EXAMINATION REPORT

FACILITY LICENSE: Reed College
Portland, Oregon

FACILITY DOCKET NO.: 50-288

FACILITY LICENSE NO.: R-112

Examinations administered at Reed College in Portland, Oregon.

Chief Examiner:	John P O'Brien FOR John D. Smith	6-24-85 Date Signed
Examiner:	John P O'Brien FOR Dr. J. W. Upton, Jr.	6-24-85 Date Signed
Approved By:	John Elin John Elin, Section Leader	6/24/85 Date Signed

SUMMARY:

Examinations on May 14-16, 1985

Mr. Ron Maines, NRC Headquarters, was in attendance solely for the purpose of certifying Dr. Joseph W. Upton, Jr., as a research reactor license examiner. Dr. Upton was certified during this visit.

Written examinations were administered to four (4) SRO candidates and three (3) RO candidates. Oral examinations were administered to three (3) SRO and two (2) RO candidates. One (1) SRO and one (1) RO candidate declined to take the oral examination. This resulted in an automatic denial of these licenses. Three (3) SRO candidates passed these examinations. All others failed.

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REPORT DETAILS

1. EXAMINERS

   J. D. Smith, PNL, Chief Examiner
   J. W. Upton, PNL, Examiner

2. EXAMINATION REVIEW MEETING

   At the conclusion of the written examinations, the examiners met with M. Kay and Q. Hanley of the Reed Reactor Facility to review the written examinations and the answer keys. As a result of the review, changes were made to the exam key as described in the enclosed facility comments and resolution.

3. EXIT MEETING

   At the conclusion of the site visit the examiner met with Dr. Michael Kay of the facility staff to discuss the results of the examinations. Those individuals who clearly passed the oral examination were identified in this meeting. The examiners made the following observation concerning the training program.

   a. An area of generic weakness was found related to what to expect and how to proceed in the event of a total loss of offsite power. No procedure is written for this event. The facility commited to place more emphasis in this area in future training programs.

FACILITY COMMENTS AND RESOLUTION

Comment	Resolution
Ans. A.4 Answer incorrect for K_{eff} of 0.88	Key incorrect. Changed to 11.7 cpm
Ans. B.1 Drawing in key incorrect	Current drawing supplied by facility added to key
Ans. C.5 Answer incorrect	Key in error (typo), answer changed to "d"
Ans. C.7 Samples are dropped by gravity into Lazy Susan).	Key changed to reflect new loading technique.
Ans. F.1 - 4 Hi/low water alarm	Key changed to hi/Low
Ans. H.1 Cell and inhomogeneties not taught. Z_rH is largest contributor	Key changed to accept Z_rH for largest
Ans. H.4 β = 0.0075 at RRF	Key changed to accept either $\sim$-\$1.37 or $\sim$-\$1.28
Ans. H.5 Generation time is 12.3 sec.	Key in error changed, time to 12.3 sec.
Ans. 1.9 Answer is yes	Key in error, changed to yes
Ans. J.1 - 1 $\sim$ 106% Current - 2 4 sec. values - 4 $\sim$ 107% and - 5 Hi voltage terminology - 6 110 AC power	Key changed to reflect current values and terminology
Ans. J.2 or dashpot action	Added dashpot action to key
Ans. J.3 May give setpoint which is <6cps	No change to key

Ans. J.4 No calibrate position on range switch only linear calibrate	Change key to read: "Reg. rod insertion if on 250 KW range, linear scram if on any other range"
Ans. J.7 May use rule of thumb to calculate	Accept 1°C per 103.5 KWH ~112°F
Ans. K.2 ~10'	Changed key to ~10'
Ans. K.3 Answer specific to Reg. Rod	No change to key
Ans. K.4 $1.35 fixed $1.0 moving	Added $1.00 moving to key
Ans. K.7 Drawing incorrect	Current drawing supplied by Facility added to key
Ans. K.8 Although in lesser quantities, bromine will escape too	No change to key
Ans. K.10 Current worth a. ~$4.50 b. ~$4.50 c. ~$1.80	Key changed to reflect current values
Ans. L.2 ROC approves restart from unexplained scram	Changed key to read inadvertent scram
Ans. L.6 <$3.00 Tech Spec limit	No change to key

U.S. NUCLEAR REGULATORY COMMISSION

SENIOR REACTOR OPERATOR LICENSE EXAMINATION

Facility: REED COLLEGE

Reactor Type: TRIGA

Date Administered: MAY 14, 1985

Examiner: SMITH/UPTON

Applicant: ANSWER KEY MASTER

INSTRUCTIONS TO APPLICANT:

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

Category Value	% of Total	Applicant's Score	% of 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.

____

Applicant's Signature

H. REACTOR THEORY

(20.0)

Points Available

QUESTION H.1

Give the three (3) effects (components) that contribute to the large prompt negative fuel-temperature coefficient of the TRIGA Fuel, and indicate which has the largest and which has the smallest. (3.0)

ANSWER H.1

Cell and inhomogenities (largest) **(+1.0)** ACCEPT $Z_R H$ AS LARGEST (CELL AND INHOMOGENITIES NOT TAUGHT)
Doppler **(+1.0)**
Core Leakage (smallest) **(+1.0)**

Reference(s)

G.A. TRIGA Training Manual, Chapter 6, paragraph 6.2.3.

- Section H continued on next page -

Points Available

QUESTION H.2

Answer the following TRUE or FALSE (and briefly explain your answer):

(a.) If the Half-life of I-135 was larger than the half-life of Xe-135, the Xe-135 concentrations would not build up to a peak following a shutdown after an extended operation. (1.0)

(b.) The time it takes to achieve peak Xe conditions fol;owing a shutdown (SCRAM) is independent of the preceding equilibrium power level. (1.0)

(c.) The equilibrium Xe-135 concentration at 50% power is less than half the Xe-135 concentration at 100% power. (1.0)

ANSWER H.2

(a.) TRUE. The slower decay time (half-life) of the precursor would govern and not the induced concentration (buildup of Xe). **(+1.0)**

(b.) FALSE. The lower the equilibrium power, the earlier the xenon peaks. **(+1.0)**

(c.) FALSE. It is about 70% due to higher burnout factor or Xe-135 at 100% power. **(+1.0)**

Reference(s)

G.A. TRIGA Training Manual, Chapter 6, paragraph 6.3.7

- Section H continued on next page -

Points Available

QUESTION H.3

If the Reactor is shutdown by 5% delta k/k with a count rate (CR) of 10:

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. Explain why there is a difference between the values obtained for part (a.) and Part (b.) above. (1.0)

ANSWER H.3

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

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

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

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

Reactivity added = 0.975 - 0.95 = 2.5% delta k/k

- ANSWER H.3 continued on next page -

Points Available

ANSWER H.3 (contd)

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

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

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

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

$K_2 = 2K_1 - 1$ Where $K_1 = 1-0.05$

$K_1 = 0.95$

$K_2 = 1.90-1 - 0.90$

Negative reactivity inserted = 0.95 - 0.90 ≈ 5% delta k/k

c. The count rate is inversely dependent on delta k. Hence, for any initial value of delta k and CR it will take more change in delta k to reduce the CR than to increase the CR.

Reference(s)

G.A. TRIGA Manual, Chapter 6, Reactor Theory.

