U.S. NUCLEAR REGULATORY COMMISSION REGION I
OPERATOR LICENSING EXAMINATION REPORT

EXAMINATION REPORT NO. 50-20/85-03 (OL)

FACILITY DOCKET NO. 50-20

FACILITY LICENSE NO. R-37

LICENSEE: Massachusetts Institute of Technology
138 Albany Street
Cambridge, Massachusetts 02139

FACILITY: MIT

EXAMINATION DATES: September 30, October 1, 1985

CHIEF EXAMINER: David M Silk 10/31/85
David M. Silk, Reactor Engineer Examiner — Date

REVIEWED BY: R M Keller 11/4/85
R. Keller, Chief, Projects Section IC — Date

APPROVED BY: H B Kister 11/8/85
Harry B. Kister, Chief, Projects Branch No. 1 — Date

SUMMARY: Operator Licensing examinations were conducted at M.I.T. September 30, and October 1, 1985. One SRO candidate and two RO candidates were administered written and oral examinations. One RO candidate failed the oral examination.

REPORT DETAILS

TYPE OF EXAMS: Initial___ Replacement_X__ Requalification____

EXAM RESULTS:

	RO Pass/Fail	SRO Pass/Fail
Written Exam	2/0	1/0
Oral Exam	1/1	1/0
Overall	1/1	1/0

1. CHIEF EXAMINER AT SITE: David M. Silk

2. OTHER EXAMINER: Robert M. Keller

1. Summary of generic strengths of deficiencies noted on oral exams:

   Candidates displayed a good understanding of the plant. SRO candidate displayed a weakness in not assuming all responsibilities assigned to SRO by transferring responsibilities to plant management personnel who hold SRO licenses.

2. Summary of generic strengths or deficiencies noted from grading of written exams:

   Candidates were not familiar with:

   - relationship of early xenon peaking to harder neutron spectrum
   - modes of operation for the 1-inch pneumatic tube system
   - the hazard of drying out charcoal filters
   - how to seal beam ports

3. Comments on availability of, and candidate familiarization with plant reference material in the control room:

   Candidates were familiar with plant reference material.

4. Personnel Present at Exit Interview.

NRC Personnel

David Silk

Facility Personnel

John Bernard
Kwan Kwok

5. Summary of NRC Comments made at exit interview:

- Two of the three candidates were clear passes on the oral examination.

- Facility training material provided for examination preparation was well organized.

6. CHANGES MADE TO WRITTEN EXAM DURING EXAMINATION REVIEW:

Question No.	Change	Reason
A.2	Delete question.	The question called for a comparative knowledge of reactor types.
B.2	Include in answer "Verify system pressure".	Expands answer Key.
B.6	Delete from answer "the pitch of fan blades can be changed".	Inoperable at present.
C.1	Delete from question "The reactor has just been started".	Can mislead candidate. Clarifies question.
C.7	Also accept Answer a).	Unusual Occurrence Report #81-4 justifies answer a).
D.5	Delete question.	This experiment (FCE) has been out of the reactor for two years.

Question No.	Change	Reason
E.5	Also accept Answer c).	If some loads are shed, the battery could supply power for about 12 hours.
E.7	Include in answer - Weekend - Intrusion (Interior/ Exterior) - Fuel Vaults - Operator Incapacitated - Panic Button (In control room or receptionist desk)	These alarms will transmit a signal to the campus Patrol Alarm System.
G.1	Include in answer "Check radiation levels" "Order personnel out"	Expands answer Key.
G.3	Also accept Answer c).	Surface contamination includes beta radiation.
G.8	Include in answer "Gas monitor on reactor floor by main airlock".	Expands answer Key.
G.11	Include in answer: "To prevent nitric acid formation from nitrous oxide".	Expands answer Key.
J.2	Include in answer a). - Reactor floor hot - 36V's if not sealed - A drop in building temperature Include in answer b). - Use helium gas - Seal ports	Expands answer Key.

Attachments:

1. Written Examination and Answer Key (RO)
2. Written Examination and Answer Key (SRO)

ATTACHMENT 1
MASTER

U.S. NUCLEAR REGULATORY COMMISSION

REACTOR OPERATOR LICENSE EXAMINATION

Facility: MITR-II

Reactor Type: HWR/LWR Cooled/Moderated

Date Administered: October 1, 1985

Examiner: W. J. Apley/ J. C. Huenefeld

Candidate: Answer Key

INSTRUCTIONS TO CANDIDATE:

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	Candidate's Score	% of Cat. Value	Category
15.0	14.9			A. Principles of Reactor Operation
13.0 ~~14.0~~	13.9			B. Features of Facility Design
14.5	14.4			C. General Operating Characteristics
15.0	14.9			D. Instruments and Controls
15.0	14.9			E. Safety and Emergency Systems
13.5	13.4			F. Standard and Emergency Operating Procedures
14.0	13.9			G. Radiation Control and Safety
100 ~~101.0~~				TOTALS

Final Grade ________ %

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

Candidate's Signature

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October 1, 1985

A. PRINCIPLES OF REACTOR OPERATION (15.0)

Points Available

QUESTION A.1

When calculating an estimated critical position, the operator uses the previous week's position and corrects for five different delta K changes. List four (4) of those delta K changes. (2.0)

ANSWER A.1

Delta K due to temperature change
due to sample loading
due to Xenon
due to fuel loading
due to burnup

(4 of 5 for full credit)

REFERENCE A.1

PM 3.1.1.2, p.11

QUESTION A.2

The MITR-II reactor produces a relatively fast response to a given reactivity input. Explain that response in terms of what the values of neutron generation time and delayed neutron fraction are at MITR-II. (I.e., are both Beta and generation time small, one small and the other large, etc.) (2.0)

ANSWER A.2

The sensitive response is due to the short neutron generation time for the MITR-II, even though its delayed neutron fraction is large (beta-bar = 0.00786). The large Beta effective is predominately due to a large source of "slow born" photo neutrons developed in the reflector.

REFERENCE A.2

RSM 10.5

-Section A Continued on Next Page-

Points
Available

QUESTION A.3

Why isn't the MTR type elements cladding thicker or thinner? (1.5)

ANSWER A.3

It's thick enough to retain fission products (+0.5), and thin enough to not introduce a long delay time for heat removal in the event of a fast transient (+0.5).

REFERENCE A.3

Tech Spec 5-4

QUESTION A.4

Explain the two (2) ways that the control elements affect reactivity as they are moved in the core. (1.5)

ANSWER A.4

When inserted in the annular space between the core and the core housing assembly, these control elements decrease reactivity both by the direct absorption of neutrons and, to a lesser extent, by warping the core flux distribution, thereby increasing neutron leakage.

(+1.0 for absorbtion/+0.5 for increasing leakage)

REFERENCE A.4

RSM 10.5

-Section A Continued on Next Page-

Points Available

QUESTION A.5

If the reactor is on a stable 25-second period, how long will it take to change power level 2 decades (show calculation)? (2.0)

ANSWER A.5

From equation sheet:

$$Sur = \frac{26.06}{T} = \frac{26.06}{25.00} = 1.0424$$

$$P = P_o 10^{sur\ t}$$

$$\frac{P}{P_o} = 100 = 10^{sur\ t}$$

$$2 = sur\ t$$

$$t = 2/1.0424 = 1.92 \text{ minutes}$$

If the candidate doesn't know about SUR (which is checked w/o calculation in A.1), then he can calculate using formula sheet.

$$P = P_o e\ t/T$$

$$P/P_o = 100 = e^{t/25 \text{ sec}}$$

$$\ln 100 = t/25 \text{ sec}$$

$$t = (25 \text{ sec})(\ln 100)$$

$$= 115.13 \text{ seconds} = 1.92 \text{ minutes.}$$

REFERENCE A.5

Glasstone and Sesonske (MITR Trng Progr. Ref.)
PM 1.16.2, p.1

-Section A Continued on Next Page-

Points
Available

QUESTION A.6

TRUE or FALSE: Xenon peaks earlier in MITR-II after shutdown due to a harder neutron spectrum. (0.5)

ANSWER A.6

True

REFERENCE A.6

RSM 10.7

QUESTION A.7

Describe the two (2) phenomena that contribute to the temperature coefficient of reactivity for MITR-II. (2.0)

ANSWER A.7

The first is the temperature rise of the light water due to an increase in the thermal output of the reactor core. Any such temperature rise will insert negative reactivity by causing a hardening in the neutron spectrum. (This means that the average neutron takes longer to thermalize so there are fewer fissions.) The second phenomenon is the radiation heating of the heavy water reflector. Temperature rises of this type add negative reactivity by allowing more neutron leakage to increase. This second process lags the temperature rise of the light water in the core proper.

