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

EXAMINATION REPORT NO.: 50-225/85-02 (OL)

FACILITY DOCKET NO.: 50-225

FACILITY LICENSE NO.: CX-22

LICENSEE: Rensselaer Polytechnic Institute
Troy, New York

FACILITY: Rensselaer Polytechnic Institute

EXAMINATION DATES: July 22-24, 1985

CHIEF EXAMINER: N F Dudley 9/5/85
N. F. Dudley, Lead Reactor Engineer Date

REVIEWED BY: RM Keller 9/5/85
R. M. Keller, Chief, Projects Section 1C Date

APPROVED BY: HB Kister 9/5/85
H. B. Kister, Chief, Projects Branch No. 1 Date

SUMMARY: Written and oral examinations were administered to two Senior Reactor Operator (SRO) candidates and two licenses were issued.

REPORT DETAILS

TYPE OF EXAMS: Replacement

EXAM RESULTS:

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

1. Chief Examiner at Site: R. G. Clark, PNL

2. At the conclusion of the site visit, the examiner met with the representative of the plant staff to discuss the results of the examination. Those individuals who clearly passed the oral examination were identified in this meeting.

3. Comments made by facility reviewers and the resolution of comments are given below:

Answer No.	Change	Reason
H-1	Add "1. Improve signal to noise ratio; 2. Improve statistics."	Expands answer to include other benefits of strong startup source.
H-6	Add $\tau = \ell/\ell-\beta$; $\partial N/dt = \Delta k - \beta/\ell$	Provides other equations which illustrates effect of adding reactivity.
H-10	Add "Also low fuel temperature of RPI reactor."	Provides additional reason why doppler effect is minor.
L-2 Question	Change "Which" to "Give".	More than two safety channels may be bypassed.
L-2	Add "3. Log Count Rate."	Provides third safety channel which may be bypassed.
L-3 Question	Change "full" to "fill".	Corrects terminology.
L-3a	Change "2" to "3".	Corrects for a.

Attachments:
1. Written Examination (SRO)
2. Answer Key (SRO)

ATTACHMENT 1 TO ENCLOSURE MASTER

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

Facility: Rensselaer Polytechnic Inst.

Reactor Type: Critical Facility (Nonpower)

Date Administered: July 23, 1985

Examiner: R. G. Clark

Candidate: ____________________

INSTRUCTIONS TO APPLICANT:

Print your name on the line above marked "Candidate." The grade points available for each question are indicated within parentheses after each question. The passing grade is at least 70% in each of the four (4) categories and is at least 80% for the total grade. Use separate paper for your answers and write on only one (1) side of the paper, unless a specific question instructs you otherwise. Staple this question package to your answer sheets. The examination questions and answers will be picked up six (6) hours after the examination was started. Read the statement at the bottom of this page. When you have finished this examination, affirm the statement by signing your name.

Category Value	% of Total	Applicant's Score	% of Cat. Value	Category
20	20			H. Reactor Theory
20	20			I. Radioactive Materials Handling, Disposal, and Hazards
20	20			J. Specific Operating Characteristics
20	20			K. Fuel Handling and Core Parameters
20	20			L. Administrative Procedures, Conditions, and Limitations
100				TOTALS

Final Grade ________%

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

____
Candidate's Signature

H.0 REACTOR THEORY (20)

Points Available

QUESTION H-1

Give two benefits during start-up for having a strong neutron source as compared to a start-up with a weak source. (1.0)

QUESTION H-2

Give the reason for the very small fraction of delayed neutrons having such a large effect on the operator's ability to control the reactor. (1.5)

QUESTION H-3

Will doubling the time a target nuclide is irradiated (1.0)

a. double the activity
b. more than double the activity
c. less than double the activity

Briefly explain your choice.

- Section H continued on next page -

Points Available

QUESTION H-4

The reactor is shut down by 5% ΔK/K with a count rate (CR) of 10.

Note: $\frac{CR_2}{CR_1} = \frac{1-K_1}{1-K_2}$

a. How much positive reactivity would have to be added to double the count rate? Show work. (1.0)

b. How much negative reactivity would have to be inserted to reduce the count rate by 1/2? Show work. (1.0)

c. Would an identical small positive change in reactivity have the same effect on count rate if the reactor were subcritical by 1% ΔK/K as compared to the reactor being subcritical by 5% ΔK/K? Assume the same initial count rate in both conditions. Explain your answer. (2.0)

QUESTION H-5

Why is β_{eff} different than β? (1.0)

QUESTION H-6

What would be the significance of adding reactivity equal to β-effective to a just critical reactor? Include a relationship (formula) that illustrates your answer. (1.0)

QUESTION H-7

Give the nuclear reactions within the source used at RPI that result in source neutrons. (1.0)

- Section H continued on next page -

Points Available

QUESTION H-8

Given the variations of the six factor formula

(1) $K_{eff} = \eta\epsilon p f \cdot P_F \cdot P_{TH}$ or
(2) $K_{eff} = \eta\epsilon f P_{NL}$

a. Identify the <u>two</u> factors in formula (2) which contribute most to a temperature coefficient. (1.0)

b. Draw a curve of temperature (ordinates) vs. K_{eff} (abscissa) that depicts the effect of temperature on K_{eff} relative to its moderating affect on the care of a reactor. (2.0)

QUESTION H-9

a. What does the use of gold foils measure? (0.5)
b. Why are gold foils a good tool? (0.5)
c. Give the activation reaction of this material with neutrons. (0.5)

QUESTION H-10

Briefly discuss the Doppler coefficient and why its contributions to the RPI reactor are minor. (2.0)

QUESTION H-11

Explain why two start-ups with the same <u>initial</u> fuel loading, source position, count rate, and shut down margin can achieve criticality at two different count rates. (3.0)

- End of Section H -

I.0 RADIOACTIVE MATERIALS HANDLING, DISPOSAL, AND HAZARDS (20)

Points Available (20)

QUESTION I-1

What three (3) principles are used to control radiation exposures? (1.5)

QUESTION I-2

Give the relationship that defines the biological dose unit rem. (0.5)

QUESTION I-3

What are the two (2) main sources of gamma radiation at the RPI facility which the shielding is designed to attenuate? (2.0)

QUESTION I-4

Why are TLDs a more desirable personnel monitoring device than film badges? (1.0)

QUESTION I-5

Fill in the blanks with the proper words.

a. A cadmium covered gold foil would be activated primarily by ______________. (0.5)

b. A bare U^{235} foil would be activated by ________________. (0.5)

c. U^{235} foils are used to ______________ and ______________. (0.5)

QUESTION I-6

What kind of portable instrument is required to evaluate high gamma fields? Explain your choice. (2.0)