- Section H continued on next page -

Points Available

QUESTION H.4

Calculate the reactivity change (delta k/k) in dollars and cents which would occur if the reactor water temperature is maintained constant and the fuel temperature is increased 100°C. (1.0)

ANSWER H.4

% Δk/k

$-9.6 \times 10^{-5} \times 100 = -9.6 \times 10^{-3}$

$\frac{-9.6 \times 10^{-3}}{7.0 \times 10^{-3}} = -\$1.37$ or -\$1.28 if .0075 used for β

Reference(s)

G.A. Training Manual, Chapter 6, Reactor Theory, pp. B-2.

(CAF)

- Section H continued on next page -

Points Available

QUESTION H.5

Explain why the delayed neutrons have such a large effect on the operators ability to control the reactor when the delayed neutron population is only about 0.6% of the total neutron population in the core. (2.0)

ANSWER H.5

Even though the percentage of delayed neutrons is small, their relative effect is great because their generation to generation time may be on the order of ~~4 x 10^-5~~ 12.3 seconds.

The effective $_0n^1$ lifetime is:

(% prompt $_0n^1$) (lifetime prompt neutrons) +

(% delayed $_0n^1$) (lifetime delayed neutrons)

Reference(s)

G.A. Training Manual, Chapter 6, Reactor Theory.

- Section H continued on next page -

Points Available

QUESTION H.6

Doubling the time a target nuclide is irradiated will ________. (Select from the following the statement that correctly completes the sentence.) (1.0)

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

ANSWER H.6

Less than double the activity which results from the decay of the nuclide generated expressed in terms of its decay constant λ as the decay factor $(1-e^{-\lambda t})$

Reference(s)

Stephenson, McGraw-Hill.

- Section H continued on next page -

Points Available

QUESTION H.7

If the REED Reactor is taken critical and maintained on a stable 25 second period, how long will it take to increase power level two (2) decades. (Show your calculation). (2.0)

ANSWER H.7

T = 25 seconds

$$SUR = \frac{26.06}{T} = \frac{26.06}{25} = 1.0424$$

$$P = P_o\, 10^{SURt}$$

$$\frac{P}{P_o} = 100 = 10^{SURt}$$

$$2 = SURt$$

$$t = \frac{2}{1.0424} = \underline{\underline{1.92 \text{ minutes}}}$$

or

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

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

$$\text{Ln } 100 = t/25$$

$$t = (25)(\text{Ln}100)$$

$$= \underline{\underline{115.13}} \text{ second} = \underline{\underline{1.92 \text{ minutes}}}$$

- Section H continued on next page -

Points Available

QUESTION H.8

Explain what is meant by a dollars worth of reactivity in terms of K-effective and the delayed neutron reaction (Beta). (2.0)

ANSWER H.8

$\$ = \frac{\rho}{\beta}$

Where ρ = reactivity = $\frac{K_{eff}-1}{K_{eff}}$

and β is the delayed ${}_0n^1$ fraction

Reference(s)

TRIGA Training Manual, Section 6.2.4, pp. 6-12.

QUESTION H.9

Which of the following factors plays the most important role in determining the worth of a control rod? (Select one) (1.0)

a. The flux shape
b. Reactor power
c. The value of the delayed neutron fraction
d. The rod speed

ANSWER H.9

a.

Reference(s)

Stephenson, R. McGraw-Hill

- Section H continued on next page -

Points Available

QUESTION H.10

A thermal neutron is: (Select one) (1.0)

a. A neutron possessing thermal, rather than kinetic energy.

b. A neutron that experiences no net change in energy after several collisions with atoms of the diffusing media.

c. A neutron that has been produced in a significant time (on the order of seconds) after its initiating fission took place.

d. The primary source of thermal energy increase in the reactor coolant during reactor operation.

ANSWER H.10

b.

Reference(s)

Stephenson, R. McGraw-Hill

- Section H continued on next page -

Points
Ava'lable

QUESTION H.11

Which of the following statements best accounts for the fact that irradiated fuel elements are radioactive? (Select one) (1.0)

a. The high-neutron flux activates impurities in the fuel cladding and matrix, therefore yielding radioactivity.

b. Fission products, like the parent U-235 atom, are very neutron rich, and therefore tend to decay into more stable elements via beta minus decay.

c. Uranium is highly radioactive, and becomes even more activated under a thermal neutron flux.

d. After fission the fission products are very neutron deficient and therefore decay into more stable elements via beta plus decay.

ANSWER H.11

b.

Reference(s)

Stephenson, R., McGraw-Hill

- End of Section H -

I. RADIOACTIVE MATERIALS HANDLING, DISPOSAL AND HAZARDS (20.0)

Points Available

QUESTION I.1

Briefly describe the construction and principle of a thermo luminescent dosimeter (TLD). (2.0)

ANSWER I.1

Any reasonable explanation incorporating the use of lithium fluoride as the detector and the use of heat and light sensitive equipment to measure the exposure will be accepted.

Reference(s)

Reed Reactor Theory Training Manual, pp. 2-42/43.

QUESTION I.2

What is the advantage of a TLD over a film dosimeter? (1.0)

ANSWER I.2

Film badge susceptible to aging, also requires interpretation of exposure.

Reference(s)

Reed Reactor Theory Training Manual, pp. 2-40/41.

- Section H continued on next page -

I.1

Thermoluminescence Dosimetry or TLD

Phosphors that have been used the most in studies of thermoluminescence include manganese-activated calcium fluoride (CaF_2:Mn) and lithium fluoride (LiF). Other substances, such as $CaSO_4$:Mn, MgF_2:Mn, and Al_2O_3, have also been used. In these substances, electrons are moved from their normal places when the solid is exposed to ionizing radiation. They migrate about until "trapped" by lattice defects in the solid. At normal temperature, the electrons remain there for quite some time, but are released from the traps by heating. The luminescence appears when the electrons return to their normal positions. This light can be measured and related to the absorbed dose in the phosphor.

For readout of the accumulated absorbed dose, the phosphor is heated electrically and the intensity of the resulting luminescence is measured by a photomultiplier tube whose output signal is applied to a suitable readout instrument, such as an ammeter. The instrument is calibrated by measuring the intensity of light from phospors that had been exposed to known doses of radiation. Since the intensity of luminescence is proportional to the quantity of the phosphor as well as to the radiation absorbed dose, the amount of phosphor used in making a measurement must be kept as close as possible to the amount used in calibrating the instrument.

Thermoluminescent dosimeters respond quantitatively to X-rays, gamma-rays, betas and protons over a range that extends from about 10 mrad to about 100,000 rad. LiF thermoluminescent dosimeters are approximately tissue equivalent. The response of a LiF thermoluminescent dosimeter is almost energy independent from about 100 keV to 1.3 MeV gamma-rays.

- Section I continued on next page -

Points Available

QUESTION I.3

Explain the Reed Reactor design feature that reduces gamma activity above the pool associated with N-16. (2.0)

ANSWER I.3

The discharge line for the TRIGA Mark I reactor terminates in a flow deflector box just above the core where approximately 2/3 of the discharge flow entering the deflector box is discharged at right angles to the sides of the reactor tank through a slit in the side of the box. This action increases the flow time of radioactive gases from the core to the surface of the coolant shielding water, thereby providing a longer decay time for short-lived radioisotopes. The remaining 1/3 of the inlet flow is discharged toward the bottom of the tank through an orificed pipe attached to the bottom of the deflector box.

Reference(s)

Triga TM, p. 1-30.