REFERENCE A.7

RSM 10.8

-Section A Continued on Next Page-

Points
Available

QUESTION A.8

If heavy water leaks into the light water system, what type of reactivity effect will it have if:

A. The leakage of pure, uncontaminated heavy water is into either the light water reflector above the top of the core, or the light water reflector below the top of the core that is formed by the annular space between the core and the sides and bottom of the core tank. (0.5)

B. Leakage of heavy water is into the core proper. (0.5)

C. The in-leaking D_2O progressively replaced the entire light water system. (0.5)

ANSWER A.8

A. Positive reactivity
B. Strong, negative reactivity
C. Strong, negative reactivity

REFERENCE A.8

RSM 10.11

-Section A Continued on Next Page-

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Points Available

QUESTION A.9

A nuclear reactor has a shutdown margin of 7% delta k/k and a neutron detector is recording 20 cpm. What will this detector read when $k_{eff} = 0.99$? (2.0)

ANSWER A.9

$$\frac{1 - K_1}{K_1} = 0.07$$

$$1 = K_1 + 0.07\, K_1$$

$$1 = 1.07\, K_1$$

$$K_1 = 1/1.07 = 0.93$$

$$\frac{1 - K_1}{1 - K_2} = \frac{C_{R2}}{CR_1}$$

$$\frac{0.07}{0.01} = \frac{CR_2}{20}$$

$$CR_2 = 140 \text{ cpm}$$

REFERENCE A.9

1. Generic: "Academic Program for Nuclear Power Plant Personnel," Volume II, pp. 5-6 through 5-13, General Physics corporation.

2. Glasstone and Sesonske (MITR Trng. Progr. Rev.) PM 1.16.2, p.1

-End of Section A-

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B. FEATURES OF FACILITY DESIGN (14.0)

Points Availble

QUESTION B.1

Describe the four (4) modes of operation for the 1-inch pneumatic tube system. (2.0)

ANSWER B.1

A. Insertion and removal at the hot cell or primary chem room in the reactor basement.

B. Insertion at the hot cell and transfer of the irradiated sample to the NW-13 hot lab via the connecting pneumatic tube.

C. Insertion from the NW-13 hot lab, into the reactor, and transfer of the irradiated sample back to the NW-13 hot lab.

D. Transfer of a rabbit from the basement hot cell to the NW-13 hot lab.

REFERENCE B.1

PM 1.10, p. 7

QUESTION B.2

How does the operator verify that the secondary system is properly lined up to cooling tower basins? (1.5)

ANSWER B.2

Verify secondary system is propery lined up to cooling tower basins by either checking HV-14 of HV-14A open or by checking HM-1A running with flow through HF-3 at 60% of scale. (Either answer correct.)

REFERENCE B.2

PM 3.1.1.1, p. 2

-Section B Continued on Next Page-

Points
Available

QUESTION B.3

What design safety feature ensures that fuel loaded into the core will normally have access to only one core position at a time? (1.25)

ANSWER B.3

Hold-down grid latch must be released and the grid rotated to permit core access. Grid design prevents multiple position access.

REFERENCE B.3

PM 2.7, p.3

QUESTION B.4

If the pressure relief system's charcoal filters become submerged, what problems will exist during filter housing and exhaust dryout? (1.25)

ANSWER B.4

The charcoal generates heat while drying out and may cause spontaneous combustion.

REFERENCE B.4

PM 5.2.14, p. 2

-Section B Continued on Next Page-

Points
Available

QUESTION B.5

Explain how the anti-syphon valves work. (1.0)

ANSWER B.5

Ball float valves installed at the top of the core shroud. Inlet flow forces ball up closing outlet at top; w/o flow gravity forces ball down to break syphon.

REFERENCE B.5

RSM 1.7

QUESTION B.6

List three (3) ways to reduce the degree of cooling tower efficiency on cold days. (2.0)

ANSWER B.6

The yard booster pumps may be bypassed partially or completely, as may the towers themselves. One of the cooling tower fans may be operated at half-speed, the pitch of the fan blades can be changed, and the air admitted to the towers can be restricted by rearranging the external boards and flaps.

(Any three.)

REFERENCE B.6

RSM 3.12

-Section B Continued on Next Page-

Points
Available

QUESTION B.7

How are beam ports sealed? (1.5)

ANSWER B.7

A. A plug is placed in port
B. Gas seals
C. Gasketed cover bolted over beam port's opening

REFERENCE B.7

RSM 2.4

QUESTION B.8

Assume a loss of external electrical power feeders occurred. When normal power is later restored, what will happen to all the transfer switches and the motor generator set? (1.0)

ANSWER B.8

A. Transfer switches return to normal.

B. Relay at the motor-generator set is energized, thereby stopping the unit.

REFERENCE B.8

RSM 8.32

-Section B Continued on Next Page-

Points Available

QUESTION B.9

Draw a top view of the core, including location of the: 1.5 ~~(1.0)~~

A. Regulating rod (.5)
B. Shim blades (.5)
C. Radial absorber plates (.25)
D. Hexagonal absorber plates (.25)

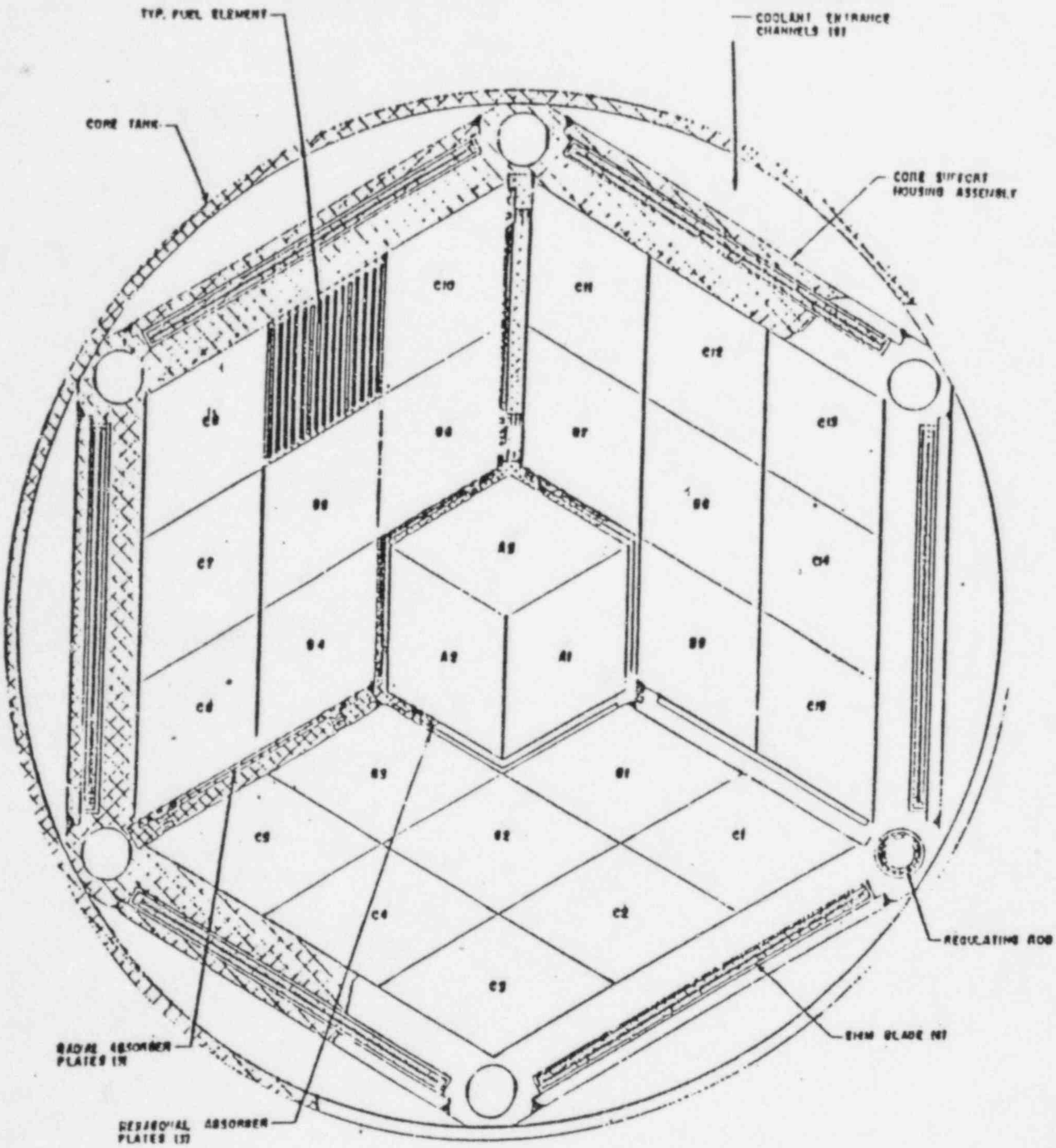
ANSWER B.9

See next page.

REFERENCE B.9

See attachment .

-Section B continued on next page-



Answer B.9

Core Section M.I.T.R. II

Reactor Systems Manual

-End of Section B-

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C. GENERAL OPERATING CHARACTERISTICS (14.5)

Points Available

QUESTION C.1

The reactor has just been started up. Explain why nuclear instrumentation must be frequently calibrated in terms of thermal power as short lived fission product poisons (such as Xenon) build up in the reactor core. (3.0)

ANSWER C.1

Compensation for the negative reactivity associated with the building in of equilibrium xenon is achieved by withdrawing the shim blades. The out-motion of the shim bank causes the axial flux profile of the reactor to change with the point of maximum flux moving upward. That, in turn, alters the leakage flux which is what is viewed by the nuclear instrumentation. This affects reactor control in the following manner. The automatic control system controls the reactor by maintaining a constant flux at the location of the chamber that feeds the auto-control network. Hence, as the axial flux profile changes with shim bank height, the auto-control channel will detect a "power-change". In reality, of course, there is no net change in power, but a redistribution of power within the core. This is why it is essential to determine the thermal power output of the reactor by means of a heat balance which is not affected by flux distribution.

