect brittle failure.

Reference 78, pages 13-60 through 13-62.

14. C

Reference 78, pages 13-64 through 13-68.

15.

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, heatup rate is one of the factors affecting pressure limitations.

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 factor affecting the pressure-temperature curve.

Reference 66, page B 3/4 4-4.

16.

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 78, pages 13-60 through 13-68.

17. D

The basis for cooldown limitations is to prevent thermal shock/ brittle fracture.

Reference 04, page 28.

18. C

All other choices will result in a tensile stress being applied to the outer wall.

Reference 78, pages 13-64 through 13-66.

19. A

The cooldown transient is the most limiting because the composite of tensile pressure stress and tensile cooldown stress at the inner wall is greatest.

Reference 78, page 13-58.

20. B

Pressure stress is always tensile across a vessel wall.

Reference 78, 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 32, chapter 11.

22. B

Reference 78.

23. D

Reference 78.

24. 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.

25. C

RT^{NDT} will increase (occur earlier) due to changes in the grain structure of the vessel steel.

Reference 78, page 13-61.

26. 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 78, page 13-62.

27. D

A, B, and C are all incorrect because

- A: change in NDT in wrong direction
- B: implies flux dependency
- C: ductile versus brittle

D is correct because of the definition of NDT.

Reference 78, page 13-62.

28. D

Reference 78, page 13-62.

29. D

Reference 78, page 13-62.

30. D

Reference 78, page 13-62.

31.

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 78, page 13-61.

32.

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 78, page 13-61 through 13-68.

33. A

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 3

Define brittle fr.

K1.01 Questions 4, 5

Differentiate between brittle and ductile failure in metals.

K1.01 Question 2, 7, 8

State the conditions that affect the probability of brittle fracture.

K1.01 Question 6

Describe the relationship betv brittle fracture and nil-ductility temperature.

K1.02, 1.03 Questions 9-12

Define nil-ductility transition temperature..

K1.04 Questions 13-15, 17-23

State how operating limitations affect the probability of brittle fracture.

K1.04 Question 16

Describe the stresses on the reactor pressure vessel.

K1.05 Questions 24, 26, 33

Identify factors affecting the value of the reference temperature for nil-ductility transition.

K1.05 Questions 25, 27-32

State the effect of fast neutron irradiation on reactor vessel metals.

APPENDIX A

REFERENCE EQUATIONS AND FACTS

REFERENCE EQUATIONS AND FACTS

$P = P_o 10^{SUR(t)}$

$P = P_o e^{t/T}$

$\rho = (k_{eff} - 1) / k_{eff}$

$\rho = ((\ell^* / T) + \bar{\beta}_{eff} / (1 + \bar{\lambda} T)$

$T = ((\ell^* / \rho) + (\bar{\beta}_{eff} - \rho) / \bar{\lambda} \rho$

$\Delta\rho = (k_2 - k_1) / k_2 k_1$

$P = P_o \bar{\beta}_{eff} / (\bar{\beta}_{eff} - \rho)$

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 average decay constant.
4. Examinees also may 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.

1. Alter, Harry, *Glossary of Terms in Nuclear Science and Technology*, American Nuclear Society, La Grange Park, IL, 1986.

2. American Institute of Chemical Engineers, *Pump Manual*, American Institute of Chemical Engineers, New York, NY, 1960.

3. Anderson, Norman A., *Instrumentation for Process Measurement and Control*, 3rd ed., Chiffon, Radnor, PA, 1980.

4. Buenaflor, *TS-15, Pressurized Thermal Shock and Brittle Fracture*, South Carolina Electric & Gas, Jenkinsville, SC, March 28, 1988.