- Section I continued on next page -

Points Available

QUESTION I-7

Assume 4 centimeters of lead glass will reduce the gamma radiation level from 100 mr/hr to 50 mr/hr

a. How many centimeters of lead glass will be required to reduce a gamma radiation level from 200 mr/hr to 100 mr/hr? (1.0)

b. How many centimeters of lead glass would be required to reduce a gamma radiation level from 100 mr/hr to 12.5 mr/hr? (1.0)

QUESTION I-8

Assume a point source reads 10 R/hr at 3 meters.

a. What would the aproximate dose rate be at 1 meter?
b. At 10 meters? (+1.5)

QUESTION I-9

Give the three goals in the design of the shielding of the reactor. (1.5)

QUESTION I-10

RGL

Give $\beta = 0.007$; $\lambda = 0.1/\text{sec}$, the RPI reactor is brought to a condition such that $K_{eff} = 1.0035$ with control rods partially inserted. For this condition calculate:

1. ρ (\$) (1.0)

2. steady state period in seconds (1.0)

3. time for power to increase from 0.1 watt to the maximum allowable of 135 watts. (1.0)

- Section I continued on next page -

Points Available

QUESTION I-11

Give the action point, i.e., when must action be taken, and the actions required (3) when contamination is detected by the swipe technique. (3.5)

- End of Section I -

J.0 SPECIFIC OPERATING CHARACTERISITCS (20)

Points Available

QUESTION J-1

Draw a one-line functional diagram of the interlock system for the rod control system at the RPI critical facility. (4.0)

QUESTION J-2

The start-up procedure requires that a check be made by adjusting the fine voltage ±50 volts.

a. What indicates an acceptable check? (0.75)
b. What must be done if the check is unacceptable? (0.75)

QUESTION J-3

Give the two (2) conditions that must be satisfied to be allowed to recover from a scram. (2.0)

QUESTION J-4

a. Which decay mode listed below is closest to that of AR^{41}? (0.5)

1. half life = 3.81 hr, β^- decay, no γ decay
2. half life = 1.83 hr, β^- decay, 1-2 MeV γ decay
3. half life = 7.35 sec, β^+ decay, 6-8 MeV γ decay
4. half life = 21.7 min, β^+ decay, no γ decay

b. What is the source of this isotope at the RPI facility? (1.0)

c. What design features, if any, are in place to cope with it? (1.0)

- Section J continued on next page -

Points Available

QUESTION J-5

Some safety circuit functions at the RPI facility can be by-passed. Identify these and give the occasion (reason) for by-pass for each. (3.0)

QUESTION J-6

Some valves in the water piping system at the RPI critical facility are designed to fail to a pre-set position on loss of power. Identify two, their failed position, and give the reason for this failed configuration. (3.0)

QUESTION J-7

The operator interface for the Solenoid Interupt Circuit module consists of 2 voltmeters, 5 milliameters, an off-on switch, and a reset button. What information is given to the operator by the milliameters? (1.5)

QUESTION J-8

What seven (7) safety trips will drop the rods AND open the dump valve? (1.5)

QUESTION J-9

Fill in the blanks in the following excerpts from the operating procedures with the proper terms.

a. During start-up, a normal operating period is _____ to _____ seconds. (0.5)

b. When the reactor is just critical, the period is _____, and the source position is _____. (+0.5)

- End of Section J -

K.0 FUEL HANDLING AND CORE PARAMETERS (20)

Points Available

QUESTION K-1

Give the four (4) reactor parameters that shall be determined during the initial testing of an unknown or previously untested core configuration. (4.0)

QUESTION K-2

The procedure that requires the operator to initially load the control rod assemblies, results in a flawed fuel loading technique, as additional fuel is subsequently loaded. Briefly tell why. (1.0)

if the control rods remain in place RGC

QUESTION K-3

Consider subcritical multiplication M. In order to apply with validity the reciprocal of M, 1/M, in a 1/M plot during a fuel load, two conditions must be met. Name them. (2.0)

QUESTION K-4

Complete the sentences in the following guidelines for safe loading procedures with the proper terms.

a. All fueling operations will cease if at any time the count rate on any channel increases by ________________ during a single fuel element addition. (0.5)

b. Throughout loading, each fuel element will be placed in a lattice position that will preserve as nearly as possible ________________. (0.5)

c. Fuel additions will be limited to one fuel element when ________________. (1.0)

- Section K continued on next page -

Points Available

QUESTION K-5

Draw a typical core configuration showing a loading of 25 fuel assemblies and four control rods. Indicate fuel plate orientation in the fuel assembly and typical number of fuel plates per fuel assembly for each location. Include a neutron source and detectors, relative to the core. (4.0)

QUESTION K-6

Identify two key design features that make the fuel storage vault a critically safe assembly. (1.5)

QUESTION K-7

What are the consequences to a fuel loading procedure if the detector is too close to the neutron source. Briefly describe. (1.5)

QUESTION K-8

Identify two techniques for generating control rod calibration curves. Include the conditions that guide the use of each. (2.0)

QUESTION K-9

Briefly describe an experimental technique at RPI for determining void coefficients using stationary fuel elements. (2.0)

- End of Section K -

L.0 ADMINISTRATIVE PROCEDURES, CONDITIONS, AND LIMITATIONS (20)

Points Available

QUESTION L-1

Give the reasons (bases) for the following specifications:

a. A minimum flux level of 2 c/s as a safety system setting on the reactor power. (0.5)

b. A maximum thermal power level of 270 watts. (0.5)

c. A minimum period of 5 seconds as a safety system setting on reactor power. (0.5)

d. A minimum operating temperature of 50°F. (1.0)

QUESTION L-2

a. ~~Which~~ Give two (2) safety system channels that may be bypassed? RAC (1.5)

b. Who may authorize bypassing these safety system channels? (0.5)

QUESTION L-3

For each interlock given below, identify the proper action if that interlock is not satisfied. Choose from the action statements also given below.