(+1.0 - change in axial flux profile)
(+1.0 - auto-control "sees" power change)
(+1.0 - need to re-calibrate to thermal, not distributed power)

REFERENCE C.1

PM 2.4, p.1

-Section C Continued on Next Page-

Points Available

QUESTION C.2

What is the maximum amount of reactivity in percent of delta k/k that may be added to the critical reactor without causing damage to the fuel integrity by the resulting power transient? (1.0)

ANSWER C.2

1.8%

REFERENCE C.2

Tech Specs 3-8

QUESTION C.3

Why does it take 24 hours for the reactor to be in thermal equilibrium, such that a heat balance can be conducted? (1.0)

ANSWER C.3

Graphite reflector has a large heat capacity and is slow to attain an equilibrium temperature distribution.

REFERENCE C.3

RSM 6.4

-Section C Continued on Next Page-

Points
Available

QUESTION C.4

Why is "blowdown" of the water in the Forced Draft Cooling Towers required? (1.0)

ANSWER C.4

Forced draft cooling towers concentrate the solids in the makeup water and collect atmospheric dust. Hence, a feed-and-bleed purge is maintained while they are in operation in order to keep the level of dissolved solids within a factor of three to five times that of the makeup water. A small portion of the water is diverted through a flow accumulation meter directly to the sewer. This flow is called "blowdown".

REFERENCE C.4

RSM 3.12

-Section C Continued on Next Page-

Points
Available

QUESTION C.5

A. Explain how the reactivity effect of dumping the radial reflector varies with the position of the shim blades. (1.5)

B. Why is the radial heavy water reflector pumped up with the shim bank in the fully inserted position? (1.0)

ANSWER C.5

A. In as much as the shim blades also operate in the region between the core and the radial heavy water reflector, the reactivity worth of dumping this radial reflector is dependent on the position of the shim blade bank. This effect can be considered as being due to the shadowing influence that the blade bank exerts on the reflector. These results show that the reactivity worth of dumping the radial heavy water reflector when the shim bank is fully inserted is about two-thirds that of the corresponding value when the bank is at the top of the active core.

(+0.5 for reason, +1.0 for knowing more reactivity with rods at top.)

B. Safety considerations dictate that the radial heavy water reflector be pumped up with the shim bank in the fully-inserted position. This ensures that the reactivity insertion for this process will not occur when the reactor is or could go critical.

REFERENCE C.5

RSM 10.6

-Section C Continued on Next Page-

Points
Available

QUESTION C.6

You receive a high temperature shield coolant outlet alarm. The shield coolant outlet temperature is rising slowly, and there is no evidence of a loss of shield flow or level. Operationally, what is the probable cause? (1.5)

ANSWER C.6

The secondary side of the heat exchanger is probably clogged with mud. (Will accept other answers alluding to degraded HX performance.)

REFERENCE C.6

PM 5.4.8

QUESTION C.7

Approximately how long after a failure of the pneumatic blower (at full power), will the temperature in the pneumatic tubes reach 100 degrees C (select best answer)? (1.0)

A. Instantly
B. 5 Minutes
C. 30 Minutes
D. Never

ANSWER C.7

B. 5 Minutes

REFERENCE C.7

PM 5.5.1

-Section C Continued on Next Page-

Points Available

QUESTION C.8

TRUE or FALSE: It does require bypassing a number of safety functions, but it is possible to operate in the 100 kw mode with no forced circulation of primary coolant. (0.5)

ANSWER C.8

True

REFERENCE C.8

PM 2.2

QUESTION C.9

Describe how to calculate the total thermal power output of the reactor. (3.0)

ANSWER C.9

Primary Power = (2.62×10^{-4})(Primary Flow)(Primary delta T)

Reflector Power = (2.91×10^{-4})(D_2O Flow)(D_2O delta T)

Shield Power = (2.62×10^{-4})(Shield Flow)(Shield delta T)

Total Power = Primary + Reflector + Shield Power

#s not important, just the parameters and three constituents of total power.

REFERENCE C.9

PM 2.4, p.5

-End of Section C-

D. INSTRUMENTS AND CONTROL (15.0)

Points Available

QUESTION D.1

What is the purpose of the AUTO TRANSFER ABORT switch in the reactor control room? (1.5)

ANSWER D.1

The AUTO TRANSFER ABORT switch in the reactor control room is used to eject a sample from the reactor, and cause it to exit into the reactor rabbit station, thus blocking its transfer to the NW-13 hot lab. The rabbit tube it controls (1PH1 or 2PH1) is determined by the position of the AUTO TRANSFER SELECTOR switch at the rabbit station. Also, in the case of 1PH1, a sample which had been previously ejected and was being monitored at the stop pin could be exited into the station.

Full credit for answer 1; half-credit for 2 only.

REFERENCE D.1

PM 1.10, p. 11

-Section D Continued on Next Page-

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Points
Available

QUESTION D.2

If automatic reactor operation is desired, the power-set is adjusted to bring the power-setpoint deviation indication to zero at the desired power level. Why must the scale be adjusted on channel #9 (the automatic control channel) so that its signal is reading mid-range on the indicating meter? (2.0)

ANSWER D.2

If this signal is at either the low or high end of the display meter, the automatic control will either not take control or be sluggish in its response.

REFERENCE D.2

PM 2.3, p. 5

QUESTION D.3

Small changes in power may be made through the automatic control system. This is done by slowly varying the setpoint of the power-set potentiometer and adjusting the scales of the other instruments as necessary.

What would happen if the operator moved the setting too rapidly? (1.5)

ANSWER D.3

The deviation meter trip would be exceeded and reactor control would trip off automatic.

REFERENCE D.3

PM 2.4, p. 4

-Section D Continued on Next Page-

Points
Available

QUESTION D.4

If a 3 GV hole that contains a Nuclear instrument detector is flooded, what will happen to the detector output? Explain why. (1.5)

ANSWER D.4

Output will decrease (+1.0) due to the increased attenuation of the neutrons (+0.5).

REFERENCE D.4

PM 5.4.11

QUESTION D.5

The fatique cracking experiment alarm is actuated. Name two (2) of the four (4) abnormal conditions which could cause such an alarm. (2.0)

ANSWER D.5

Two of the four needed.

a. A high sample temperature
b. A very high sample temperature
c. A GM counter alarm
d. Low air pressure

REFERENCE D.5

PM 5.7.9

-Section D Continued on Next Page-

Points
Available

QUESTION D.6

Once the reactor-ready lamp is on, the regulating rod can be moved to any position of travel. However, shim blade withdrawal motion is limited to 4 inches by the "sub-critical position" interlock circuit. What are the three (3) reasons for the sub-critical position interlock circuit? (1.5)

ANSWER D.6

1. To maintain the shim blade bank programmed at a uniform height during final approach to criticality.

2. To establish a level, below the critical position, to which the shim blades may be individually withdrawn in one step.

3. To provide a convenient reference point at which the operator can pause to make a complete instrument check before bringing the reactor to criticality.

REFERENCE D.6

RSM 4.3

QUESTION D.7

TRUE or FALSE: Channel 9 (automatic control) operates on a gamma-sensitive detector, not a compensated ion chamber. (0.5)

ANSWER D.7

True

REFERENCE D.7

RSM 5.9

-Section D Continued on Next Page-

Points
Available

QUESTION D.8

There are two (2) primary coolant conductivity cells: MC-1 and 2. Why is MC-1 normally selected? (1.5)

ANSWER D.8

Conductivity cell MC-1, which is positioned in a filter line at the inlet to the ion exchange column, is normally selected. The other cell, MC-2, is positioned in the outlet filter return line. Obviously inlet measures highest and most conservative conductivity, unless the ion exchanger is leaching out.

REFERENCE D.8

RSM 6.1

QUESTION D.9

How are flows in the reflector secondary coolant and shield coolant measured? (1.0)

ANSWER D.9

Orifice plates and d/p cells.

REFERENCE D.9

RSM 6.6

-Section D Continued on Next Page-

Points
Available

QUESTION D.10

Explain how the reading on the linear N-16 monitor would change as reactor power increases. (2.0)

ANSWER D.10

N-16 production is directly proportional to the fast neutron flux, and therefore if the primary flow was constant, the radiation reading on this monitor would directly indicate reactor power.

REFERENCE D.10

RSM 7.3

-End of Section D-

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E. SAFETY AND EMERGENCY SYSTEMS (15.0)

Points Available

QUESTION E.1

What are the three (3) major safety requirements associated with operating MITR-II (according to the Standard Operating Plan General Instructions)? (3.0)

ANSWER E.1

The first, and most important, is that the release of radioactive materials to the environment be restricted to the lowest practical amount. The second safety requirement is that on-site personnel be protected from contamination and that exposure to radiation be kept as low as is reasonably achievable. The third requirement is that equipment, especially the reactor itself, be operated and maintained properly and that nothing be done that would jeopardize future reactor operation.