- Section I continued on next page -

Points Available

QUESTION I.4

Explain how radioactive contaminants are removed from the reactor coolant. (2.0)

ANSWER I.4

Particulate by filtration soluable by ionic exchange.

Reference(s)

Reed SAR 5.2.6, pp. 5-7.

QUESTION I.5

Define the following at the Reed Triga facility.

a. Radiation area. (1.0)
b. High radiation area. (1.0)

ANSWER I.5

a. >5 mrem/hr - >500 mrem/5 days.
b. >100 mrem/hr.

Reference(s)

10 CFR 20.

- Section I continued on next page -

Points Available

QUESTION I.6

Which decay mode listed below is closest to that of:

a. AR-41 (0.5)

(1) $t_{1/2}$ = 3.81 hr-beta minus decay - no gamma.

(2) $t_{1/2}$ = 1.83 hr-beta minus decay - 1/2 mev gamma.

(3) $t_{1/2}$ = 7.35 sec-beta minus decay - 5-8 mev gamma

(4) $t_{1/2}$ = 21.7 min-beta plus decay - no gamma

b. N-16 (0.5)

(1) $t_{1/2}$ = 1.83 hr-alpha decay - no gamma

(2) $t_{1/2}$ = 35.7 sec-beta minus decay - 1/2 mev gamma

(3) $t_{1/2}$ = 7.35 sec-beta minus decay - 6-8 mev gamma

(4) $t_{1/2}$ = 21.7 min-beta plus decay - no gamma

ANSWER I.6

a. (2)
b. (3)

Reference(s)

Stephenson, R., McGraw-Hill.

- Section I continued on next page -

Points Available

QUESTION I.7

If two (2) centimeters of lead will reduce gamma radiation level from 100 mr/hr to 50 mr/hr. How many centimeters of lead will be required to reduce a gamma radiation level from:

a. 400 mr/hr to 50 mr/hr. (1.0)
b. 50 mr/hr to 25 mr/hr. (1.0)

ANSWER I.7

a. 6 cm
b. 2 cm

Reference(s)

Reed Reactor Theory Training Manual (Half-Value), pp. 2-27.

QUESTION I.8

Explain how both liquid and solid radioactive waste is handled and disposed of at Reed college. (2.0)

ANSWER I.8

The essence of SOP-52 (Radioactive Materials Transfer) will be accepted for an answer.

LIQUIDS ARE SOLIDIFIED. SOLIDS ARE PACKAGED IN SEALED CONTAINERS AND SHIPPED TO HANFORD.

- Section I continued on next page -

RADIOACTIVE MATERIALS TRANSFER: SOP52

52.1 PURPOSE:

To comply with Federal and State Regulations requiring RRF to keep track of all radioactive materials leaving the reactor facility such as irradiated samples, produced isotopes, and sources of all types.

52.2 FREQUENCY:

Whenever any radioactive materials are shipped or removed from RRF or transferred to the Reed College licence.

52.3 SPECIAL EQUIPMENT:

Two RADIOACTIVE MATERIALS TRANSFER forms separated by a sheet of carbon paper.
A completed IR form (for irradiated samples).
A portable GM monitor.
The low background GM counter.
One Kimwipe
Methanol

52.4 PERSONNEL:

One RRF staff member.
The person(s) removing/shipping the radioactive materials.
(These may and have, at times, been one and the same)

52.5 PRELIMINARY ACTIONS:

Set up the low background counter in the reactor room and start a five minute background count.

52.6 PROCEDURE:

Fill out the first two sections of the RADIOACTIVE MATERIALS TRANSFER form obtaining the transfer number by adding one to the latest transfer number posted on the blackboard. Check the appropriate box for materials shipped or removed (materials removed are those taken away by the experimenters themselves rather than being shipped via a public carrier. Indicate the means of transport used in the box provided ie. private auto, UPS, etc. The recipients license number must be found on a copy of their current licence in the console room file cabinet. No material shall be released without a copy of the recipient's licence on file. Indicate the general type of material being transferred, whether geological samples, physiological saline, etc. and the estimated activity in millicuries.

Before packaging, monitor the material itself at one foot from its surface with the GM portable monitor and record this reading on the transfer form. After packaging, monitor the package at its surface and at one meter from its surface. Next, moisten a Kimwipe with methanol and wipe a representative area, usually a bottom edge and corner and the top and closure of the container and place the kimwipe in the low background counter for a one minute count and determine the net beta-gamma counts above back- ground, record all of this monitoring information on the trandsfer form and applicable parts in the appropriate blanks of the IR form. In the blank for remarks record the type of packaging, la-

belling, and any other useful information about the package and shipping procedure. See the appendix to this sop and the Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials to be found on file in the console room under "shipping information" for further information.

52.7 ADJUSTMENTS:

Insure that all labelling on the packages to be shipped or removed is correct and that the materials are not in violation of the applicable state and/or federal regulations by adding more shielding or packaging, or by breaking a large shipment up into smaller ones.

52.8 CLEANUP:

Check to see that all blanks have been filled in and that all signatures have been obtained on the transfer form and IR form. Make sure the package has a seal such as tape or wire. Give the carbon of the transfer form and the orange sheet of the IR to the experimenter/shipper with the materials involved and file the originals in the console room filing cabinet. Turn off the low background counter and the portable monitors.

52.9 LOGGING IN:

Log the shipment in the console log book and update the "latest transfer" number on the blackboard.

52.10 APPENDIX:

Useful information from the Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials:

I. Removable contamination is considered insignificant if the net beta-gamma count is < 2,200 dps/100sq.cm.

II. Labelling:

A. white radioactive I label:	< 0.5 mR/hr at surface
B. yellow radioactive II label:	< 10 mR/hr at surface < 0.5 mR/hr at 1 meter or Transport Index < 0.5
C. yellow radioactive III label:	> 10 mR/Hr fissile class III see Federal Regs.

III. Packaging:

Package must have a seal over opening to ensure contents arrive undisturbed ie. tape or lead wire.
No dimension of the package may be less than 4" for shipping by public carrier.
No package may read > 200 mR/hr at its surface or > 10 mR/hr at 1 meter for postal shipping.

Points Available

QUESTION I.9

Which of the following isotopes has the longest half-life? (1.0)

a. Cobalt 60.
b. Nitrogen 16.
c. Argon 41.
d. Xenon 135.

ANSWER I.9

a. Cobalt 60.

Reference(s)

Stephenson, R., McGraw-Hill.

QUESTION I.10

a. Define rem. Clarify whether or not a rem is a measure of energy, or a measure of biological damage. (1.0)

b. Is a rem received as a result of alpha radiation equivalent to a rem received as a result of gamma radiation? Explain. (1.0)

ANSWER I.10

a. Rem reflects the amount of energy dissipated and biological damage derived from such energy dissipation.

b. YES [redacted]. Alpha has quality factor X20. INCLUDED

Reference(s)

Reed Reactor Theory Training Manual, pp. 2-2/3.

- Section I continued on next page -

Points Available

QUESTION I.11

Explain what might be potential sources of radiation above the pool under both normal and abnormal conditions. (3.0)

ANSWER I.11

N-16.
Direct radiation.
Leaking fuel (I-131, xe-135, etc.).

Reference(s)

Generic.