Interlocks

a. Moderator-reflector water fill on. RAC (0.5)

b. Failure of Line Voltage to Recorders. (0.5)

c. Neutron flux >2 cps. (0.5)

d. Reactor console keys "on". (0.5)

Action Statements

1. Scram
2. Stops water fill
3. Prevents control rod withdrawal

- Section L continued on next page -

Points Available

QUESTION L-4

What actions, if any, must be taken if it is determined during power operations that the cumulative terminal power has reached 210 kilowatt hours this year? (3.0)

QUESTION L-5

Fill in the blanks in the following specifications for conducting experiments at the RPI critical facility.

a. The maximum positive step insertion of reactivity which can be caused by an experimental accident or experimental equipment failure of a moveable or unsecured experiment shall not exceed ________. (0.5)

b. Moving parts of an experiment worth less than ________ may be oscillated in the core at frequencies higher than \$.20/sec. (0.5)

c. The reactor shall be subcritical by more than ________ with the most reactive control rod fully withdrawn. (0.5)

QUESTION L-6

Give the events requiring the direction of the Operations Supervisor. (2.0)

QUESTION L-7

Give the major responsibility of each of the following:

a. Lincensed Reactor Operators (1.0)
b. Operations Supervisor (1.0)

- Section L continued on next page -

Points Available

QUESTION L-8

Emergency Priorities

From the following steps give the order of their priorities when immediate actions must be taken if emergency conditions develop at the reactor facility, i.e., which is first consideration, second, etc. (2.0)

a. Steps to prevent the spread of hazards associated with accident conditions.

b. Steps to minimize the extent of damage to the critical facility and its equipment.

c. Steps for human safety.

QUESTION L-9

Give four situations that result in an emergency alert. (2.0)

QUESTION L-10

Answer the following TRUE or FALSE.

a. Any trip of the criticality monitor automatically initiates the critical facility emergency alarm. (0.5)

b. Three portable extinguishers at the control facility are available to RPI staff in case of emergencies. (0.5)

- End of Section L -

END OF EXAMINATION

ATTACHMENT 2 TO ENCLOSURE

MASTER

U.S. NUCLEAR REGULATORY COMMISSION

SENIOR REACTOR OPERATOR LICENSE EXAMINATION

Facility: Rensselaer Polytechnic Inst.

Reactor Type: Critical Facility (Nonpower)

Date Administered: July 23, 1985

Examiner: R. G. Clark

Candidate: Answer Key

INSTRUCTIONS TO APPLICANT:

Print your name on the line above marked "Candidate." The grade points available for each question are indicated within parentheses after each question. The passing grade is at least 70% in each of the four (4) categories and is at least 80% for the total grade. Use separate paper for your answers and write on only one (1) side of the paper, unless a specific question instructs you otherwise. Staple this question package to your answer sheets. The examination questions and answers will be picked up six (6) hours after the examination was started. Read the statement at the bottom of this page. When you have finished this examination, affirm the statement by signing your name.

Category Value	% of Total	Applicant's Score	% of Cat. Value	Category
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20	20			I. Radioactive Materials Handling, Disposal, and Hazards
20	20			J. Specific Operating Characteristics
20	20			K. Fuel Handling and Core Parameters
20	20			L. Administrative Procedures, Conditions, and Limitations
100				TOTALS

Final Grade ________ %

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

Candidate's Signature

H.0 REACTOR THEORY (20)

Points Available

QUESTION H-1

Give two benefits during start-up for having a strong neutron source as compared to a start-up with a weak source. (1.0)

ANSWER H-1

A strong source will reduce the counting time necessary **(+0.5)**, and increase the accuracy of the predicted point of critical **(+0.5)**.

Refererence(s) KEY WORDS RELATIVE TO REDUCING COUNTING TIME NECESSARY WOULD BE STATISTICS, S/N RATIO etc. (ACCEPTED)

1. Manual of Experiments, p. 49.

QUESTION H-2

Give the reason for the very small fraction of delayed neutrons having such a large effect on the operator's ability to control the reactor. (1.5)

ANSWER H-2

The generation to generation time of delayed neutron is about 6 orders of magnitude longer (10^6) while their number is only about 3 orders of magnitude fewer such that the average effective neutron lifetime in a reactor is controlled by the delayed fraction. **(+1.5)**

Reference(s)

1. Manual of Experiments, p. 61.

- Section H continued on next page -

Points Available

QUESTION H-3

Will doubling the time a target nuclide is irradiated (1.0)

a. double the activity
b. more than double the activity
c. less than double the activity

Briefly explain your choice.

ANSWER H-3

c. (+0.5) This results from the radioactive decay during the generation time of the nuclide of interest. (+0.5)

Reference(s)

1. Manual of Experiments, p. 111.

- Section H continued on next page -

Points Available

QUESTION H-4

The reactor is shut down by 5% ΔK/K with a count rate (CR) of 10.

Note: $\frac{CR_2}{CR_1} = \frac{1-K_1}{1-K_2}$

a. How much positive reactivity would have to be added to double the count rate? Show work. (1.0)

b. How much negative reactivity would have to be inserted to reduce the count rate by 1/2? Show work. (1.0)

c. Would an identical small positive change in reactivity have the same effect on count rate if the reactor were subcritical by 1% ΔK/K as compared to the reactor being subcritical by 5% ΔK/K? Assume the same initial count rate in both conditions. Explain your answer. (2.0)

ANSWER H-4

a. $\frac{CR_2}{CR_1} = \frac{1-K_1}{1-K_2}$ and $\frac{CR_2}{CR_1} = 2$

$2 = \frac{1-K_1}{1-K_2}$ or $2 - 2K_2 = 1-K_1$

$K_2 = \frac{K_1 + 1}{2}$ but $K_1 = 1-0.05 = 0.95$

$K_2 = \frac{0.95 + 1}{2} = 0.975$

Reactivity added = 0.975 - 0.95 = 2.5% ΔK/K.
(+1.0)

- Section H continued on next page -

Points
Available

ANSWER H-4 (contd)

b. $\frac{CR_2}{CR_1} = \frac{1 - K_1}{1 - K_2}$; $\frac{CR_2}{CR_1} = 1/2$

$$\frac{1}{2} = \frac{1 - K_1}{1 - K_2}$$

$$\frac{1}{2} - \frac{1}{2} K_2 = 1 - K_1$$

$$1 - K_2 = 2 - 2K_1$$

$K_2 = 2K_1 - 1$ where

$K_1 = 1 - 0.5$ (given)

$= 0.95$

$K_2 = 1.90 - 1 = 0.90$

Neg. Reactivity inserted = 0.95 - 0.90 = .05 = 5% $\Delta K/K$. **(+1.0)**

c. No. The count rate depends on the margin (nearness) to criticality. The closer you get to criticality, the more pronounced an incremental change in $\Delta K/K$ will have. (+2.0)

Reference(s)

1. Manual of Experiments, p. 28.

- Section H continued on next page -

Points Available

QUESTION H-5

Why is β_{eff} different than β? (1.0)

ANSWER H-5

The reason is the difference in the energy distribution between the prompt and delayed neutrons. Delayed neutrons have a lower energy distribution, and hence are thermalized more readily, and have less opportunity to escape from the core before thermalization or absorption. **(+1.0)**

Reference(s)