REFERENCE E.1

PM 2.1, p. 1

QUESTION E.2

Why must the reactor be shut down if the compressed air system is lost? (2.0)

ANSWER E.2

If neither compressor is capable of maintaining system pressure, the dump valve will open, the pneumatic instrumentation will be lost, and all airlock gaskets will deflate once the air within them leaks out past system check valves. You'll eventually lose containment integrity.

REFERENCE E.2

PM 5.5.4

-Section E continued on next page-

Points
Available

QUESTION E.3

For each of the three (3) cases below, describe how emergency core cooling would be made available. (3.0)

a. Assumptions: 1. Loss of normal electric power supply from Cambridge Electric Company.

2. All process systems are normal except for the loss of power.

b. Assumptions: 1. Level in the core tank cannot be maintained at the overflow level, but it has been determined that it is not dropping below the reactor inlet penetration (inlet penetration at -52 inches).

c. Assumptions: 1. Level in the core tank cannot be maintained at the level of the reactor inlet penetration.

2. The lost water is being collected in the equipment room sump and/or a source of makeup other than city water is immediately available.

ANSWER E.3

a. The system will be aligned as per normal shutdown cooling except that MM-2 will be supplied power from the facility's emergency power supply and HE-2 will be cooled by city water.

b. The systems will be aligned as per modes 3 and 4, but these modes will not be initiated until required. As long as the conditions assumed for mode 2 prevail, natural circulation up through the core and down through the flow shroud check valves will suffice. Heat will be lost to ambient, the reflector tank, and the off-gas system.

c. MM-2 will be aligned to take a suction on either the equipment room sump through the portable hose and strainer, or the other source of makeup, and discharged directly to the 8 inch reactor inlet line through MV-60 or through the spray nozzles at the top of the core tank.

REFERENCE E.3

RSM 3.4.5

-Section E continued on next page-

Points
Available

QUESTION E.4

What two (2) mechanisms add negative reactivity to shut down the reactor when dump valve DV-4 is opened? (1.5)

ANSWER E.4

- When contents of reflector "dumps" to dump tank, negative reactivity added due to increased leakage (loss of reflector) (+1.0).

- There is a microswitch on the vale which provides a SCRAM when the dump valve is opened (+0.5).

REFERENCE E.4

RSM 3.8

QUESTION E.5

How long would the emergency batteries provide expected instrument and pump power following a loss of both external electrical power feeders? (Select best answer.) (0.5)

a. 40 minutes
b. 4 hours
c. 12 hours
d. 24 hours

ANSWER E.5

b. 4 hours

REFERENCE E.5

RSM 8.31

-Section E continued on next page-

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Points
Available

QUESTION E.6

Explain the difference between a major and minor SCRAM. (2.5)

ANSWER E.6

All automatic reactor scrams cause the current to the magnets holding the shim blades to be interrupted. This causes the absorber sections to drop into the core and shut the reactor down. This action is defined as a minor scram. A major scram is initiated by depressing a major scram pushbutton. This action secures the ventilation system, seals the containment shell, dumps the top part of the D_2O reflector, and interrupts the withdraw permit circuit thereby dropping the shim blades.

(+0.5 for minor scram definition)
(+2.0 for major scram four parts, +0.5 each)

REFERENCE E.6

RSM 9.8

QUESTION E.7

There are eight safety and emergency related alarm conditions that will transmit a signal to the Campus Patrol Alarm System. Name five (5). (2.5)

ANSWER E.7

Any five of below

- High Temperature Reactor Outlet, MTS-1
- Low Level Core Tank
- Low Pressure HM-1A
- High Level Radiation Monitor
- Smoke Detector System
- Waste Tanks
- Low Pressure Helium Supply
- Leak Primary and D_2O System

REFERENCE E.7

RSM 9.15

-End of Section E-

F. STANDARD AND EMERGENCY OPERATING PROCEDURES (13.5)

Points Available

QUESTION F.1

Both shim blades and the regulating rod can be driven under automatic control provided the associated reactivity is less than ________% delta k/k. (1.0)

ANSWER F.1

1.8% delta k/k

REFERENCE F.1

Tech. Spec 3.9 (recent change)

QUESTION F.2

What increase in reactor power requires the authorization and witnessing by the duty shift supervisor? (0.75)

ANSWER F.2

>10%

REFERENCE F.2

PM 1.3, p. 2

QUESTION F.3

List five (5) entries made in the Reactor Console Log for criticality data during a startup. (2.5)

ANSWER F.3

i. time
ii. reactor power and period
iii. shim bank and regulating rod positions
iv. core outlet temperature
v. reflector outlet temperature

REFERENCE F.3

PM 1.8, p. 2

-Section F continued on next page-

Points Available

QUESTION F.4

What maximum pH value in primary system water requires immediate corrective action? (0.75)

ANSWER F.4

7.0

REFERENCE F.4

PM 3.1.1.1, p. 12

QUESTION F.5

What three (3) requirements must be met for the reactor to be in a "SECURED CONDITION"? (3.0)

ANSWER F.5

1. The reactor is shutdown.
2. The console key switch is off with the key removed and in the proper custody.
3. No work is in progress within the main core tank involving fuel or experiments, or maintenance of the core structure, installed control blades, or installed control blade drives when not visibly decoupled from the control blade.

REFERENCE F.5

PM 2.2, p. 3

-Section F continued on next page-

Points
Available

QUESTION F.6

TRUE or FALSE: As defined in the MITR-II startup checklists, the ECP is actually not calculated for the infinite-period critical position, but for a supercritical position with a positive 50-second period. (0.5)

ANSWER F.6

True

REFERENCE F.6

PM 2.3, p. 2

QUESTION F.7

What are the four (4) emergency classifications addressed in your emergency plan (PM 4.4)? (2.0)

ANSWER F.7

1. Unusual Event
2. Alert
3. Site Area Emergency
4. General Emergency

REFERENCE F.7

PM 4.4, p. 1

-Section F continued on next page-

Points Available

QUESTION F.8

The reactor is critical. You receive an alarm indicating that the primary coolant level has dropped 4.0" below the overflow point. List your required immediate actions. (3.0)

ANSWER F.8

1. Acknowledge the alarm. (+0.25)

2. Scram the reactor (minor) if it has not already scrammed. Verify that reactor power is decreasing. (+0.5)

3. Notify the reactor shift supervisor. (+0.5)

4. Check the core tank level indicators, ML-3A and ML-3B, both to determine the actual coolant level and to decide if it is dropping or remaining constant. (+0.25)

5. Prepare to initiate emergency cooling. Install the quick-connect hoses located in the control room and in the utility room between valves MV-69/MV-70 and city water lines. (+0.25)

6. Refer to Procedure 4.4.4.1 (Safety Limit Exceeded). (+0.5)

7. Notify the Assistant Reactor Superintendent, the Superintendent, and the Director of Operations. If a safety limit was exceeded, notify the Reactor Radiation Protection Officer. (+0.20)

REFERENCE F.8

PM 4.4.4.4, p. 1

-End of Section F-

MITR-II
October 1, 1985

G. RADIATION CONTROL AND SAFETY (14.0)

Points Available

QUESTION G.1

What action should the Operator-In-Charge take if the rabbit radiation monitor trips? (1.0)

ANSWER G.1

Inform the shift supervisor (before investigation and resolution).

REFERENCE G.1

PM 1.10

QUESTION G.2

What is the basis of the maximum irradiation time limit on the rabbit (60-megawatt hours at a neutron flux of 10^{13})? (1.5)

ANSWER G.2

Embrittlement of the polyethylene containers.

REFERENCE G.2

PM 1.10, p. 10

QUESTION G.3

There must be no direct contact with fingers on the irradiated container or samples because of: (Select best answer.) (1.0)

a. high probable gamma radiation
b. high probable beta radiation
c. high probable surface contamination
d. high probable alpha contamination

ANSWER G.3

b. beta

REFERENCE G.3

PM 1.10, p. 10

-Section G continued on next page-

Points Available

QUESTION G.4

What two (2) types of dosimetry are all personnel working at the MIT reactor required to wear? (2.0)

ANSWER G.4

1. Beta-Gamma Monitoring Badge
2. Pocket Dosimeter (gamma)

REFERENCE G.4

PM 2.5, p. 1

QUESTION G.5

Why is a spill of heavy water a radiological concern? (1.0)

ANSWER G.5

Tritium content

REFERENCE G.5

PM 4.5, p. 4

QUESTION G.6

If the containment building's ventilation system fails, what is the principal radioactive gas that will buildup in containment? (1.0)

ANSWER G.6

Ar-41

REFERENCE G.6

PM 4.5, p. 5

-Section G continued on next page-

Points
Available

QUESTION G.7

TRUE or FALSE: When washing contaminated skin, it is important to use hot water to open and clean out potentially contaminated pores. (0.5)

ANSWER G.7

False

REFERENCE G.7

PM 4.4.4.10, p. 4

QUESTION G.8

Operation of the Blanket Test Facility (BTF) will cause certain radiation monitor detectors to read higher than normal. Which of the radiation monitors are most affected by use of the BTF? (1.0)

ANSWER G.8

Secondary Water Monitors

REFERENCE G.8

PM 5.6.2, p. 1

QUESTION G.9

Explain the difference in extent of qualification for blue, red, and yellow film badges. Which badged group(s) are permitted to escort members of the general public through the Reactor Building? (1.5)

ANSWER G.9

Blue - beginning experimental work, must be supervised
Red - allowed to operate experiment by themselves
Yellow - sufficiently knowledgeable to escort public

REFERENCE G.9

PM 1.12, p. 1

-Section G continued on next page-

Points
Available

QUESTION G.10

List three (3) independent measurements or indicators used to monitor or detect heavy water leakage into the secondary coolant. (2.0)

ANSWER G.10

1. The secondary water monitor is a gamma-sensitive scintillation detector. It cannot detect tritium but is sensitive to N^{16} and F-17, also present in the heavy water when the reactor is operating.