- End of Section I -

J. SPECIFIC OPERATING CHARACTERISTICS (20.0)

Points Available

QUESTION J.1

List the six (6) scrams possible at the Reed Triga Reactor. Include setpoints where applicable. (4.0)

ANSWER J.1

1. Rx power 20-110% adjustable vic. LINEAR POWER 106%
2. Rx period <3 sec adjustable to inf. PERIOD 4 SEC
3. Manual.
4. Rx power CIC. % POWER 107%
5. Ion chamber power supply. HIGH VOLTAGE
6. Console power failure. 110V AC

Reference(s)

Reed SAR, pp. 5-16.

QUESTION J.2

What facility design feature reduces the impact of a control rod when the reactor is scrammed. Explain. (2.0)

ANSWER J.2

Slot type shock absorber added to control rod.
DASHPOT ACTION

Reference(s)

Reed SAR, pp. 5-11.

- Section J continued on next page -

Points Available

QUESTION J.3

Describe the activation and function of the control rod interlocks at the REED TRIGA reactor. (3.0)

ANSWER J.3

No control element withdrawal with <2 neutron induced counts per second.

Simultaneous withdrawal of two (2) control elements.

Reference(s)

Tech. Specifications, p. 9.

QUESTION J.4

Explain the effect and possible result of switching the reactor power range switch to the calibrate position while operating in the automatic mode. (2.0)

ANSWER J.4

Will result in a regulating rod withdrawal and possible period or power scram.

Reference(s)

Triga-Generic.

REG. ROD INSERTION IF ON THE 250 KW RANGE. RX LINEAR SCRAM IF ON ANY OTHER RANGE.

- Section J continued on next page -

Points Available

QUESTION J.5

TRUE or FALSE: As criticality is approached, the withdrawal increments should be increased. Explain. (1.0)

ANSWER J.5

False. Should be lessened. Possibly too short of a period.

Reference(s)

Triga-Generic.

QUESTION J.6

Explain why it is undesirable to have too high of a flow rate through the demineralizer. (2.0)

ANSWER J.6

Too high a flow rate will produce channeling and possible flushing of particulates

- Section J continued on next page -

Points Available

QUESTION J.7

Assume the combined specific heat of the reactor coolant/reactor components is 0.8. If the reactor coolant is at 70°F, and the reactor is operating at 200 kw when the secondary cooling system fails.

a. How many BTUs will have been added two (2) hours after the failure? Show calculation. (1.0)

b. What will the reactor coolant temperature be three (3) hours after the failure? Show calculation. (2.0)

c. What is the Tech. Spec. limit on pool temperature? (1.0)

ANSWER J.7

a. 13.651×10^5 BTU.

b. Pool 10' x 15' x 24' deep ≅ ~~224,000#~~ 192244 H_2O **(+0.5)**

200 kW at 3 hr = 20.478×10^5 BTU

$(2.24 \times 10^5)(0.8) =$ ~~1.792~~ 1.537 $\times 10^5 \frac{BTU}{°F}$

$\frac{20.478 \times 10^5}{\text{~~1.792~~ } 1.537 \times 10^5} =$ ~~11.43°~~ 13.32

70°F + ~~11.43~~ 13.32°F = ~~81.43~~ 83.32°F. **(+1.5)**

ACCEPT ANS. BASED ON 1°C PER 103.5 KWH ≅ 112°F

c. 120°F.

Reference(s)

Tech. Specification D-1, p. 2.

- Section J continued on next page -

Points Available

QUESTION J.8

Briefly describe how the rabbit equipment is operated. Include in the discussion valving and motive media. (2.0)

ANSWER J.8

The operator brings the reactor to the desired power (having done a core excess check if necessary) and logs the present core excess. The irradiation may now start.

The rabbit operator must complete the following actions:
1. make certain that the butterfly valves venting the rabbit hood are placed in the correct position to vent the hood. These valves are found just inside the radiochem lab from the rabbit hood; the handle on the valve goes in the same direction as the valve plate.
2. Extend the security area to its outer limits (see SOP 12) and be sure that the door between the exit corridor and the console room is hooked open. 3. The large yellow sign is placed outside the door at the bottom of the stairs indicating to those coming down the stairs that a radiation field may be present. 4. The reactor operator has the completed IR. 5. A working ion chamber is placed in the "on" position and is in the rabbit hood about a foot away from the terminal. 6. Be sure that the PA system is working between the rabbit terminal and the reactor console room.
7. Obtain and be wearing your TLD badges--both whole body and ring badge. 8. Before attempting to turn the rabbit motor on, be sure to notify the reactor operator; it may be necessary to also turn on the motor switch in the reactor mechanical room.

Reference(s) ACCEPT USE OF DRAWING TO SUPPORT EXPLANATION

SOP-51.

- End of Section J -

K. FUEL HANDLING AND CORE PARAMETERS (20.0)

Points Available

QUESTION K.1

During fuel handling, by what amount must the reactor be subcritical? (1.0)

a. 2.00% Delta K/K
b. 2.25% Delta K/K
c. 2.50% Delta K/K
d. 2.75% Delta K/K

ANSWER K.1

b.

Reference(s)

Tech. Specification E-2, p. 3.

QUESTION K.2

When moving a fuel element, what is the minimum water level that should be maintained over the element to provide adequate shielding? (1.0)

ANSWER K.2

~~5-6 ft~~ ~ 10 FT

Reference(s)

(CAF)

- Section K continued on next page -

Points Available

QUESTION K.3

Explain how a control rod calibration is performed. (3.0)

ANSWER K.3

1. Establish critical conditions at 3 watts by raising the Safety and Shim Rods, leaving the Reg Rod in the core.

2. Allow the power level to stabilize for 5-7 minutes.

3. Record the rod positions as in the sample format below.

4. Withdraw Reg Rod to get a period meter reading of about +25 - +~~3~~5 seconds and stop withdrawal.

5. Allow the power level to increase one full range so that the "transient period" decays out.

6. Beginning on the 30 watt scale, use the electronic timers to measure the time it takes the power to increase by a factor of 2 (either 30% to 60% or 40% to 80%). Repeat measurement as the power increases on the 100 watt and 300 watt ranges then return the power level to 3 watts by lowering the shim Rod. Do not reposition the Reg Rod. Do not allow the power level to exceed 1 kW.

7. Record the data, average the doubling times obtained, and using the table of the IN Hour relation determine the reactivity worth of the withdrawn section of the Reg Rod.

8. Continue until the rod is fully withdrawn.

Reference(s)

SOP 33.

- Section K continued on next page -

Points Available

QUESTION K.4

The technical specification for the reactivity worth of a single experiment shall be less than ___?___ dollars. Fill in the blank. (1.0)

ANSWER K.4

$1.35 FIXED $1.00 MOVING

Reference(s)

Tech. Specification J-4a, p. 6.

QUESTION K.5

Fuel element bowing will directly lead to a rapid fuel element failure. (TRUE or FALSE) (1.0)

ANSWER K.5

False. (Fuel clad will not fail with core uncovered.)

Reference(s)

Reed SAR.

- Section K continued on next page -

Points Available

QUESTION K.6

According to the REED technical specifications, fuel elements being stored shall always be arranged in a geometrical array where the k-effective is less than __?__ for all conditions of moderation. (Select one). (1.0)

a. 0.7
b. 0.75
c. 0.85
d. 0.8

ANSWER K.6

d.

Reference(s)

Tech. Specification H-1, p. 4.

