U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-186/OL-86-02

Docket No. 50-186 License No. R-103

Licensee: University of Missouri
Research Park
Columbia, MO 65201

Facility Name: University of Missouri at Columbia Research Reactor

Examination Administered At: University of Missouri at Columbia Research Reactor

Examination Conducted: July 1, 2, and 3, 1986

Examiners: R. L. Higgins — 7/9/86 Date

D. E. Hills — 7/9/86 Date

Approved By: T. M. Burdick — 7/9/86 Date

Examination Summary

Examination administered on July 1, 2, and 3, 1986 (Report No. 50-186/OL-86-02)
Examinations were administered to one upgrade senior operator candidate and one operator candidate.
Results: Both candidates passed.

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REPORT DETAILS

1. Examiners

*R. L. Higgins
D. E. Hills
K. R. Ridgway

*Chief Examiner

2. Examination Review Meeting

An examination review meeting is no longer conducted. Specific facility comments concerning written examination questions, followed by the NRC response, are enumerated in the following paragraphs.

a. Two comments were made concerning the reactor operator written examination.

Question A.01

Facility Comment: ln 5000 = 8.5 instead of 9.5.

NRC Response: Agree. The answer was changed to 255 seconds or 4.25 minutes, in accordance with the correct value for ln 5000.

Question D.02

Facility Comment: Point distribution on answer sheet did not appear to total assigned point value of problem.

NRC Response: Agree. The point value for each portion of the answer was modified to equal the total point value for the problem.

b. Four comments were made concerning the senior operator written examination.

Question I.05

Facility Comment: Answer should conform to SOP VIII.3.5.3 Rabbit Stuck in Tube. The "laboratory supervisor" position no longer exists at this facility, an operator should advise the health physicist or the reactor shift supervisor. The "laboratory supervisor" reference in Hazards Summary will be revised.

NRC Response: Agree. The answer was changed to "notify shift supervisor." The facility is admonished to revise its reference material to reflect the current facility organization.

Question J.08.c.

Facility Comment: Should be phosphate corrosion control (Dearborn 4630) instead of chromates. The university environmental health office notified the facility several years ago that we needed to shift from chromate corrosion control. This informational reference in SOP should have been changed then but was overlooked. We will change it in the next SOP revision.

NRC Response: Agree. The answer was changed to "phosphates (Dearborn 4630)." The facility is admonished to revise its literature to reflect current facility practices.

Question K.12

Facility Comment: The aluminum protective head may also be called the "top hat" due to its shape.

NRC Response: Agree. The answer was modified to also grant full credit for the response "install the top hat."

Question K.16.b

Facility Comment: The pH limits for the secondary have changed several times in the past year. Our Dearborn representative and secondary chemist have been varying the pH operating band to find the optimum range for our system (currently 7.8 to 8.2).

NRC Response: Agree. The answer was changed to 7.8 to 8.2. The facility is admonished to revise its literature to reflect current practices.

3. Exit Meeting

At the conclusion of the startup portion of the plant walk-through examination an exit meeting was held. The following personnel attended this exit meeting:

Facility Representatives:

W. A. Meyer, Acting Reactor Manager
N. Tritschler, Shift Supervisor

NRC Representatives:

R. L. Higgins, Chief Operator Licensing Examiner
D. E. Hills, Operator Licensing Examiner
K. R. Ridgway, Operator Licensing Examiner

The following observations and generic issues were discussed:

a. The literature provided to the NRC for the purpose of examination preparation was not completely adequate. No prints were included, and some references needed to be revised.

b. "No Smoking" signs should be installed in the emergency generator room.

c. Procedures should be kept near the location of components which may have to be operated locally during an emergency.

d. Administrative procedures need to give more specific guidance in situations such as lost keys and missing tags.

e. Personnel were observed with coffee cups and lighted cigarettes on the reactor pool deck.

f. Some examinees were unfamiliar with the steps needed to change the inputs to the Area Radiation Monitoring System.

g. One examinee crossed a boundary marked "contact Health Physics Prior to Entry" without contacting Health Physics.

h. Neither the senior operator examinee nor the reactor operator examinee referred to the startup procedure during the actual plant startup.

i. Some examinees were not well informed on certain aspects of reactor theory such as subcritical multiplication and samarium.

j. Some examinees could not locate the applicable Facility Emergency Procedure when required to do so.

k. The facility itself was quite clean, except for the hallway leading to the mechanical equipment room.

l. Facility personnel were cooperative throughout the course of the examinations.

U. S. NUCLEAR REGULATORY COMMISSION
REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: UNIVERSITY OF MISSOURI

REACTOR TYPE: TEST

DATE ADMINISTERED: 86/07/01

EXAMINER: HILLS, D.

APPLICANT: _____

INSTRUCTIONS TO APPLICANT:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheets. Points for each question are indicated in parentheses after the question. The passing grade requires at least 70% in each category

Examination papers will be picked up six (6) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	APPLICANT'S SCORE	% OF CATEGORY VALUE	CATEGORY
14.50	14.50	_____	_____	A. PRINCIPLES OF REACTOR OPERATION
14.50	14.50	_____	_____	B. FEATURES OF FACILITY DESIGGN
14.50	14.50	_____	_____	C. GENERAL OPERATING CHARACTERISTICS
14.00	14.00	_____	_____	D. INSTRUMENTS AND CONTROLS
13.50	13.50	_____	_____	E. SAFETY AND EMERGENCY SYSTEMS
15.00	15.00	_____	_____	F. STANDARD AND EMERGENCY OPERATING PROCEDURES
14.00	14.00	_____	_____	G. RADIATION CONTROL AND SAFETY
100.00	100.00	_____	_____	TOTALS

FINAL GRADE _____%

All work done on this examination is my own. I have neither given nor received aid.

_____
APPLICANT'S SIGNATURE

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. **Cheating on the examination means an automatic denial of your application and could result in more severe penalties.**
2. **Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.**
3. **Use black ink or dark pencil only to facilitate legible reproductions.**
4. **Print your name in the blank provided on the cover sheet of the examination.**
5. **Fill in the date on the cover sheet of the examination (if necessary).**
6. **Use only the paper provided for answers.**
7. **Print your name in the upper right-hand corner of the first page of each section of the answer sheet.**
8. **Consecutively number each answer sheet, write "End of Category ___" as appropriate, start each category on a new page, write on only one side of the paper, and write "Last Page" on the last answer sheet.**
9. **Number each answer as to category and number, for example, 1.4, 6.3.**
10. **Skip at least three lines between each answer.**
11. **Separate answer sheets from pad and place finished answer sheet face down on your desk or table.**
12. **Use abbreviations only if they are commonly used in facility literature.**
13. **The point value for each question is indicated in parentheses after the question and can be used as a guide for the depth of answer required.**
14. **Show all calculations, methods, or assumptions used to obtain an answer to mathematical problems whether indicated in the question or not.**
15. **Partial credit may be given. Therefore, ANSWER ALL PARTS OF THE QUESTION AND DO NOT LEAVE ANY ANSWER BLANK.**
16. **If parts of the examination are not clear as to intent, ask questions of the examiner only.**

17. You must sign the statement on the cover sheet that indicates that the work is your own and you have not received or been given assistance in completing the examination. This must be done after the examination has been completed.

18. When you complete your examination, you shall:

    a. Assemble your examination as follows:

        (1) Examination questions on top.

        (2) Examination aids - figures, tables, etc.

        (3) Answer pages including figures which are a part of the answer.

    b. Turn in your copy of the examination and all pages used to answer the examination questions.

    c. Turn in all scrap paper and the balance of the paper that you did not use for answering the questions.

    d. Leave the examination area, as defined by the examiner. If after leaving, you are found in this area while the examination is still in progress, your license may be denied or revoked.

QUESTION A.01 (1.00)

Reactor power is 100 watts and increasing on a 30 second period. How long will it take for the reactor power to reach 500 kilowatts? (Neglect heating effects.) (1.0)

QUESTION A.02 (2.00)

a. Explain what the difference is between k-infinite and k-effective. (1.0)

b. K-effective of a reactor is given as 1.0795 delta k/k. What k-excess does the reactor have? (0.5)

c. What reactivity is associated with this k-effective? (0.5)

QUESTION A.03 (1.00)

Explain what is meant by the term "delayed neutron fraction." (1.0)

QUESTION A.04 (2.00)

a. A step insertion of a small amount of positive reactivity is made to a reactor while critical in the very low power range. Describe the changes in neutron flux after the reactivity addition. (Neglect heating effects.) (1.0)

b. Describe the changes in neutron flux following a reactor scram from full power operation. (1.0)

QUESTION A.05 (1.50)

a. What is the purpose of the "moderator" in the reactor? (1.0)

b. Indicate which one of the following is considered an important aspect of a good moderator. (0.5)

(1) low mass number
(2) large absorption cross section
(3) small scattering cross section

(***** CATEGORY A CONTINUED ON NEXT PAGE *****)

QUESTION A.06 (2.00)

Indicate whether each of the following statements concerning fission product poisons are TRUE or FALSE. (If FALSE explain why it is False.) (2.0)

a. The equilibrium xenon concentration increases with increasing power level while the equilibrium samarium concentration significantly decreases with increasing power level.

b. A reactor startup several days after a scram from extended high power operation is considered xenon and samarium free.

QUESTION A.07 (2.00)

What effect does a moderator temperature increase have on the following? Explain each.

a. Core Reactivity (1.0)

b. Control Rod Worth (1.0)

QUESTION A.08 (2.00)

a. Describe how an operator can determine when the reactor is critical during a startup. (1.0)

b. A person being trained on the reactor has developed a system for reactor startups. He noted that the last time he did a startup the reactor was critical at 5000 CPS. He reasons that for his next startup (some months later) when he reaches 5000 CPS the reactor will be critical. Is this person's system valid? Explain your answer. (1.0)

QUESTION A.09 (1.00)

a. What pressure in psig corresponds to 65 psia? (0.5)

b. What is the saturation temperature corresponding to 65 psia? (0.5)

(***** END OF CATEGORY A *****)

B. FEATURES OF FACILITY DESIGN

QUESTION B.01 (3.50)

Indicate the component which corresponds to each letter designation (A through G) on the attached cross-sectional view of the reactor core. (3.5)

QUESTION B.02 (2.00)

a. Explain why it is important to maintain antisiphon system pressure within minimum and maximum values. (1.0)

b. Explain how the pressure within the antisiphon system is maintained. (1.0)

QUESTION B.03 (2.50)

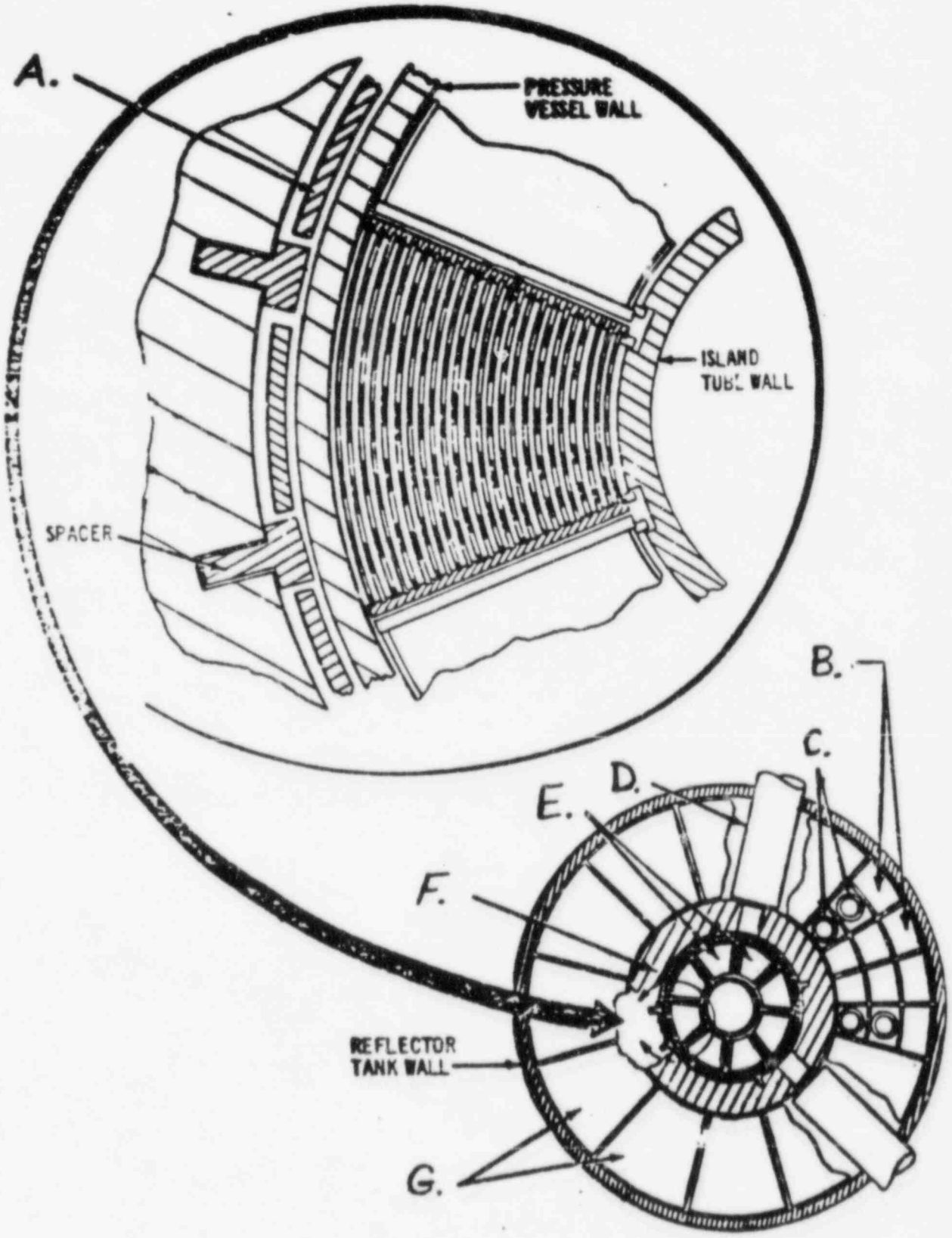
a. Describe how the Reactor Loop Vent System Liquid Level Controllers LC925A and LC925B operate in conjunction with the venting of gases from in-pool primary piping. Be sure to include ALL automatic actions associated with signals from these controllers. (1.5)

b. Describe the flowpath for the exhaust line from the vent tank including major components and final exhaust point location. (1.0)

QUESTION B.04 (2.50)

Describe the response of Containment Building Exhaust System Isolation Valves 16A and 16B upon loss of electrical power to their respective Schrader valves. Be sure to describe the mechanism by which each of these valves 16A and 16B perform the resulting action including the source of the motive force for that action. (2.5)

(***** CATEGORY B CONTINUED ON NEXT PAGE *****)



Core Arrangement - Cross-Sectional View

QUESTION B.05 (1.50)

Indicate for each of the following statements whether it applies to shim rods or to the regulating rod.

a. Utilized to compensate for the large reactivity changes which occur during the day in the core due to cyclic poison effects and long term effects such as fuel burnup. (0.5)

b. Worth less than 1 % delta k/k (0.5)

c. Will drive in upon a rod run-in signal (0.5)

QUESTION B.06 (2.50)

a. List both the primary and secondary functions of the nitrogen system. (1.0)

b. Describe all automatic actions and alarms associated with a slow drop in nitrogen system transmitting line pressure from 140 psig to 100 psig. Include the setpoint for each of the actions or alarms. (1.5)

(***** END OF CATEGORY B *****)

QUESTION C.01 (2.00)

Describe three methods of normal reactor loop cooling system operation. Include any differences in major equipment used and any applicable system flow rates and power levels for each. (2.0)

QUESTION C.02 (1.00)

Explain why, during normal operating conditions, the reactor will scram if the Reactor Convective Loop Valves 546A and 546B are opened. (1.0)

QUESTION C.03 (1.50)

Describe three distinct major hazards involved with beamport experiments. (1.5)

QUESTION C.04 (2.00)

a. Describe the criteria used in establishing the flowrate for the Pool Loop Coolant System. (1.0)

b. Why must the Pool Loop Cooling System remain in operation for a minimum of five minutes after a normal reactor shutdown ? (0.5)

c. What is the purpose of Pool Holdup Tank T504 ? (0.5)

QUESTION C.05 (2.50)

Give the normal operating range for each of the following parameters. (Include units.)

a. Reactor Outlet Coolant Temperature (0.5)
b. Pool Coolant Flow, 5 Megawatt Operation (0.5)
c. Nitrogen System Bank Pressure When Full (0.5)
d. Pool Outlet Temperature (Hot Leg) (0.5)
e. Antisiphon System Pressure (0.5)

(***** CATEGORY C CONTINUED ON NEXT PAGE *****)

QUESTION C.06 (2.00)

a. Explain why the worth of the cannister and samples placed in the central flux trap is limited to a specific amount. (1.0)

b. Explain why reactivity effects are more of a concern in the central flux trap than in the other experimental facilities. (1.0)

QUESTION C.07 (2.50)

Indicate whether each of the following reactivity coefficients are positive or negative for the indicated locations.

a. Void Coefficient of the Flux Trap (0.5)
b. Void Coefficient of the Core (0.5)
c. Temperature Coefficient of the Core (0.5)
d. Temperature Coefficient of the Pool (0.5)
e. Temperature Coefficient of the Flux Trap (0.5)

QUESTION C.08 (1.00)

State two reasons for maintaining water chemistry control in the primary coolant system. (1.0)

(***** END OF CATEGORY C *****)

QUESTION D.01 (3.00)

Indicate what type of nuclear detector is utilized by each of the following nuclear instrumentation channels and describe how in each the effect of gamma rays is prevented from causing an erroneous indication of neutron flux.

a. Channel 1 Source Range Monitor (1.0)
b. Channels 2 and 3 Intermediate Range Monitors (1.0)
c. Channels 5 and 6 Power Range Monitors (1.0)

QUESTION D.02 (3.00)

Describe four types of trips associated with the nuclear instrumentation intermediate range channels and how each trip is reset. (3.0)

QUESTION D.03 (2.00)

Indicate the primary purpose of each of the following activity monitors and describe its respective sample location in relation to major system components within the applicable system.

a. Fission Product Monitor (1.0)
b. Secondary Loop Monitor (1.0)

QUESTION D.04 (2.00)

Describe four conditions that must be met prior to automatic operation of the regulating rod. (2.0)

QUESTION D.05 (1.00)

Explain why the cleanup flow is subtracted from the indicated flow in reactor loops A and B when determining the pot setting for the reactor power calculator flow potentiometer. (1.0)

(***** CATEGORY D CONTINUED ON NEXT PAGE *****)

QUESTION D.06 (1.00)

Explain how the automatic shim control circuit repositions the shim rods. Include the various conditions which will cause rod movement and subsequent stopping by this circuit. (1.0)

QUESTION D.07 (2.00)

For each status description "a" through "d" of the Alarm and Annunciate System indicate which of the conditions (1) through (4) would result in that status.

STATUS DESCRIPTIONS

a. Illumination On Dim (0.5)
b. Illumination Flashing (0.5)
c. Illumination On Bright (0.5)
d. Illumination Off (0.5)

CONDITIONS

(1) Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.
(2) Alarm was received but the operator has not yet pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.
(3) Alarm was received and the operator pressed the Acknowlege pushbutton. The alarm condition subsequently cleared but the operator has not yet pressed the Reset button.
(4) Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition subsequently cleared and the operator pressed the Reset button.

(***** END OF CATEGORY D *****)

QUESTION E.01 (2.00)

The reactor is operating at 5 Megawatts with a core inlet pressure of 65 psia. For some unexplained reason pressure slowly begins to increase. Describe all actions (including alarms) that will be taken by the pressurizer and safety systems to control or impede this pressure increase. (Include setpoints.) (2.0)

QUESTION E.02 (1.50)

a. Describe how a Reactor Loop Low Pressure Scram initiated by signals from pressure transmitters PT944A or PT944B must be reset. (0.5)

b. Explain why this type of lockout was installed. (0.5)

c. When can this type of scram be bypassed? (0.5)

QUESTION E.03 (1.50)

List six conditions or signals which will cause automatic rod run-in. (Setpoints not required.) (1.5)

QUESTION E.04 (2.50)

a. Describe two conditions or signals which will cause automatic start of the emergency generator. (1.0)

b. Explain why the emergency generator continues to run for five minutes after site power has been restored. (0.5)

c. Which of the following loads can be supplied from the emergency generator? (1.0)

(1) Exhaust Fan EF-13
(2) Truck Entry Door Motor
(3) Containment Building Personnel Elevator
(4) Supply Ventilation Fan SF2
(5) Primary Pump P501A

(***** CATEGORY E CONTINUED ON NEXT PAGE *****)

QUESTION E.05 (1.00)

Which of the following components can be supplied with air from the Emergency Backup Air Compressor? (1.0)

(1) Pool Loop Isolation Valve 509
(2) Reactor Loop Isolation Valve 507A
(3) Containment Building Exhaust Isolation Valve 16A
(4) Emergency Generator
(5) Freight Door 101 Gasket

QUESTION E.06 (3.00)

a. From what two locations can the Facility Evacuation Alarm be manually initiated. (1.0)

b. Describe four automatic actions which will result from a Facility Evacuation alarm. (2.0)

QUESTION E.07 (2.00)

Which of the following conditions will result in a reactor scram? (2.0)

(1) Source Range Monitor Channel 1 Inoperative
(2) Low Pool Level
(3) Thermal Column Door Open
(4) High Off-gas Activity
(5) Low Reflector Differential Pressure
(6) Low Pressurizer Level
(7) Low Pool Flow

(***** END OF CATEGORY E *****)

QUESTION F.01 (2.00)

a. List the five Facility Emergency classifications. (1.25)

b. List three action levels for emergency classes. (0.75)

QUESTION F.02 (2.00)

Describe four responsibilities of the Duty Operator prior to leaving containment in the event of a Facility Evacuation. (2.0)

QUESTION F.03 (1.00)

a. Define "hot startup". (0.5)

b. State whether the following is TRUE or FALSE: (0.5)

Operations affecting changes in core reactivity other than normal steady state power control (i.e. refueling and startup) are required to be directly supervised by a senior reactor operator. However, a senior reactor operator is not required to be present during a "hot startup".