5. Bureau of Naval Personnel, *Basic Electricity*, Dover Publications, New York, NY, 1970.

6. Bureau of Naval Personnel, *IC Electrician 2*, U.S. Navy, Washington, DC, 1955.

7. Burn, R. R., *Introduction to Nuclear Reactor Operations*, University of Michigan, Ann Arbor, MI, 1988.

8. Burn, R. R., *Nuclear Reactor Operation: Reactor Theory*, Power Safety International, Lynchburg, VA, 1985.

9. Clinton Power Station, *Exam Questions*, Illinois Power, Clinton, IL.

10. Combustion Engineering, *Steam Tables*, Combustion Engineering, Windsor, CT, 1987.

11. Commonwealth Edison, *Power Plant Electrical Fundamentals Book 6*, Commonwealth Edison, Chicago, IL, 1979.

12. Connecticut Yankee, *Question Bank Item No. 01821*, Northeast Utilities, Waterford, CT.

13. Connolly, Thomas J., *Foundations of Nuclear Engineering*, John Wiley and Sons, New York, NY, 1978.

14. Crocker, Sabin, *Piping Handbook*, 5th ed., McGraw-Hill, New York, NY, 1967.

15. Curfman, C. A., *Reactor Operating Principles: Reactor Shutdown*, Virginia Power, Surry, VA, June 10, 1988.

16. Duane Arnold Energy Center, *Heat Transfer*, Iowa Electric Light and Power, Palo, IA.

17. El-Wakil, M. M., *Nuclear Heat Transport*, American Nuclear Society, La Grange Park, IL, 1981.

18. El-Wakil, M. M., *Nuclear Power Engineering*, McGraw-Hill, New York, NY, 1962.

19. Farley Nuclear Plant, *Circuit Breaker Racking Procedure SOP-36.6*, Alabama Power Company, Ashford, AL, 1987.

20. General Electric, *Basic Engineering Training Volume 4: Introduction to Materials*, General Electric, San Jose, CA, 1981.

21. General Electric, *BWR Academic Series*, General Electric, Morris, IL, 1987.

22. General Electric, *BWR 6 Technology: Reactor Physics*, General Electric, Tulsa, OK.

22.1. General Electric, *BWR 6 Technology: Reactor Recirculation System*, General Electric, Tulsa, OK, 1983.

23. General Electric, *GEK-37896A*, General Electric, San Jose, CA.

24. General Electric, *GEK-46372*, General Electric, San Jose, CA.

25. General Electric, *NEDO Volume I - Station Nuclear Engineering*, General Electric, San Jose, CA.

26. General Electric Nuclear Training Services, *Heat Transfer and Fluid Flow*, General Electric, Morris, IL, 1986.

27. General Physics, *Academic Program for Nuclear Plant Personnel*, General Physics, Columbia, MD, 1981.

28. General Physics, *Fundamentals of Thermodynamics, Heat Transfer, and Fluid Flow*, General Physics, Columbia, MD, 1981.

29. General Physics, *Introduction to BWR Nuclear Power Plants*, General Physics, Columbia, MD, 1980.

30. General Physics, *Nuclear Power Plant Steam and Mechanical Fundamentals*, General Physics, Columbia, MD, 1981.

31. Gilbert, R. W., *Reactor Theory*, General Electric, Morris, IL, 1986.

32. Glasstone, Samuel, and Sesonske, Alexander, *Nuclear Reactor Engineering*, 3rd ed., Van Nostrand Reinhold, New York, NY, 1981.

33. Granet, Irving, *Thermodynamics and Heat Power*, Reston Publishing, Reston, VA, 1985.

34. Hooper and Lyons, *Electrical Science*, General Electric, San Jose, CA, 1986.

35. Hopkins and Johnson, *Instrumentation and Control*, General Electric, San Jose, CA, 1986.

36. Howarth and Powers, *Process Instrumentation and Controls Fundamentals*, General Physics, Columbia, MD, 1978.

37. Institute of Nuclear Power Operations, *Assessment of Motor-operated Valve Failures, 83-37*, Institute of Nuclear Power Operations, Atlanta, GA, 1983.

38. Institute of Nuclear Power Operations, *Good Practice OP-216: Valve Operations*, preliminary, Institute of Nuclear Power Operations, Atlanta, GA;December 1988.

39. Kaiser, *Electrical Power*, Goodheart-Wellcox, South Holland, IL, 1982.

40. Karassik, I. J.; Krutzsch, W. C.; Fraser, W. H.; and Messina, J. P.; *Pump Handbook*, 2nd ed., McGraw-Hill, New York, NY, 1985.

41. Karlekar, A. V., and Desmond, R. M., *Engineering Heat Transfer*, West Publishing, St. Paul, MN, 1977.

42. King, C. D., *Nuclear Power Systems: An Introductory Text*, MacMillan, New York, NY, 1964.

43. Kirk and Rimboi, *Instrumentation*, American Technical, Homewood, IL, 1975.

44. Lamarsh, John R., *Introduction to Nuclear Engineering*, Addison-Wesley, Reading, MA, 1977.

45. Lamarsh, John R., *Introduction to Nuclear Reactor Theory*, Addison-Wesley, Reading, MA, 1972.

46. Lahey, R. T., and Moody, F. J., *The Thermal-Hydraulics of a Boiling Water Nuclear Reactor*, American Nuclear Society, La Grange Park, IL, 1984.

47. Lapedes, D. N., *McGraw-Hill Dictionary of Scientific and Technical Terms*, McGraw-Hill, New York, NY, 1978.

48. Leopard and Buenaflor, *TS-10, Fluid Mechanics in Pumps and Piping*, South Carolina Electric & Gas, Jenkinsville, SC, March 28, 1988.