QUESTION K.7

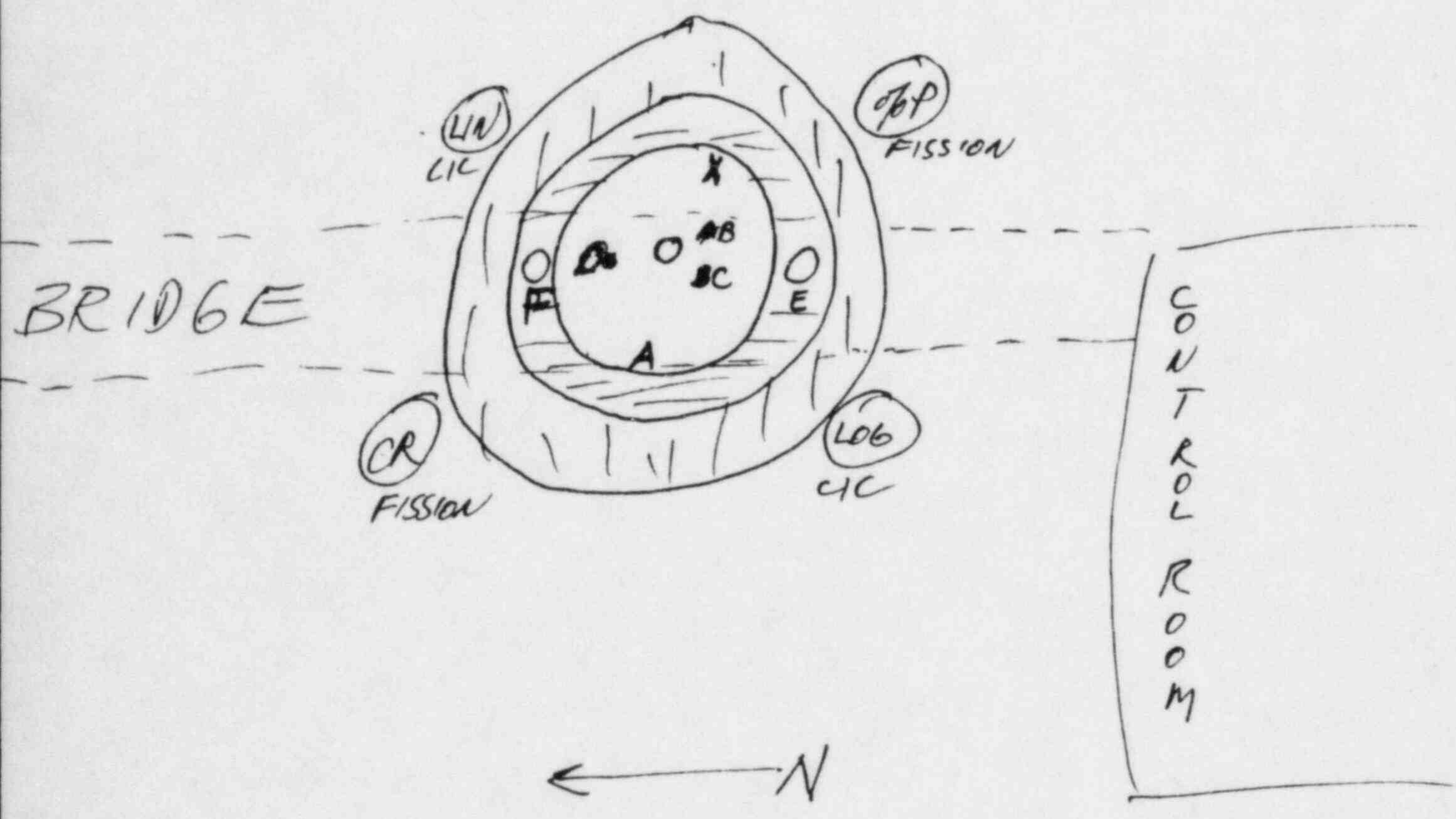
Draw a top view of the reactor core grid array showing the location of the: (4.0)

a. source
b. core orientation relative to the control room
c. control rod
d. rabbit in core terminus
e. shim rods
f. fission chamber
g. ion chamber
h. lazy susan

ANSWER K.7

See attached.

- Section K continued on next page -



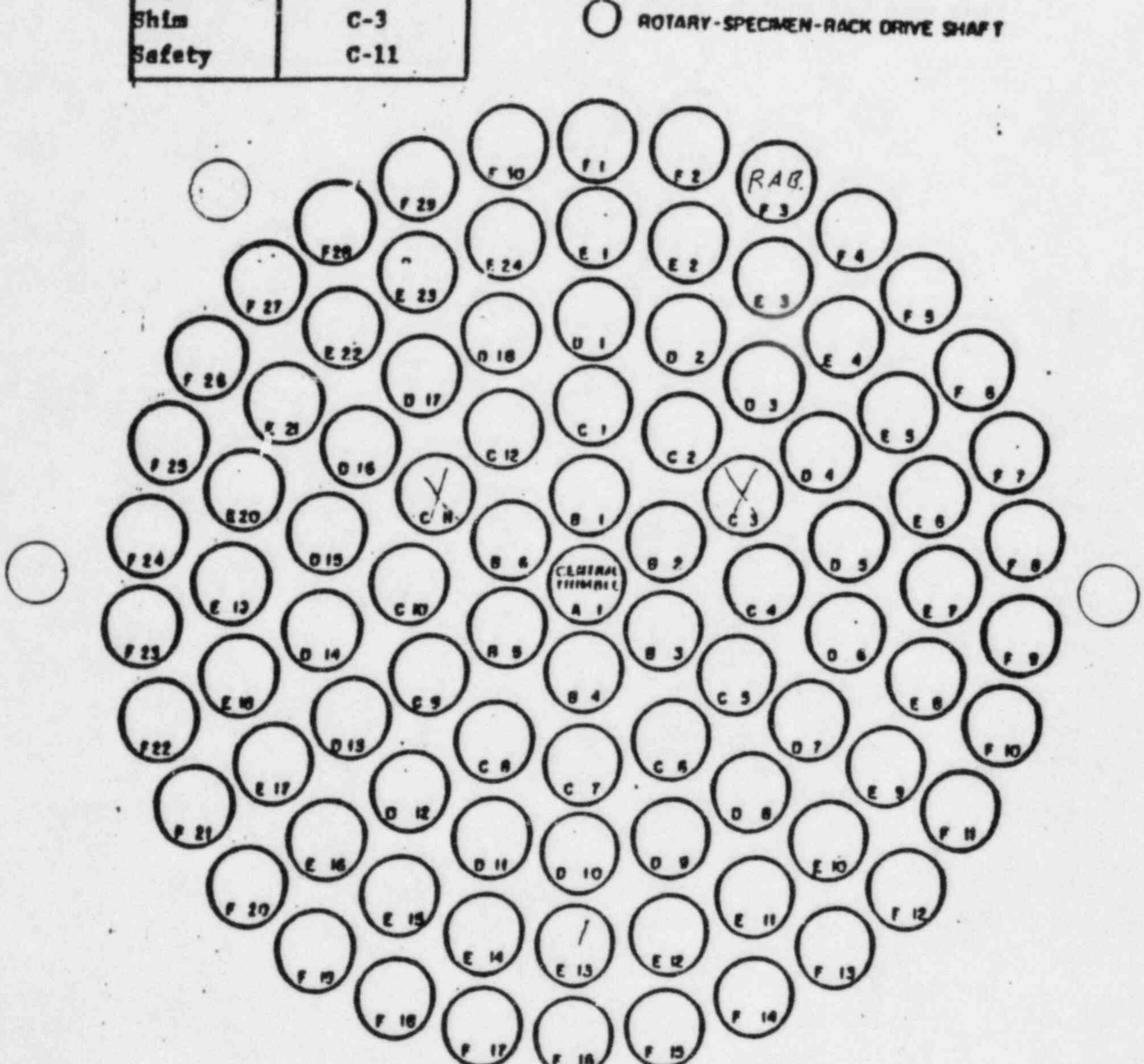
X = Rabbit Terminus
A = SOURCE
B = Safety Rod
C = Shim Rod
D = Reg Rod
E = LS drive shaft
F = LS drop tube