QUESTION F.04 (1.00)

Choose all of the following conditions which require the reactor operator to IMMEDIATELY scram the reactor. (1.0)

(1) Reactor Bridge Area Radiation Monitor not functioning
(2) Experimental Equipment is operating in a manner hazardous to personnel and the hazard is due to radiation from the reactor.
(3) Complete loss of secondary flow due to trip of a secondary pump
(4) Inoperative control rod drive mechanism

(***** CATEGORY F CONTINUED ON NEXT PAGE *****)

QUESTION F.05 (3.00)

a. Describe the symtoms which may indicate an electrical anomaly such as single phasing or a reduction in line voltage. (1.0)

b. Describe the immediate actions to be taken by the reactor operator in the event of a single phasing or low voltage condition. (2.0)

QUESTION F.06 (2.50)

Describe five conditions which could cause a loss or reduction in secondary flow. (2.5)

QUESTION F.07 (1.50)

Describe three methods to open the Emergency Core Cooling Valves 546A and 546B should both valves fail to automatically open following a scram due to loss of pressure or flow. (1.5)

QUESTION F.08 (2.00)

a. Explain why it is desirable to secure both Pool Cooling System Pumps P508A and P508B simultaneously as prescribed in the Pool Cooling System Shutdown Procedure SOP/V-3. (1.0)

b. Explain why the Pool Cooling System Startup Procedure SOP/V-1 requires the outlet valve of the heat exchanger not in service to be placed in its throttled position as opposed to shutting it as was done for the inlet valve. (1.0)

(***** END OF CATEGORY F *****)

QUESTION G.01 (1.00)

Which of the following Area Radiation Monitoring System detectors at the described location are capable of causing an automatic reactor isolation? (1.0)

(1) Reactor Bridge
(2) Fuel Storage Room
(3) Beamport Floor North Wall
(4) Containment Exhaust Air Plenum

QUESTION G.02 (3.00)

a. Changes were made to a reactor experiment which could lead to a significant alteration in area radiation levels as reactor power is increased. In accordance with facility procedures, a Health Physics Technician with direct communications to the control room is continuously monitoring the experiment during the subsequent normal reactor startup. At what four points (conditions or power levels) is the Control Room required to inform the Health Physics Technician of the reactor status or power level. (2.0)

b. What action is required if direct communications are lost or if one of these reports is not acknowledged? (1.0)

QUESTION G.03 (1.00)

What are the conditions requiring issuance of a Radiation Work Permit? (1.0)

(***** CATEGORY G CONTINUED ON NEXT PAGE *****)

QUESTION G.04 (2.50)

a. Describe three methods available to remove radioactive waste from the liquid waste retention system in the form of dry active waste. (1.5)

b. Fill in the blanks:

If the 10 CFR 20 limits are not exceeded and the total activity of radionuclides does not exceed 10 mCi of tritium or 2 mCi of other nuclides, the _____(1)_____ may authorize the water to be pumped to the sanity sewer. Any tank containing water with an activity greater than 2 mCi of other nuclides will be discharged only with the approval of the _____(2)_____. (1.0)

QUESTION G.05 (2.00)

Describe the monitoring requirements that are to be implemented when moving radioactive material in the pool during the following situations. (Include type of personnel responsible for those actions.)

a. Causes a working area dose rate greater than 100 millirem per hour. (1.0)

b. Causes a working area dose rate of less than 100 millirem per hour. (1.0)

QUESTION G.06 (1.00)

Consider two point sources, each having the same curie strength (for example, 1 curie each). Source A's gammas have an energy of 1 MeV whereas Source B's gammas have an energy of 2 MeV. You obtain a reading from the same Geiger counter 10 feet from each source. Would the reading from Source A be about twice, one-half, or about the same as that from Source B? Explain you answer. (1.0)

(***** CATEGORY G CONTINUED ON NEXT PAGE *****)

QUESTION G.07 (.50)

Assuming equal absorbed doses (measured in rads), which one of the following types of radiation will have the greatest biolcgical effect on the body: (0.5)

(1) beta
(2) gamma
(3) thermal neutrons
(4) fast neutrons

QUESTION G.08 (2.00)

a. If the dose rate from a radiation point source is 100 mrem/hr at 1 meter, what is the dose rate at 25 cm? Show your work. (1.0)

b. How long could you be 25 cm from the source before exceeding the 10 CFR 20 quarterly whole body dose limit? Show you work. (1.0)

QUESTION G.09 (1.00)

What two design features of the pneumatic tube system serve to limit the radiation hazard from these tubes? (1.0)

(***** END OF CATEGORY G *****)
(********** END OF EXAMINATION **********)

EQUATIONS

REACTOR THEORY

$$P = P_o e^{t/\tau} = P_o 10^{SUR \cdot t}$$

$$\tau = \frac{\bar{l}_g}{\rho} + \frac{\beta - \rho}{\lambda\rho} \quad \text{or} \quad \tau = \frac{\beta - \rho}{\lambda\rho}$$

$$\rho = \frac{k - 1}{k} \qquad \frac{k_2 - k_1}{k_2 k_1} = \Delta\rho$$

$$\frac{cps_2}{cps_1} = \frac{1 - k_1}{1 - k_2} \qquad k < 1$$

$$\frac{1}{M} = 1 - k$$

$$\frac{1}{M} = \frac{cps_o}{cps_n}$$

$$\rho_{net} = \Delta(\rho_{doppler} + \rho_{mod} + \rho_{void} + \rho_{Xe} + \rho_{Sm} + \rho_{Pu} + \rho_{Boron} + \rho_{rod} + \rho_{fuel} + \rho_{Poisons})$$

$$k_2 = k_1 + \delta k$$

$$\delta k = k - 1$$

$$SUR = \frac{26.06}{\tau}$$

$$P = \frac{\Sigma\phi V}{3.1 \times 10^{10}}$$

$$\Sigma = N\sigma$$

$$\phi = nv$$

Defect = Coeff x Δ Parameter

RADIATION

$$N = N_o e^{-\lambda t}$$

$$A = \lambda N$$

$$I = I_o e^{-\mu x} = I_o 10^{-x/TVT}$$

$$\lambda T_{\frac{1}{2}} = 0.693$$

$$R/hr \text{ @ } d \text{ feet} = \frac{6CE}{d^2}$$

$$I_1 d_1^2 = I_2 d_2^2 \qquad \text{point source}$$

$$I_1 d_1 = I_2 d_2 \quad \text{- line source}$$

R/hr x time = R

Rad x QF = Rem

$$T_{\frac{1}{2}eff} = \frac{T_{\frac{1}{2}Bio} \times T_{\frac{1}{2}Rad}}{T_{\frac{1}{2}Bio} + T_{\frac{1}{2}Rad}}$$

MATH

$$y^a = b$$

$$\log_y b = a$$

$$\log x^c = c \log x$$

$$\log \frac{x}{y} = \log x - \log y$$

$$\log xy = \log x + \log y$$

FLUIDS/THERMO/HEAT TRANSFER

$$\dot{m} = A_1\rho_1 V_1 = A_2\rho_2 V_2$$

$$Q = A_1 V_1 = A_2 V_2$$

$$E_{in} = E_{out} + \Delta E_{stored}$$

$$E = KE + PE + U + pV + Q + W$$

$$PE = \frac{mg}{g_c} Z$$

$$KE = \tfrac{1}{2} m \frac{V^2}{g_c}$$

reduced for - turbine, SG pump, nozzle, orifice, condenser, pipe, Rx

flow α $\sqrt{dp}$

$$\text{head loss} = f\frac{L}{D}\frac{V^2}{2g_c} \quad \text{or head loss } \alpha\ V^2 \quad \text{head loss } \alpha\ \Delta p$$

$$p = h + p_{ambient} \qquad = k\frac{V^2}{2g_c}$$

$$F = pA$$

$$\Delta P_{2\,phase} = \Delta P_{1\,phase} \times K$$

k = f(quality & Pressure)

Pump laws speed α flow
(speed)^2 α pressure
(speed)^3 α power

$$Q = kA\Delta T = hA\Delta T = UA\Delta T$$

$$Q = mc_p\Delta T$$

$$Q = m\Delta h$$

$$Q = \varepsilon\sigma T$$

$$\Delta H = mc_p\Delta T$$

$$\Delta U = mc_v\Delta T$$

$$H = U + pV$$

$$\Delta S = \frac{\Delta Q}{T}$$

$$pV = nRT$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$C_1V_1 + C_2V_2 = C_3(V_1 + V_2)$$

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press Lb per Sq In. p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat. Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat. Vapor s_g	Temp Fahr t
32.0*	0.08859	0.016022	3304.7	3304.7	−0.0179	1075.5	1075.5	0.0000	2.1873	2.1873	32.0*
34.0	0.09600	0.016021	3061.9	3061.9	1.996	1074.4	1076.4	0.0041	2.1762	2.1802	34.0
36.0	0.10395	0.016020	2839.0	2839.0	4.008	1073.2	1077.2	0.0081	2.1651	2.1732	36.0
38.0	0.11249	0.016019	2634.1	2634.2	6.018	1072.1	1078.1	0.0122	2.1541	2.1663	38.0
40.0	0.12163	0.016019	2445.8	2445.8	8.027	1071.0	1079.0	0.0162	2.1432	2.1594	40.0
42.0	0.13143	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	42.0
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	44.0
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	46.0
48.0	0.16514	0.016021	1830.0	1830.0	16.051	1066.4	1082.5	0.0321	2.1006	2.1327	48.0
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	50.0
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	52.0
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	56.0
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	58.0
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	60.0
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	62.0
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	64.0
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	66.0
68.0	0.33889	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	68.0
70.0	0.36292	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	70.0
72.0	0.38844	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	72.0
74.0	0.41550	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9709	2.0529	74.0
76.0	0.44420	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	76.0
78.0	0.47461	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	78.0
80.0	0.50683	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0358	80.0
82.0	0.54093	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	82.0
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	84.0
86.0	0.61518	0.016087	527.5	527.5	54.026	1045.0	1099.0	0.1043	1.9151	2.0193	86.0
88.0	0.65551	0.016093	496.8	496.8	56.022	1043.9	1099.9	0.1079	1.9060	2.0139	88.0
90.0	0.69813	0.016099	468.1	468.1	58.018	1042.7	1100.8	0.1115	1.8970	2.0085	90.0
92.0	0.74313	0.016105	441.3	441.3	60.014	1041.6	1101.6	0.1151	1.8881	2.0033	92.0
94.0	0.79062	0.016111	416.3	416.3	62.010	1040.5	1102.5	0.1188	1.8792	1.9980	94.0
96.0	0.84072	0.016117	392.8	392.9	64.009	1039.3	1103.3	0.1224	1.8704	1.9928	96.0
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	98.0
100.0	0.94924	0.016130	350.4	350.4	67.999	1037.1	1105.1	0.1295	1.8530	1.9825	100.0
102.0	1.00789	0.016137	331.1	331.1	69.995	1035.9	1105.9	0.1331	1.8444	1.9775	102.0
104.0	1.06963	0.016144	313.1	313.1	71.992	1034.8	1106.8	0.1366	1.8358	1.9725	104.0
106.0	1.1347	0.016151	296.38	296.38	73.99	1033.6	1107.6	0.1402	1.8273	1.9675	106.0
108.0	1.2030	0.016158	280.28	280.30	75.98	1032.5	1108.5	0.1437	1.8188	1.9626	108.0
110.0	1.2750	0.016165	265.37	265.39	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110.0
112.0	1.3509	0.016173	251.37	251.38	79.98	1030.2	1110.2	0.1507	1.8021	1.9528	112.0
114.0	1.4309	0.016180	238.22	238.22	81.97	1029.1	1111.0	0.1542	1.7938	1.9480	114.0
116.0	1.5133	0.016188	225.84	225.85	83.97	1027.9	1111.9	0.1577	1.7856	1.9433	116.0
118.0	1.6009	0.016196	214.20	214.21	85.97	1026.8	1112.7	0.1611	1.7774	1.9386	118.0
120.0	1.6927	0.016204	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120.0
122.0	1.7891	0.016213	192.94	192.95	89.96	1024.5	1114.4	0.1680	1.7613	1.9293	122.0
124.0	1.8901	0.016221	183.23	183.24	91.96	1023.3	1115.3	0.1715	1.7533	1.9247	124.0
126.0	1.9959	0.016229	174.08	174.09	93.96	1022.2	1116.1	0.1749	1.7453	1.9202	126.0
128.0	2.1068	0.016238	165.45	165.47	95.96	1021.0	1117.0	0.1783	1.7374	1.9157	128.0
130.0	2.2230	0.016247	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130.0
132.0	2.3445	0.016256	149.64	149.66	99.95	1018.7	1118.6	0.1851	1.7217	1.9068	132.0
134.0	2.4717	0.016265	142.40	142.41	101.95	1017.5	1119.5	0.1884	1.7140	1.9024	134.0
136.0	2.6047	0.016274	135.55	135.57	103.95	1016.4	1120.3	0.1918	1.7063	1.8980	136.0
138.0	2.7438	0.016284	129.09	129.11	105.95	1015.2	1121.1	0.1951	1.6986	1.8937	138.0
140.0	2.8892	0.016293	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140.0
142.0	3.0411	0.016303	117.21	117.22	109.95	1012.9	1122.8	0.2018	1.6834	1.8852	142.0
144.0	3.1997	0.016312	111.74	111.76	111.95	1011.7	1123.6	0.2051	1.6759	1.8810	144.0
146.0	3.3653	0.016322	106.58	106.59	113.95	1010.5	1124.5	0.2084	1.6684	1.8769	146.0
148.0	3.5381	0.016332	101.68	101.70	115.95	1009.3	1125.3	0.2117	1.6610	1.8727	148.0
150.0	3.7184	0.016343	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150.0
152.0	3.9065	0.016353	92.66	92.68	119.95	1007.0	1126.9	0.2183	1.6463	1.8646	152.0
154.0	4.1025	0.016363	88.50	88.52	121.95	1005.8	1127.7	0.2216	1.6390	1.8606	154.0
156.0	4.3066	0.016374	84.56	84.57	123.95	1004.6	1128.6	0.2248	1.6318	1.8566	156.0
158.0	4.5191	0.016384	80.82	80.83	125.96	1003.4	1129.4	0.2281	1.6245	1.8526	158.0
160.0	4.7414	0.016395	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160.0
162.0	4.9722	0.016406	73.90	73.92	129.96	1001.0	1131.0	0.2345	1.6103	1.8448	162.0
164.0	5.2124	0.016417	70.70	70.72	131.96	999.8	1131.8	0.2377	1.6032	1.8409	164.0
166.0	5.4623	0.016428	67.67	67.68	133.97	998.6	1132.6	0.2409	1.5961	1.8371	166.0
168.0	5.7223	0.016440	64.78	64.80	135.97	997.4	1133.4	0.2441	1.5892	1.8333	168.0
170.0	5.9926	0.016451	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2736	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5656	0.016474	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8690	0.016486	54.59	54.61	143.99	992.6	1136.6	0.2568	1.5616	1.8184	176.0
178.0	7.1840	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

*The states shown are metastable

Table 1. Saturated Steam: Temperature Table—*Continued*

Temp Fahr t	Abs Press Lb per Sq In. p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat. Vapor s_g	Temp Fahr t
388.0	7.6110	0.016510	38.71	38.72	348.80	990.2	1338.2	0.7531	1.5488	1.3111	388.0
392.0	7.850	0.016522	40.172	40.189	350.01	989.0	1339.0	0.7562	1.5413	1.3075	392.0
396.0	8.703	0.016534	41.737	41.749	352.01	987.8	1339.8	0.7594	1.5346	1.3040	396.0
396.0	9.564	0.016547	44.383	44.400	354.02	986.5	1340.5	0.7725	1.5279	1.3004	400.0
400.0	8.947	0.016559	42.821	42.838	356.03	985.3	1341.3	0.7756	1.5213	1.2969	400.0
400.0	9.340	0.016572	40.941	40.957	358.04	984.1	1342.1	0.7787	1.5148	1.2934	400.0
402.0	9.747	0.016585	39.337	39.354	360.05	982.8	1342.9	0.7818	1.5082	1.2900	402.0
404.0	10.168	0.016598	37.808	37.824	362.05	981.6	1343.7	0.7848	1.5017	1.2865	404.0
406.0	10.605	0.016611	36.348	36.364	364.06	980.4	1344.4	0.7879	1.4952	1.2831	406.0
408.0	11.058	0.016624	34.954	34.970	366.08	979.1	1345.2	0.7910	1.4888	1.2797	408.0
410.0	11.526	0.016637	33.622	33.639	368.09	977.9	1346.0	0.7940	1.4824	1.2764	410.0
412.0	12.012	0.016664	31.135	31.151	372.11	975.4	1347.5	0.8001	1.4697	1.2698	412.0
414.0	13.568	0.016691	28.862	28.878	376.14	972.8	1349.0	0.8061	1.4571	1.2632	414.0
416.0	14.695	0.016719	26.782	26.799	380.17	970.3	1350.5	0.8121	1.4447	1.2568	416.0
418.0	15.901	0.016747	24.878	24.894	384.20	967.8	1352.0	0.8181	1.4323	1.2505	418.0
420.0	17.186	0.016775	23.131	23.148	388.23	965.2	1353.4	0.8241	1.4201	1.2442	420.0
422.0	18.556	0.016805	21.529	21.545	392.27	962.6	1354.9	0.8300	1.4081	1.2380	422.0
424.0	20.015	0.016834	20.056	20.073	396.31	960.0	1356.3	0.8359	1.3961	1.2320	424.0
426.0	21.567	0.016864	18.701	18.718	400.35	957.4	1357.8	0.8417	1.3842	1.2260	426.0
428.0	23.216	0.016895	17.454	17.471	404.40	954.8	1359.2	0.8476	1.3725	1.2201	428.0
430.0	24.968	0.016926	16.304	16.321	408.45	952.1	1360.6	0.8535	1.3609	1.2142	430.0
432.0	26.826	0.016958	15.243	15.260	412.50	949.5	1362.0	0.8593	1.3494	1.2085	432.0
434.0	28.795	0.016990	14.264	14.281	416.56	946.8	1363.4	0.8649	1.3379	1.2028	434.0
436.0	30.879	0.017022	13.358	13.375	420.62	944.1	1364.7	0.8706	1.3266	1.1972	436.0
438.0	33.091	0.017055	12.520	12.538	424.69	941.4	1366.1	0.8763	1.3154	1.1917	438.0
440.0	35.427	0.017089	11.745	11.762	428.76	938.6	1367.4	0.8819	1.3043	1.1862	440.0
442.0	37.894	0.017123	11.025	11.042	432.83	935.9	1368.7	0.8876	1.2933	1.1808	442.0
444.0	40.500	0.017157	10.358	10.375	436.91	933.1	1370.0	0.8932	1.2823	1.1755	444.0
446.0	43.249	0.017193	9.738	9.755	440.99	930.3	1371.3	0.8987	1.2715	1.1702	446.0
448.0	46.147	0.017228	9.162	9.180	445.08	927.5	1372.5	0.9043	1.2607	1.1650	448.0
450.0	49.200	0.017264	8.627	8.644	449.17	924.6	1373.8	0.9098	1.2501	1.1599	450.0
452.0	52.414	0.01730	8.1280	8.1453	453.3	921.7	1375.0	0.9154	1.2395	1.1548	452.0
454.0	55.795	0.01734	7.6634	7.6807	457.4	918.8	1376.2	0.9208	1.2290	1.1498	454.0
456.0	59.350	0.01738	7.2301	7.2475	461.5	915.9	1377.4	0.9263	1.2186	1.1449	456.0
458.0	63.084	0.01741	6.8259	6.8433	465.6	913.0	1378.6	0.9317	1.2082	1.1400	458.0
460.0	67.005	0.01745	6.4483	6.4658	469.7	910.0	1379.7	0.9372	1.1979	1.1351	460.0
462.0	71.119	0.01749	6.0955	6.1130	473.8	907.0	1380.9	0.9426	1.1877	1.1303	462.0
464.0	75.433	0.01753	5.7655	5.7830	478.0	904.0	1382.0	0.9479	1.1776	1.1256	464.0
466.0	79.953	0.01757	5.4566	5.4742	482.1	901.0	1383.1	0.9533	1.1676	1.1209	466.0
468.0	84.688	0.01761	5.1673	5.1849	486.3	897.9	1384.1	0.9586	1.1576	1.1162	468.0
470.0	89.643	0.01766	4.8961	4.9138	490.6	894.8	1385.2	0.9640	1.1477	1.1116	470.0
472.0	94.826	0.01770	4.6418	4.6595	494.8	891.6	1386.2	0.9693	1.1378	1.1071	472.0
474.0	100.245	0.01774	4.4030	4.4208	498.7	888.5	1387.2	0.9745	1.1280	1.1025	474.0
476.0	105.907	0.01779	4.1788	4.1966	502.9	885.3	1388.2	0.9798	1.1183	1.0981	476.0
478.0	111.820	0.01783	3.9681	3.9859	507.1	882.1	1389.1	0.9850	1.1086	1.0936	478.0
480.0	117.992	0.01787	3.7695	3.7878	511.3	878.8	1390.1	0.9902	1.0990	1.0892	480.0
482.0	124.430	0.01792	3.5834	3.6013	515.5	875.5	1391.0	0.9954	1.0894	1.0849	482.0
484.0	131.142	0.01797	3.4078	3.4258	519.7	872.2	1391.1	1.0006	1.0799	1.0806	484.0
486.0	138.138	0.01801	3.2423	3.2603	523.9	868.9	1392.7	1.0058	1.0705	1.0763	486.0
488.0	145.424	0.01806	3.0863	3.1044	528.1	865.5	1393.6	1.0110	1.0611	1.0721	488.0
490.0	153.010	0.01811	2.9392	2.9573	532.3	862.1	1394.4	1.0161	1.0517	1.0678	490.0
492.0	160.903	0.01816	2.8002	2.8184	536.5	858.6	1395.2	1.0212	1.0424	1.0637	492.0
494.0	169.113	0.01821	2.6691	2.6873	540.8	855.1	1395.9	1.0263	1.0332	1.0595	494.0
496.0	177.648	0.01826	2.5451	2.5633	545.0	851.6	1396.7	1.0314	1.0240	1.0554	496.0
498.0	186.517	0.01831	2.4279	2.4462	549.3	848.1	1397.4	1.0365	1.0148	1.0513	498.0
500.0	195.729	0.01836	2.3170	2.3353	553.6	844.5	1398.0	1.0416	1.0057	1.0473	500.0
504.0	205.294	0.01842	2.2120	2.2304	557.9	840.8	1398.7	1.0466	0.9966	1.0432	504.0
508.0	215.220	0.01847	2.1126	2.1311	562.2	837.2	1399.3	1.0516	0.9876	1.0392	508.0
512.0	225.516	0.01853	2.0184	2.0369	566.5	833.4	1399.9	1.0567	0.9786	1.0352	512.0
516.0	236.193	0.01858	1.9291	1.9477	570.8	829.7	1400.4	1.0617	0.9696	1.0313	516.0
520.0	247.259	0.01864	1.8444	1.8630	575.1	825.9	1401.0	1.0667	0.9607	1.0274	520.0
524.0	258.725	0.01870	1.7640	1.7827	579.4	822.0	1401.5	1.0717	0.9518	1.0234	524.0
528.0	270.600	0.01875	1.6877	1.7064	583.8	818.2	1401.9	1.0766	0.9429	1.0195	528.0
532.0	282.894	0.01881	1.6152	1.6340	588.1	814.2	1402.4	1.0816	0.9341	1.0157	532.0
536.0	295.617	0.01887	1.5463	1.5651	592.5	810.2	1402.8	1.0866	0.9253	1.0118	536.0
540.0	308.780	0.01894	1.4808	1.4997	596.9	806.2	1403.1	1.0915	0.9165	1.0080	540.0
544.0	322.391	0.01900	1.4184	1.4374	601.3	802.2	1403.5	1.0964	0.9077	1.0042	544.0
548.0	336.463	0.01906	1.3591	1.3782	605.7	798.0	1403.7	1.1014	0.8990	1.0004	548.0
552.0	351.00	0.01913	1.30266	1.32179	610.1	793.9	1404.0	1.1063	0.8903	0.9966	552.0
556.0	366.03	0.01919	1.24887	1.26806	614.6	789.7	1404.2	1.1112	0.8816	0.9928	556.0
560.0	381.54	0.01926	1.19761	1.21687	619.0	785.4	1404.4	1.1161	0.8729	0.9890	560.0
564.0	397.56	0.01933	1.14874	1.16806	623.5	781.1	1404.6	1.1210	0.8643	0.9853	564.0
568.0	414.09	0.01940	1.10212	1.12152	628.0	776.7	1404.7	1.1259	0.8557	0.9815	568.0
572.0	431.14	0.01947	1.05764	1.07711	632.5	772.3	1404.8	1.1308	0.8471	0.9778	572.0
576.0	448.73	0.01954	1.01518	1.03472	637.0	767.8	1404.8	1.1356	0.8385	0.9741	576.0