2. Daily sampling of the secondary water will allow detection of very small leaks.

3. Because of the nature of the reflector system, any loss of D_2O inventory will be reflected by a decrease in the D_2O level in the dump tank.

REFERENCE G.10

Tech Specs, p. 3-30

QUESTION G.11

Why is the Thermal Column Hohlraum maintained under a carbon dioxide purge? (1.0)

ANSWER G.11

To prevent activation of argon that would result if air entered the facility.

REFERENCE G.11

RSM 2.2

-Section G continued on next page-

Points
Available

QUESTION G.12

TRUE or FALSE: The purpose of the shield coolant system is to remove the heat deposited in the lead thermal shields by neutron radiation. (0.5)

ANSWER G.12

False (gamma)

REFERENCE G.12

RSM 3.13

-End of Section G-

Attachment 2

MASTER

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

FACILITY: MASS. INSTITUTE OF TECH.

REACTOR TYPE: TEST

DATE ADMINISTERED: 85/10/02

EXAMINER: SILK, D.

APPLICANT: Answer Key

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 80%. 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

QUESTION H.01 (3.00)

How much reactivity has been added to a subcritical reactor if the count rate has increased from 100 cps to 150 cps and if the initial value of Keff was .95? Show all calculations and assumptions.

QUESTION H.02 (3.00)

If heavy water were mixed with light water cooling the core:

a. Would the neutron lifetime increase, decrease, or remain the same? (0.7)

b. Would the migration length increase, decrease, or remain the same? (0.7)

c. What is the overall reactivity effect? Explain. (1.6)

QUESTION H.03 (3.00)

Explain the different modes of heat transfer by which the heat of fission is removed from the fuel. Include major components involved in the heat removal process starting with the fuel and ending at the ultimate heat sink. (3.0)

QUESTION H.04 (1.00)

Why are delayed neutrons important?

QUESTION H.05 (3.00)

Explain the effect of the temperature coefficient on reactivity if the thermal power of the MITR II core increases. Include both light and heavy water effects.

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

QUESTION H.06 (3.00)

The reactor operator is conducting a routine reactor startup after it has been shutdown for several days. Prior to withdrawing a shim blade he reads a stable count of 50 cps on the startup channel. Immediately after withdrawing this blade he reads a count of 80 cps.

a. If he performed no blade motion for five minutes, would the count rate increase, decrease or remain the same? Explain, assuming the reactor is subcritical at 80 cps.

b. After 5 minutes he withdraws another blade the same distance but the reactor is still subcritical. Would the change in count rate (time and magnitude) be different than he saw in part (a) above? Explain.

c. What indications would the operator observe to determine when the reactor had gone critical?

QUESTION H.07 (4.00)

Xenon and Samarium are two poisons which have a significant effect on reactor operations. Discuss and compare these two poisons for the following:

a. Sources of the poisons in the core (1.0)

b. Means of removal from the core (1.0)

c. Effect on reactor operations after shutdown (2.0)

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

QUESTION I.01 (4.00)

A 23 year old individual has accumulated a lifetime occupational dose of 24 rem of whole body exposure documented in accordance with 10CFR20 and has received no exposure during the present calender quarter.

a. How long may he work in a 3 mrem/hr area if he works an 8 hour day Monday through Friday? Show your work.

b. An individual in a restricted area may be allowed to receive a whole body dose in excess of the quarterly limit under certain conditions. Name three conditions.

QUESTION I.02 (2.00)

A mixed gamma and beta source in liquid form spills on the floor. Readings at 10 feet indicate 1.0 mrem/hr on a beta-gamma survey meter. If beta's are not detected further than six feet from the spill and if the combined beta-gamma dose rate at one foot is 120 mrem/hr, what is the beta to gamma ratio? Show your calculations.

QUESTION I.03 (3.00)

a. Does the biological effect of a 100 REM dose depend on whether it is a neutron or gamma dose? Explain.

b. Does the biological effect resulting from bodily intake of a given quantity (in terms of microcuries) of a radioactive material depend on which particular isotope is involved? Explain.

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

QUESTION I.04 (3.00)

A fuel element is suspended in the Reactor Pool approximately 1 meter under water. A radiation survey meter held at the surface of the water reads 100 mrem/hr.

a. Ignoring buildup, what radiation level would you expect if the fuel element broke the water? Assume an attenuation coefficient of 0.035 cm^-1. (1.0)

b. If the radioactive isotopes in the fuel element had an average half life of 30 minutes, how long would it take for the radiation level at the surface of a one inch lead shield cask to drop to 20 mrem/hr? Assume an initial contact dose of 2 R/hr for the fuel element and a tenth thickness of two inches for lead. (2.0)

QUESTION I.05 (3.00)

To assure that experiments in the reactor do not affect the safety of the reactor, Technical Specifications demand that all experiments within the reactor shall confirm to a set a conditions. List six of the seven conditions set forth in the Technical Specifications.

QUESTION I.06 (3.00)

For the case of a radiological emergency, list seven immediate actions that the on-shift supervisor must ensure have been completed. (Assume no medical assistance and no radiation surveys by Campus Police are required).

QUESTION I.07 (2.00)

Does the number of disintegrations per minute (dpm) from a radioactive source equal the counts per minute (cpm) obtained from a survey instrument? Briefly explain.

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

QUESTION J.01 (3.00)

What three actions must be taken when 1 microcurie/liter of tritium is present in the secondary coolant water?

QUESTION J.02 (3.00)

a. If the Reactor Floor Ar-41 Monitor gives an 'High Level Radiation Monitor' alarm, where are five likely places for the Ar-41 to originate? (2.0)

b. What is done to prevent the production of Ar-41? (1.0)

QUESTION J.03 (2.00)

Briefly describe the natural convection valves, how they work, and what is their function?

QUESTION J.04 (3.00)

What does the 'subcritical position' interlock circuit do and give three reasons why it is incorporated into the shim blade control circuit.

QUESTION J.05 (3.00)

Figure 1 shows the differential regulating rod worth curve for your reactor. Give two reasons why the curve peaks at the location shown.

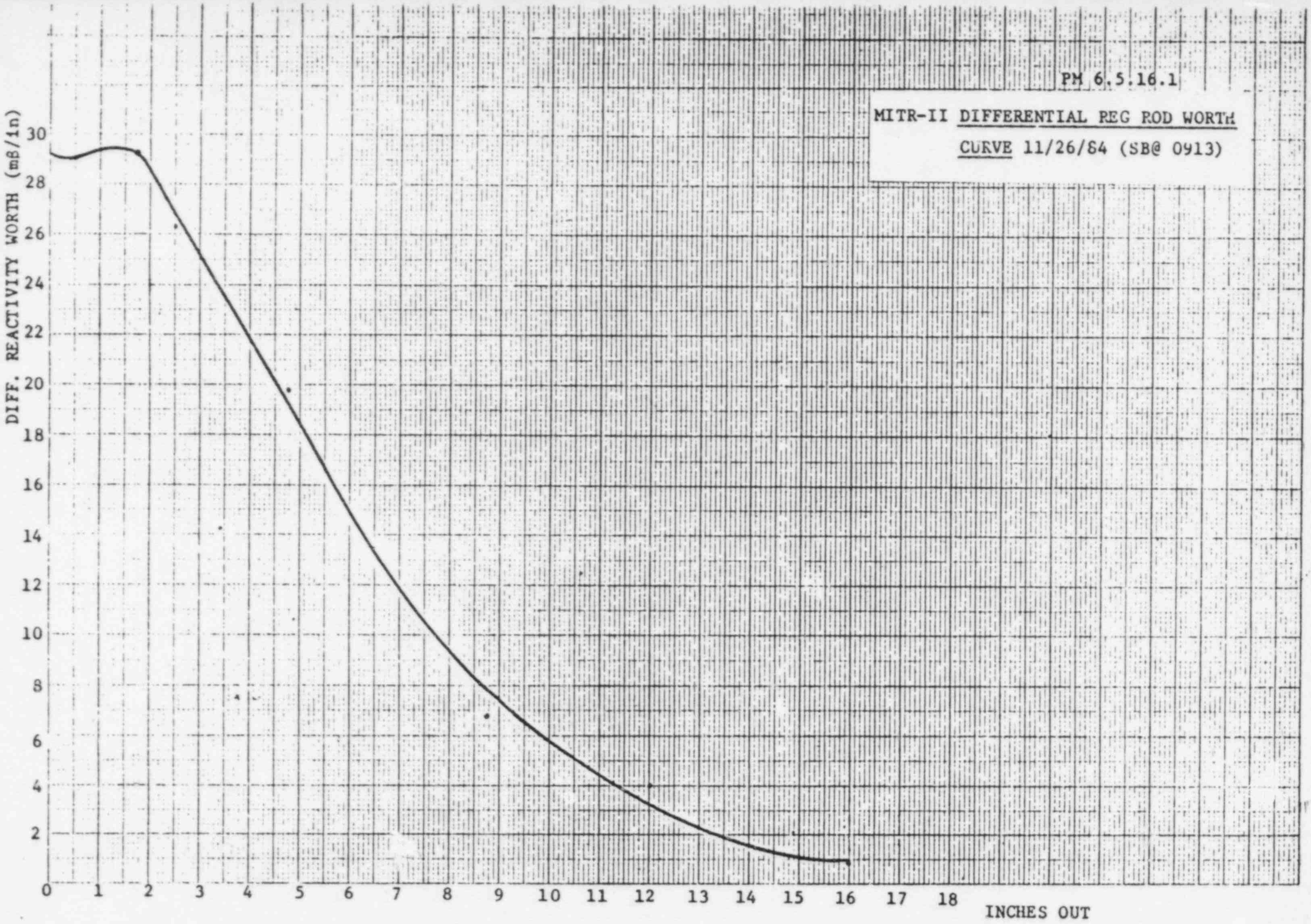
QUESTION J.06 (3.00)

a. Briefly explain why the reactivity worth of the D2O Reflector Dump is dependent on the position of the shim blade bank.

b. What is the required position of the shim bank when the radial heavy water reflector is pumped into place? Briefly explain why.