49. Meadows, T. R., and Price, M. T., *Heat Transfer and Fluid Flow*, General Electric, Morris, IL, 1985.

50. Mileaf, Harry, *Electricity One-Seven*, Hayden, Rochelle Park, NJ, 1978.

51. Nelson, Carl A., *Millwrights and Mechanics Guide*, MacMillan; New York, NY, 1986.

52. NUS Corporation, *Maintenance Training: Heat Exchangers*, NUS Corporation, Rockville, MD, 1979.

53. NUS Corporation, *Nuclear Energy Training Module 2: Basic Nuclear Concepts*, NUS Corporation, Rockville, MD, 1977.

54. NUS Corporation, *Nuclear Energy Training Module 3: Reactor Operation*, NUS Corporation, Rockville, MD, 1977.

55. NUS Corporation, *Nuclear Energy Training Module 4: Plant Performance*, NUS Corporation, Rockville, MD, 1977.

55.1 NUS Corporation, *Nuclear Energy Training Module 7: Instrumentation and Operational Analysis*, NUS Corporation, Rockville, MD, 1977.

56. NUS Corporation, *Valve Maintenance*, NUS Corporation, Rockville, MD, 1978.

57. Powell, C. H., *Thermodynamics, Heat Transfer, and Fluid Flow*, General Electric, Morris, IL, 1982.

58. Quick, Rusty, *SB-4, Pumps*, South Carolina Electric & Gas, Jenkinsville, SC, May 12, 1988.

59. Reynolds, W. C., and Perkins, H. C., *Engineering Thermodynamics*, McGraw-Hill, New York, NY, 1977.

60. Schultz, M. A., *Control of Nuclear Reactors and Power Plants*, McGraw-Hill, New York, NY, 1961.

61. Schweitzer, Philip A., *Handbook of Valves*, Robert E. Krieger Publishing, Malabar, FL, 1982.

62. Smeaton, R. W., *Switchgear and Control Handbook*, McGraw-Hill, New York, NY, 1977.

63. Strauss, S. D., "Ion Exchange" *Power Magazine*, September 1980.

64. TPC Training Systems, *Three-Phase Systems*, Technical Publishing, Barrington, IL, 1974.

65. U.S. Navy, *Machinist Mate 3 & 2*, Naval Education and Training Program Development Center, Washington, DC, 1981.

66. U.S. Nuclear Regulatory Commission, *NUREG-0123: Standard Technical Specifications for General Electric Boiling Water Reactors (BWR/5)*, rev. 3, U.S. Nuclear Regulatory Commission, Washington, DC, December 1980.

67. U.S. Nuclear Regulatory Commission, *NUREG-0212: Standard Technical Specifications for Combustion Engineering Pressured Water Reactors*, rev. 2, U.S. Nuclear Regulatory Commission, Washington, DC, September 1980.

68. Wark, Kenneth, *Thermodynamics*, 3rd ed., McGraw-Hill, New York, NY, 1977.

69. *Webster's Collegiate Dictionary*, 150th ed., G&C Merriam, Springfield, MA, 1981.

70. Westinghouse, *Applied I&C Technology for Power Plant Operations*, Westinghouse, Pittsburgh, PA, 1986.

71. Westinghouse, *Electrical Maintenance Hints Volume I: General Maintenance*, Westinghouse, Trafford, PA, 1984.

72. Westinghouse, *Electrical Science Lesson Text*, Westinghouse, Pittsburgh PA, 1983.

73. Westinghouse, *Fundamentals of Nuclear Reactor Physics*, Westinghouse, Pittsburgh, PA, 1983.

74. Westinghouse, *Mitigating Core Damage*, Westinghouse, Pittsburgh, PA, 1984.

75. Westinghouse, *Plant Information Manual*, Westinghouse, Pittsburgh, PA, 1981.

76. Westinghouse, *Radiation, Chemistry, and Corrosion Considerations for Nuclear Power Plant Application*, Westinghouse, Pittsburgh, PA, 1983.

77. Westinghouse, *Reactor Core Control for Large Pressurized Water Reactors*, Westinghouse, Pittsburgh, PA, 1983.

78. Westinghouse, *Thermal-Hydraulic Principles and Applications to the Pressurized Water Reactor*, Volumes I & II, Westinghouse, Pittsburgh, PA, 1982.

79. Westinghouse Owners Group Emergency Response Guidelines Subcommittee, *Background Information for Westinghouse Owners Group Emergency Response Guidelines: Generic Issue - Pressurized Thermal Shock*, Westinghouse Owners Group, Pittsburgh, PA, September 1, 1983.

80. Westinghouse Owners Group Emergency Response Guidelines Subcommittee, *Pressurized Thermal Shock Training - Volume I*, Westinghouse Owners Group, Pittsburgh, PA, 1984.

APPENDIX C

FEEDBACK FORM

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