Table 1. Saturated Steam: Temperature Table—Continued

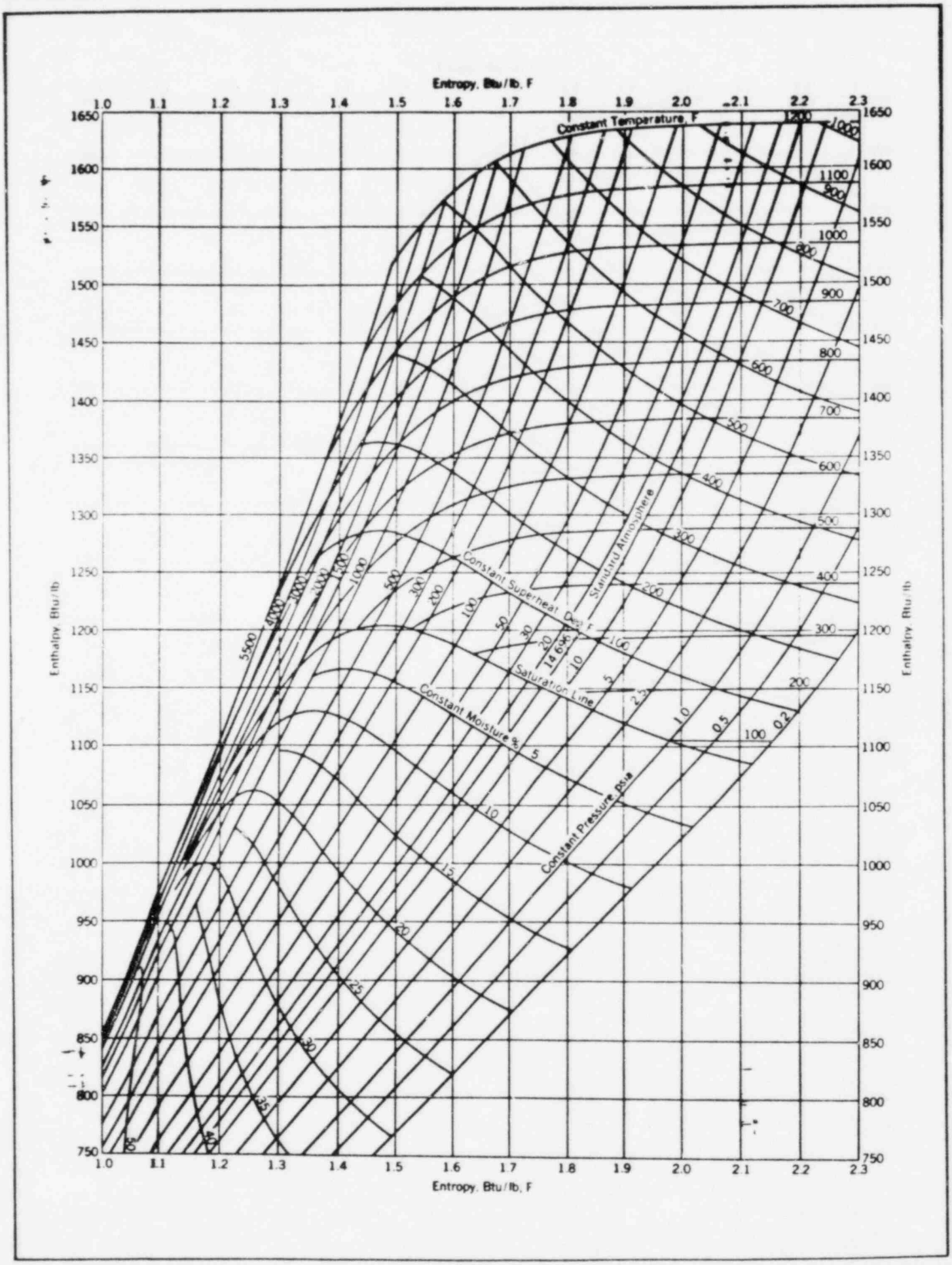
Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat Vapor s_g	Temp Fahr t
680.0	486.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6485	0.8299	1.4784	680.0
684.0	495.56	0.01969	0.93588	0.95557	446.1	758.6	1204.7	0.6494	0.8213	1.4707	684.0
688.0	504.83	0.01976	0.89885	0.91862	450.7	754.0	1204.6	0.6502	0.8127	1.4629	688.0
692.0	514.67	0.01984	0.86345	0.88329	455.2	749.3	1204.5	0.6511	0.8042	1.4552	692.0
696.0	525.11	0.01992	0.82958	0.84950	459.8	744.5	1204.3	0.6519	0.7956	1.4475	696.0
700.0	536.15	0.02000	0.79716	0.81717	464.5	739.6	1204.1	0.6528	0.7871	1.4398	700.0
704.0	547.81	0.02009	0.76613	0.78622	469.1	734.7	1203.8	0.6536	0.7785	1.4321	704.0
708.0	560.10	0.02017	0.73641	0.75658	473.8	729.7	1203.5	0.6545	0.7700	1.4244	708.0
712.0	573.03	0.02026	0.70794	0.72820	478.5	724.6	1203.1	0.6553	0.7614	1.4167	712.0
716.0	586.61	0.02034	0.68065	0.70100	483.2	719.5	1202.7	0.6562	0.7528	1.4090	716.0
720.0	600.86	0.02043	0.65448	0.67492	487.9	714.3	1202.2	0.6570	0.7443	1.4013	720.0
724.0	615.78	0.02053	0.62938	0.64991	492.7	709.0	1201.7	0.6579	0.7357	1.3936	724.0
728.0	631.40	0.02062	0.60530	0.62592	497.5	703.7	1201.1	0.6587	0.7271	1.3858	728.0
732.0	647.72	0.02072	0.58218	0.60289	502.3	698.2	1200.5	0.6596	0.7185	1.3781	732.0
736.0	664.76	0.02081	0.55997	0.58079	507.1	692.7	1199.8	0.6605	0.7099	1.3703	736.0
740.0	682.53	0.02091	0.53864	0.55956	512.0	687.0	1199.0	0.6613	0.7013	1.3626	740.0
744.0	701.04	0.02102	0.51814	0.53916	516.9	681.3	1198.2	0.6622	0.6926	1.3548	744.0
748.0	720.31	0.02112	0.49843	0.51955	521.8	675.5	1197.3	0.6631	0.6839	1.3470	748.0
752.0	740.34	0.02123	0.47947	0.50070	526.8	669.6	1196.4	0.6640	0.6752	1.3392	752.0
756.0	761.17	0.02134	0.46123	0.48257	531.7	663.6	1195.4	0.6649	0.6665	1.3313	756.0
760.0	782.79	0.02146	0.44367	0.46513	536.8	657.5	1194.3	0.6658	0.6577	1.3234	760.0
764.0	805.22	0.02157	0.42677	0.44834	541.8	651.3	1193.1	0.6667	0.6489	1.3155	764.0
768.0	828.49	0.02169	0.41048	0.43217	546.9	645.0	1191.9	0.6676	0.6400	1.3076	768.0
772.0	852.59	0.02182	0.39479	0.41660	552.0	638.5	1190.6	0.6685	0.6311	1.2996	772.0
776.0	877.55	0.02194	0.37966	0.40160	557.2	632.0	1189.2	0.6695	0.6222	1.2917	776.0
780.0	903.38	0.02207	0.36507	0.38714	562.4	625.3	1187.7	0.6704	0.6132	1.2837	780.0
784.0	930.08	0.02221	0.35096	0.37320	567.6	618.5	1186.1	0.6714	0.6041	1.2756	784.0
788.0	957.70	0.02235	0.33731	0.35975	572.9	611.5	1184.5	0.6723	0.5950	1.2675	788.0
792.0	986.24	0.02249	0.32409	0.34678	578.3	604.5	1182.7	0.6733	0.5859	1.2594	792.0
796.0	1015.74	0.02264	0.31128	0.33426	583.7	597.2	1180.9	0.6743	0.5766	1.2512	796.0
800.0	1046.17	0.02279	0.29887	0.32216	589.1	589.9	1179.0	0.6753	0.5673	1.2430	800.0
804.0	1077.57	0.02295	0.28683	0.31048	594.6	582.4	1176.9	0.6763	0.5580	1.2347	804.0
808.0	1109.93	0.02311	0.27515	0.29919	600.1	574.7	1174.8	0.6773	0.5485	1.2264	808.0
812.0	1143.27	0.02328	0.26382	0.28827	605.7	566.8	1172.6	0.6783	0.5390	1.2179	812.0
816.0	1177.61	0.02345	0.25282	0.27770	611.4	558.8	1170.2	0.6793	0.5293	1.2095	816.0
820.0	1212.96	0.02364	0.24214	0.26747	617.1	550.6	1167.7	0.6804	0.5196	1.2010	820.0
824.0	1249.33	0.02382	0.23174	0.25757	622.9	542.2	1165.1	0.6814	0.5097	1.1924	824.0
828.0	1286.73	0.02402	0.22162	0.24796	628.8	533.6	1162.4	0.6824	0.4996	1.1838	828.0
832.0	1325.17	0.02422	0.21177	0.23865	634.8	524.7	1159.5	0.6834	0.4894	1.1751	832.0
836.0	1364.66	0.02444	0.20216	0.22960	640.8	515.6	1156.4	0.6845	0.4790	1.1663	836.0
840.0	1405.21	0.02466	0.19279	0.22081	646.9	506.3	1153.2	0.6855	0.4683	1.1574	840.0
844.0	1446.83	0.02489	0.18363	0.21226	653.1	496.6	1149.8	0.6866	0.4574	1.1484	844.0
848.0	1489.54	0.02514	0.17468	0.20394	659.5	486.7	1146.1	0.6877	0.4462	1.1393	848.0
852.0	1533.35	0.02539	0.16594	0.19583	665.9	476.4	1142.2	0.6888	0.4347	1.1301	852.0
856.0	1578.28	0.02566	0.15738	0.18792	672.4	465.7	1138.1	0.6900	0.4229	1.1208	856.0
860.0	1624.34	0.02595	0.14901	0.18021	679.1	454.6	1133.7	0.6912	0.4107	1.1114	860.0
864.0	1671.54	0.02625	0.14082	0.17269	685.9	443.1	1129.0	0.6924	0.3981	1.1019	864.0
868.0	1719.90	0.02657	0.13278	0.16534	692.9	431.1	1124.0	0.6937	0.3850	1.0923	868.0
872.0	1769.43	0.02691	0.12490	0.15816	700.0	418.7	1118.7	0.6950	0.3715	1.0825	872.0
876.0	1820.14	0.02728	0.11717	0.15115	707.4	405.7	1113.1	0.6964	0.3574	1.0726	876.0
880.0	1872.06	0.02768	0.10959	0.14431	714.9	392.1	1107.0	0.6979	0.3427	1.0626	880.0
884.0	1925.19	0.02811	0.10217	0.13767	722.9	377.7	1100.6	0.6995	0.3273	1.0524	884.0
888.0	1979.56	0.02858	0.09491	0.13087	731.5	362.1	1093.5	0.7013	0.3110	1.0420	888.0
892.0	2035.18	0.02911	0.08781	0.12424	740.2	345.7	1085.9	0.7032	0.2939	1.0314	892.0
896.0	2092.07	0.02970	0.08089	0.11769	749.2	328.5	1077.6	0.7052	0.2757	1.0205	896.0
900.0	2150.26	0.03037	0.07414	0.11117	758.5	310.1	1068.5	0.7075	0.2564	1.0093	900.0
904.0	2209.77	0.03114	0.06759	0.10463	768.2	290.2	1058.4	0.7100	0.2357	0.9977	904.0
908.0	2270.64	0.03206	0.06125	0.09799	778.8	268.2	1047.0	0.7128	0.2133	0.9861	908.0
912.0	2332.90	0.03313	0.05497	0.09110	790.5	243.1	1033.6	0.7163	0.1885	0.9728	912.0
916.0	2396.59	0.03455	0.04916	0.08371	804.4	212.8	1017.2	0.7205	0.1604	0.9589	916.0
920.0	2461.74	0.03662	0.03857	0.07519	822.4	172.7	995.2	0.7261	0.1240	0.9401	920.0
924.0	2528.40	0.03824	0.03173	0.06997	835.0	144.7	979.7	0.7300	0.0978	0.9278	924.0
928.0	2596.61	0.04108	0.02192	0.06300	854.2	102.0	956.2	0.7359	0.0597	0.9096	928.0
932.0	2666.41	0.04427	0.01304	0.05730	873.0	61.4	934.4	0.7415	0.0227	0.8942	932.0
935.47*	2729.2	0.05078	0.00000	0.05078	906.0	0.0	906.0	0.7512	0.0000	0.7512	935.47*