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

PM 6.5.16.1


MITR-II DIFFERENTIAL REG ROD WORTH
CURVE 11/26/84 (SB@ 0913)
DIFF. REACTIVITY WORTH (mβ/in)
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
INCHES OUT

QUESTION J.07 (3.00)

Briefly explain the most reliable method of determining the steady state power at full power and when this method can be used.

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

QUESTION K.01 (3.00)

After each refueling or change in core loading, the reactor shall not be operated above a power level of 1.0 KW unless an evaluation is made to ensure that two Technical Specifications are satisfied.

a. What are the two Technical Specifications? (2.0)

b. What persons shall complete and approve these evaluations? (1.0)

QUESTION K.02 (3.00)

Give the basis for the following specifications:

a. The reactivity worth of the regulating rod connected to the automatic control system is less than 0.7% delta k/k.

b. The maximum controlled reactivity addition rate is no more than 5x10^-4 delta k/k /sec.

c. The reactivity worth of the D2O reflector dump is greater than the reactivity worth of the most reactive shim blade.

QUESTION K.03 (4.00)

During refueling, what are two designed safety features associated with the hold-down grid plate and what do they prevent?

QUESTION K.04 (3.00)

a. Under what condition, during refueling, is the heavy water reflector not dumped? (2.0)

b. What Technical Specification requirement must be checked if the heavy water reflector is not dumped? (1.0)

QUESTION K.05 (2.00)

What two Technical Specifications requirements must be met before approval is given to remove the spent fuel from the reactor vessel to the transfer flask?

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

QUESTION K.06 (3.00)

According to your Technical Specifications what safety channels must be operable to move fuel in the core and what are the set points, if any?

QUESTION K.07 (2.00)

According to your Technical Specifications, when is your reactor considered secured?

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

QUESTION L.01 (2.50)

In accordance with your Administration Procedures:

a. Briefly describe the administrative procedures followed if a safety function required by Technical Specifications as a Limiting Condition for Operation is to be temporarily bypassed (assume it is not a part of an approved procedure). Include in your answer who may authorize the bypass, condition of the reactor and recording requirements. (1.5)

b. What additional requirements are necessary if a jumper is used? (1.0)

QUESTION L.02 (4.50)

Indicate whether or not each of the following is a violation of procedures and/or Technical Specifications. Briefly explain why it is or it is not a violation.

a. Operating with five shim blades, the sixth shim blade is fully inserted

b. Operating at 2 MW with one primary pump and 1000 gpm primary coolant flow rate

c. Operating at 150 KW with the emergency cooling system inoperable

d. Operating at 100 KW without emergency power available

e. Operating at full power with one of the three reactor floor area radiation monitors inoperative

f. Increasing the reactor power from 200 KW to 300 KW with the duty shift supervisor in the Utilities Room.

(0.75 each)

QUESTION L.03 (3.00)

Any change to a component or system which involves an 'unreviewed safety question' is a 'Class A' proposal. A proposal change 'shall be deemed to involve an unreviewed safety question' if what three criteria are met?

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

QUESTION L.04 (1.50)

List five of the services that the Reactor Radiation Protection Office is responsible for providing for radiation protection and compliance with governmental regulations.

QUESTION L.05 (1.00)

Under what conditions may some one be authorized to incur radiation exposures in excess of the 10 CFR 20 limits?

QUESTION L.06 (3.00)

In regards to General Safety Rules, once permission is granted, what are three joint responsibilities of the operator-in-charge and the personnel entering either the reactor top, the medical therapy room, or the equipment room when the reactor is operating?

QUESTION L.07 (2.00)

a. What are four variables associated with the core thermal and hydraulic performance?

b. What is the objective of the Safety Limits?

QUESTION L.08 (2.50)

a. Given the events below, state which emergency classification should be declared. (0.5 pts each)

   1. A large crowd of protesters marching around the reactor building.
   2. A fire damaging an experiment which causes the release of radioactive materials.
   3. A tornado damaging the containment building.
   4. A slow and uncontrollable decrease in core tank level such that level remains above the anti-syphon valves.

b. What criteria is used for classifying emergency conditions? (0.5)

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

Table 4.5.3-1: EALs for Notification of Unusual Events

1. Confirmed abnormal radiation levels leading to actual or projected radiological effluents at the site boundary exceeding 10 MPC for unrestricted areas when averaged over 24 hours. This level corresponds to an exposure of 15 mrem whole body accumulated over 24 hours. (PM 4.4.4.15b)
2. Report or observation that severe natural phenomena are either imminent or existing. These include storms with tornado or hurricane force winds that could strike the facility, earthquakes that could adversely affect the reactor's safety systems, and floods that could adversely affect the reactor's safety systems. (PM 4.4.4.2)
3. Threats to or breaches of security. (PM 4.4.4.5/4.4.4.6)
4. A reactor safety limit's being exceeded such that a fuel damage accident that could release radionuclides to the containment building is possible. (PM 4.4.4.1)
5. A fire within the containment building that lasts beyond the incipient stage or for more than ten minutes. (PM 4.4.4.3)
6. Receipt of a bomb threat. (PM 4.4.4.7)

Table 4.5.3-2: EALs for an Alert

1. Confirmed abnormal radiation levels leading to actual or projected radiological effluents at the site boundary exceeding 50 MPC for unrestricted areas when averaged over 24 hours. This level corresponds to an exposure of 75 mrem whole body accumulated over 24 hours. (PM 4.4.4.15b)
2. Same as #1 except the effluents could cause an integrated exposure of 100 mrem thyroid. (PM 4.4.4.15b)
3. Radiation levels at the site boundary of 20 mrem/hour sustained for one hour. (PM 4.4.4.14b/4.4.4.11)
4. Abnormal loss of primary coolant such that the core tank level remains at or above the anti-syphon valves. (PM 4.4.4.4)
5. Loss of radioactive material control that causes radiation dose rates or airborne radionuclides to increase above permissible exposure levels by a factor of 1000 throughout the containment building. (PM 4.4.4.12)
6. Radiation dose rates throughout the containment building in excess of 100 mrem/hour sustained for one hour. These levels would necessitate evacuation of all personnel. (PM 4.4.4.12)
7. A fire leading to loss of radioactive material control within the containment building. (PM 4.4.4.3)
8. An imminent or existing hazard such as:
   (a) Missile(s) impacting on the containment building.
   (b) An explosion that affects facility operation.
   (c) An uncontrolled release of toxic or flammable gases into the containment building. (PM 4.4.4.9)

Table 4.5.3-3: EALs for a Site Area Emergency

1. Confirmed abnormal radiation levels leading to actual or projected radiological effluents at the site boundary exceeding 250 MPC for unrestricted areas when averaged over 24 hours. This level corresponds to an exposure of 375 mrem whole body accumulated over 24 hours. (PM 4.4.4.15b)
2. Same as #1 except the effluents could cause an integrated exposure of 500 mrem thyroid. (PM 4.4.4.15b)
3. Radiation levels at the site boundary of 100 mrem/hour sustained for one hour. (PM 4.4.4.14b/4.4.4.11)
4. Abnormal loss of primary coolant such that the core tank level drops below the anti-syphon valves. (Note: This accident is not considered credible, but procedures exist for coping with it.) (PM 4.4.4.4)
5. Imminent loss of physical control of the reactor. (PM 4.4.4.6)
6. Severe natural events being experienced. These include:
   (a) An earthquake that is causing observable damage to the reactor safety equipment within the containment building.
   (b) A flood that is affecting the operability of any reactor safety system.
   (c) Tornado or hurricane force winds that are damaging the containment building. (PM 4.4.4.2)