1. Manual of Experiments, p. 61.

QUESTION H-6

What would be the significance of adding reactivity equal to β-effective to a just critical reactor? Include a relationship (formula) that illustrates your answer. (1.0)

ANSWER H-6

Reactor would go prompt critical. **(+0.5)**

$dn/dt = \frac{\rho - \beta}{\ell^*} n$ **(+0.5)**

ALSO ACCEPTED AS FORMULAS

$T = \ell / \rho - \beta$

$dN/dt = \Delta K - \beta / \ell N$

$P = P_0 e^{t/\ell^*}$

Reference(s)

1. Manual of Experiments, pp. 60, 61, and 62.

- Section H continued on next page -

Points Available

QUESTION H-7

Give the nuclear reactions within the source used at RPI that result in source neutrons. (1.0)

ANSWER H-7

$_2\alpha^4 + {}_4Be^9 \rightarrow \underline{{}_0n^1} + {}_6C^{12}$; $_2\alpha^4$ from Pu^{238} **(+1.0)**

Reference(s)

1. Manual of Experiments, p. 12.

- Section H continued on next page -

Points
Available

QUESTION H-8

Given the variations of the six factor formula

(1) $K_{eff} = \eta\varepsilon\rho f \cdot P_F \cdot P_{TH}$ or
(2) $K_{eff} = \eta\varepsilon f P_{NL}$

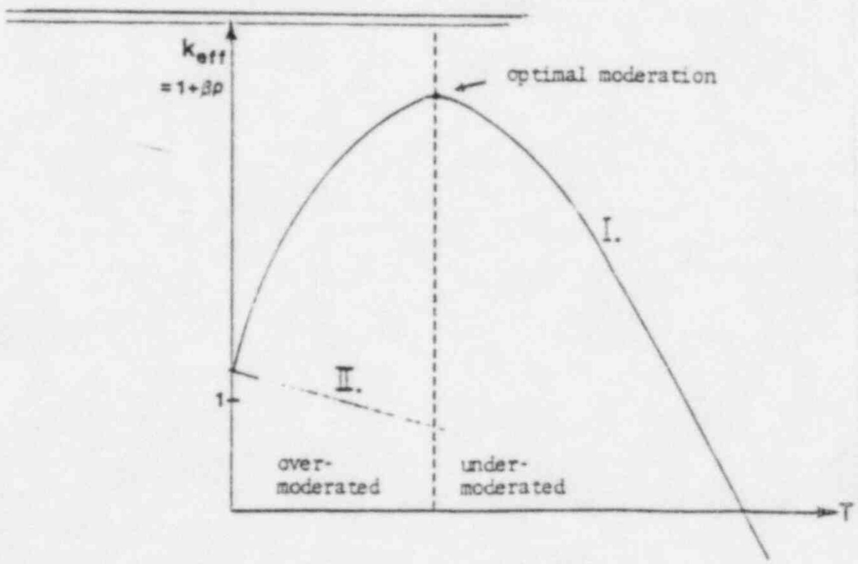
a. Identify the two factors in formula (2) which contribute most to a temperature coefficient. (1.0)

b. Draw a curve of temperature (ordinates) vs. K_{eff} (abscissa) that depicts the effect of temperature on K_{eff} relative to its moderating affect on the care of a reactor. (2.0)

ANSWER H-8

a. f (+0.5), P_{NL} (+0.5)

b. Figure (+2.0)



FIGURE

Reference(s)

1. Manual of Experiments, p. 87.

- Section H continued on next page -

Points Available

QUESTION H-9

a. What does the use of gold foils measure? (0.5)
b. Why are gold foils a good tool? (0.5)
c. Give the activation reaction of this material with neutrons. (0.5)

ANSWER H-9

a. Average thermal neutron flux. **(+0.5)**

b. Au^{197} has a strong neutron absorption cross section and a relatively short decay half-life. **(+0.5)**

c. $_0n^1 + Au^{197} \rightarrow Au^{198} \xrightarrow[t_{1/2} = 2.693 \text{ da}]{\beta^-} Hg^{198}$ **(+0.5)**

Reference(s)

1. Manual of Experiments, p. 111.

- Section H continued on next page -

Points Available

QUESTION H-10

Briefly discuss the Doppler coefficient and why its contributions to the RPI reactor are minor. (2.0)

ANSWER H-10

The overall Doppler effect of temperature is to make ^{238}U resonance peaks broader and lower, the resonance escape probability decreases, i.e., more neutrons are absorbed in fuel (nonfission absorption) as temperature goes up. **(+1.0)**

For RPI with highly enriched (93% ^{235}U) this is a minor effect, for power reactors with low enrichment (3% ^{235}U, 99% ^{238}U, this is a significant effect. **(+1.0)**

Reference(s)

1. Manual of Experiments for RPI, p. 86

QUESTION H-11

Explain why two start-ups with the same initial fuel loading, source position, count rate, and shut down margin can achieve criticality at two different count rates. (3.0)

ANSWER H-11

a. Order of rod withdrawal **(+0.75)**
b. Rate of rod withdrawal **(+0.75)**
c. Differences in experimental positions **(+0.75)**
d. Differences in moderator temperature **(+0.75)**

Note: a and b can be expressed as equal different reactivity insertion rates. **(+1.5)**

Reference(s)

1. Manual of Experiments, pp. 50, 55, 66, 77, and 96.

- End of Section H -

I.0 RADIOACTIVE MATERIALS HANDLING, DISPOSAL, AND HAZARDS (20)

Points Available (20)

QUESTION I-1

What three (3) principles are used to control radiation exposures? (1.5)

ANSWER I-1

By the application of three principles

Time (+0.5)
Shielding (+0.5)
Distance (+0.5)

Reference(s)

Manual of Experiments, Section 10, p. 146.