*Critical temperature

Table 2: Saturated Steam: Pressure Table

Abs Press. Lb/Sq In. p	Temp Fahr t	Specific Volume: Sat. Liquid v_f	Specific Volume: Evap v_{fg}	Specific Volume: Sat. Vapor v_g	Enthalpy: Sat. Liquid h_f	Enthalpy: Evap h_{fg}	Enthalpy: Sat. Vapor h_g	Entropy: Sat. Liquid s_f	Entropy: Evap s_{fg}	Entropy: Sat. Vapor s_g	Abs Press. Lb/Sq In. p
0.08865	32.018	0.016022	3302.4	3302.4	0.0003	1075.5	1075.5	0.0000	2.1872	2.1872	0.08865
0.25	59.323	0.016032	1235.5	1235.5	27.382	1060.1	1087.4	0.0542	2.0425	2.0967	0.25
0.50	79.586	0.016071	641.5	641.5	47.623	1048.6	1096.3	0.0925	1.9446	2.0370	0.50
1.0	101.74	0.016136	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	1.0
5.0	162.24	0.016407	73.515	73.532	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	5.0
10.0	193.21	0.016592	38.404	38.420	161.26	982.1	1143.3	0.2836	1.5043	1.7879	10.0
14.696	212.00	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	14.696
15.0	213.03	0.016726	26.274	26.290	181.21	969.7	1150.9	0.3137	1.4415	1.7552	15.0
20.0	227.96	0.016834	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	20.0
30.0	250.34	0.017009	13.7266	13.7436	218.9	945.2	1164.1	0.3682	1.3313	1.6995	30.0
40.0	267.25	0.017151	10.4794	10.4965	236.1	933.6	1169.8	0.3921	1.2844	1.6765	40.0
50.0	281.02	0.017274	8.4967	8.5140	250.2	923.9	1174.1	0.4112	1.2474	1.6586	50.0
60.0	292.71	0.017383	7.1562	7.1736	262.2	915.4	1177.6	0.4273	1.2167	1.6440	60.0
70.0	302.93	0.017482	6.1875	6.2050	272.7	907.8	1180.6	0.4411	1.1905	1.6316	70.0
80.0	312.04	0.017573	5.4536	5.4711	282.1	900.9	1183.1	0.4534	1.1675	1.6208	80.0
90.0	320.28	0.017659	4.8779	4.8953	290.7	894.6	1185.3	0.4643	1.1470	1.6113	90.0
100.0	327.82	0.017740	4.4133	4.4310	298.5	888.6	1187.2	0.4743	1.1284	1.6027	100.0
110.0	334.79	0.01782	4.0306	4.0484	305.8	883.1	1188.9	0.4834	1.1115	1.5950	110.0
120.0	341.27	0.01789	3.7097	3.7275	312.6	877.8	1190.4	0.4919	1.0960	1.5879	120.0
130.0	347.33	0.01796	3.4364	3.4544	319.0	872.8	1191.7	0.4998	1.0815	1.5813	130.0
140.0	353.04	0.01803	3.2010	3.2190	325.0	868.0	1193.0	0.5071	1.0681	1.5752	140.0
150.0	358.43	0.01809	2.9958	3.0139	330.6	863.4	1194.1	0.5141	1.0554	1.5695	150.0
160.0	363.55	0.01815	2.8155	2.8336	336.1	859.0	1195.1	0.5206	1.0435	1.5641	160.0
170.0	368.42	0.01821	2.6556	2.6738	341.2	854.8	1196.0	0.5269	1.0322	1.5591	170.0
180.0	373.08	0.01827	2.5129	2.5312	346.2	850.7	1196.9	0.5328	1.0215	1.5543	180.0
190.0	377.53	0.01833	2.3847	2.4030	350.9	846.7	1197.6	0.5384	1.0113	1.5498	190.0
200.0	381.80	0.01839	2.2689	2.2873	355.5	842.8	1198.3	0.5438	1.0016	1.5454	200.0
210.0	385.91	0.01844	2.16373	2.18217	359.9	839.1	1199.0	0.5490	0.9923	1.5413	210.0
220.0	389.88	0.01850	2.06779	2.08629	364.2	835.4	1199.6	0.5540	0.9834	1.5374	220.0
230.0	393.70	0.01855	1.97991	1.99846	368.3	831.8	1200.1	0.5588	0.9748	1.5336	230.0
240.0	397.39	0.01860	1.89909	1.91769	372.3	828.4	1200.6	0.5634	0.9665	1.5299	240.0
250.0	400.97	0.01865	1.82452	1.84317	376.1	825.0	1201.1	0.5679	0.9585	1.5264	250.0
260.0	404.44	0.01870	1.75548	1.77418	379.9	821.6	1201.5	0.5722	0.9508	1.5230	260.0
270.0	407.80	0.01875	1.69137	1.71013	383.6	818.3	1201.9	0.5764	0.9433	1.5197	270.0
280.0	411.07	0.01880	1.63169	1.65049	387.1	815.1	1202.3	0.5805	0.9361	1.5166	280.0
290.0	414.25	0.01885	1.57597	1.59482	390.6	812.0	1202.6	0.5844	0.9291	1.5135	290.0
300.0	417.35	0.01889	1.52384	1.54274	394.0	808.9	1202.9	0.5882	0.9223	1.5105	300.0
350.0	431.73	0.01912	1.30642	1.32554	409.8	794.2	1204.0	0.6059	0.8909	1.4968	350.0
400.0	444.60	0.01934	1.14162	1.16095	424.2	780.4	1204.6	0.6217	0.8630	1.4847	400.0
450.0	456.28	0.01954	1.01224	1.03179	437.3	767.5	1204.8	0.6360	0.8378	1.4738	450.0
500.0	467.01	0.01975	0.90787	0.92762	449.5	755.1	1204.7	0.6490	0.8148	1.4639	500.0
550.0	476.94	0.01994	0.82183	0.84177	460.9	743.3	1204.3	0.6611	0.7936	1.4547	550.0
600.0	486.20	0.02013	0.74962	0.76975	471.7	732.0	1203.7	0.6723	0.7738	1.4461	600.0
650.0	494.89	0.02032	0.68811	0.70843	481.9	720.9	1202.8	0.6828	0.7552	1.4381	650.0
700.0	503.08	0.02050	0.63505	0.65556	491.6	710.2	1201.8	0.6928	0.7377	1.4304	700.0
750.0	510.84	0.02069	0.58880	0.60949	500.9	699.8	1200.7	0.7022	0.7210	1.4232	750.0
800.0	518.21	0.02087	0.54809	0.56896	509.8	689.6	1199.4	0.7111	0.7051	1.4163	800.0
850.0	525.24	0.02105	0.51197	0.53302	518.4	679.5	1198.0	0.7197	0.6899	1.4096	850.0
900.0	531.95	0.02123	0.47968	0.50091	526.7	669.7	1196.4	0.7279	0.6753	1.4032	900.0
950.0	538.39	0.02141	0.45064	0.47205	534.7	660.0	1194.7	0.7358	0.6612	1.3970	950.0
1000.0	544.58	0.02159	0.42436	0.44596	542.6	650.4	1192.9	0.7434	0.6476	1.3910	1000.0
1050.0	550.53	0.02177	0.40047	0.42224	550.1	640.9	1191.0	0.7507	0.6344	1.3851	1050.0
1100.0	556.28	0.02195	0.37863	0.40058	557.5	631.5	1189.1	0.7578	0.6216	1.3794	1100.0
1150.0	561.82	0.02214	0.35859	0.38073	564.8	622.2	1187.0	0.7647	0.6091	1.3738	1150.0
1200.0	567.19	0.02232	0.34013	0.36245	571.9	613.0	1184.8	0.7714	0.5969	1.3683	1200.0
1250.0	572.38	0.02250	0.32306	0.34556	578.8	603.8	1182.6	0.7780	0.5850	1.3630	1250.0
1300.0	577.42	0.02269	0.30722	0.32991	585.6	594.6	1180.2	0.7843	0.5733	1.3577	1300.0
1350.0	582.32	0.02288	0.29250	0.31537	592.3	585.4	1177.8	0.7906	0.5620	1.3525	1350.0
1400.0	587.07	0.02307	0.27871	0.30178	598.8	576.5	1175.3	0.7966	0.5507	1.3474	1400.0
1450.0	591.70	0.02327	0.26584	0.28911	605.3	567.4	1172.8	0.8026	0.5397	1.3423	1450.0
1500.0	596.20	0.02346	0.25372	0.27719	611.7	558.4	1170.1	0.8085	0.5288	1.3373	1500.0
1550.0	600.59	0.02366	0.24235	0.26601	618.0	549.4	1167.4	0.8142	0.5182	1.3324	1550.0
1600.0	604.87	0.02387	0.23159	0.25545	624.2	540.3	1164.5	0.8199	0.5076	1.3274	1600.0
1650.0	609.05	0.02407	0.22143	0.24551	630.4	531.3	1161.6	0.8254	0.4971	1.3225	1650.0
1700.0	613.13	0.02428	0.21178	0.23607	636.5	522.2	1158.6	0.8309	0.4867	1.3176	1700.0
1750.0	617.12	0.02450	0.20263	0.22713	642.5	513.1	1155.6	0.8363	0.4765	1.3128	1750.0
1800.0	621.02	0.02472	0.19390	0.21861	648.5	503.8	1152.3	0.8417	0.4662	1.3079	1800.0
1850.0	624.83	0.02495	0.18558	0.21052	654.5	494.6	1149.0	0.8470	0.4561	1.3030	1850.0
1900.0	628.56	0.02517	0.17761	0.20278	660.4	485.2	1145.6	0.8522	0.4459	1.2981	1900.0
1950.0	632.22	0.02541	0.16999	0.19540	666.3	475.8	1142.0	0.8574	0.4358	1.2931	1950.0
2000.0	635.80	0.02565	0.16266	0.18831	672.1	466.2	1138.3	0.8625	0.4256	1.2881	2000.0
2100.0	642.76	0.02615	0.14885	0.17501	683.8	446.7	1130.5	0.8727	0.4053	1.2780	2100.0
2200.0	649.45	0.02669	0.13603	0.16272	695.5	426.7	1122.2	0.8828	0.3848	1.2676	2200.0
2300.0	655.89	0.02727	0.12406	0.15133	707.2	406.0	1113.2	0.8929	0.3640	1.2569	2300.0
2400.0	662.11	0.02790	0.11287	0.14076	719.0	384.8	1103.7	0.9031	0.3430	1.2460	2400.0
2500.0	668.11	0.02859	0.10209	0.13068	731.7	361.6	1093.3	0.9139	0.3206	1.2345	2500.0
2600.0	673.91	0.02938	0.09172	0.12110	744.5	337.6	1082.0	0.9247	0.2977	1.2225	2600.0
2700.0	679.53	0.03029	0.08165	0.11194	757.3	312.3	1069.7	0.9356	0.2741	1.2097	2700.0
2800.0	684.96	0.03134	0.07171	0.10305	770.7	285.1	1055.8	0.9468	0.2491	1.1958	2800.0
2900.0	690.22	0.03262	0.06158	0.09420	785.1	254.7	1039.8	0.9588	0.2215	1.1803	2900.0
3000.0	695.33	0.03428	0.05073	0.08500	801.8	218.4	1020.3	0.9728	0.1891	1.1619	3000.0
3100.0	700.28	0.03681	0.03771	0.07452	824.0	169.3	993.3	0.9914	0.1460	1.1373	3100.0
3200.0	705.08	0.04472	0.01191	0.05663	875.5	56.1	931.6	1.0351	0.0482	1.0832	3200.0
3208.2*	705.47	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	3208.2*

*Critical pressure



Mollier diagram (h-s) for steam.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER A.01 (1.00)

P=P*exp(t/T)
500,000=100*exp(t/30)
ln 5000=t/30
t=30*~~9.5~~/8.5 = ~~285~~/255 seconds = 4.75 minutes (1.0)
4.25

REFERENCE
Basic Reactor Theory

ANSWER A.02 (2.00)

a. K-infinite is the multiplication constant for a theoretical reactor with zero leakage. K-effective takes into account neutrons lost due to slow and fast leakage (k-eff = k-inf * slow and fast non-leakage probability.) (1.0)
b. k-excess = k-effective-1 = 1.0795-1 = 0.0795 delta k (0.5)
c. Reactivity = (k-effective-1)/k-effective = (1.0795-1)/1.0795 = 0.0736 delta k/k (0.5)

REFERENCE
Basic Reactor Theory

ANSWER A.03 (1.00)

The fraction of all neutrons in a given generation which are emitted from the decay of fission fragments at a significant time after the actual fission event. (1.0)

REFERENCE
Basic Reactor Theory

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER A.04 (2.00)

a. There is a "prompt jump" increase in neutron flux due to the immediate effects of prompt neutrons. (0.5)
Power then increases on a stable period the value of which is determined by the amount of reactivity inserted and the delayed neutron generation time. (0.5)

b. Following a scram there is a prompt drop in neutron flux as prompt neutron generation is stopped. (0.5)
Flux then gradually decreases as delayed neutrons continue to be generated from the decay of the precursor groups. (0.5)

REFERENCE
Basic Reactor Theory

ANSWER A.05 (1.50)

a. Neutrons of low energy have the highest probability of causing fission in the fuel. Most neutrons are born at high energy levels. The moderator reduces the neutron energy level. (1.0)

b. (1) low mass number (0.5)

REFERENCE
Basic Reactor Theory

ANSWER A.06 (2.00)

a. False (0.5) - After reaching equilibrium the samarium concentration remains constant. (0.5)

b. False (0.5) - It may be xenon free but samarium will not decay away. (0.5)

REFERENCE
Basic Reactor Theory

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER A.07 (2.00)

a. Core reactivity is decreased. (0.5)
The temperature increase causes a density decrease in the moderator. There is less moderation and more neutron leakage which is a negative reactivity effect. (0.5)

b. Control rod worth increases. (0.5)
As moderation is decreased and the probability of leakage into a control rod increases, the effectiveness of the control rods increases. (0.5)

REFERENCE
Basic Reactor Theory

ANSWER A.08 (2.00)

a. Observe period and flux level instrumentation. When power level continues to increase and period remains positive after rod withdrawal, the reactor is supercritical. The exact critical position is difficult to differentiate from subcritical multiplication. (1.0)

b. Not valid (0.5) - The count rate at critical is a function of starting count rate (source) and the shutdown margin. Also several months later burnup, poisons, and any changes in experiments will have some effect. (0.5)

REFERENCE
Basic Reactor Theory

ANSWER A.09 (1.00)

REFERENCE
a. 50 psig (0.5)
b. 297 degrees F (0.5)

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER B.01 (3.50)

A. Control Blade (0.5)
B. Small Graphite Reflector Elements (0.5)
C. Irradiation Elements (0.5)
D. Beamport (0.5)
E. Fuel Elements (0.5)
F. Beryllium Reflector (0.5)
G. Large Graphite Reflector Elements (0.5)

REFERENCE
MURR Training Manual, p. I-2.

ANSWER B.02 (2.00)

a. Need minimum pressure to ensure sufficient air to break the siphon should a double ended pipe rupture occur. (0.5)
Maximum pressure must be maintained below the operating core pressure to minimize possibility of air leakage into the primary coolant due to leaking antisiphon valves. (0.5)
b. Manually introducing air from the facility air supply (0.5) and venting the system through particulate and charcoal filters. (0.5)

REFERENCE
MURR Training Manual, p. I-29.

ANSWER B.03 (2.50)

a. LC925A vents the tank through vent valve 552A on low level in the vent tank. (0.5)
If water level continues to recede LC925B operates a parallel vent valve 552B (0.5) and initiates a rod run-in (0.5).
b. Exhaust line diverges to parallel paths each containing a strainer, check valve, and solenoid valve (0.25). Exhaust line converges and passes through pressure regulator (0.25) and charcoal filter (0.25) and then to the pool sweep (0.25).

REFERENCE
MURR Training Manual, p. I-31.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER B.04 (2.50)

For valve 16A, loss of electrical power to either Schrader valve will vent air from the actuator (0.5) and allow the spring to close the valve (0.5). For valve 16B, loss of electrical power to either Schrader valve on the open side of the actuator will vent air from the open side (0.5). On loss of electrical power to the Schrader valves on the close side of the actuator, these valves will supply air to the close side (0.5) from an accumlator tank (0.25) supplied by a dedicated air compressor (0.25).

REFERENCE
MURR Training Manual, p. I-87.

ANSWER B.05 (1.50)

a. Shim Rods (0.5)
b. Regulating Rod (0.5)
c. Shim Rods (0.5)

REFERENCE
MURR Training Manual, p. II-76, II-79.

ANSWER B.06 (2.50)

a. Primary - To provide pressurized non-contaminated gas to the pressurizer. (0.5)
   Secondary - To act as a backup to the air in the valve opeating system. (0.5)
b. Automatic switching of banks (0.5) at 120 psig (0.25). Nitrogen System Low Pressure alarm on annunciator unit in control room (0.5) at 115 psig (0.25).

REFERENCE
MURR Training Manual, p. IV-1, IV-2.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER C.01 (2.00)

Natural convection to pool with vessel head removed and flanged port open (0.25) - Limited to 100 kilowatts (0.25).
Reactor loop pressurized with only one pump and one heat exchanger in use (0.25) - 1850 (+50,-50) gpm flowrate (0.25) - 5 megawatts (0.25).
Reactor loop pressurized with two pumps and two heat exchangers in use (0.25) - 3700 gpm (+50,-50) gpm flowrate (0.25) - 10 megawatts (0.25)

REFERENCE
MURR Hazards Summary Report, p. 5-1.

ANSWER C.02 (1.00)

Will cause water to bypass the core resulting in low differential pressure. (0.5) Differential pressure switch 929 signal will cause trip unit to reach flow scram setpoint. (0.5)

REFERENCE
MURR Training Manual, p. I-26.

ANSWER C.03 (1.50)

Changes in reactor reactivity due to beamport activities such as draining or flooding a beamport.
Exposure of personnel to radiation as a result of movements of shielding or inadequate shielding.
Release of radioactive gases such as Ar-41 which are produced in the beamport.
A production of explosive or toxic materials in the beamports.
(3 required - 0.5 pts. each)

REFERENCE
MURR Training Manual, p. I-20.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER C.04 (2.00)

a. Flowrates were adjusted according to the composition of the special reflector elements in the reflector irradiation area such that the pressure drop across the reflector region is kept constant. (1.0)
b. To remove core decay heat from the reflector and experimental facility. (0.5)
c. To allow oxygen and nitrogen activity to decay before coolant water is returned to the pool. (0.5)

REFERENCE
MURR Training Manual, p. I-38, I-39.

ANSWER C.05 (2.50)

a. 134 degrees F (0.5)
b. 600 (+100,-100) gpm (0.5)
c. 2000-2200 psig (0.5)
d. 105 degrees F (0.5)
e. 30-45 psig (0.5)

REFERENCE
SOP/1-14, VII-54

ANSWER C.06 (2.00)

a. To ensure that the reactivity insertion is less than that which would cause fuel element failure. (1.0)
b. The other experimental facilities are decoupled from the reactor by means of the beryllium reflector and thus reactivity effects are minimal. (1.0)

REFERENCE
MURR Training Manual, p. I-12, I-14.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER C.07 (2.50)

a. positive (0.5)
b. negative (0.5)
c. negative (0.5)
d. positive (0.5)
e. positive (0.5)

REFERENCE
MURR Hazards Summary Report, p. 4-14.
SOP/VIII-7.
Critical Parameters List

ANSWER C.08 (1.00)

To minimize the corrosion rate. (0.5)
To minimize induced activity. (0.5)

REFERENCE
SOP/II-4.

D. INSTRUMENTS AND CONTROLS

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER D.01 (3.00)

a. Fission Chamber (0.5) - Pulse Height Discriminator (0.5)
b. Compensated Ion Chamber (0.5) - Gamma-ray induced currents are automatically subtracted from total current readings. (0.5)
c. Uncompensated Ion Chamber (0.5) - Neutron flux is of sufficient intensity that gamma current is insignificant. (0.5)

REFERENCE
MURR Training Manual, p. II-4, II-12.

ANSWER D.02 (3.00)

Drawer Inoperative (0.25) - Drawer inoperative panel light will light, annunciator will sound a "nuclear instrument anomaly" alarm, reactor will scram (0.25) - Automatic Reset (0.25)
Period Scram Trip (0.25) - Causes reactor scram (0.25) - Lockout trip must be reset using the reset switch (0.25)
Short Period Rod Run-In Trip (0.25) - Causes run-in of control rods (0.25) - Automatic Reset (0.25)
Period Automatic Control Interlock Trip (0.25) - Prevents the regulating control rod from being operated in the automatic mode (0.25) - Automatic Reset (0.25)

REFERENCE
MURR Training Manual, p. II-30, II-31, II-32.

ANSWER D.03 (2.00)

a. To indicate possible fuel failure (0.5) - Monitors effluent from the reactor on the discharge of heat exchangers 503A and 503B (0.5).
b. To detect leaks into the secondary system from the pool or primary (0.5) - Located on the return line from the heat exchanger (0.5).

REFERENCE
MURR Training Manual, p. II-46, II-49.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER D.04 (2.00)

The period as indicated by both IRM-2 and IRM-3 must indicate not less than 35 seconds. (0.5)
The WRM selector switch must be in the 5 kilowattt red scale position or above. (0.5)
The power trace pointer (black) on the WRM recorder must be reading greater than the auto control prohibits setpoint (red). (0.5)
The regulating blade position must be greater than 60% withdrawn such that the 60% annunciator alarm is energized. (0.5)

REFERENCE
MURR Training Manual, p. II-79.

ANSWER D.05 (1.00)

Primary system cleanup flow bypasses the core and yet it flows through the primary flow orifice. (1.0)

REFERENCE
SOP/I-9, VII-1.

ANSWER D.06 (1.00)

Shim rods will qutomatically insert when the regulating rod reaches the 20% withdrawn position. (0.5) The insertion will be a sufficient amount to drive the regulating rod to its 60% withdrawn position at which point the signal is terminated. (0.5)

REFERENCE
MURR Training Manual, p. II-81.

ANSWER D.07 (2.00)

a. (3) (0.5)
b. (2) (0.5)
c. (1) (0.5)
d. (4) (0.5)

REFERENCE
MURR Training Manual, p. II-68
MURR Hazards Summary Report, p. 9-19

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER E.01 (2.00)

When pressurizer pressure exceeds 105% of 70 psi valve 545 will open to bleed off nitrogen gas to the offgas system. (0.5) If pressure exceeds 110% of 70 psi pressurizer high pressure alarm will sound in the control room. (0.5) A reactor scram occurs at 115% of 70 psi. (0.5) At still a higher pressure the excess pressure will be vented through safety relief valve 537 to the offgas system. (0.5)

REFERENCE
MURR Training Manual, p. I-47.

ANSWER E.02 (1.50)

a. Master Control Switch (151) has been turned to "test" and then back to "on". (0.5)
b. With the present antisyphon system the core stays pressurized and the 944c can relate, causing cycling of the pumps and valves if not for the circuit lockout. (0.5)
c. Can be bypassed in 50 kilowatt mode. (0.5)

REFERENCE
MURR Training Manual, p. I-34, p. II-75.

ANSWER E.03 (1.50)

High Power
Short Period
Low Pool Level
Vent Tank Low Level
Rod Not In Contact With Magnet
Anti-siphon Line High Level
Truck Entry Door Seal Deflated
Regulating Blade Position less than 10% withdrawn or bottomed
(6 required - 0.25 pts. each)

REFERENCE
SOP/I-15,I-16,I-17,I-18.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER E.04 (2.50)

a. Loss of site electrical power at substation "B". (0.5)
   Signal from seven day clock plant exerciser. (0.5)
b. To assume the load should any additional power interruptions occur. (0.5)
c. (1) and (2)
   (2 required - 0.5 pts. each - Will subtract 0.5 pts. for each incorrect answer given up to value of question.)

REFERENCE
MURR Training Manual, p. III-10, III-11, III-12.

ANSWER E.05 (1.00)

(3) and (5)
(2 required - 0.5 pts. each - Will subtract 0.5 pts. for each incorrect answer given up to value of question.)

REFERENCE
MURR Training Manual, p. IV-5.

ANSWER E.06 (3.00)

a. Reactor Control Room (0.5)
   Lobby Control Center (0.5)
b. Reactor scrams
   Containment ventilation system isolation doors close
   Containment exhaust isolation valves close
   Facility horn sounds
   Flashing red light exterior to the containment personnel airlock door is energized
   (4 required - 0.5 pts. each)

REFERENCE
FEP-1, p. 1.

ANSWER E.07 (2.00)

(2), (5), (6), (7)
(4 required - 0.5 pts each - Will subtract 0.5 pts. for each incorrect answer given up to total value of question)

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

REFERENCE
SOP/I-15, I-16, I-17, I-18

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER F.01 (2.00)

a. Facility Evacuation (0.25)
Reactor Isolation (0.25)
Fire (0.25)
Medical (0.25)
Security (0.25)
b. Unusual Event (0.25)
Alert (0.25)
Site Area Emergency (0.25)

REFERENCE
FEP's
SEP-1, p. 1.

ANSWER F.02 (2.00)

Verify that the reactor has scrammed as indicated by the instrumentation.
Verify that all shim rods have bottomed as indicated by the console lights.
Verify that the containment has sealed as indicated by the ventilation door and the exhaust valve lights.
Ensure all personnel are cleared from fifth, fourth, third, and second levels of the containment building and exit via personnel air lock doors.
If the Assistant Duty Operator is not known to be in containment, the Duty Operator shall also ensure that all personnel are cleared from the beamport floor.
(4 required - 0.5 pts. each)

REFERENCE
FEP-2, p. 2,3.

ANSWER F.03 (1.00)

a. A "hot startup" is a startup within two hours of any shutdown, in which re-start capability is in doubt. (0.5)
b. False (0.5)

REFERENCE
SOP/I-3, I-4, I-7.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER F.04 (1.00)

(1) and (4)
(2 required - 0.5 pts. each - Will subtract 0.5 pts. for each incorrect answer given up to total value of question.)