Table 4.5.3-4: EALs for a General Emergency

1. Actual or projected doses at the site boundary in the exposure pathway of 1 rem whole body or 5 rem thyroid for unrestricted areas when averaged over one hour. Note: Figure 4.7.2.2-1 lists the conditions and instrument readings corresponding to a projected off-site dose of 1 rem/hour. (PM 4.4.4.15a)
2. Sustained actual or projected radiation levels at the site boundary of 500 mrem/hour whole body. (PM 4.4.4.14a/4.4.4.11/4.4.4.12)
3. Blockage of fuel element channels thereby causing a loss of coolant to the affected channels and a fuel melt. This is the design basis accident. (PM 4.4.4.15a)
4. Loss of physical control of either the containment building which includes the control room or of auxiliary areas that house vital equipment. (PM 4.4.4.5/4.4.4.6).
5. Events that have caused or will cause massive facility and/or reactor system damage that could lead to the melting of fuel. (PM 4.4.4.15a)

$f = ma$ $v = s/t$ Cycle efficiency = (Network out)/(Energy in)

$w = mg$ $s = V_o t + 1/2\ at^2$

$E = mc^2$

$KE = 1/2\ mv^2$ $a = (V_f - V_o)/t$ $A = \lambda N$ $A = A_o e^{-\lambda t}$

$PE = mgh$

$V_f = V_o + at$ $w = \theta/t$ $\lambda = \ln 2/t_{1/2} = 0.693/t_{1/2}$

$W = v\ \Delta P$ $t_{1/2}eff = \frac{[(t_{1/2})(t_b)]}{[(t_{1/2}) + (t_b)]}$

$\Delta E = 931\ \Delta m$

$I = I_o e^{-\Sigma x}$

$\dot{Q} = \dot{m} Cp \Delta t$

$\dot{Q} = UA\Delta t$ $I = I_o e^{-\mu x}$

$Pwr = W_f \Delta h$ $I = I_o\ 10^{-x/TVL}$

$TVL = 1.3/\mu$

$P = P_o 10^{sur(t)}$ $HVL = -0.693/\mu$

$P = P_o e^{t/T}$

$SUR = 26.06/T$ $SCR = S/(1 - K_{eff})$

$CR_x = S/(1 - K_{effx})$

$SUR = 26\rho/\ell^* + (\beta - \rho)T$ $CR_1(1 - K_{eff1}) = CR_2(1 - k_{eff2})$

$T = (\ell^*/\rho) + [(\bar{\beta} - \rho)/\lambda\rho]$ $M = 1/(1 - K_{eff}) = CR_1/CR_o$

$T = \ell/(\rho - \beta)$ $M = (1 - K_{effo})/(1 - K_{eff1})$

$T = (\beta - \rho)/(\lambda\rho)$ $SDM = (1 - K_{eff})/K_{eff}$

$\rho = (K_{eff} - 1)/K_{eff} = \Delta K_{eff}/K_{eff}$ $\ell^* = 10^{-5}$ seconds

$\bar{\lambda} = 0.1\ \text{seconds}^{-1}$

$\rho = [(\ell^*/(T K_{eff})] + [\bar{\beta}_{eff}/(1 + \bar{\lambda} T)]$

$I_1 d_1 = I_2 d_2$

$P = (\Sigma\phi V)/(3 \times 10^{10})$ $I_1 d_1^{\ 2} = I_2 d_2^{\ 2}$

$\Sigma = \sigma N$ $R/hr = (0.5\ CE)/d^2(\text{meters})$

$R/hr = 6\ CE/d^2\ (\text{feet})$

<u>Water Parameters</u>

1 gal. = 8.345 lbm.
1 gal. = 3.78 liters
1 ft^3 = 7.48 gal.
Density = 62.4 lbm/ft^3
Density = 1 gm/cm^3
Heat of vaporization = 970 Btu/lbm
Heat of fusion = 144 Btu/lbm
1 Atm = 14.7 psi = 29.9 in. Hg.
1 ft. H_2O = 0.4335 $lbf/in.^2$

<u>Miscellaneous Conversions</u>

1 curie = 3.7×10^{10}dps
1 kg = 2.21 lbm
1 hp = 2.54×10^3 Btu/hr
1 mw = 3.41×10^6 Btu/hr
1in = 2.54 cm
°F = 9/5°C + 32
°C = 5/9 (°F-32)
1 BTU = 778 ft-lbf

ANSWERS -- MASS. INSTITUTE OF TECH. -85/10/02-SILK, D.

ANSWER H.01 (3.00)

```
cr1 /cr2  = (1-Keff2) / (1-Keff1)                 [0.9]
100/150   = (1-Keff2) / (1-0.95)                  [0.5]
1-Keff2   = 10/15 x 0.05
Keff2     = 0.967                                 [0.1]

Change in reactivity = [1-Keff2/Keff2] - [1-Keff1/Keff1]
                     = Keff2 - Keff1 / Keff1 x Keff2        [0.9]
                     = 0.967 - 0.95  /  0.95 x 0.967        [0.5]
                     = 1.85 % delta K/K                     [0.1]
```

REFERENCE

Procedure Manual (PM) 2.3 pg. 1,2

ANSWER H.02 (3.00)

a. Increase (0.7)

b. Increase (0.7)

c. The increased migration length would tend to increase neutron lifetime and leakage and thus add negative reactivity. (1.6)

REFERENCE

Reactor Systems Manual (RSM) pg. 10.10

ANSWER H.03 (3.00)

Conduction through fuel.
Conduction transfer from fuel to coolant.
Forced convection to heat exchanger.
Conduction across heat exchanger.
Forced convection to cooling towers.
Evaporation to atmosphere. (0.5 pts each)

REFERENCE

Introduction to Nuclear Engineering, chapter 8; J R Lamarsh
RSM pgs. 3.1, 3.2, 3.10 to 3.12

ANSWER H.04 (1.00)

The delayed neutrons increase generation time which increases the period and thus the reactor can be controlled.

REFERENCE
Introduction to Nuclear Engineering, chapter 7 pg. 245; J R Lamarsh

ANSWER H.05 (3.00)

Increasing the temperature of the light water will insert nagative reactivity by causing the neutrons to take longer to thermalize so there are fewer fissions (1.5). Heating of the heavy water reflector will add negative reactivity by allowing neutron leakage to increase (1.5).

REFERENCE
RSM pg. 10.8

ANSWER H.06 (3.00)

a. Increase slightly then level out(0.6) due to subcritical multiplication (0.4).

b. Larger increase(0.3) and longer to level out(0.3) due to greater number of generations to reach equilibrium(0.4).

c. Steadily increasing count rate or slight positive period with no rod withdrawal. (1.0)

REFERENCE
PM 2.3 pg. 1,2

ANSWER H.07 (4.00)

a. Both are produced directly from fission and from their respective decay chain. Te-135 decays to I-135 which decays to Xe-135. Nd-149 decays to Pm-149 which decays to Sm-149. (1.0)

b. Both can be removed from the core by neutron absorption. Xe-135 can also be removed by radioactive decay, whereas Sm-149 is stable. (1.0)

c. When the reactor is shutdown, both poisons increase in concentration due to production from their decay chains and because neither are being removed by neutron absorption. Sm-149's increase is relatively small and reaches a maximum and remains there until the reactor is operated again. Xe-135 will increase to a peak and then decrease slowly as more Xe-135 is decaying than is being produced by the decay of I-135. (2.0)

REFERENCE
RSM pg. 10.6 to 10.8

ANSWER I.01 (4.00)

a. 5(N-18) = 5(23-18) = 25
25 - 24 = 1.0 Rem = Max. Dose (1.0)
Max. Dose = Dose Rate X Time
1.00 Rem = 0.003 Rem/hr X 8 hr/day X No. of Days
No. of Days= 41.6 days (1.0)

b. Provided that (1) He does not exceed 3 rem per quarter (.66)

(2) His radiation history is known and recorded on the proper form (NRC Form 4) (.67)

(3) The dose received when added to his radiation history does not exceed 5(N-18) rems where N = the person's age at his last birthday (.67)

REFERENCE
10 CFR 20.101

ANSWER I.02 (2.00)

d x (r)^2 = D x (R)^2
1 mr/hr x (10)^2 = D x (1)^2
D =100 mr/hr [1.0]

Beta dose = 120mr/hr -100 mr/hr
= 20 mr/hr

Beta to gamma ratio = 20/100 = 1/5 [1.0]

REFERENCE
Introduction to Nuclear Engineering, chapter 9 pg 409,410; J R Lamarsh

ANSWER I.03 (3.00)

a. No [0.5] A Rem dose accounts for the type and energy of radiation. [1.0]

b. Yes [0.5] Internal dose depends on biological and physical T 1/2, referred organ, type of radiation. [1.0]

REFERENCE

Introduction to Nuclear Engineering, chapter 9; J R Lamarsh

ANSWER I.04 (3.00)

a. I = Io e{-ux}

100 mrem/hr = Io e{-0.035 cm(-1) 100 cm}

Io = 3311 mrem [1.0]

b. I = Io 10 {-x/TVL} (TVL is tenth thickness)

Io = I 10 {x/TVL} = 63.25 mrem/hr [1.0]

Io = Ii e{-(.693/half life)t} (where Ii is initial contact dose)

t = -(half life/.693) ln(Io/Ii)

t = -(30 min/.693) ln(63.25/2000) = 149.5 minutes [1.0]

REFERENCE

Introduction to Nuclear Engineering, pgs 22, 83; J R Lamarsh

ANSWER I.05 (3.00)

Reactivity Effects
Thermal-Hydraulic Effects
Chemical Effects
Radiolytic Decomposition
Experiment Scram
Prototype Testing
Radioactive Release (@ 0.5 pts, any six for 3.0)

REFERENCE

Technical Specifications (T.S.) 6.1, pg. 6-1 to 6-7

ANSWER I.06 (3.00)

a. The reactor is shut down
b. The containment building is isolated
c. Experimenters are evacuated
d. Off-duty licensed and radiation protection personnel are notified
e. The MIT Campus Police are requested to stand-by
f. Radiation levels are monitored on-site and tracked off-site using the MITR Radiation Protection Office's remote monitors
g. Off-duty personnel are briefed as they arrive

REFERENCE
Procedure Manual (PM) 4.3 pg. 3

ANSWER I.07 (2.00)

No. The cpm must be corrected for efficiency of the detector and the geometry of the source in relation to the detector.