QUESTION I-2

Give the relationship that defines the biological dose unit rem. (0.5)

ANSWER I-2

rem = (dose in rads) x (RBE) **(+0.5)**

Reference(s)

1. Manual of Experiments, Section 10, p. 149.

- Section I continued on next page -

Points Available

QUESTION I-3

What are the two (2) main sources of gamma radiation at the RPI facility which the shielding is designed to attenuate? (2.0)

ANSWER I-3

1. Primary radiations from the reactor core. (+1.0)

2. Secondary radiations resulting from various interactions between neutrons and nuclei outside the core. (+1.0)

Reference(s)

1. Manual of Experiments, Section 10, p. 146.

QUESTION I-4

Why are TLDs a more desirable personnel monitoring device than film badges? (1.0)

ANSWER I-4

They are more accurate. (+0.5)
They are reusable after heating. (+0.5)

Reference(s)

1. Manual of Experiments, Section 10, p. 150.

- Section I continued on next page -

Points Available

QUESTION I-5

Fill in the blanks with the proper words.

a. A cadmium covered gold foil would be activated primarily by _____________. (0.5)

b. A bare U^{235} foil would be activated by _______________. (0.5)

c. U^{235} foils are used to ______________ and _____________. (0.5)

ANSWER I-5

a. fast neutrons **(+0.5)**
b. fast and thermal neutrons **(+0.5)**
c. indicate reactor power and support gold foil results **(+0.5)**

Reference(s)

1. Manual of Experiments, pp. 114, 119, 121, 124.

QUESTION I-6

What kind of portable instrument is required to evaluate high gamma fields? Explain your choice. (2.0)

ANSWER I-6

A portable ionization chamber - a Cutie pie. **(+1.0)**

A portable G-M or scintillation detector would be too sensitive for a high gamma field and would saturate resulting in erroneous readings. **(+1.0)**

Reference(s)

Manual of Experiments, pp. 150 and 151.

- Section I continued on next page -

Points Available

QUESTION I-7

Assume 4 centimeters of lead glass will reduce the gamma radiation level from 100 mr/hr to 50 mr/hr

a. How many centimeters of lead glass will be required to reduce a gamma radiation level from 200 mr/hr to 100 mr/hr? (1.0)

b. How many centimeters of lead glass would be required to reduce a gamma radiation level from 100 mr/hr to 12.5 mr/hr? (1.0)

ANSWER I-7

(a) 4 cm **(+1.0)**

(b) 12 cm (3 hvl): $[\frac{100}{12.5} = 8 = (\frac{1}{2})^3]$; i.e., 3 half value layers

3 hvl x 4 cm = 12 cm **(+1.0)**

Reference(s)

Glasston Sesonske, Shielding Chapter.

- Section I continued on next page -

Points
Available

QUESTION I-8

Assume a point source reads 10 R/hr at 3 meters.

a. What would the aproximate dose rate be at 1 meter?
b. At 10 meters? (+1.5)

ANSWER I-8

a. 90 R/hr **(+0.75)**
b. 900mrem/hr **(+0.75)**

900 mrem/hr · RGC

Reference(s)

1. Manual of Experiments, p. 145.

QUESTION I-9

Give the three goals in the design of the shielding of the reactor. (1.5)

ANSWER I-9

1. Slow down the fast neutrons. **(+0.5)**

2. Capture (absorb) the slowed down neutrons and the initially slow neutrons. **(+0.5)**

3. Attenuate all forms of gamma radiation. **(+0.5)**

Reference(s)

1. Manual of Experiments, p. 146.

- Section I continued on next page -

Points Available

QUESTION I-10

RGC

Give β = 0.007; λ = 0.1/sec, the RPI reactor is brought to a condition such that K_{eff} = 1.0035 with control rods partially inserted. For this condition calculate:

1. ρ (\$) (1.0)

2. steady state period in seconds (1.0)

3. time for power to increase from 0.1 watt to the maximum allowable of 135 watts. (1.0)

ANSWER I-10

$$\rho = \frac{K_{eff} - 1}{\beta}$$

a) $\rho = \frac{.0035}{.007} = \frac{3.5}{7} = .5 = 50¢$ **(+1.0)**

b) $T = \frac{1 - \rho}{\lambda\rho} = \frac{1 - .5}{(.1)(.5)} = \frac{.5}{.05} = \frac{50}{5}$ **(+1.0)**

$T = 10$ sec.

c) $\Delta t = T \ln N_2/N$

$\Delta t = 10 \ln \frac{135}{0.1} = 10 \ln 1350 = 72.1$ sec **(+1.0)**

Reference(s)

1. Manual of Experiments, pp. 58, 59, 64.

- Section I continued on next page -

Points Available

QUESTION I-11

Give the action point, i.e., when must action be taken, and the actions required (3) when contamination is detected by the swipe technique. (3.5)

ANSWER I-11

Action Point: action point is 1000 pCi/1000 cm^2 (+0.5)

Actions
1. isolation of the area (+1.0)
2. decontamination (+1.0)
3. Notification of the Director of the Office of Radiation Safety. (+1.0)

Reference(s)

Question 9, Formal Review Questions, License Renewal Application.

- End of Section I -

J.0 SPECIFIC OPERATING CHARACTERISITCS (20)

Points Available

QUESTION J-1

Draw a one-line functional diagram of the interlock system for the rod control system at the RPI critical facility. (4.0)

ANSWER J-1

See attached Figure J-1 on page 20.

(+0.8 for each interlock [box] shown--maximum +4.0 points)

Reference(s)

1. RPI Critical Facility, Section 11.

- Section J continued on next page -

INTERLOCK SYSTEM. Critical Facility at RPI.