REFERENCE
REP-13-2.

ANSWER F.05 (3.00)

a. This type of anomaly may not be obvious. Symtoms include dimming of lights, loss of some containment lights, or loss of some process system equipment. (1.0)
b. Scram the reactor/or if already scrammed, check reactor shutdown. (0.5
Turn OFF all pump and cooling tower fans in an expeditious manner. (0.5)
Place all valve controls in the normal shutdown position and manual mode. (0.5
Trip the auto transfer switch on substation "B". (0.5)

REFERENCE
REP-9-1.

ANSWER F.06 (2.50)

Mechanical failure of a secondary cooling pump.
Air binding of a secondary cooling pump.
A break in the secondary cooling line.
Loss of water in the cooling tower causing pump to shutoff when low sump level switch is tripped.
Restriction in flow due to a faulty check valve on the discharge side of a running sump pump.
Failure in low sump level cutout circuitry (proper sump level, but pumps trip off.)
Clogged suction strainer.
(5 required - 0.5 pts. each)

REFERENCE
REP-13-1.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER F.07 (1.50)

Open manually from control room with valve control switch. (0.5)
Open manually with T-wrench locally at valve. (0.5)
Close the air supply line to the valve at th bridge and disconnect copper tubing on the valve side of the 3-way solenoid. (0.5)

REFERENCE
REF-19-1.

ANSWER F.08 (2.00)

a. To minimize check valve slam. (1.0)
b. To prevent excessive pressure that could occur in an isolated heat exchanger. (1.0)

REFERENCE
SOP/V-1, V-3.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER G.01 (1.00)

(1) and (4)
(2 required - 0.5 pts. each - Will subtract 0.5 pts. for each incorrect answer given up to total value of question.)

REFERENCE
MURR Training Manual, p. II-50, II-51
FEP-2, p. 1

ANSWER G.02 (3.00)

a. When the reactor reaches criticality. (0.5)
When reactor power reaches 50 kilowatts. (0.5)
When reactor power reaches 5 megawatts (2.5 megawatts if operating in Mode II). (0.5)
When reactor power reaches 10 megawatts (5 megawatts if operating in Mode II). (0.5)
b. Reactor power will be maintained at a steady level until the problem is corrected. (1.0)

REFERENCE
SOP/I-7, I-8.

ANSWER G.03 (1.00)

Significant potential for exposure of personnel to radiation or the spreading or release of airborne or surface contamination. (1.0)

REFERENCE
SOP/I-11

ANSWER G.04 (2.50)

a. Sludge Settlement (0.5)
Cuno Filters (0.5)
Chemical Precipitant Treatment (0.5)
b. (1) Shift Supervisor (0.5)
(2) Reactor Manager (0.5)

REFERENCE
SOP/VII-44, VII-45.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

ANSWER G.05 (2.00)

a. Health Physics will monitor the operation to minimize radiation exposure to personnel, terminating the operation if neccessary. (1.0)
b. Presence of member of Health Physics staff ^not required if, and only if, a licensed Reactor Operator or qualified sample handler surveys the operation. (1.0)

REFERENCE
SOP/VIII-8.

ANSWER G.06 (1.00)

About the same. (0.5) - Gm not sensitive to energy. (0.5)]

REFERENCE
Basic Theory

ANSWER G.07 (.50)

(4) fast neutrons (0.5)

REFERENCE
10 CFR 20.4

ANSWER G.08 (2.00)

a. 100 mrem/1 hr * (1 m/(25 cm * (1 m/100 cm)))**2 = 1600 mrem/hr (1.0)
b. Quarterly dose limit = 1.25 rem or 1250 mrem (0.5)
1250 mrem * (1 hr/1600 mrem) = .78 hours or 47 minutes (0.5)

REFERENCE
Basic Theory
10 CFR 20.101

ANSWER G.09 (1.00)

Distance of the tubes from personnel working in the area. (0.5)
Speed at which the sample container is transported through the system. (0.5)

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HILLS, D.

REFERENCE
Hazards Summary 8-25

QUESTION	VALUE	REFERENCE
A.01	1.00	HED0000057
A.02	2.00	HED0000058
A.03	1.00	HED0000059
A.04	2.00	HED0000060
A.05	1.50	HED0000061
A.06	2.00	HED0000062
A.07	2.00	HED0000063
A.08	2.00	HED0000064
A.09	1.00	HED0000110
	14.50	
B.01	3.50	HED0000065
B.02	2.00	HED0000066
B.03	2.50	HED0000067
B.04	2.50	HED0000068
B.05	1.50	HED0000069
B.06	2.50	HED0000070
	14.50	
C.01	2.00	HED0000071
C.02	1.00	HED0000072
C.03	1.50	HED0000073
C.04	2.00	HED0000074
C.05	2.50	HED0000075
C.06	2.00	HED0000076
C.07	2.50	HED0000077
C.08	1.00	HED0000078
	14.50	
D.01	3.00	HED0000079
D.02	3.00	HED0000080
D.03	2.00	HED0000081
D.04	2.00	HED0000082
D.05	1.00	HED0000083
D.06	1.00	HED0000084
D.07	2.00	HED0000085
	14.00	
E.01	2.00	HED0000086
E.02	1.50	HED0000087
E.03	1.50	HED0000088
E.04	2.50	HED0000089
E.05	1.00	HED0000090
E.06	3.00	HED0000091
E.07	2.00	HED0000092
	13.50	
F.01	2.00	HED0000093

QUESTION	VALUE	REFERENCE
F.02	2.00	HED0000094
F.03	1.00	HED0000095
F.04	1.00	HED0000096
F.05	3.00	HED0000097
F.06	2.50	HED0000098
F.07	1.50	HED0000099
F.08	2.00	HED0000100
	15.00	
G.01	1.00	HED0000101
G.02	3.00	HED0000102
G.03	1.00	HED0000103
G.04	2.50	HED0000104
G.05	2.00	HED0000105
G.06	1.00	HED0000106
G.07	.50	HED0000107
G.08	2.00	HED0000108
G.09	1.00	HED0000109
	14.00	
	100.00	

Master

U. S. NUCLEAR REGULATORY COMMISSION
SENIOR REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: UNIVERSITY OF MISSOURI

REACTOR TYPE: TEST

DATE ADMINISTERED: 86/07/01

EXAMINER: HIGGINS, R.

APPLICANT:

INSTRUCTIONS TO APPLICANT:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheets. Points for each question are indicated in parentheses after the question. The passing grade requires at least 70% in each category and a final grade of at least 70%. Examination papers will be picked up six (6) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	APPLICANT'S SCORE	% OF CATEGORY VALUE	CATEGORY
20.00	20.00			H. REACTOR THEORY
20.00	20.00			I. RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS
20.00	20.00			J. SPECIFIC OPERATING CHARACTERISTICS
20.00	20.00			K. FUEL HANDLING AND CORE PARAMETERS
20.00	20.00			L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS
100.00	100.00			TOTALS

FINAL GRADE _____ %

All work done on this examination is my own. I have neither given nor received aid.

APPLICANT'S SIGNATURE

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.

2. Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.

3. Use black ink or dark pencil only to facilitate legible reproductions.

4. Print your name in the blank provided on the cover sheet of the examination.

5. Fill in the date on the cover sheet of the examination (if necessary).

6. Use only the paper provided for answers.

7. Print your name in the upper right-hand corner of the first page of each section of the answer sheet.

8. Consecutively number each answer sheet, write "End of Category ___" as appropriate, start each category on a new page, write on only one side of the paper, and write "Last Page" on the last answer sheet.

9. Number each answer as to category and number, for example, 1.4, 6.3.

10. Skip at least three lines between each answer.

11. Separate answer sheets from pad and place finished answer sheet face down on your desk or table.

12. Use abbreviations only if they are commonly used in facility literature.

13. The point value for each question is indicated in parentheses after the question and can be used as a guide for the depth of answer required.

14. Show all calculations, methods, or assumptions used to obtain an answer to mathematical problems whether indicated in the question or not.

15. Partial credit may be given. Therefore, ANSWER ALL PARTS OF THE QUESTION AND DO NOT LEAVE ANY ANSWER BLANK.

16. If parts of the examination are not clear as to intent, ask questions of the examiner only.

17. You must sign the statement on the cover sheet that indicates that the work is your own and you have not received or been given assistance in completing the examination. This must be done after the examination has been completed.

18. When you complete your examination, you shall:

    a. Assemble your examination as follows:

        (1) Examination questions on top.

        (2) Examination aids - figures, tables, etc.

        (3) Answer pages including figures which are a part of the answer.

    b. Turn in your copy of the examination and all pages used to answer the examination questions.

    c. Turn in all scrap paper and the balance of the paper that you did not use for answering the questions.

    d. Leave the examination area, as defined by the examiner. If after leaving, you are found in this area while the examination is still in progress, your license may be denied or revoked.

QUESTION H.01 (1.00)

Give two reasons why the 10 MW equilibrium reactivity value of xenon is greater than that of samarium.

QUESTION H.02 (1.00)

Why does xenon reactivity peak after a trip from high power?

QUESTION H.03 (.50)

What is (are) the mechanism(s) by which samarium 149 is removed from the core?

QUESTION H.04 (2.00)

a. The reactor is initially subcritical with a source range count rate of 10 cps. Rods are withdrawn to raise the count rate to 16 cps. If rods are again withdrawn to insert the same amount of reactivity as was inserted by the first rod withdrawal, what will be the new equilibrium count rate? Show your work. (1.5)

b. Why does it take longer to reach this new equilibrium count rate than it did to reach 16 cps? (0.5)

QUESTION H.05 (1.00)

When is a 1/M plot required to be performed during a reactor startup?

QUESTION H.06 (1.50)

Why does the effective delayed neutron fraction differ from the delayed neutron fraction?

QUESTION H.07 (1.00)

Why is the stable reactor period after a reactor trip equal to -80 seconds?

(***** CATEGORY H CONTINUED ON NEXT PAGE *****)

QUESTION H.08 (2.50)

a. By procedure, what is the fastest reactor period which can be used when raising reactor power to 50 KW? (0.5)

b. Assuming reactor power is being raised at the shortest permissible period, how long will it take to raise reactor power from 2.5 MW to 5 MW? (1.0)

c. Explain why, with the same reactor period, it takes less time to increase power from 5 MW to 7.5 MW than it does to increase power from 2 MW to 5 MW? (1.0)

QUESTION H.09 (1.50)

Explain how source neutrons are generated at the MURR.

QUESTION H.10 (1.50)

a. What two conditions are necessary to cause a rapid aluminum-water reaction? (1.0)

b. What gas would be evolved by an aluminum-water reaction? (0.5)

QUESTION H.11 (2.00)

What four parameters are used to determine the reactor safety limit curve?

QUESTION H.12 (1.00)

Why is one of the safety limit criteria at the MURR the requirement to maintain the hot channel coolant exit temperature below saturation?

QUESTION H.13 (2.50)

a. What is nucleate boiling? (1.0)

b. What is meant by the term "DNBR"? (1.0)

c. What is the DNBR limitation for the MURR? (0.5)

(***** CATEGORY H CONTINUED ON NEXT PAGE *****)

QUESTION H.14 (1.00)

a. What pressure in psig corresponds to 65 psia? (0.5)

b. What is the saturation temperature corresponding to 65 psia? (0.5)

(***** END OF CATEGORY H *****)

QUESTION I.01 (2.00)

a. What three conditions must be satisfied to permit whole body radiation exposure in excess of 1.25 rems per quarter? (1.5)

b. What is the legal limit for skin exposure to individuals less than 18 years of age? (0.5)

QUESTION I.02 (1.00)

Why is iodine the only fission product to be considered when determining the internal dose due to the ingestion of fission products?

QUESTION I.03 (1.00)

In addition to radiation surveys, how is radiation leakage from beam port experiments detected?

QUESTION I.04 (1.00)

What two design features of the pneumatic tube system serve to limit the radiation hazard from these tubes?

QUESTION I.05 (1.00)

What action should you as reactor operator take if an experimenter informs you that the irradiation container has become lodged somewhere in the pneumatic tube?

QUESTION I.06 (2.00)

a. In addition to the individual himself, whose permission must be obtained in order to allow emergency radiation exposure in excess of 10CFR20 limits? (0.5)

b. What are the voluntary emergency exposure guidelines for saving a life? (0.5)

c. List two personnel selection criteria which are used when deciding who will be permitted to receive radiation exposures in excess of 10CFR20 limits. (1.0)

(***** CATEGORY I CONTINUED ON NEXT PAGE *****)

QUESTION 1.07 (2.00)

One of the immediate action steps of the Site Area Emergency procedure is to send an operator to west tower with a radiation monitor. What four actions must this individual take?

QUESTION 1.08 (1.50)

What three actions must be taken during a Site Area Emergency if the radionuclide concentration responsible is determined to be in excess of 50,000 MPC?

QUESTION 1.09 (1.00)

Why does the Site Area Emergency procedure require that the operator sent to west tower communicate by intercom rather than by portable radio?

QUESTION 1.10 (1.50)

a. In addition to the film badge rack in the hallway near the lobby, in what two locations are PCs kept for issuance to offsite personnel during an emergency? (1.0)

b. Can film badges in the badge rack be assigned to offsite personnel? (0.5)

QUESTION 1.11 (.50)

What immediate action must be taken if the reactor bridge area radiation monitoring system is determined not to be functioning?

QUESTION 1.12 (.50)

What immediate action must be taken if there is an abnormally high level of radioactivity in the primary cooling system?

(***** CATEGORY I CONTINUED ON NEXT PAGE *****)

QUESTION I.13 (1.00)

What additional health physics requirement is imposed during a reactor startup when a change is made to a beamport or other reactor experiment which could lead to significant alterations in area radiation levels as reactor power is increased?

QUESTION I.14 (1.00)

What health physics requirement must be met prior to allowing entry into controlled access high radiation areas following a reactor shutdown?

QUESTION I.15 (2.00)

a. Who determines whether or not a Radiation Work Permit (RWP) is required? (0.5)

b. What type of work requires an RWP? (0.5)

c. Where is the approved RWP posted? (0.5)

d. After the job has been completed and the job site decontaminated, what is done with the RWP? (0.5)

QUESTION I.16 (1.00)

a. How is argon 41 produced? (0.5)

b. What radiological hazard is caused by argon 41? (i.e. airborne particulate, internal exposure, external exposure, surface contamination, etc.) (0.5)

(***** END OF CATEGORY I *****)

QUESTION J.01 (1.00)

Other than during power reduction or reactor shutdown, when can the control blades be moved in gang control after the reactor is critical?

QUESTION J.02 (4.00)

State the approximate values for the following parameters:

a. Temperature coefficient of the primary coolant system.

b. Temperature coefficient of the pool.

c. Total clean core rod worth.

d. Effective delayed neutron fraction.

e. Void coefficient of the flux trap.

f. Reactivity worth of equilibrium samarium at 10 MW.

g. Reactivity worth of equilibrium xenon at 10 MW.

h. Fuel enrichment.

QUESTION J.03 (2.50)

a. What is the purpose of the antisiphon system? (1.0)

b. In order for the antisiphon system to perform its function, what water level limitation must be observed? (0.5)

c. What action must be taken to maintain reactor operation if antisiphon system pressure decreases to the low pressure alarm setpoint? (0.5)

d. The reactor shall be shutdown if the antisiphon system pressure drops below _____ psig. (0.5)

QUESTION J.04 (1.00)

Why should the primary system remain in service for 15 minutes after reactor shutdown?

(***** CATEGORY J CONTINUED ON NEXT PAGE *****)

QUESTION J.05 (1.50)

For Mode II operation only one pump and one heat exchanger are required to be used.

a. What should be done to prevent inadvertent operation of the pump which will not be used? (0.5)

b. Why is the outlet valve of the heat exchanger not in service left in the throttled position? (1.0)

QUESTION J.06 (2.50)

a. After starting one secondary pump, it is necessary to wait _____ minutes prior to starting the second pump. (0.5)

b. Why cannot two secondary pumps be started at the same time? (1.0)

c. Why is SP-3 the preferred secondary pump to be used during single pump operation? (1.0)

QUESTION J.07 (1.00)

a. TRUE or FALSE. The cooling tower fan vibration trip will stop the fan if excess vibration occurs and can be relied upon to prevent damage due to ice accumulation. (0.5)

b. TRUE or FALSE. All three cooling tower bays may be deiced at the same time. (.5)

QUESTION J.08 (1.50)

What chemical(s) is (are) added to the secondary system to control:

a. algae? (0.5)

b. pH? (0.5)

c. corrosion? (0.5)

(***** CATEGORY J CONTINUED ON NEXT PAGE *****)

QUESTION J.09 (1.50)

What three immediate actions must be taken by the reactor operator if the rods fail to run-in automatically when required by the protection system?

QUESTION J.10 (2.00)

What four immediate actions must be taken if the lights in the reactor building dim concurrent with a loss of some containment lights and some process equipment?

QUESTION J.11 (1.50)

What three immediate actions must be taken if the reactor operator detects a stuck control rod?

(***** END OF CATEGORY J *****)

QUESTION K.01 (.50)

All fuel transfers will be authorized by the _____.

QUESTION K.02 (.50)

How many new fuel elements may be handled at any one time?

QUESTION K.03 (1.00)

When, if at all, is the auxiliary operator allowed to assist in fuel movement?

QUESTION K.04 (.50)

Choose the CORRECT response. Fuel elements should be moved such that the (concave end; side plate; convex end) faces oncoming obstacles.

QUESTION K.05 (1.00)

What precaution is taken to ensure irradiated fuel being shipped will not melt even if all coolant water drains from the shipping cask?

QUESTION K.06 (1.00)

How does the operator verify that the air operated fuel handling tool has properly latched onto a fuel element?

QUESTION K.07 (.50)

TRUE or FALSE. The technique for unlatching the air operated fuel handling tool from fuel elements inserted into the reactor is to lift the tool off the element.

(***** CATEGORY K CONTINUED ON NEXT PAGE *****)

QUESTION K.08 (1.00)

What problem could occur if the fuel handling tool is not properly released from a fuel element after inserting it into the reactor?

QUESTION K.09 (.50)

Who prepares the fuel handling sequence?

QUESTION K.10 (1.00)

Why is the SRM scaler and chart recorder turned on and the fission chamber inserted to the 1000 counts per second position prior to moving fuel in or out of the reactor?

QUESTION K.11 (2.00)

What two precautions must be taken prior to removing a control blade offset mechanism?

QUESTION K.12 (1.00)

If the pressure vessel head is to be left off after refueling is completed what must be done to protect the core?

QUESTION K.13 (1.00)

Why is the bridge ARMS placed in the upscale position prior to removing a control blade offset mechanism?

QUESTION K.14 (1.00)

What action must be taken if the offset mechanism does not break loose from its reflector platform after applying a reasonable amount of tension?

(***** CATEGORY K CONTINUED ON NEXT PAGE *****)

QUESTION K.15 (.50)

TRUE or FALSE. After the control blade offset mechanism has cleared the guide pins it is completely removed from the gap.

QUESTION K.16 (1.00)

a. The pH limit for the primary system is _____. (0.5)

b. The pH limit for the secondary system is _____. (0.5)

QUESTION K.17 (5.00)

State the setpoint for the following scrams:

a. period.

b. primary coolant flow.

c. reactor inlet temperature.

d. reactor outlet temperature.

e. primary coolant low pressure.

f. high power.

g. pool coolant flow.

h. pool level.

i. pressurizer low level.

j. pressurizer high pressure.

QUESTION K.18 (1.00)

"If a resin bed has a reduced DF, consider changing to a newly regenerated resin." What is meant by the term "DF"?

(***** END OF CATEGORY K ******)

QUESTION L.01 (.50)

The minimum number of reactor operators for reactor operation will be _____ licensed individuals, with at least _____ of these licensed as a senior operator.

QUESTION L.02 (.50)

TRUE or FALSE. If the cause of an unscheduled scram can not be determined, the Reactor Manager or his designated representative may still approve a reactor startup provided all systems are found to be normal.

QUESTION L.03 (.50)

Only observers approved by the Reactor Manager or the _____ are allowed in the control room during a reactor startup or shutdown.

QUESTION L.04 (.50)

TRUE or FALSE. Control of the reactor can be transferred from one operator to another during power transient operations provided the transfer is directly supervised by a licensed senior reactor operator.

QUESTION L.05 (1.00)

What is a "hot startup"?

QUESTION L.06 (1.00)

Containment integrity is required to be maintained at all times unless two conditions are met. Name them.

QUESTION L.07 (2.00)

Name four of the six conditions which must be met in order for reactor containment integrity to be satisfied.

(***** CATEGORY L CONTINUED ON NEXT PAGE *****)

QUESTION L.08 (1.00)

What is the minimum shutdown margin requirement at the MURR?

QUESTION L.09 (2.00)

The reactor is not allowed to be started up unless there is adequate neutron flux level monitoring. Name the two ways which are mentioned in Technical Specifications by which this requirement can be satisfied.

QUESTION L.10 (1.00)

What is the basis for establishing Technical Specification limits for average fuel burnup?

QUESTION L.11 (1.00)

What are the Tech Spec limits for:

a. pool temperature? (.5)

b. volume of primary grade water required to be connected to the reactor makeup water system? (.5)

QUESTION L.12 (1.00)

What are the two situations which require that a Full Power prestartup checksheet be completed?

QUESTION L.13 (1.00)

When can a startup be made without having to prepare a Startup Checksheet of any kind?

QUESTION L.14 (1.00)

What are the two situations in which the Reactor Physicist is required to perform or approve an ECP?