≡ Lazy Susan
|||| Reflector

Points Available

Sketch for Question B.1

Type of Control Rod	Control Rod Location Steady-State Reactors
Regulating	E-13
Shim	C-3
Safety	C-11



- Section B continued on next page -

Points Available

QUESTION K.8

In the event of a fuel element failure, which of the isotopes listed below will escape from the core? Indicate where they might be detected.

NOTE: More than one answer may be correct. (1.0)

a. bromine
b. iodine
c. xenon
d. krypton

ANSWER K.8

b. iodine (CONDUCTIVITY METER)
c. xenon (CAM, RAM)
d. krypton (CAM, RAM)

Reference(s)

Stephenson, R. McGraw-Hill

QUESTION K.9

How does a fuel element worth change (compared to water) as the element is moved from the outer core ring toward the center of the core? (1.0)

ANSWER K.9

Increases

Reference(s)

Stephenson, R., McGraw-Hill.

- Section K continued on next page -

Points Available

QUESTION K.10

Fill in the value of the rod worth. (1.5)

a. shim I 1. $________
b. ~~shim II~~ SAFETY 2. $________
c reg rod 3. $________

ANSWER K.10

a. ~~$3.73~~ ~$4.50
b. ~~$3.73~~ ~$4.50
c. ~~$1.33~~ ~$1.80

Reference(s)

Reed SAR 5.2.7, pp. 5-8.

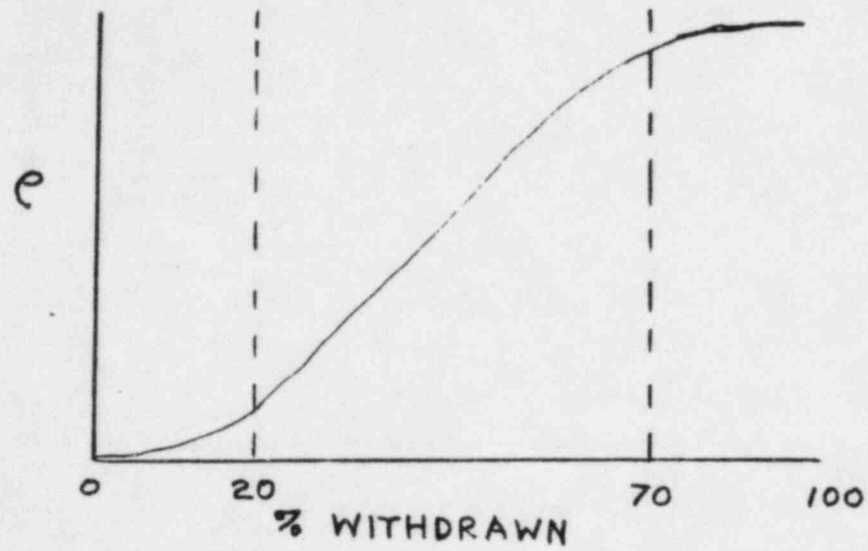
- Section K continued on next page -

Points Available

QUESTION K.11

Draw a plot of integral rod worth (reactivity versus % withdrawal) for either a shim rod or reg rod. Explain the shape of the curve for 0-200% withdrawn, 20-70% withdrawn and 70-100% withdrawn. (2.5)

ANSWER K.11



Because the flux is depressed in the top and bottom of the core the rod poison does not have as significant an effect as it does in the middle.

Reference(s)

Triga-Generic.

- Section K continued on next page -

Points Available

QUESTION K.12

When a fuel element is being moved to and from the core, what two (2) indications should the control room operator be observing? (2.0)

ANSWER K.12

Area Rad. Monitor
Rx Power

Reference(s)

Triga-Generic.

- End of Section K -

L. ADMINISTRATIVE PROCEDURES, CONDITIONS, AND LIMITATIONS (20.0)

Points Available

QUESTION L.1

Give the limitation on reactivity for experiments at the Reed Reactor. (1.0)

a. Reactivity worth of a single experiment.
b. Total absolute reactivity worth of a combination of experiments.

ANSWER L.1

a. \$1.35 FIXED \$1.00 MOVING
b. \$2.00

Reference(s)

Tech. Specification 4-a and b.

QUESTION L.2

List three (3) situations during which an SRO must be physically present on the site. (3.0)

ANSWER L.2

During reactor maintenance.
During core or experimental changes.
During maintenance requiring movement of control rods.
To approve restart from unplanned or unscheduled shutdown.
INADVERTENT SCRAM

- Section L continued on next page -

Points Available

QUESTION L.3

Describe how the pool water low water alarm is tested. Include any notification or precautions that are required. (2.0)

ANSWER L.3

Notify director. Post staff member outside facility to explain red light. Depress plunger underneath bridge (do not bend).

Reference(s)

SOP-63.

QUESTION L.4

During the performance of special experiments, all of the following must be present at the facility. (TRUE or FALSE) (1.0)

- SRO
- RO
- Reactor supervisor
- Director

ANSWER L.4

False.

Reference(s)

Admin. Procedure 4.2.3, p. 16.

- Section L continued on next page -

Points Available

QUESTION L.5

Explain the procedures that must be followed in the event of:

a. A manual scram. (1.0)
b. An inadvertent scram. (1.0)
c. An unexplained scram. (1.0)

ANSWER L.5

The essence of SOP-08, 8.1 for Part (a), 8.3 for Part (b) and 8.4 for Part (c) will be accepted for full credit.

Reference(s)

SP-0.8.

QUESTION L.6

Explain when and why the excess reactivity of the core must be measured. (2.0)

ANSWER L.6

Normally upon reaching (5) watts of power during startup, but may be variable (1-20 watts). Is done to insure adequate shutdown margin.
1ST STARTUP OF EACH DAY

Reference(s)

SOP-03.

- Section L continued on next page -

L.5

SCRAMS: sop08

8.0 SCRAMS

SCRAMs can be divided into two general groups: manual and automatic. The manual SCRAMs are further divided into pre-planned and emergency response SCRAMs. The automatic SCRAMS are divided into inadvertent and unexplained SCRAMs of the various console systems such as per-cent power or linear.

8.1 PRE-PLANNED MANUAL SCRAMS

This action is one of the two normal ways of shutting down the reactor. While less desirable than simply driving the rods in, occasions, such as a demonstration, often call for pre-planned manual SCRAMs. A manual SCRAM should be done only when the reactor is in the steady state mode. The time and action ("manual SCRAM") are recorded in the log book and then the SCRAM bar is pushed down. It is important that all 5 console contact lights are depressed simultaneously to achieve a manual SCRAM. More on this mode of shutting down the reactor is discussed in Section 7.0.