REFERENCE
RSM pgs 5.2, 7.1

ANSWER J.01 (3.00)

The cooling tower spray shall be shut down

The secondary system water discharge shall be stopped

The D2O reflector heat exchanger shall be isolated

REFERENCE
T.S. 3.8, pg. 3-26

ANSWER J.02 (3.00)

a. High flux regions such as the thermal column, pipe tunnel, lid space, experimental port and instrument lead boxes. (2.0)

b. The high flux regions are sealed and/or flooded with carbon dioxide in order to exclude as much air as possible since Ar-40 is present in air. (1.0)

REFERENCE
RSM pg. 7.5

ANSWER J.03 (2.00)

Natural convection valves are ball type pressure-operated check valves located on the wall between the inlet and outlet of the core that are designed to open on a loss of primary pump pressure to allow natural convective flow around the core.

REFERENCE
SAR pg. 6.5 and 15.12

ANSWERS -- MASS. INSTITUTE OF TECH. -85/10/02-SILK, D.

ANSWER J.04 (3.00)

It limits shim blade withdrawal motion to four inches.

1. It maintains shim blade bank programmed at a uniform height during final approach to criticality.
2. It establishes a level, below the critical position, to which the shim blades may be individually withdrawn in one step.
3. It provides a convenient reference point at which the operator can pause to make a complete instrument check before bringing the reactor to criticality

(.75 pts each)

REFERENCE
RSM pg. 4.3

ANSWER J.05 (3.00)

The peak in the differential regulating rod worth occurs at low rod height because the full in position for the regulating rod is six inches above the bottom of the fuel elements and once the regulating rod is withdrawn any appreciable amount, it is heavily shadowed by the adjacent shim blades.

REFERENCE
RSM pg. 10.6

ANSWER J.06 (3.00)

a. The blade bank exerts a shadowing influence on the reflector
b. Full in - this insures that the reactivity insertion for this process will not occur when the reactor is or could go critical

REFERENCE
RSM pg. 10.6

ANSWER J.07 (3.00)

A heat balance calculated from the primary, reflector, and shield system flows and temperature rises once these systems are in thermal equilibrium.

REFERENCE
PM 2.4, pg. 2

ANSWER K.01 (3.00)

a. The ratio $F_{HC} F_p / d_f F_f$ is predicted to be less than 2.9

The core is predicted to operate below incipient boiling at every point in the core.

b. Two Senior Reactor Operators.

REFERENCE

T.S. 3.1, pg. 3-1

ANSWER K.02 (3.00)

a. The total worth of the rod is to be limited such that the complete withdrawal of the rod will not make the reactor prompt critical

b. This value is conservatively within the range of reactivity insertion rates normally accepted for reactor operation. Control systems in this range give ample margin for proper human response during approach to critical and power operations.

c. The additional independent capability for reactivity control provided by the D2O reflector dump gives added assurance that the reactor can be made subcritical under an adverse condition of fuel loading or control blade malfunction.

REFERENCE

T.S. 3.9, pg. 3-32 to 3-35

ANSWER K.03 (4.00)

1. The grid is designed so that there is normally access to only one core position at a time (1.0). This limits the amount of water that can be in the core at any one time by making it difficult, though not impossible, for more than one core position to be defueled at time.(1.0)

2. The grid's latch is interlocked with the primary coolant pumps so that if the latch is released, the coolant pumps stop and remain off until the grid is latched again (1.0). This protects the fuel elements from damage and the reactor as a whole from inadvertent criticality(1.0)

ANSWERS -- MASS. INSTITUTE OF TECH. -85/10/02-SILK, D.

REFERENCE
PM 2.7, pg. 3

ANSWER K.04 (3.00)

a. If dumping would cause the nuclear instrumentation startup channels to indicate less than 10 counts per minute. (2.0)

b. The shutdown margin would have to be checked. (1.0)

REFERENCE
PM 2.7, pg. 3

ANSWER K.05 (2.00)

1. The element to be moved cannot be moved unless it has not been operated in the core at a power level above 100 KW for at least four days.

2. The K-effective of any storage area outside of the reactor core shall be less than 0.90

REFERENCE
T.S. 3.10.4, pg. 3-37

ANSWER K.06 (3.00)

Safety channels operable	Set points
Period (2 channels)	> 3 sec
Neutron Flux Level (2 channels)	100 KW
D2O Dump Valve Selector Switch (1)	-
Manual major scram (2)	-

(0.5 each response)

REFERENCE
T.S. 3.7.2, pg. 3-21,22

ANSWER K.07 (2.00)

a. The reactor is shutdown (.66)

b. Console key switch off and key is in proper custody (.67)

c. No work in progress within the main core tank involving fuel or experiments, or maintenance of the core structure, installed control blades or installed control blade drives when not visibly decoupled from the control blade (.67)

REFERENCE

T.S. 1.1, pg 1-1

ANSWER L.01 (2.50)

a. i. The reactor must be shutdown and the bypass must be removed before reactor startup (0.5)

ii. Must be approved by Duty-Shift-Supervisor or Reactor Superintendent (0.5)

iii. The bypass authorizor's initials must be recorded on the bypass log sheet (0.5)

b. If Jumpers are used, the jumper must be tagged; a warning tag placed on the shim blade control handle stating that the reactor is not to be started up until the bypass is removed. (1.0)

REFERENCE
PM 1.9, pg. 1

ANSWER L.02 (4.50)

a. Violation of Technical Specifications (T.S.)(.25), sixth shim blade must be at the operating position or higher (except if < 1 KW for blade calibration) (0.5)

b. No violation (.25), with one pump 3.0 MW allowed and minimum of 900 gpm (0.5)

c. Violation of T.S. (.25), power levels in excess of 100 KW require the emergency cooling system to be operable (0.5)

d. Violation of T.S. (.25), emergency power must be available whenever the reactor is operating (0.5)

e. No violation (.25), T.S. requires at least one area radition monitor on the reactor floor to be operating (0.5)

f. Violation of procedure (.25), the duty shift supervisor must authorize and witness both startups and increases in reactor power of greater than 10% (0.5)

REFERENCE
a. T.S. pg. 3-32
b. T.S. pg. 2-5
c. T.S. pg. 3-19
d. T.S. pg. 3-21

ANSWERS -- MASS. INSTITUTE OF TECH. -85/10/02-SILK, D.

e. T.S. pg. 3-27
f. PM 1.3, pg. 2

ANSWER L.03 (3.00)

1. If the probability of occurence of the consequences of an accident or malfunction of equipment important to safety previously evaluated in the safety analysis report may be increased.

2. If a possibility for an accident or malfunction of a different type than any evaluated previously in the safety analysis report may be created.

3. If the margin of safety as defined in the basis for any technical specification is reduced.

REFERENCE
PM 1.4, pg.2

ANSWER L.04 (1.50)

a. Registration and instruction of radiation workers

b. Personnel monitoring of radiation exposure

c. Radioisotope laboratory inspections, radiation surveys, and area monitoring

d. Radioactive waste collection

e. Calibration and repair of radiation protection instruments

f. Calibration of reactor radiation detection instruments

g. Environmental monitoring

h. Leak-testing of sealed radioactive sources

i. Advice in radiation emergencies, and special decontamination operations

j. Maintenance of radiation protection records (any five, .30 pts each)

REFERENCE
PM 1.11, pg. 1

ANSWER L.05 (1.00)

To save a human life (0.5) or to insure nuclear safety (0.5)

REFERENCE
PM 4.3, pg. 14

ANSWER L.06 (3.00)

1. To determine that normal radiation levels exist based on control room and/or local instrumentation.
2. To assess the need for a radiation survey with a portable detector.
3. To evaluate the potential for dose rate changes during occupancy.

REFERENCE
PM 1.14, pg. 6

ANSWER L.07 (2.00)

a. Total reactor thermal power

Reactor coolant total flow rate

Reactor coolant outlet temperature

Height of water above the outlet end of the heated section of the hottest fuel channel (.25 pts each)

b. To establish limits within which the integrity of the fuel clad is maintained (1.0)

REFERENCE
T.S. 2.1, pg. 2-1

ANSWER L.08 (2.50)

a. 1. Notification of Unusual Event

2. Alert

3. Site Area Emergency

4. Alert (0.5 pts each)

b. Potential radiological consequences (0.5)

REFERENCE

a. PM 4.5, pgs. 10 to 12

b. PM 4.4, pg. 2