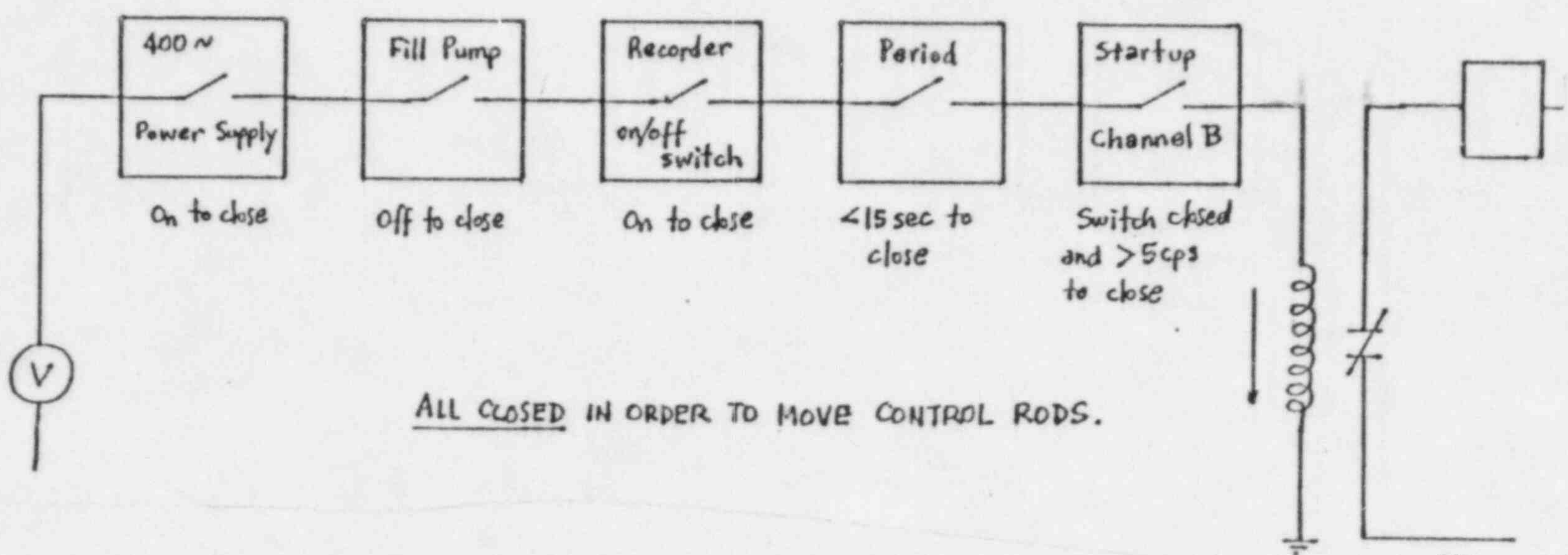


FIGURE J-1

- Section J continued on next page -

Points Available

QUESTION J-2

The start-up procedure requires that a check be made by adjusting the fine voltage ±50 volts.

a. What indicates an acceptable check? (0.75)
b. What must be done if the check is unacceptable? (0.75)

ANSWER J-2

a. Count rate is essentially the same at both voltage points. **(+0.75)**

b. Calibrate for a new voltage plateau. **(+0.75)**

Reference(s)

1. Manual, Start-up Procedures 1.3.

QUESTION J-3

Give the two (2) conditions that must be satisfied to be allowed to recover from a scram. (2.0)

ANSWER J-3

1. The cause of the scram has been determined. **(+1.0)**
2. The conditions for operation have returned to normal. **(+1.0)**

Reference(s)

1. Operating Procedure, p. 3.

- Section J continued on next page -

Points Available

QUESTION J-4

a. Which decay mode listed below is closest to that of AR^{41}? (0.5)

1. half life = 3.81 hr, β^- decay, no γ decay
2. half life = 1.83 hr, β^- decay, 1-2 MeV γ decay
3. half life = 7.35 sec, β^+ decay, 6-8 MeV γ decay
4. half life = 21.7 min, β^+ decay, no γ decay

b. What is the source of this isotope at the RPI facility? (1.0)

c. What design features, if any, are in place to cope with it? (1.0)

ANSWER J-4

a. 2. **(+0.5)**

b. Any air dissolved in the pool and the atmosphere above the pool within the reactor room during a run. **(+1.0)**

c. None, as this is a short-lived gas in low concentrations. **(+1.0)**

Reference(s)

1. Reference Manual, Table, Appendix D.

- Section J continued on next page -

Points Available

QUESTION J-5

Some safety circuit functions at the RPI facility can be by-passed. Identify these and give the occasion (reason) for by-pass for each. (3.0)

ANSWER J-5

a. Door Interlock **(+0.5)** - to permit reactor room entry during required S.U. checks with reactor shutdown by at least 2% **(+0.5)**.

b. Dump Relay **(+0.5)** - to permit S.U. testing without dumping the water from the reactor tank **(+0.5)**.

c. Period meter scram during steady-state operation **(+1.0)**.

Reference(s)

1. Section 11, Instrumentation and Interlock Diagrams, Block Diagram Operating Procedures - Bypass Conditions.

- Section J continued on next page -

Points Available

QUESTION J-6

Some valves in the water piping system at the RPI critical facility are designed to fail to a pre-set position on loss of power. Identify two, their failed position, and give the reason for this failed configuration. (3.0)

ANSWER J-6

Any 2 **(+3.0 max. points)**

a. Quick operating dump valve fails OPEN. **(+0.5)**
   To assure reactor shutdown during loss of power transient. **(+1.0)**

b. Pump discharge (reactor tank fill valve) fails CLOSE. **(+0.5)**
   To prevent inadvertent filling of the reactor tank during abnormal conditions. **(+1.0)**

c. Pump suction (return valve) fails OPEN. **(+0.5)**
   To provide a drain line from the reactor tank to the storage tank during times of abnormal conditions. **(+1.0)**

Reference(s)

1. Section 11, Instrumentation and Interlock Diagrams.

- Section J continued on next page -

Points Available

QUESTION J-7

The operator interface for the Solenoid Interupt Circuit module consists of 2 voltmeters, 5 milliameters, an off-on switch, and a reset button. What information is given to the operator by the milliameters? (1.5)

ANSWER J-7

Solenoid current to each of the four control rod clutch solenoids. **(+0.75)**

Solenoid current to the water dump valve solenoid. **(+0.75)**

Reference(s)

1. Section 11, Instrumentation and Interlock Diagrams, p. 5.

- Section J continued on next page -

Points Available

QUESTION J-8

What seven (7) safety trips will drop the rods AND open the dump valve? (1.5)

ANSWER J-8

Three instrument conditions

1. High log power (+0.2)
2. Short period (+0.2)
3. Either of 2 high linear powers (+0.3)

Four power supply conditions

1. Loss of power to reactor building (+0.2)
2. Magnet switch on control panel to off (+0.2)
3. Red (scram) button on control panel (+0.2)
4. Reactor door open (unless by-passed) (+0.2)

Reference(s)

1. Section 11, Solenoid Interrupt Circuit, p.3.

- Section J continued on next page -

Points Available

QUESTION J-9

Fill in the blanks in the following excerpts from the operating procedures with the proper terms.

a. During start-up, a normal operating period is _____ to _____ seconds. (0.5)

b. When the reactor is just critical, the period is _____, and the source position is _____. (+0.5)

ANSWER J-9

a. 30 to 50 **(+0.5)**
b. Infinite; either out or in, unimportant; noncontributing, etc. **(+0.5)**

Reference(s)

1. Operating Procedures, pp. 1-2.

- End of Section J -

K.0 FUEL HANDLING AND CORE PARAMETERS (20)

Points Available

QUESTION K-1

Give the four (4) reactor parameters that shall be determined during the initial testing of an unknown or previously untested core configuration. (4.0)

ANSWER K-1

1. Control rod blank reactivity worth (+1.0)
2. Temperature and void coefficients of reactivity (+1.0)
3. Reactor power measurements (+1.0)
4. Shutdown margin (+1.0)

Refernce(s)

1. Technical Specification 4.2.

QUESTION K-2

The procedure that requires the operator to initially load the control rod assemblies, results in a flawed fuel loading technique, as additional fuel is subsequently loaded. Briefly tell why. if the control rods remain in place (1.0)

ANSWER K-2

No backup safety system is available if unwanted excess reactivity is added. Hence fuel loading should be done with at least one rod partially or fully withdrawn. (+1.0)

Refernce(s)