8.2 EMERGENCY MANUAL SCRAMS

Any time an operator feels it is important to shut down quickly, a manual SCRAM should be used.

8.3 INADVERTENT AUTOMATIC SCRAMS

When one of the pre-set scram points has been exceeded through actions such as operator carelessness, an inadvertent SCRAM will ensue. There is a fine line between an inadvertent and unexplained SCRAM when console electronic problems such as switch noise cause the SCRAM. If it is a recurring problem that has been well documented in the recent past, the SCRAM may be classified as inadvertent; otherwise, it is an unexplained SCRAM.

All inadvertent and unexplained SCRAMs must be logged in the SCRAM BOOK. The time, date, operator, type of SCRAM, and full explanation of the reasons for the SCRAM are to be documented. An SRO'S permission to restart is required. While not necessary, if the operator is an SRO and another SRO is available, it is a good idea to have the second SRO check and sign the SCRAM BOOK.

8.4 UNEXPLAINED SCRAMS

The name here is self-explanatory. Any unexplained SCRAM should be immediately reported to the Reactor Supervisor and/or the Director. Every effort to determine the cause of the SCRAM should be made prior to contacting the Operations Committee prior to restarting the reactor.

As with an inadvertent SCRAM, an unexplained SCRAM must be logged into the SCRAM BOOK.

8.5 RESTARTING AFTER A SCRAM OCCURRING DURING A POWER CHANGE

In this situation, the purpose stamp for the power change is not completed. A log entry of the SCRAM is made. After proper approval, a new purpose stamp is made and the power change to the desired power continues from the low power level present after the SCRAM.

- Section L continued on next page -

Points Available

QUESTION L.7

List the responsibilities of a senior reactor operator. (3.0)

ANSWER L.7

1. Operating the reactor in accordance with the pertaining administrative and operating procedures approved by the Reactor Operations Committee and within the limitations of the appropriate Facility License and Technical Specifications.

2. Preparing the logs and records of the reactor operation.

3. Reporting all unusual conditions and events pertaining to the facility and its operation to the Reactor Supervisor.

4. The radiation safety of all personnel inside the Reactor Room during operation of the reactor, in accordance with 10 CFR 20.

5. Insertion and removal of experiments with the written approval of the Reactor Supervisor.

6. Proper shielding and storage of radioactive materials removed from the reactor, until they are turned over to a person authorized by the Reactor Supervisor to receive them.

Reference(s)

Admin. Procedures, Section II, pp. 4-5.

- Section L continued on next page -

Points
Available

QUESTION L.8

List the minimum required responses in the event that an Emergency Alert is declared at the Reed facility. (3.0)

ANSWER L.8

1. Shut down the reactor.

2. Notify someone on the ENCL.

3. If appropriate, evacuate the facility. See Appendix C for proper procedure.

4. If appropriate, the necessary circuit breakers should be turned off. The main facility circuit breaker is on the south wall of Room 7 (across the hall from the entrance to the stockroom). The keys to this room and circuit breaker are found in the emergency grab-bag.

5. If appropriate, notify the police. See Appendix A for emergency phone numbers.

6. In case of civil unrest, the four facility doors will be dead-bolt locked with a key located on the key ring in the mechanical room.

Reference(s)

Reed Emergency Plan, Section IV-A.

- Section L continued on next page -

Points Available

QUESTION L.9

Describe the personnel requirements for startup and operation of the Reed Reactor. Include allowable location for each individual. (2.0)

ANSWER L.9

At least two persons must be present within the Reactor Facility whenever the reactor is not shut down, as defined in the technical specifications. At least one of the persons present must be a AEC-Licensed Operator. A Senior Reactor Operator must be present in the Reactor Facility (or the adjoining Chemistry Building) and the operator must know the whereabouts of this individual prior to beginning operation. All reactivity changes will be made by, or in the presence and under the direction of, an individual licensed to operate the reactor.

Reference(s)

Admin. Procedure 3.1.4, p. 9.

- End of Section L -

END OF EXAMINATION

EQUATION SHEET

Where $\dot{m}_1 = \dot{m}_2$

$(density)_1(velocity)_1(area)_1 = (density)_2(velocity)_2(area)_2$

$KE = \frac{mv^2}{2}$ $PE = mgh$ $PE_1 + KE_1 + P_1V_1 = PE_2 + KE_2 + P_2V_2$ where V = specific volume, P = Pressure

---

$Q = \dot{m}c_p(T_{out} - T_{in})$ $Q = UA\ (T_{ave} - T_{stm})$ $Q = \dot{m}(h_1 - h_2)$

$P = P_o 10^{(SUR)(t)}$ $P = P_o e^{t/T}$ $SUR = \frac{26.06}{T}$ $T = 1/\text{Delta } k$

$\text{delta } K = (K_{eff} - 1)/K_{eff}$ $CR_1(1 - K_{eff1}) = CR_2(1 - K_{eff2})$ $CR = S/(1 - K_{eff})$

$M = \frac{(1 - K_{eff1})}{(1 - K_{eff2})}$ $SDM = \frac{(1 - K_{eff}) \times 100\%}{K_{eff}}$

$\text{decay constant} = \frac{\ln(2)}{t_{1/2}} = \frac{0.693}{t_{1/2}}$ $A_1 = A_o e^{-(\text{decay constant}) x (t)}$

Water Parameters

1 gallon = 8.345 lbs
1 gallon = 3.78 liters

1 ft^3 = 7.48 gallons

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 psia = 29.9 in Hg

Miscellaneous Conversions

1 Curie = 3.7×10^{10} dps
1 kg = 2.21 lbs

1 hp = 2.54×10^3 Btu/hr

1 MW = 3.41×10^6 Btu/hr
1 Btu = 778 ft-lbf

Degrees F = (1.8 x Degrees C) + 32
1 inch = 2.54 centimeters
g = 32.174 ft-lbm/lbf-sec^2

U.S. NUCLEAR REGULATORY COMMISSION

REACTOR OPERATOR LICENSE EXAMINATION

Facility: REED COLLEGE

Reactor Type: TRIGA

Date Administered: MAY 14, 1985

Examiner: SMITH/UPTON

Candidate: ANSWER KEY MASTER

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheet. Points for each question are indicated in parenthesis 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	Candidate's Score	% of Cat. Value	Category
14	14			A. Principles of Reactor Power Operation
16	16			B. Features of Facility Design
14	14			C. General Operating Characteristics
14	14			D. Instruments and Controls
14	14			E. Safety and Emergency Systems
14	14			F. Standard and Emergency Operating Procedures
14	14			G. Radiation Control and Safety
100				TOTALS

Final Grade _______ %

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

____

Applicant's Signature

A. PRINCIPLES OF REACTOR OPERATION (14.0)

Points Available

QUESTION A.1

Specify the letter designation of the most correct statement from those listed below. (1.0)

(a.) The energy spectrum of neutrons obtained from the fissioning of U-235 atoms follows a Maxwell-Bottgmon distribution.

(b.) The energy spectrum of neutrons obtained from the thermal-neutron fissioning of U-235 atoms is narrowly peaked in the range of 4 MeV.

(c.) The energy spectrum of neutrons obtained from the fissioning of U-235 atoms contains two peaks, the thermal-neutron peak and the fast-neutron peak.