(***** CATEGORY L CONTINUED ON NEXT PAGE *****)

QUESTION L.15 (1.00)

What action must be taken if, while conducting a startup using an estimated ECP, the difference between actual and estimated critical position exceeds the allowable tolerance?

QUESTION L.16 (1.00)

Name two of the three situations during a reactor startup which require reactor status announcements to be made over the public address system?

QUESTION L.17 (1.00)

What is the minimum nuclear instrumentation for a reactor startup?

QUESTION L.18 (1.00)

A certain checksheet must be completed if the control room will be unattended for an extended period of time following a shutdown.

a. What is the name of this checksheet? (.5)

b. Who is responsible for ensuring its completion? (.5)

QUESTION L.19 (1.00)

What is the purpose of the following tags?

a. Red tag? (.5)

b. White tag? (.5)

QUESTION L.20 (1.00)

a. Whose approval must be obtained before tags can be attached or removed? (.5)

b. Who is permitted to attach tags to equipment? (.5)

(***** END OF CATEGORY L *****)

(********** END OF EXAMINATION **********)

EQUATIONS

REACTOR THEORY

$$P = P_o e^{t/\tau} = P_o 10^{SUR \cdot t}$$

$$\tau = \frac{\bar{l}_e}{\rho} + \frac{\beta - \rho}{\lambda\rho} \quad \text{or} \quad \tau = \frac{\beta - \rho}{\lambda\rho}$$

$$\rho = \frac{k - 1}{k} \qquad \frac{k_2 - k_1}{k_2 k_1} = \Delta\rho$$

$$\frac{cps_2}{cps_1} = \frac{1 - k_1}{1 - k_2} \qquad k < 1$$

$$\frac{1}{M} = 1 - k$$

$$\frac{1}{M} = \frac{cps_e}{cps_n}$$

$$\rho_{net} = \Delta(\rho_{doppler} + \rho_{mod} + \rho_{void} + \rho_{Xe} + \rho_{Sm} + \rho_{Pu} + \rho_{Boron} + \rho_{rod} + \rho_{fuel} + \rho_{Poisons})$$

$$k_2 = k_1 + \delta k$$

$$\delta k = k - 1$$

$$SUR = \frac{26.06}{\tau}$$

$$P = \frac{\Sigma\phi V}{3.1 \times 10^{10}}$$

$$\Sigma = N\sigma$$

$$\phi = nv$$

Defect = Coeff x Δ Parameter

RADIATION

$$N = N_o e^{-\lambda t}$$

$$A = \lambda N$$

$$I = I_o e^{-\mu x} = I_o 10^{-x/TVT}$$

$$\lambda T_{\frac{1}{2}} = 0.693$$

$$R/hr \text{ @ } d \text{ feet} = \frac{6CE}{d^2}$$

$I_1 d_1^2 = I_2 d_2^2$ point source

$I_1 d_1 = I_2 d_2$ - line source

R/hr x time = R

Rad x QF = Rem

$$T_{\frac{1}{2}_{eff}} = \frac{T_{\frac{1}{2}_{Bio}} \times T_{\frac{1}{2}_{Rad}}}{T_{\frac{1}{2}_{Bio}} + T_{\frac{1}{2}_{Rad}}}$$

MATH

$$y^a = b$$

$$\log_{y_c} b = a$$

$$\log x^c = c \log x$$

$$\log \frac{x}{y} = \log x - \log y$$

$$\log xy = \log x + \log y$$

FLUIDS/THERMO/HEAT TRANSFER

$$\dot{m} = A_1\rho_1 V_1 = A_2\rho_2 V_2$$

$$Q = A_1 V_1 = A_2 V_2$$

$$E_{in} = E_{out} + \Delta E_{stored}$$

$$E = KE + PE + U + pV + Q + W$$

$$PE = \frac{mg}{g_c} Z$$

$$KE = \tfrac{1}{2} m \frac{V^2}{g_c}$$

reduced for - turbine, SG pump, nozzle, orifice, condenser, pipe, Rx

flow $\alpha \sqrt{dp}$

$$\text{head loss} = f\frac{L}{D}\frac{V^2}{2g_c} \quad \text{or head loss } \alpha\ V^2$$

head loss $\alpha\ \Delta p$

$$p = h + p_{ambient} = k\frac{V^2}{2g_c}$$

$$F = pA$$

$$\Delta p_{2\,phase} = \Delta p_{1\,phase} \times K$$

k = f(quality & Pressure)

Pump laws speed α flow

(speed)$^2\alpha$ pressure

(speed)$^3\alpha$ power

$$Q = kA\Delta T = hA\Delta T = UA\Delta T$$

$$Q = mc_p\Delta T$$

$$Q = m\Delta h$$

$$Q = \varepsilon\sigma T$$

$$\Delta H = mc_p\Delta T$$

$$\Delta U = mc_v\Delta T$$

$$H = U + pV$$

$$\Delta S = \frac{\Delta Q}{T}$$

$$pV = nRT$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$C_1V_1 + C_2V_2 = C_3(V_1 + V_2)$$

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Evap v_{fg}	Sat Vapor v_g	Enthalpy Sat Liquid h_f	Evap h_{fg}	Sat Vapor h_g	Entropy Sat Liquid s_f	Evap s_{fg}	Sat Vapor s_g	Temp Fahr t
32.0*	0.08859	0.016022	3304.7	3304.7	-0.0179	1075.5	1075.5	0.0000	2.1873	2.1873	32.0*
34.0	0.09600	0.016021	3061.9	3061.9	1.996	1074.4	1076.4	0.0041	2.1762	2.1802	34.0
36.0	0.10395	0.016020	2839.0	2839.0	4.008	1073.2	1077.2	0.0081	2.1651	2.1732	36.0
38.0	0.11249	0.016019	2634.1	2634.2	6.018	1072.1	1078.1	0.0122	2.1541	2.1663	38.0
40.0	0.12163	0.016019	2445.8	2445.8	8.027	1071.0	1079.0	0.0162	2.1432	2.1594	40.0
42.0	0.13143	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	42.0
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	44.0
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	46.0
48.0	0.16514	0.016021	1830.0	1830.0	16.053	1066.4	1082.5	0.0321	2.1006	2.1327	48.0
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	50.0
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	52.0
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	56.0
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	58.0
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	60.0
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	62.0
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	64.0
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	66.0
68.0	0.33885	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	68.0
70.0	0.36279	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	70.0
72.0	0.38814	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	72.0
74.0	0.41500	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9708	2.0529	74.0
76.0	0.44340	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	76.0
78.0	0.47341	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	78.0
80.0	0.50513	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0359	80.0
82.0	0.54063	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	82.0
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	84.0
86.0	0.61538	0.016087	527.5	527.5	54.026	1045.0	1099.0	0.1043	1.9151	2.0193	86.0
88.0	0.65581	0.016093	496.8	496.8	56.022	1043.9	1099.9	0.1079	1.9060	2.0139	88.0
90.0	0.69813	0.016099	468.1	468.1	58.018	1042.7	1100.8	0.1115	1.8970	2.0085	90.0
92.0	0.74312	0.016105	441.3	441.3	60.014	1041.6	1101.6	0.1152	1.8881	2.0033	92.0
94.0	0.79067	0.016111	416.3	416.3	62.010	1040.5	1102.5	0.1188	1.8792	1.9980	94.0
96.0	0.84077	0.016117	393.0	393.0	64.006	1039.3	1103.3	0.1224	1.8704	1.9928	96.0
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	98.0
100.0	0.94924	0.016130	350.4	350.4	67.999	1037.1	1105.1	0.1295	1.8530	1.9825	100.0
102.0	1.00789	0.016137	331.1	331.1	69.995	1035.9	1105.9	0.1331	1.8444	1.9775	102.0
104.0	1.06965	0.016144	313.1	313.1	71.992	1034.8	1106.8	0.1366	1.8358	1.9725	104.0
106.0	1.1347	0.016151	296.16	296.18	73.99	1033.6	1107.6	0.1402	1.8273	1.9675	106.0
108.0	1.2030	0.016158	280.28	280.30	75.98	1032.5	1108.5	0.1437	1.8188	1.9626	108.0
110.0	1.2750	0.016165	265.37	265.39	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110.0
112.0	1.3509	0.016173	251.37	251.38	79.98	1030.2	1110.2	0.1507	1.8021	1.9528	112.0
114.0	1.4309	0.016180	238.21	238.22	81.97	1029.1	1111.0	0.1542	1.7938	1.9480	114.0
116.0	1.5133	0.016188	225.86	225.85	83.97	1027.9	1111.9	0.1577	1.7856	1.9433	116.0
118.0	1.6009	0.016196	214.20	214.21	85.97	1026.8	1112.7	0.1611	1.7774	1.9386	118.0
120.0	1.6927	0.016204	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120.0
122.0	1.7891	0.016213	192.94	192.95	89.96	1024.5	1114.4	0.1680	1.7613	1.9293	122.0
124.0	1.8901	0.016221	183.23	183.24	91.96	1023.3	1115.3	0.1715	1.7533	1.9247	124.0
126.0	1.9959	0.016229	174.08	174.09	93.96	1022.2	1116.1	0.1749	1.7453	1.9202	126.0
128.0	2.1068	0.016238	165.45	165.47	95.96	1021.0	1117.0	0.1783	1.7374	1.9157	128.0
130.0	2.2230	0.016247	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130.0
132.0	2.3445	0.016256	149.64	149.66	99.95	1018.7	1118.6	0.1851	1.7217	1.9068	132.0
134.0	2.4717	0.016265	142.40	142.41	101.95	1017.5	1119.5	0.1884	1.7140	1.9024	134.0
136.0	2.6047	0.016274	135.55	135.57	103.95	1016.4	1120.3	0.1918	1.7063	1.8980	136.0
138.0	2.7438	0.016284	129.09	129.11	105.95	1015.2	1121.1	0.1951	1.6986	1.8937	138.0
140.0	2.8892	0.016293	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140.0
142.0	3.0411	0.016303	117.21	117.22	109.95	1012.9	1122.8	0.2018	1.6834	1.8852	142.0
144.0	3.1997	0.016312	111.74	111.76	111.95	1011.7	1123.6	0.2051	1.6759	1.8810	144.0
146.0	3.3653	0.016322	106.58	106.59	113.95	1010.5	1124.5	0.2084	1.6684	1.8769	146.0
148.0	3.5381	0.016332	101.68	101.70	115.95	1009.3	1125.3	0.2117	1.6610	1.8727	148.0
150.0	3.7184	0.016343	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150.0
152.0	3.9065	0.016353	92.66	92.68	119.95	1007.0	1126.9	0.2183	1.6463	1.8646	152.0
154.0	4.1025	0.016363	88.50	88.52	121.95	1005.8	1127.7	0.2216	1.6390	1.8606	154.0
156.0	4.3068	0.016374	84.56	84.57	123.95	1004.6	1128.6	0.2248	1.6318	1.8566	156.0
158.0	4.5197	0.016384	80.82	80.83	125.96	1003.4	1129.4	0.2281	1.6245	1.8526	158.0
160.0	4.7414	0.016395	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160.0
162.0	4.9722	0.016406	73.90	73.92	129.96	1001.0	1131.0	0.2345	1.6103	1.8448	162.0
164.0	5.2124	0.016417	70.70	70.72	131.96	999.8	1131.8	0.2377	1.6032	1.8409	164.0
166.0	5.4623	0.016428	67.67	67.68	133.97	998.6	1132.6	0.2409	1.5961	1.8371	166.0
168.0	5.7223	0.016440	64.78	64.80	135.97	997.4	1133.4	0.2441	1.5892	1.8333	168.0
170.0	5.9926	0.016451	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2736	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5656	0.016474	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8690	0.016486	54.59	54.61	143.99	992.6	1136.6	0.2568	1.5616	1.8184	176.0
178.0	7.1840	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

*The states shown are metastable

Table 1. Saturated Steam: Temperature Table—*Continued*

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume: Sat Liquid v_f	Specific Volume: Evap v_{fg}	Specific Volume: Sat Vapor v_g	Enthalpy: Sat Liquid h_f	Enthalpy: Evap h_{fg}	Enthalpy: Sat Vapor h_g	Entropy: Sat Liquid s_f	Entropy: Evap s_{fg}	Entropy: Sat Vapor s_g	Temp Fahr t
180.0	7.5110	0.016510	50.21	50.22	148.00	990.2	1138.2	0.2631	1.5480	1.8111	180.0
182.0	7.850	0.016522	48.172	48.189	150.01	989.0	1139.0	0.2662	1.5413	1.8075	182.0
184.0	8.203	0.016534	46.232	46.249	152.01	987.8	1139.8	0.2694	1.5346	1.8040	184.0
186.0	8.568	0.016547	44.383	44.400	154.02	986.5	1140.5	0.2775	1.5279	1.8004	186.0
188.0	8.947	0.016559	42.621	42.638	156.03	985.3	1141.3	0.2756	1.5213	1.7969	188.0
190.0	9.340	0.016572	40.941	40.957	158.04	984.1	1142.1	0.2787	1.5148	1.7934	190.0
192.0	9.747	0.016585	39.337	39.354	160.05	982.8	1142.9	0.2818	1.5082	1.7900	192.0
194.0	10.168	0.016598	37.808	37.824	162.05	981.6	1143.7	0.2848	1.5017	1.7865	194.0
196.0	10.605	0.016611	36.348	36.364	164.06	980.4	1144.4	0.2879	1.4952	1.7831	196.0
198.0	11.058	0.016624	34.954	34.970	166.08	979.1	1145.2	0.2910	1.4888	1.7798	198.0
200.0	11.526	0.016637	33.622	33.639	168.09	977.9	1146.0	0.2940	1.4824	1.7764	200.0
204.0	12.512	0.016664	31.135	31.151	172.11	975.4	1147.5	0.3001	1.4697	1.7698	204.0
208.0	13.568	0.016691	28.862	28.878	176.14	972.8	1149.0	0.3061	1.4571	1.7632	208.0
212.0	14.696	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	212.0
216.0	15.901	0.016747	24.878	24.894	184.20	967.8	1152.0	0.3181	1.4323	1.7505	216.0
220.0	17.186	0.016775	23.131	23.148	188.23	965.2	1153.4	0.3241	1.4201	1.7442	220.0
224.0	18.556	0.016805	21.529	21.545	192.27	962.6	1154.9	0.3300	1.4081	1.7380	224.0
228.0	20.015	0.016834	20.056	20.073	196.31	960.0	1156.3	0.3359	1.3961	1.7320	228.0
232.0	21.567	0.016864	18.701	18.718	200.35	957.4	1157.8	0.3417	1.3842	1.7260	232.0
236.0	23.216	0.016895	17.454	17.471	204.40	954.8	1159.2	0.3476	1.3725	1.7201	236.0
240.0	24.968	0.016926	16.304	16.321	208.45	952.1	1160.6	0.3533	1.3609	1.7142	240.0
244.0	26.826	0.016958	15.243	15.260	212.50	949.5	1162.0	0.3591	1.3494	1.7085	244.0
248.0	28.796	0.016990	14.264	14.281	216.56	946.8	1163.4	0.3649	1.3379	1.7028	248.0
252.0	30.883	0.017022	13.358	13.375	220.62	944.1	1164.7	0.3706	1.3266	1.6972	252.0
256.0	33.091	0.017055	12.520	12.538	224.65	941.4	1166.1	0.3763	1.3154	1.6917	256.0
260.0	35.427	0.017089	11.745	11.762	228.76	938.6	1167.4	0.3819	1.3043	1.6862	260.0
264.0	37.894	0.017123	11.025	11.042	232.83	935.9	1168.7	0.3876	1.2933	1.6808	264.0
268.0	40.500	0.017157	10.358	10.375	236.91	933.1	1170.0	0.3932	1.2823	1.6755	268.0
272.0	43.249	0.017193	9.738	9.755	240.99	930.3	1171.3	0.3987	1.2715	1.6702	272.0
276.0	46.147	0.017228	9.162	9.180	245.08	927.5	1172.5	0.4043	1.2607	1.6650	276.0
280.0	49.200	0.017264	8.627	8.644	249.17	924.6	1173.8	0.4098	1.2501	1.6599	280.0
284.0	52.414	0.01730	8.1280	8.1453	253.3	921.7	1175.0	0.4154	1.2395	1.6548	284.0
288.0	55.795	0.01734	7.6634	7.6807	257.4	918.8	1176.2	0.4208	1.2290	1.6498	288.0
292.0	59.350	0.01738	7.2301	7.2475	261.5	915.9	1177.4	0.4263	1.2186	1.6449	292.0
296.0	63.084	0.01741	6.8259	6.8433	265.6	913.0	1178.6	0.4317	1.2082	1.6400	296.0
300.0	67.005	0.01745	6.4483	6.4658	269.7	910.0	1179.7	0.4372	1.1979	1.6351	300.0
304.0	71.119	0.01749	6.0955	6.1130	273.8	907.0	1180.9	0.4426	1.1877	1.6303	304.0
308.0	75.433	0.01753	5.7655	5.7830	278.0	904.0	1182.0	0.4479	1.1776	1.6256	308.0
312.0	79.953	0.01757	5.4566	5.4742	282.1	901.0	1183.1	0.4533	1.1676	1.6209	312.0
316.0	84.688	0.01761	5.1673	5.1849	286.3	897.9	1184.1	0.4586	1.1576	1.6162	316.0
320.0	89.643	0.01766	4.8961	4.9138	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320.0
324.0	94.826	0.01770	4.6418	4.6595	294.6	891.6	1186.2	0.4692	1.1378	1.6071	324.0
328.0	100.245	0.01774	4.4030	4.4208	298.7	888.5	1187.2	0.4745	1.1280	1.6025	328.0
332.0	105.907	0.01779	4.1788	4.1966	302.9	885.3	1188.2	0.4798	1.1183	1.5981	332.0
336.0	111.820	0.01783	3.9681	3.9859	307.1	882.1	1189.1	0.4850	1.1086	1.5936	336.0
340.0	117.992	0.01787	3.7699	3.7878	311.3	878.8	1190.1	0.4902	1.0990	1.5892	340.0
344.0	124.430	0.01792	3.5834	3.6013	315.5	875.5	1191.0	0.4954	1.0894	1.5849	344.0
348.0	131.142	0.01797	3.4078	3.4258	319.7	872.2	1191.9	0.5006	1.0799	1.5806	348.0
352.0	138.138	0.01801	3.2423	3.2603	323.9	868.9	1192.7	0.5058	1.0705	1.5763	352.0
356.0	145.424	0.01806	3.0863	3.1044	328.1	865.5	1193.6	0.5110	1.0611	1.5721	356.0
360.0	153.010	0.01811	2.9392	2.9573	332.3	862.1	1194.4	0.5161	1.0517	1.5678	360.0
364.0	160.903	0.01816	2.8002	2.8184	336.5	858.6	1195.2	0.5212	1.0424	1.5637	364.0
368.0	169.113	0.01821	2.6691	2.6873	340.8	855.1	1195.9	0.5263	1.0332	1.5595	368.0
372.0	177.648	0.01826	2.5451	2.5633	345.0	851.6	1196.7	0.5314	1.0240	1.5554	372.0
376.0	186.517	0.01831	2.4279	2.4462	349.3	848.1	1197.4	0.5365	1.0148	1.5513	376.0
380.0	195.729	0.01836	2.3170	2.3353	353.6	844.5	1198.0	0.5416	1.0057	1.5473	380.0
384.0	205.294	0.01842	2.2120	2.2304	357.9	840.8	1198.7	0.5466	0.9966	1.5432	384.0
388.0	215.220	0.01847	2.1126	2.1311	362.2	837.2	1199.3	0.5516	0.9876	1.5392	388.0
392.0	225.516	0.01853	2.0184	2.0369	366.5	833.4	1199.9	0.5567	0.9786	1.5352	392.0
396.0	236.193	0.01858	1.9291	1.9477	370.8	829.7	1200.4	0.5617	0.9696	1.5313	396.0
400.0	247.259	0.01864	1.8444	1.8630	375.1	825.9	1201.0	0.5667	0.9607	1.5274	400.0
404.0	258.725	0.01870	1.7640	1.7827	379.4	822.0	1201.5	0.5717	0.9518	1.5234	404.0
408.0	270.600	0.01875	1.6877	1.7064	383.8	818.2	1201.9	0.5766	0.9429	1.5195	408.0
412.0	282.894	0.01881	1.6152	1.6340	388.1	814.2	1202.4	0.5816	0.9341	1.5157	412.0
416.0	295.617	0.01887	1.5463	1.5651	392.5	810.2	1202.8	0.5866	0.9253	1.5118	416.0
420.0	308.780	0.01894	1.4808	1.4997	396.9	806.2	1203.1	0.5915	0.9165	1.5080	420.0
424.0	322.391	0.01900	1.4184	1.4374	401.3	802.2	1203.5	0.5964	0.9077	1.5042	424.0
428.0	336.463	0.01906	1.3591	1.3782	405.7	798.0	1203.7	0.6014	0.8990	1.5004	428.0
432.0	351.00	0.01913	1.30266	1.32179	410.1	793.9	1204.0	0.6063	0.8903	1.4966	432.0
436.0	366.03	0.01919	1.24887	1.26806	414.6	789.7	1204.2	0.6112	0.8816	1.4928	436.0
440.0	381.54	0.01926	1.19761	1.21687	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440.0
444.0	397.56	0.01933	1.14874	1.16806	423.5	781.1	1204.6	0.6210	0.8643	1.4853	444.0
448.0	414.09	0.01940	1.10212	1.12152	428.0	776.7	1204.7	0.6259	0.8557	1.4815	448.0
452.0	431.14	0.01947	1.05764	1.07711	432.5	772.3	1204.8	0.6308	0.8471	1.4778	452.0
456.0	448.73	0.01954	1.01518	1.03472	437.0	767.8	1204.8	0.6356	0.8385	1.4741	456.0