1. Manual of Experiments, p. 54.

- Section K continued on next page -

Points Available

QUESTION K-3

Consider subcritical multiplication M. In order to apply with validity the reciprocal of M, 1/M, in a 1/M plot during a fuel load, two conditions must be met. Name them. (2.0)

ANSWER K-3

a. The detecting system must be actually counting neutrons. **(+1.0)**

b. The neutron flux measured must be representative of reactor multiplication. **(+1.0)**

Reference(s)

1. Manual of Experiments for RPI, p. 46.

- Section K continued on next page -

Points
Available

QUESTION K-4

Complete the sentences in the following guidelines for safe loading procedures with the proper terms.

a. All fueling operations will cease if at any time the count rate on any channel increases by ________________ during a single fuel element addition. (0.5)

b. Throughout loading, each fuel element will be placed in a lattice position that will preserve as nearly as possible ________________. (0.5)

c. Fuel additions will be limited to one fuel element when ________________. (1.0)

ANSWER K-4

a. one-half decade (+0.5)
b. a symmetric core (+0.5)
c. critical mass is attained and until the core is loaded (+1.0)

Reference(s)

1. Manual of Experiments, pp. 50-52.

- Section K continued on next page -

Points Available

QUESTION K-5

Draw a typical core configuration showing a loading of 25 fuel assemblies and four control rods. Indicate fuel plate orientation in the fuel assembly and typical number of fuel plates per fuel assembly for each location. Include a neutron source and detectors, relative to the core. (4.0)

ANSWER K-5

See Page 33. Credit given for:

a. proper CR location **(+0.5)**

b. proper symmetry of fuel assemblies (No. of fuel plates/ assemblies **(+1.5)**

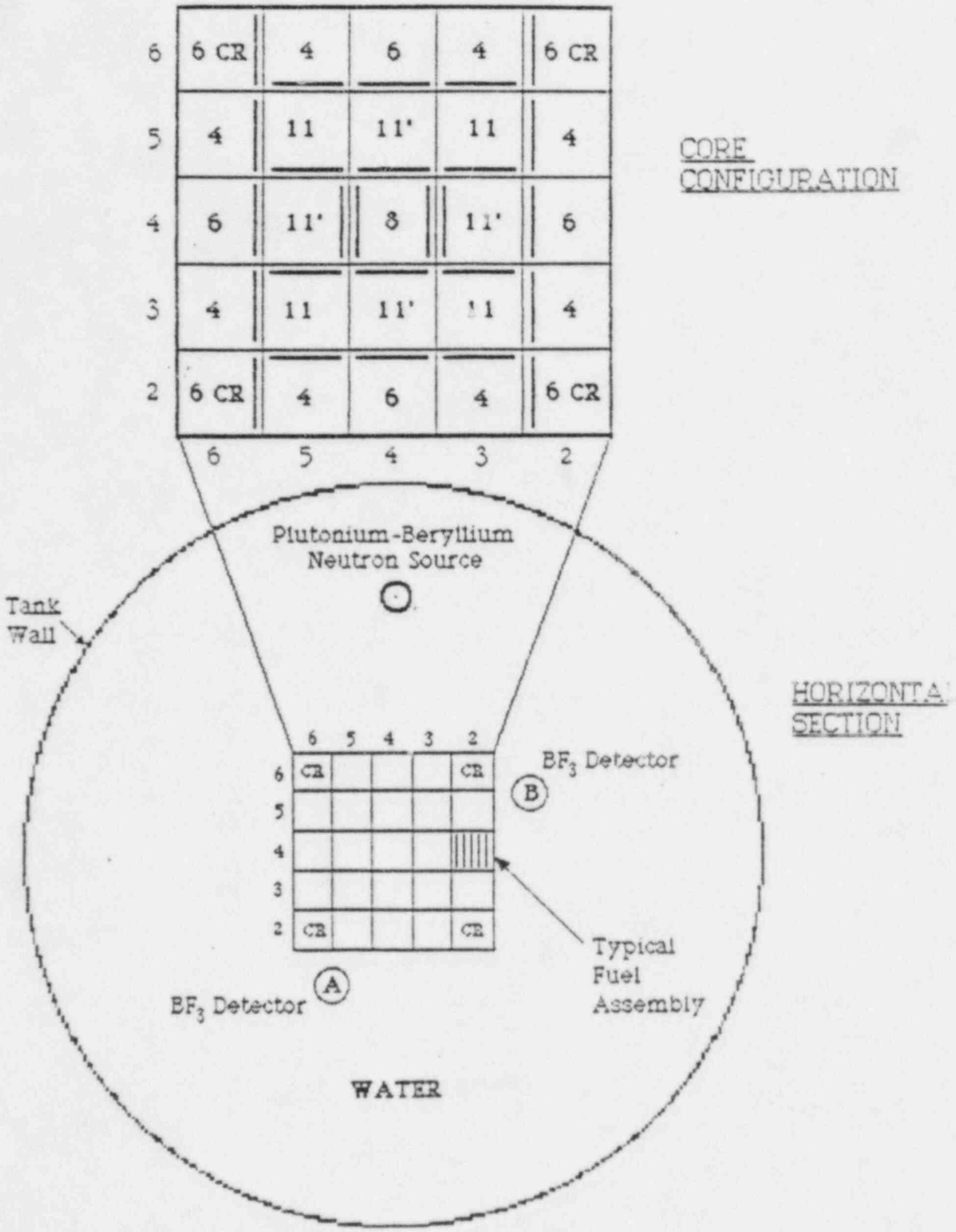
c. approximate number of fuel elements per fuel assemblies **(+0.5)**

d. proper location and orientation of source and BF_3 detectors **(+1.5)**.

Reference(s)

1. Manual of Experiments for RPI, pp. 6-7.

- Section K continued on next page -



- Section K continued on next page -

Points Available

QUESTION K-6

Identify two key design features that make the fuel storage vault a critically safe assembly. (1.5)

ANSWER

1. spacing **(+0.75)**
2. cadmium absorption (poison) on each storage tube **(+0.75)**

Reference(s)

1. Manual of Experiments, p. 4.

QUESTION K-7

What are the consequences to a fuel loading procedure if the detector is too close to the neutron source. Briefly describe. (1.5)

ANSWER K-7

The source term will tend to dominate the shape of the 1/M plot **(+0.75)**, making it concave downward. it overestimates the critical mass resulting in a nonconservative, unsafe estimate. **(+0.75)**

Reference(s)

1. Manual of Experiments, pp. 46-48.

- Section K continued on next page -

Points Available

QUESTION K-8

Identify two techniques for generating control rod calibration curves. Include the conditions that guide the use of each. (2.0)

ANSWER K-8

1. Pos'cive period **(+0.5)**, when sufficient excess reactivity is available resulting in the more accurate determination **(+0.5)**.