Table 1. Saturated Steam, Temperature Table—*Continued*

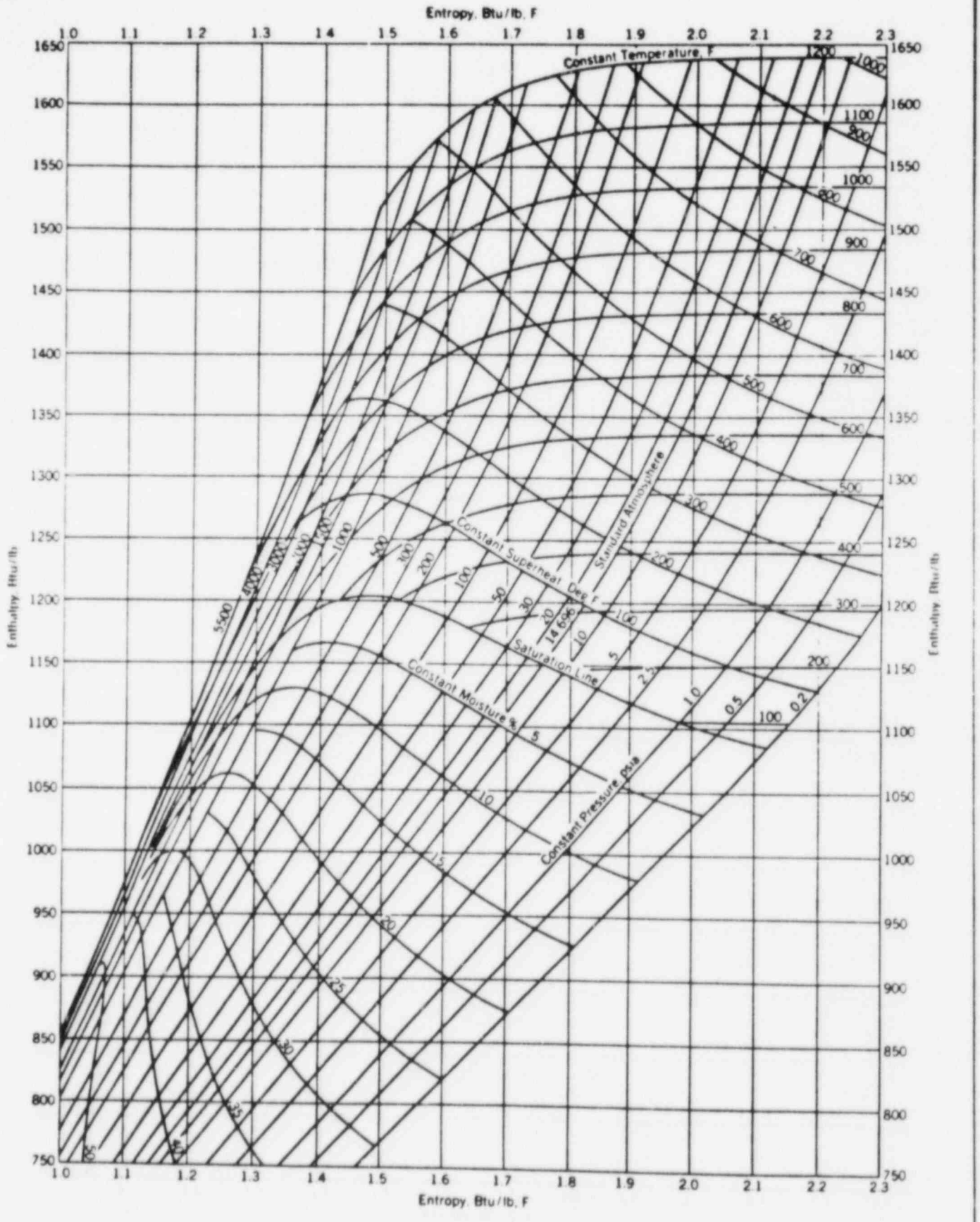
Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat Vapor s_g	Temp Fahr t
680.0	466.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6405	0.8299	1.4704	680.0
684.0	485.56	0.01969	0.93588	0.95557	446.1	758.6	1204.7	0.6454	0.8213	1.4667	684.0
688.0	504.83	0.01976	0.89885	0.91862	450.7	754.0	1204.6	0.6502	0.8127	1.4629	688.0
692.0	524.67	0.01984	0.86345	0.88329	455.2	749.3	1204.5	0.6551	0.8042	1.4592	692.0
696.0	545.11	0.01992	0.82958	0.84950	459.8	744.5	1204.3	0.6599	0.7956	1.4555	696.0
700.0	566.15	0.02000	0.79716	0.81717	464.5	739.6	1204.1	0.6648	0.7871	1.4518	700.0
704.0	587.81	0.02009	0.76613	0.78622	469.1	734.7	1203.8	0.6696	0.7785	1.4481	704.0
708.0	610.10	0.02017	0.73641	0.75658	473.8	729.7	1203.5	0.6745	0.7700	1.4444	708.0
712.0	633.03	0.02026	0.70794	0.72820	478.5	724.6	1203.1	0.6793	0.7614	1.4407	712.0
716.0	656.61	0.02034	0.68065	0.70100	483.2	719.5	1202.7	0.6842	0.7528	1.4370	716.0
720.0	680.86	0.02043	0.65448	0.67492	487.9	714.3	1202.2	0.6890	0.7443	1.4333	720.0
724.0	705.78	0.02053	0.62938	0.64991	492.7	709.0	1201.7	0.6939	0.7357	1.4296	724.0
728.0	731.40	0.02062	0.60530	0.62592	497.5	703.7	1201.1	0.6987	0.7271	1.4258	728.0
732.0	757.72	0.02072	0.58218	0.60289	502.3	698.2	1200.5	0.7036	0.7185	1.4221	732.0
736.0	784.76	0.02081	0.55997	0.58079	507.1	692.7	1199.8	0.7085	0.7099	1.4183	736.0
740.0	812.53	0.02091	0.53864	0.55956	512.0	687.0	1199.0	0.7133	0.7013	1.4146	740.0
744.0	841.04	0.02102	0.51814	0.53916	516.9	681.3	1198.2	0.7182	0.6926	1.4108	744.0
748.0	870.31	0.02112	0.49843	0.51955	521.8	675.5	1197.3	0.7231	0.6839	1.4070	748.0
752.0	900.34	0.02123	0.47947	0.50070	526.8	669.6	1196.4	0.7280	0.6752	1.4032	752.0
756.0	931.17	0.02134	0.46123	0.48257	531.7	663.6	1195.4	0.7329	0.6665	1.3993	756.0
760.0	962.79	0.02146	0.44367	0.46513	536.8	657.5	1194.3	0.7378	0.6577	1.3954	760.0
764.0	995.22	0.02157	0.42677	0.44834	541.8	651.3	1193.1	0.7427	0.6489	1.3915	764.0
768.0	1028.49	0.02169	0.41048	0.43217	546.9	645.0	1191.9	0.7476	0.6400	1.3876	768.0
772.0	1062.59	0.02182	0.39479	0.41660	552.0	638.5	1190.6	0.7525	0.6311	1.3837	772.0
776.0	1097.55	0.02194	0.37966	0.40160	557.2	632.0	1189.2	0.7575	0.6222	1.3797	776.0
780.0	1133.38	0.02207	0.36507	0.38714	562.4	625.3	1187.7	0.7625	0.6132	1.3757	780.0
784.0	1170.10	0.02221	0.35099	0.37320	567.6	618.5	1186.1	0.7674	0.6041	1.3716	784.0
788.0	1207.72	0.02235	0.33741	0.35975	572.9	611.5	1184.5	0.7725	0.5950	1.3675	788.0
792.0	1246.26	0.02249	0.32429	0.34678	578.3	604.5	1182.7	0.7775	0.5859	1.3634	792.0
796.0	1285.74	0.02264	0.31162	0.33426	583.7	597.2	1180.9	0.7825	0.5766	1.3592	796.0
800.0	1326.17	0.02279	0.29937	0.32216	589.1	589.9	1179.0	0.7876	0.5673	1.3550	800.0
804.0	1367.57	0.02295	0.28753	0.31048	594.6	582.4	1176.9	0.7927	0.5580	1.3507	804.0
808.0	1410.0	0.02311	0.27608	0.29919	600.1	574.7	1174.8	0.7978	0.5485	1.3464	808.0
812.0	1453.3	0.02328	0.26499	0.28827	605.7	566.8	1172.6	0.8030	0.5390	1.3420	812.0
816.0	1497.8	0.02345	0.25425	0.27770	611.4	558.8	1170.2	0.8082	0.5293	1.3375	816.0
820.0	1543.2	0.02364	0.24384	0.26747	617.1	550.6	1167.7	0.8134	0.5196	1.3330	820.0
824.0	1589.7	0.02383	0.23374	0.25757	622.9	542.2	1165.1	0.8187	0.5097	1.3284	824.0
828.0	1637.3	0.02402	0.22394	0.24796	628.8	533.6	1162.4	0.8240	0.4997	1.3238	828.0
832.0	1685.1	0.02422	0.21442	0.23865	634.8	524.7	1159.5	0.8294	0.4896	1.3190	832.0
836.0	1733.9	0.02444	0.20516	0.22960	640.8	515.6	1156.4	0.8348	0.4794	1.3141	836.0
840.0	1784.9	0.02466	0.19615	0.22081	646.9	506.3	1153.2	0.8403	0.4689	1.3092	840.0
844.0	1835.0	0.02489	0.18737	0.21226	653.1	496.6	1149.8	0.8458	0.4583	1.3041	844.0
848.0	1885.4	0.02514	0.17880	0.20394	659.5	486.7	1146.1	0.8514	0.4474	1.2988	848.0
852.0	1936.0	0.02539	0.17044	0.19583	665.9	476.4	1142.2	0.8571	0.4364	1.2934	852.0
856.0	2000.8	0.02566	0.16228	0.18792	672.4	465.7	1138.1	0.8628	0.4251	1.2879	856.0
860.0	2066.9	0.02595	0.15427	0.18021	679.1	454.8	1133.7	0.8686	0.4134	1.2821	860.0
864.0	2118.3	0.02625	0.14644	0.17269	685.9	443.1	1129.0	0.8746	0.4015	1.2761	864.0
868.0	2170.1	0.02657	0.13878	0.16534	692.9	431.1	1124.0	0.8806	0.3893	1.2699	868.0
872.0	2222.2	0.02691	0.13124	0.15816	700.0	418.7	1118.7	0.8868	0.3767	1.2634	872.0
876.0	2300.7	0.02728	0.12387	0.15115	707.4	405.7	1113.1	0.8931	0.3637	1.2567	876.0
880.0	2365.7	0.02768	0.11663	0.14431	714.9	392.1	1107.0	0.8995	0.3502	1.2498	880.0
884.0	2431.1	0.02811	0.10947	0.13757	722.9	377.7	1100.6	0.9064	0.3361	1.2425	884.0
888.0	2498.1	0.02858	0.10229	0.13087	731.5	362.1	1093.5	0.9137	0.3210	1.2347	888.0
892.0	2566.6	0.02911	0.09514	0.12424	740.2	345.7	1085.9	0.9212	0.3054	1.2266	892.0
896.0	2636.8	0.02970	0.08799	0.11769	749.2	328.5	1077.6	0.9287	0.2892	1.2179	896.0
900.0	2708.6	0.03037	0.08080	0.11117	758.5	310.1	1068.5	0.9365	0.2720	1.2086	900.0
904.0	2782.1	0.03114	0.07349	0.10463	768.2	290.2	1058.4	0.9447	0.2537	1.1984	904.0
908.0	2857.4	0.03206	0.06595	0.09799	778.8	268.2	1047.0	0.9535	0.2337	1.1872	908.0
912.0	2934.5	0.03313	0.05797	0.09110	790.5	243.1	1033.6	0.9634	0.2110	1.1744	912.0
916.0	3013.4	0.03455	0.04916	0.08371	804.4	212.8	1017.2	0.9749	0.1841	1.1591	916.0
920.0	3094.3	0.03662	0.03857	0.07519	822.4	172.7	995.2	0.9901	0.1490	1.1390	920.0
924.0	3176.5	0.03874	0.03173	0.06997	835.0	144.7	979.7	1.0006	0.1246	1.1252	924.0
928.0	3177.2	0.04108	0.02192	0.06300	854.2	102.0	956.2	1.0169	0.0876	1.1046	928.0
932.0	3158.3	0.04427	0.01304	0.05730	873.0	61.4	934.4	1.0329	0.0527	1.0856	932.0
705.47*	3708.2	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	705.47*

*Critical temperature

Table 2: Saturated Steam: Pressure Table

Abs Press Lb/Sq In p	Temp Fahr t	Specific Volume: Sat Liquid v_f	Specific Volume: Evap v_{fg}	Specific Volume: Sat Vapor v_g	Enthalpy: Sat Liquid h_f	Enthalpy: Evap h_{fg}	Enthalpy: Sat Vapor h_g	Entropy: Sat Liquid s_f	Entropy: Evap s_{fg}	Entropy: Sat Vapor s_g	Abs Press Lb/Sq In p
0.08865	32.018	0.016022	3302.4	3302.4	0.0003	1075.5	1075.5	0.0000	2.1872	2.1872	0.08865
0.25	59.323	0.016032	1235.5	1235.5	27.382	1060.1	1087.4	0.0542	2.0425	2.0967	0.25
0.50	79.586	0.016071	641.5	641.5	47.623	1048.6	1096.3	0.0925	1.9446	2.0370	0.50
1.0	101.74	0.016136	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	1.0
5.0	162.24	0.016407	73.515	73.532	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	5.0
10.0	193.21	0.016592	38.404	38.420	161.26	982.1	1143.3	0.2836	1.5043	1.7879	10.0
14.696	212.00	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	14.696
15.0	213.03	0.016726	26.274	26.290	181.21	969.7	1150.9	0.3137	1.4415	1.7552	15.0
20.0	227.96	0.016834	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	20.0
30.0	250.34	0.017009	13.7266	13.7436	218.9	945.2	1164.1	0.3682	1.3313	1.6995	30.0
40.0	267.25	0.017151	10.4794	10.4965	236.1	933.6	1169.8	0.3921	1.2844	1.6765	40.0
50.0	281.02	0.017274	8.4967	8.5140	250.2	923.9	1174.1	0.4112	1.2474	1.6586	50.0
60.0	292.71	0.017383	7.1562	7.1736	262.2	915.4	1177.6	0.4273	1.2167	1.6440	60.0
70.0	302.93	0.017482	6.1875	6.2050	272.7	907.8	1180.6	0.4411	1.1905	1.6316	70.0
80.0	312.04	0.017573	5.4536	5.4711	282.1	900.9	1183.1	0.4534	1.1675	1.6208	80.0
90.0	320.28	0.017659	4.8779	4.8953	290.7	894.6	1185.3	0.4643	1.1470	1.6113	90.0
100.0	327.82	0.017740	4.4133	4.4310	298.5	888.6	1187.2	0.4743	1.1284	1.6027	100.0
110.0	334.79	0.01782	4.0306	4.0484	305.8	883.1	1188.9	0.4834	1.1115	1.5950	110.0
120.0	341.27	0.01789	3.7097	3.7275	312.6	877.8	1190.4	0.4919	1.0960	1.5879	120.0
130.0	347.33	0.01796	3.4364	3.4544	319.0	872.8	1191.7	0.4998	1.0815	1.5813	130.0
140.0	353.04	0.01803	3.2010	3.2190	325.0	868.0	1193.0	0.5071	1.0681	1.5752	140.0
150.0	358.42	0.01809	2.9958	3.0139	330.6	863.4	1194.1	0.5141	1.0554	1.5695	150.0
160.0	363.55	0.01815	2.8155	2.8336	336.1	859.0	1195.1	0.5206	1.0435	1.5641	160.0
170.0	368.42	0.01821	2.6556	2.6738	341.2	854.8	1196.0	0.5269	1.0322	1.5591	170.0
180.0	373.08	0.01827	2.5129	2.5312	346.2	850.7	1196.9	0.5328	1.0215	1.5543	180.0
190.0	377.53	0.01833	2.3847	2.4030	350.9	846.7	1197.6	0.5384	1.0113	1.5498	190.0
200.0	381.80	0.01839	2.2689	2.2873	355.5	842.8	1198.3	0.5438	1.0016	1.5454	200.0
210.0	385.91	0.01844	2.16373	2.18217	359.9	839.1	1199.0	0.5490	0.9923	1.5413	210.0
220.0	389.88	0.01850	2.06779	2.08629	364.2	835.4	1199.6	0.5540	0.9834	1.5374	220.0
230.0	393.70	0.01855	1.97991	1.99846	368.3	831.8	1200.1	0.5588	0.9748	1.5336	230.0
240.0	397.39	0.01860	1.89909	1.91769	372.3	828.4	1200.6	0.5634	0.9665	1.5299	240.0
250.0	400.97	0.01865	1.82452	1.84317	376.1	825.0	1201.1	0.5679	0.9585	1.5264	250.0
260.0	404.44	0.01870	1.75548	1.77418	379.9	821.6	1201.5	0.5722	0.9508	1.5230	260.0
270.0	407.80	0.01875	1.69137	1.71013	383.6	818.3	1201.9	0.5764	0.9433	1.5197	270.0
280.0	411.07	0.01880	1.63169	1.65049	387.1	815.1	1202.3	0.5805	0.9361	1.5166	280.0
290.0	414.25	0.01885	1.57597	1.59482	390.6	812.0	1202.6	0.5844	0.9291	1.5135	290.0
300.0	417.35	0.01889	1.52384	1.54274	394.0	808.9	1202.9	0.5882	0.9223	1.5105	300.0
350.0	431.73	0.01912	1.30642	1.32554	409.8	794.2	1204.0	0.6059	0.8909	1.4968	350.0
400.0	444.60	0.01934	1.14162	1.16095	424.2	780.4	1204.6	0.6217	0.8630	1.4847	400.0
450.0	456.28	0.01954	1.01224	1.03179	437.3	767.5	1204.8	0.6360	0.8378	1.4738	450.0
500.0	467.01	0.01975	0.90787	0.92762	449.5	755.1	1204.7	0.6490	0.8148	1.4639	500.0
550.0	476.94	0.01994	0.82183	0.84177	460.9	743.3	1204.3	0.6611	0.7936	1.4547	550.0
600.0	486.20	0.02013	0.74962	0.76975	471.7	732.0	1203.7	0.6723	0.7738	1.4461	600.0
650.0	494.89	0.02032	0.68811	0.70843	481.9	720.9	1202.8	0.6828	0.7552	1.4381	650.0
700.0	503.08	0.02050	0.63505	0.65556	491.6	710.2	1201.8	0.6928	0.7377	1.4304	700.0
750.0	510.84	0.02069	0.58880	0.60949	500.9	699.8	1200.7	0.7022	0.7210	1.4232	750.0
800.0	518.21	0.02087	0.54809	0.56896	509.8	689.6	1199.4	0.7111	0.7051	1.4163	800.0
850.0	525.24	0.02105	0.51197	0.53302	518.4	679.5	1198.0	0.7197	0.6899	1.4096	850.0
900.0	531.95	0.02123	0.47968	0.50091	526.7	669.7	1196.4	0.7279	0.6753	1.4032	900.0
950.0	538.39	0.02141	0.45064	0.47205	534.7	660.0	1194.7	0.7358	0.6612	1.3970	950.0
1000.0	544.58	0.02159	0.42436	0.44596	542.6	650.4	1192.9	0.7434	0.6476	1.3910	1000.0
1050.0	550.53	0.02177	0.40047	0.42224	550.1	640.9	1191.0	0.7507	0.6344	1.3851	1050.0
1100.0	556.28	0.02195	0.37863	0.40058	557.5	631.5	1189.1	0.7578	0.6216	1.3794	1100.0
1150.0	561.82	0.02214	0.35859	0.38073	564.8	622.2	1187.0	0.7647	0.6091	1.3738	1150.0
1200.0	567.19	0.02232	0.34013	0.36245	571.9	613.0	1184.8	0.7714	0.5969	1.3683	1200.0
1250.0	572.38	0.02250	0.32306	0.34556	578.8	603.8	1182.6	0.7780	0.5850	1.3630	1250.0
1300.0	577.42	0.02269	0.30722	0.32991	585.6	594.6	1180.2	0.7843	0.5733	1.3577	1300.0
1350.0	582.32	0.02288	0.29250	0.31537	592.3	585.4	1177.8	0.7906	0.5620	1.3525	1350.0
1400.0	587.07	0.02307	0.27871	0.30178	598.8	576.5	1175.3	0.7966	0.5507	1.3474	1400.0
1450.0	591.70	0.02327	0.26584	0.28911	605.3	567.4	1172.8	0.8026	0.5397	1.3423	1450.0
1500.0	596.20	0.02346	0.25372	0.27719	611.7	558.4	1170.1	0.8085	0.5288	1.3373	1500.0
1550.0	600.59	0.02366	0.24235	0.26601	618.0	549.4	1167.4	0.8142	0.5182	1.3324	1550.0
1600.0	604.87	0.02387	0.23159	0.25545	624.2	540.3	1164.5	0.8199	0.5076	1.3274	1600.0
1650.0	609.05	0.02407	0.22143	0.24551	630.4	531.3	1161.6	0.8254	0.4971	1.3225	1650.0
1700.0	613.13	0.02428	0.21178	0.23607	636.5	522.2	1158.6	0.8309	0.4867	1.3176	1700.0
1750.0	617.12	0.02450	0.20263	0.22713	642.5	513.1	1155.6	0.8363	0.4765	1.3128	1750.0
1800.0	621.02	0.02472	0.19390	0.21861	648.5	503.8	1152.3	0.8417	0.4662	1.3079	1800.0
1850.0	624.83	0.02495	0.18558	0.21052	654.5	494.6	1149.0	0.8470	0.4561	1.3030	1850.0
1900.0	628.56	0.02517	0.17761	0.20278	660.4	485.2	1145.6	0.8522	0.4459	1.2981	1900.0
1950.0	632.22	0.02541	0.16999	0.19540	666.3	475.8	1142.0	0.8574	0.4358	1.2931	1950.0
2000.0	635.80	0.02565	0.16266	0.18831	672.1	466.2	1138.3	0.8625	0.4256	1.2881	2000.0
2100.0	642.76	0.02615	0.14885	0.17501	683.8	446.7	1130.5	0.8727	0.4053	1.2780	2100.0
2200.0	649.45	0.02669	0.13603	0.16272	695.5	426.7	1122.2	0.8828	0.3848	1.2676	2200.0
2300.0	655.89	0.02727	0.12406	0.15133	707.2	406.0	1113.2	0.8929	0.3640	1.2569	2300.0
2400.0	662.11	0.02790	0.11287	0.14076	719.0	384.8	1103.7	0.9031	0.3430	1.2460	2400.0
2500.0	668.11	0.02859	0.10209	0.13068	731.7	361.6	1093.3	0.9139	0.3206	1.2345	2500.0
2600.0	673.91	0.02938	0.09172	0.12110	744.5	337.6	1082.0	0.9247	0.2977	1.2225	2600.0
2700.0	679.53	0.03029	0.08165	0.11194	757.3	312.3	1069.7	0.9356	0.2741	1.2097	2700.0
2800.0	684.96	0.03134	0.07171	0.10305	770.7	285.1	1055.8	0.9468	0.2491	1.1958	2800.0
2900.0	690.22	0.03262	0.06158	0.09420	785.1	254.7	1039.8	0.9588	0.2215	1.1803	2900.0
3000.0	695.33	0.03428	0.05073	0.08500	801.8	218.4	1020.3	0.9728	0.1891	1.1619	3000.0
3100.0	700.28	0.03681	0.03771	0.07452	824.0	169.3	993.3	0.9914	0.1460	1.1373	3100.0
3200.0	705.08	0.04472	0.01191	0.05663	875.5	56.1	931.6	1.0351	0.0482	1.0832	3200.0
3208.2*	705.47	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	3208.2*

*Critical pressure



Mollier diagram (*h*-*s*) for steam.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER H.01 (1.00)

Xenon has a greater fission yield. (.5)
Xenon has a larger microscopic cross section for thermal neutrons. (.5)

REFERENCE
Westinghouse Reactor Core Control, Chapter 4
Hazards Summary 4-14

ANSWER H.02 (1.00)

Iodine has a shorter half life than xenon, so initially after a trip xenon will build up because the only removal mechanism remaining is xenon decay. Eventually most of the iodine will be converted to xenon, at which time xenon decay will be greater than iodine decay, causing xenon concentration to decrease.

REFERENCE
Westinghouse Reactor Core Control, Chapter 4

ANSWER H.03 (.50)

Neutron absorption.

REFERENCE
Westinghouse Reactor Core Control, Chapter 4

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER H.04 (2.00)

a. $(CR1)/(CR2) = (1 - keff2)/(1 - keff1)$ (.1)
$(CR2)/(CR3) = (1 - keff3)/(1 - keff2)$ (.1)
$keff2 = keff1 + \Delta k$ (.1)
$keff3 = keff2 + \Delta k$ (.1)
$keff3 = keff1 + 2\Delta k$ (.1)
$CR1(1 - keff1) = CR2(1 - keff1 - \Delta k)$ (.1)
$10(1 - keff1) = 16(1 - keff1 - \Delta k)$ (.1)
$10 - 10keff1 = 16 - 16keff1 - 16\Delta k$ (.1)
$16\Delta k = 6 - 6keff1 = 6(1 - keff1)$ (.1)
$\Delta k = (3/8)(1 - keff1)$ (.1)
$CR3 = CR2(1 - keff2)/(1 - keff3)$ (.1)
$CR3 = CR2[1 - (keff1 + \Delta k)]/[1 - (keff1 + 2\Delta k)]$
$CR3 = CR2[1 - keff1 - \Delta k]/[1 - keff1 - 2\Delta k]$ (.1)
$CR3 = CR2[1 - keff1 - (3/8)(1 - keff1)]/[1 - keff1 - (3/4)(1 - keff1)]$ (.1)
$CR3 = CR2(5/8)(1 - keff1)/(1/4)(1 - keff2)$ (.1)
$CR3 = CR2(5/8)/(1/4) = CR2(5/2) = 16(5/2) = 40$ cps (.1)

b. As keff approaches one, more generations contribute a significant number of neutrons, so more neutron generations are required for neutron flux to level off. (.5)

REFERENCE
NUS Reactor Operation 12.1-3 and 12.4-2

ANSWER H.05 (1.00)

The initial startup after the reactor has been loaded with a new mixed core.

REFERENCE
SOP Manual 11.2.3

ANSWER H.06 (1.50)

Delayed neutrons are born at lower energies (.75) so they are less likely to leak out of the core (.75).

REFERENCE
Prairie Island Reactor Theory Review Lesson Plan, p 103

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER H.07 (1.00)

Soon after a reactor trip power will decrease at the same rate at which the longest lived delayed neutron precursor decays. This precursor has a half life of 55.6 seconds, which corresponds to a mean life of 80 seconds.

REFERENCE
Prairie Island Reactor Theory Review Lesson Plan, p 109

ANSWER H.08 (2.50)

a. 30 seconds

b. The shortest permissible period under these circumstances is 100 seconds. (0.4)
P = P_o exp(t/) (0.3)
t = ln(P/P_o) = 100 ln(5/2.5) = 69.3 seconds (0.3)

c. Reactor period is a measure of the relative, rather than the absolute, rate of power change. 7.5 MW is 1.5 times as large as 5 MW, while 5 MW is 1.67 times as large as 3 MW.

REFERENCE
Prairie Island Reactor Theory Review Lesson Plan, p 100
SOP Manual 11.1.1.1

ANSWER H.09 (1.50)

Activated structural material emits a high-energy gamma. (0.5)
The gamma strikes a beryllium atom in the reflector (0.5), resulting in the disintegration of the beryllium atom into two alpha particles and a neutron (0.5).

REFERENCE
Hazards Summary 12-229

ANSWER H.10 (1.50)

a. Aluminum temperature is above its melting point. (.5)
Aluminum is in a finely divided form. (.5)

b. Hydrogen

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

REFERENCE
Hazards Summary 13-22

ANSWER H.11 (2.00)

Pressurizer pressure
Core flow rate
Core power
Inlet water temperature

REFERENCE
Tech Spec Figure 2.2

ANSWER H.12 (1.00)

Avoid hydraulic instability which could cause the premature onset of DNB.

REFERENCE
Hazards Summary 5-46 and 48

ANSWER H.13 (2.50)

a. Momentary formation of small bubbles on the heat transfer surface which are quickly swept into the subcooled liquid and condensed.

b. (heat flux required to cause DNB)/(local heat flux)

c. Minimum of 1.2

REFERENCE
Hazards Summary 5-52
Nuclear Engineering Handbook, p 9-76
Tech Spec 2.1

ANSWER H.14 (1.00)

a. 50 psig

b. 297 F

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

REFERENCE
Steam Tables

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER I.01 (2.00)

a. Quarterly dose less than 3 rems
Lifetime dose less than 5(N-18)
Accumulated occupational exposure is documented on NRC Form 4
(0.5 each)

b. .75 rems per quarter

REFERENCE
10CFR20.101 and 104

ANSWER I.02 (1.00)

Iodine (constitutes a large fraction of the fission yield. Iodine is volatile and it) accumulates in the thyroid.

REFERENCE
Hazard Summary 11-37

ANSWER I.03 (1.00)

Permanently installed radiation monitors located on the beam hole floor.

REFERENCE
Hazard Summary 8-15

ANSWER I.04 (1.00)

Any two of the following (.5 each):
1. Distance of the tubes from personnel working in the area.
2. Speed at which the sample container is transported through the system.
3. Double encapsulation of samples.
4. Filtering of exhaust air.
5. Suction of the facility exhaust fans provides a continuous flow through the system, preventing a large generation of radioactive argon-41 in the stagnant air in the reactor reflector irradiation position.

REFERENCE
Hazards Summary 8-25

6. When the blower switch is turned on only one blower will start & operate initially after a time delay, the second blower will start. Because of the sudden flow restriction caused by the second blower, the radioactivity will be discharged over a longer period eliminating instantaneous releases of argon-41 exceeding 2600 MPC.

Letter from Univ of Mo, Col, to NRC Dev of Reactor Licensing, 10/6/70
" " " " to NRC Directorate " , 4/18/75

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER I.05 (1.00)

Advise the health physicist or ~~laboratory~~ shift supervisor.

REFERENCE
Hazards Summary B-25

ANSWER I.06 (2.00)

a. Emergency Director

b. 100 rem

c. Any two of the following (0.5 each):
1. Women of child-bearing age shall not take part.
2. The volunteer should be over 45 years old.
3. The volunteer has not received previous exposure in excess of 10CFR20 limits.
4. The volunteer is familiar with the consequences of radiation exposure.
5. Dose-rate in the task area is measurable/known.

REFERENCE
SEP 4, immediate action step 9
SEP 11
SEP Worksheet D

ANSWER I.07 (2.00)

1. Verify the background radiation at the stack monitor.
2. Verify control room readings.
3. Mark initial needle position on analog display with time for future analysis if control room display becomes inaccessible.
4. Verify that the flow rate through the monitor is between 6 and 8 SCFM.
(0.5 each)
5. have stack filters analyzed for nuclides

REFERENCE
SEP 4, immediate action step 5

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER I.08 (1.50)

1. Secure EF-13 and 14.
2. Secure RF-1 and 2, and SF-1 and 2.
3. Secure all individual vent fans.
(0.5 each)

REFERENCE
SEP 4, immediate action step 7

ANSWER I.09 (1.00)

Portable radio affects the stack monitor.

REFERENCE
SEP 4, immediate action step 5

ANSWER I.10 (1.50)

a. 1. Lobby near the reception desk.
HP emergency locker in the
2. Health physics office on top of the computer printer cabinet.
(0.5 each)

b. No

REFERENCE
SEP 10

ANSWER I.11 (.50)

Scram the reactor.

REFERENCE
REP 6

ANSWER I.12 (.50)

Scram the reactor.

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

REFERENCE
REP 20

ANSWER I.13 (1.00)

Health physics technician will be assigned to continuously monitor that experiment throughout the startup.

REFERENCE
SOP I.4.3.J

ANSWER I.14 (1.00)

A radiation survey of the area must be made.

REFERENCE
SOP I.4.5.E

ANSWER I.15 (2.00)

a. Shift Supervisor. (.5)

b. Work involving significant potential exposure of personnel to radiation or the spreading or release of airborne or surface contamination. (.5)

c. At the job site. (.5)

d. It is placed in the health physics RWP file. (.5)

REFERENCE
SOP I.4.7

ANSWER I.16 (1.00)

a. Neutron absorption by argon 40, which comprises 1% of the atmosphere. (.5)

b. External exposure. (.5)

REFERENCE
Tech Spec 3.7

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER J.01 (1.00)

As part of the automatic shimming program.

REFERENCE
SOP 1.4.3.D

ANSWER J.02 (4.00)

a. -7 x 10 exp -5 Δk/k/F (-6 to -8 for full credit) (0.5)

b. 1.34 x 10 exp -4 Δk/k/F (1.2 to 1.4 for ful credit) (0.5)

c. 16.55% k/k (16 to 17 for full credit) (0.5)

d. .00738 (.007 to .0075 for full credit) (0.5)

e. .869 x 10 exp -5 Δk/k/cc of void (.8 to .9 for full credit) (0.5)

f. 8.275 x 10 exp -3 Δk/k (8 to 9 for full credit) (0.5)

g. 2.72 x 10 exp -2 Δk/k (2.5 to 3 for full credit) (0.5)

h. 93.15% U-235 (93 to 93.5% for full credit) (0.5)

REFERENCE
Critical Parameters and Core Characteristics

ANSWER J.03 (2.50)

a. Break a siphon of the PCS in case of a pipe rupture. (1.0)

b. Water level must be less than 6 inches above the antisiphon valves. (.5)

c. Establish normal system pressure by admitting air through the air valve and regulator on the bridge. (.5)

d. 27 (.5)

REFERENCE
SOP IV.3.1 and 2

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER J.04 (1.00)

To remove decay heat.

REFERENCE
SOP IV.2

ANSWER J.05 (1.50)

a. The pump which will not be used will be tagged out at the breaker. (0.5)

b. Prevent excessive pressure in the isolated heat exchanger. (1.0)

REFERENCE
SOP V.1.2

ANSWER J.06 (2.50)

a. 10 (0.5)

b. The basin level will be drawn down faster than the makeup water can be supplied (0.5), which will result in the actuation of a low sump level trip (0.5).

c. The check valve on SP-3 is rated for higher flows than those on SP-1 or SP-2. (1.0)

REFERENCE
SOP VI.1.H

ANSWER J.07 (1.00)

a. FALSE

b. TRUE

REFERENCE
SOP VI.3.1

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER J.08 (1.50)

a. Dearborn 712 or 717 (microbiocide) (0.5)

b. sulfuric acid (0.5)

c. ~~Zinc chromate tetrametes~~ phosphates (Dearborn 4630) (0.5)

REFERENCE
SOP VI 6.3, 6.5 and 6.6

ANSWER J.09 (1.50)

1. Scram the reactor. (0.5)
2. Ensure all the rods are full in. (0.5)
3. Ensure the reactor is shutting down as indicated by nuclear instrumentation. (0.5)

REFERENCE
REP-1

ANSWER J.10 (2.00)

1. Scram the reactor/or if already scrammed, check reactor shutdown. (0.5)
2. Turn off all pump and cooling tower fans in an expeditious manner. (0.5)
3. Place all valve controls in their normal shutdown position and manual mode. (0.5)
4. Trip the auto transfer switch on substation "B". (0.5)

REFERENCE
REP-9

ANSWER J.11 (1.50)

1. Scram the reactor, noting approximate stuck position. (0.5)
2. Place the master switch in test to prevent the mechanisms from driving in. (0.5)
3. Verify the reactor is shutting down by nuclear instrumentation. (0.5)

REFERENCE
REP-8

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER K.01 (.50)

Reactor Manager

REFERENCE
SOP II.2.1.A

ANSWER K.02 (.50)

One

REFERENCE
SOP II.2.1.D

ANSWER K.03 (1.00)

Only when passing the fuel element across the weir divider (0.5) and only under the direct supervision of a senior reactor operator (0.5).

REFERENCE
SOP II.2.1.H

ANSWER K.04 (.50)

Sideplate

REFERENCE
SOP II.2.1.I

ANSWER K.05 (1.00)

Irradiated fuel is not transferred until after adequate decay time.

REFERENCE
Hazards Summary II-17

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER K.06 (1.00)

Observing that the red indicator on the horizontal cylinder is fully retracted.

REFERENCE
SOP II.2.1.L

ANSWER K.07 (.50)

False

REFERENCE
SOP II.2.1.L

ANSWER K.08 (1.00)

Accidently lifting and leaving the element a few inches off of its seated position.

REFERENCE
SOP II.2.1.L

ANSWER K.09 (.50)

The Reactor Physicist

REFERENCE
SOP II.2.2.A

ANSWER K.10 (1.00)

Ensure that core reactivity is continuously monitored to prevent inadvertent criticality.

REFERENCE
SOP II.2.2.F

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER K.11 (2.00)

1. Defuel the core of two fuel elements. (1.0)
2. Keep the other three blades in their fully inserted position (unless permitted to raise them by the Reactor Manager). (1.0)

REFERENCE
SOP 11.3.1.C

ANSWER K.12 (1.00)

Install the aluminum protective head (tophat) on the pressure vessel.

REFERENCE
SOP 11.2.2.M

ANSWER K.13 (1.00)

Prevent a building isolation alarm while the blade is being handled out of water.

REFERENCE
SOP 11.3.2.A

ANSWER K.14 (1.00)

Relieve the tension on the lifting tool (.5) and determine the reason for the difficulty before continuing the attempt to lift the mechanism (.5).

REFERENCE
SOP II.3.3.L

ANSWER K.15 (.50)

False

REFERENCE
SOP 11.3.3.M

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER K.16 (1.00)

a. 5-7
b. ~~7.0-7.4~~ 7.8-8.2

REFERENCE
SOP II-15

ANSWER K.17 (5.00)

a. 8 seconds. (0.5)
b. 1725 gpm. (0.5)
c. 150 F. (0.5)
d. 170 F. (0.5)
e. 63 psid (0.5)
f. 120%. (0.5)
g. 490 gpm. (0.5)
h. 23 feet. (0.5)
i. 13-14 inches below centerline. (0.5)
j. 78 psig. (0.5)

REFERENCE
SOP I, Table IV

ANSWER K.18 (1.00)

DF is the decontamination factor, the ratio of the impurity concentration upstream of the resin bed to the impurity concentration downstream of the resin bed.

REFERENCE
SOP V.5.2.D

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER L.01 (.50)

2 (.25), 1 (.25)

REFERENCE
SOP 1.4.2.C

ANSWER L.02 (.50)

True

REFERENCE
SOP 1.4.3.A

ANSWER L.03 (.50)

Shift Supervisor

REFERENCE
SOP 1.4.3.B

ANSWER L.04 (.50)

False

REFERENCE
SOP 1.4.3.C

ANSWER L.05 (1.00)

A startup within two hours of any shutdown in which restart capability is in doubt.

REFERENCE
SOP 1.4.3.E

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER L.06 (1.00)

1. The reactor is secured. (0.5)
2. No irradiated fuel is being handled which has a decay time less than 60 days. (0.5)

REFERENCE
Tech Spec 3.5.a

ANSWER L.07 (2.00)

Any four of the following (0.5 each):
1. Truck entry door closed and sealed.
2. Utility seal trench filled with water to the depth required to maintain a minimum water seal of 4.25 feet.
3. All containment building ventilation system automatically closing doors and valves are operable or closed.
4. The reactor mechanical equipment room exhaust system, including the particulate and halogen filters, is operable.
5. The personnel airlock door is operable.
6. The most recent building leak test was satisfactory.

REFERENCE
Tech Spec 1.15

ANSWER L.08 (1.00)

The reactor shall be subcritical by a margin of at least .02 Δk (0.5), with any one shim blade fully withdrawn (0.5).

REFERENCE
Tech Spec 3.1.e

ANSWER L.09 (2.00)

1. Source range indicates at least 1 cps and wide range indicates a power level greater than 1 watt. (1.0)
2. Source range indicates at least 2 cps and is verified to be responding to neutrons just prior to startup. (1.0)

REFERENCE
Tech Spec 3.4.e

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER L.10 (1.00)

Limit fuel plate swelling to less than 10%.

REFERENCE
Tech Spec 3.8.a

ANSWER L.11 (1.00)

a. 120 F. (0.5)
b. 2000 gal. (0.5)

REFERENCE
Tech Spec 3.4.b and 3.10.b

ANSWER L.12 (1.00)

1. Operation above 50 KW. (0.5)
2. Operation below 50 KW with forced convection cooling. (0.5)

REFERENCE
SOP I.4.3.F

ANSWER L.13 (1.00)

When the reactor is returned to power within two hours after a shutdown from full power (0.5), providing the status of any system covered by the prestartup checksheets has not changed since the last power generation (.25), or the shift supervisor determines that no system has been affected by the cause of the shutdown (.25).

REFERENCE
SOP I.4.1.2

ANSWER L.14 (1.00)

1. A startup following a shutdown in which fuel handling has taken place. (0.5)
2. When requested by the shift supervisor. (0.5)

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

REFERENCE
SOP 1.4.3.G.2 and 3

ANSWER L.15 (1.00)

Insert control rods and calculate the ECP.

REFERENCE
SOP 1.4.3.G.4

ANSWER L.16 (1.00)

Any two of the following (0.5 each):
1. Commencement of the reactor startup.
2. When power level will be held constant for more than 5 minutes.
3. When the desired power level is attained.

REFERENCE
SOP 1.4.3.1

ANSWER L.17 (1.00)

1 Source Range (.25)
2 Intermediate Range (.25)
2 Power Range (.25)
1 Wide Range (.25)

REFERENCE
SOP 1.4.3.H

ANSWER L.18 (1.00)

a. Shutdown checksheet (0.5).
b. Shift Supervisor. (0.5)

REFERENCE
SOP 1.4.5.F

ANSWERS -- UNIVERSITY OF MISSOURI -86/07/01-HIGGINS, R.

ANSWER L.19 (1.00)

a. Prevent injury to personnel. (0.5)
b. Provide supplemental information concerning operating procedures. (0.5)

REFERENCE
SOP 1.4.10.2

ANSWER L.20 (1.00)

a. Shift Supervisor. (0.5)
b. Licensed Operators. (0.5)

REFERENCE
SOP I.4.10.2 and 3