2. Subcritical multiplication **(+0.5)**, when reactor cores have the minimal excess reactivity required for initial or intermediate rod withdrawal steps **(+0.5)**.

Reference(s)

1. Manual of Experiments, pp. 55-56.

QUESTION K-9

Briefly describe an experimental technique at RPI for determining void coefficients using stationary fuel elements. (2.0)

ANSWER K-9

Use polystyrene inserts with dimensions slightly smaller than a fuel plate for a stationary element. Introduce them in the reactive side of fuel plates, and compare the configuration to the clean core to determine the reactivity worths of the voids. **(+2.0)**

Reference(s)

1. Manual, pp. 102-103.

- End of Section K -

L.0 ADMINISTRATIVE PROCEDURES, CONDITIONS, AND LIMITATIONS (20)

Points Available

QUESTION L-1

Give the reasons (bases) for the following specifications:

a. A minimum flux level of 2 c/s as a safety system setting on the reactor power. (0.5)

b. A maximum thermal power level of 270 watts. (0.5)

c. A minimum period of 5 seconds as a safety system setting on reactor power. (0.5)

d. A minimum operating temperature of 50°F. (1.0)

ANSWER L-1

a. To prevent source-out startup. **(+0.5)**

b. Damage to reactor components or to integrity of the fuel clad will not occur due to temperature changes. **(+0.5)**

c. Sufficient time is permitted to allow safety system channels to respond before safety limits are exceeded. **(+0.5)**

d. 50°F establishes the lower end of the temperature range for which the net positive reactivity limit can be applied. **(+1.0)**

Reference(s)

a. Technical Specification 2.2.
b. Technical Specification 2.1.
c. Technical Specification 2.2.
d. Technical Specification 3.2.

- Section L continued on next page -

Points Available

QUESTION L-2

a.	~~Which~~ Give two (2) safety system channels that may be bypassed?	(1.5)
b.	Who may authorize bypassing these safety system channels?	(0.5)

RGC

ANSWER L-2 (Any Two)

a. 1. Log N period **(+0.75)**
   2. reactor Door Scram **(+0.75)**
   3. Log Count Rate

b. Operations Supervisor **(+0.5)**

RGC

Reference(s)

1. Technical Specification 3.1.

- Section L continued on next page -

Points
Available

QUESTION L-3

For each interlock given below, identify the proper action if that interlock is not satisfied. Choose from the action statements also given below.

Interlocks

a. Moderator-reflector water fill on. (0.5)
b. Failure of Line Voltage to Recorders. (0.5)
c. Neutron flux >2 cps. (0.5)
d. Reactor console keys "on". (0.5)

Action Statements

1. Scram
2. Stops water fill
3. Prevents control rod withdrawal

ANSWER L-3

a. 3 (+0.5)
b. 3 (+0.5)
c. 3 (+0.5)
d. 1 (+0.5)

Reference(s)

1. Technical Specification 3.3, Table 3-3.

- Section L continued on next page -

Points Available

QUESTION L-4

What actions, if any, must be taken if it is determined during power operations that the cumulative terminal power has reached 210 kilowatt hours this year? (3.0)

ANSWER L-4

Any three (3).

a. Shut reactor down. **(+1.0)**

b. Safety limit violation reported to level-one authority and NSRB. **(+1.0)**

c. Notify NRC by phone within 24 hours. **(+1.0)**

d. Prepare a Safety Limit Violation Report. **(+1.0)**

Reference(s)

1. Technical Specification, 2.1, 6.4.1, 6.5.3.

- Section L continued on next page -

Points Available

QUESTION L-5

Fill in the blanks in the following specifications for conducting experiments at the RPI critical facility.

a. The maximum positive step insertion of reactivity which can be caused by an experimental accident or experimental equipment failure of a moveable or unsecured experiment shall not exceed ________. (0.5)

b. Moving parts of an experiment worth less than ________ may be oscillated in the core at frequencies higher than $.20/sec. (0.5)

c. The reactor shall be subcritical by more than ________ with the most reactive control rod fully withdrawn. (0.5)

ANSWER L-5

a. $.60 (+0.5)
b. $.35 (+0.5)
c. $.70 (+0.5)

Reference(s)

1. Technical Specifications 3.1 and 3.4.

- Section L continued on next page -

Points Available

QUESTION L-6

Give the events requiring the direction of the Operations Supervisor. (2.0)

ANSWER L-6

1. All fuel or control rod relocations within the reactor core. **(+1.0)**

2. Recovery from an unplanned or unscheduled shutdown. **(+1.0)**

Reference(s)

1. Technical Specification 6.2.

QUESTION L-7

Give the major responsibility of each of the following:

a. Lincensed Reactor Operators (1.0)
b. Operations Supervisor (1.0)

ANSWER L-7

a. Licensed Reactor Operators are responsible for daily reactor operations. **(+1.0)**

b. Operations Supervisor is responsible for the reactor facility operation and management. **(+1.0)**

Reference(s)

1. Technical Specification 6.1.

- Section L continued on next page -

Points
Available

QUESTION L-8

Emergency Priorities

From the following steps give the order of their priorities when immediate actions must be taken if emergency conditions develop at the reactor facility, i.e., which is first consideration, second, etc. (2.0)

a. Steps to prevent the spread of hazards associated with accident conditions.

b. Steps to minimize the extent of damage to the critical facility and its equipment.

c. Steps for human safety.

ANSWER L-8

a. second (+0.67)
b. third (+0.66)
c. first (+0.67)

Reference(s)

1. Emergency Procedures, p. 3.

- Section L continued on next page -

Points Available

QUESTION L-9

Give four situations that result in an emergency alert. (2.0)

ANSWER L-9

Any four

1. bomb threat
2. civil disorder
3. contaminated moderator
4. power failure
5. smoke or fire
6. water leak

(+0.5 for each, +2.0 maximum)

Reference(s)

1. Emergency Plan, p. 5.

- Section L continued on next page -

Points Available

QUESTION L-10

Answer the following TRUE or FALSE.

a. Any trip of the criticality monitor automatically initiates the critical facility emergency alarm. (0.5)

b. Three portable extinguishers at the control facility are available to RPI staff in case of emergencies. (0.5)

ANSWER L-10

a. false (manual only) **(+0.5)**
b. ~~false~~ (4) **(+0.5)** RAC
true

Reference(s)

1. Emergency Plan, p. 8.
2. Emergency Procedures, p. 13.

- End of Section L -

END OF EXAMINATION