(d.) Thermal neutrons have an energy spectrum with a peak at 0.025 eV for a reactor at room temperature.

ANSWER A.1

(d.). **(+1.0)**

Reference(s)

1. Reed: Reed Training Document, Technical Education Research Center-Southwest, "Nuclear Technology," pp. 12-1-13 to 12-1.18.

- Section A continued on next page -

Points Available

QUESTION A.2

a. If the Reed Triga Reactor were increasing power with a period of 25 sec, how much time is required for the power level to increase by 2 decades? Show your calculational procedures. (2.0)

b. If the mean lifetime of neutrons in the reactor were 8×10^{-2} sec, what is the reactivity of the core? (1.0)

ANSWER A.2

a. $T = 25$ sec

$P/P_o = 100 = e^{t/25}$ **(+1.0)**

$\ln 100 = t/25$

$t = 25 \ln 100$

$= 115$ sec **(+1.0)**

$= 1.92$ min

b. $T = \ell/\Delta k$ **(+0.5)**

$\Delta k = \ell/T$

$= \frac{8 \times 10^{-2} \text{ sec}}{25 \text{ sec}}$

$= 3.2 \times 10^{-3}$

Reference(s)

1. Reed: Reed training Document, Technical Education Research Center-Southwest, "Nuclear Technology," pp. 12-1-13 to 12-1-18.

- Section A continued on next page -

Points Available

QUESTION A.3

Consider the "doppler broading" effect that takes place in the fuel of the Triga Reactor.

a. Describe the phenomena of doppler broading. (1.0)

b. As the temperature of the fuel increases what impact does this phenomena have on K_{eff}? What parameter of the six-factor formula is predominantly affected? (1.0)

c. Does this phenomena in the Triga reactor lead to a positive or negative temperature coefficient and is the temperature coefficient considered a "slow (delayed)" or "fast (prompt)" coefficient? (1.0)

ANSWER A.3

a. An increase in the fuel temperature causes a broadening of the neutron absorption peaks (the resonance peaks); on graph of neutron absorption cross-section as a function of energy the cross-section peaks widening (and become lower in (magnitude). **(+0.5)** The broadening is due to the increased vibrational energy as the temperature increases. **(+0.5)** The peaks in the absorption cross-sections of U-235 and U-238 are the primary contributors to the effect in the Triga Reactor. **(+0.5)**

(1.0 max)

b. As the fuel temperature increases, the widening of the resonance peaks causes the resonance escape probability **(+0.5)** to decrease and hence for K_{eff} to decrease. **(+0.5)**

c. The fuel temperature coefficient is a negative temperature coefficient **(+0.5)** and is considered a prompt coefficient. **(+0.5)**

Reference(s)

Reed: Reed training Document, Technical Education Research Center-Southwest, "Nuclear Technology," pp. 12-7-8 to 12-1-9.

- Section A continued on next page -

Points Available

QUESTION A.4

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} = 0.88 and 0.99? (2.0)

ANSWER A.4

$$\frac{\Delta k_1}{k_1} = 0.07$$

$$\frac{1-k_1}{k_1} = 0.07$$

$$1 = k_1 + 0.07\,k_1$$

$$1 = 1.07\,k_1$$

$k_1 = 1/1.07 = 0.93$ **(+0.5)**

$\frac{1-k_1}{1-k_2} = \frac{CR_2}{CR_1}$ **(+0.5)**

CR_2 = (20) ~~(3.50)~~ (0.583)

= ~~70 cps~~ 11.7 CPM **(+0.5)**

$$\frac{0.07}{0.01} = \frac{CR_3}{20}$$

CR_3 = 140 cpM **(+0.5)**

Reference(s)

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

- Section A continued on next page -

Points
Available

QUESTION A.5

Why is the worth of a control rod dependent on the position of that control rod? (1.0)

ANSWER A.5

The reactivity effect, i.e. worth, of a control rod depends on the impact that the material of the control rod has on the absorption rate of neutrons (assuming a poison-type of control rod). The reactivity worth of a small-sized absorber can be expressed as dependent on the (relative) neutron flux in the vicinity of the absorber and the impact that a change in that location will have on the total neutron population. Mathematically, the result is that the effect is proportional to the square of the neutron flux at the location where the change is made in absorber concentration. Hence, changing the amount of absorber material near the center of the reactor core will have the largest effect on reactivity. **(+1.0)**

Reference(s)

1. GA Technologies.

- Section A continued on next page -

Points Available

QUESTION A.6

List the letter designations of all those statements given below that are correct statements. (2.0)

(a.) An increasing concentration in the reactor core of Xe-135 reduces the thermal utilization factor, f, and hence the multiplication factor, K_{eff}, of the reactor core.

(b.) The thermal-neutron microscopic absorption cross section of Xe-135 is greater than 10^6 barns.

(c.) Xe-135 is produced both directly as a fission product and as the result of a decay chain from other fission products.

(d.) A good approximation (in determining the production in a reactor core of Xe-135 is to assume that the Xe-135 is produced from the decay of Cs-135.

(e.) The removal rate of Xe-135 is due to the neutron absorption rate in Xe-135 atoms and due to the radioactive decay of Xe-135 atoms.

ANSWER A.6

The correct statements correspond to designations (a.), (b.) (c.) and (e.). **[0.5 each, -0.5 for (d.)]**

Reference(s)

1. Generic: Academic Program for Nuclear Power Plant Personnel, Volume II, General Physics Operation, pp. 4-144f.

2. GA Technologies: Syllabus and Triga Training Manual, GA Technologies, Inc., pp. 6-25.

3. Reed: Reed Training Document, Technical Education Research Center-Southwest, "Nuclear Technology," pp. 12-7-12f.

- Section A continued on next page -

Points Available

QUESTION A.7

Numerically estimate the reactivity change in ¢ which occurs in the Triga reactor core if the water temperature is maintained constant and the fuel temperature is raised 30°C. (1.0)

ANSWER A.7

$\alpha_f \cong 10^{-4}/°C$ **(+0.3)**

$\frac{\Delta k}{k} = (10^{-4})(30)$ **(+0.3)**

$\$ = \frac{3 \times 10^{-3}}{0.007}$ **(+0.5)**

= 43¢.

Reference(s)

1. GA Technologies: Syllabus and Triga Training Manual, GA Technologies, Inc., pp. 6-17f.
2. University of Arizona: "General Information on the University of Arizona Triga Reactor," NE 420, p. 1.

- Section A continued on next page -

Points Available

QUESTION A.8

Choose, by specifying a letter designation, the most correct statement from those given below. (1.0)

(a.) The unit (of measure) of the "barn" is a measure for the macroscopic neutron cross section.

(b.) Delayed neutrons have at birth a harder energy spectrum than neutrons produced from fissioning by thermal neutrons.

(c.) The microscopic cross-section for neutron interaction with a given material is a function of the isotopic composition of the material and of the energy of the neutron.

(d.) The reactor rate for neutron absorption in a given material follows a "1/(neutron flux)" variation.

ANSWER A.8

(c.). **(+1.0)**

Reference(s)

1. Generic: "Academic Program for Nuclear Power Plant Personnel," Volume I, General Physics Corporation, pp. 4-25f.

- End of Section A -

B. FEATURES OF FACILITY DESIGN (14.0)

Points Available

QUESTION B.1

Draw a sketch of a view looking down on the core showing fuel element addresses and the location of shim, safety and regulating rod. (3.0)

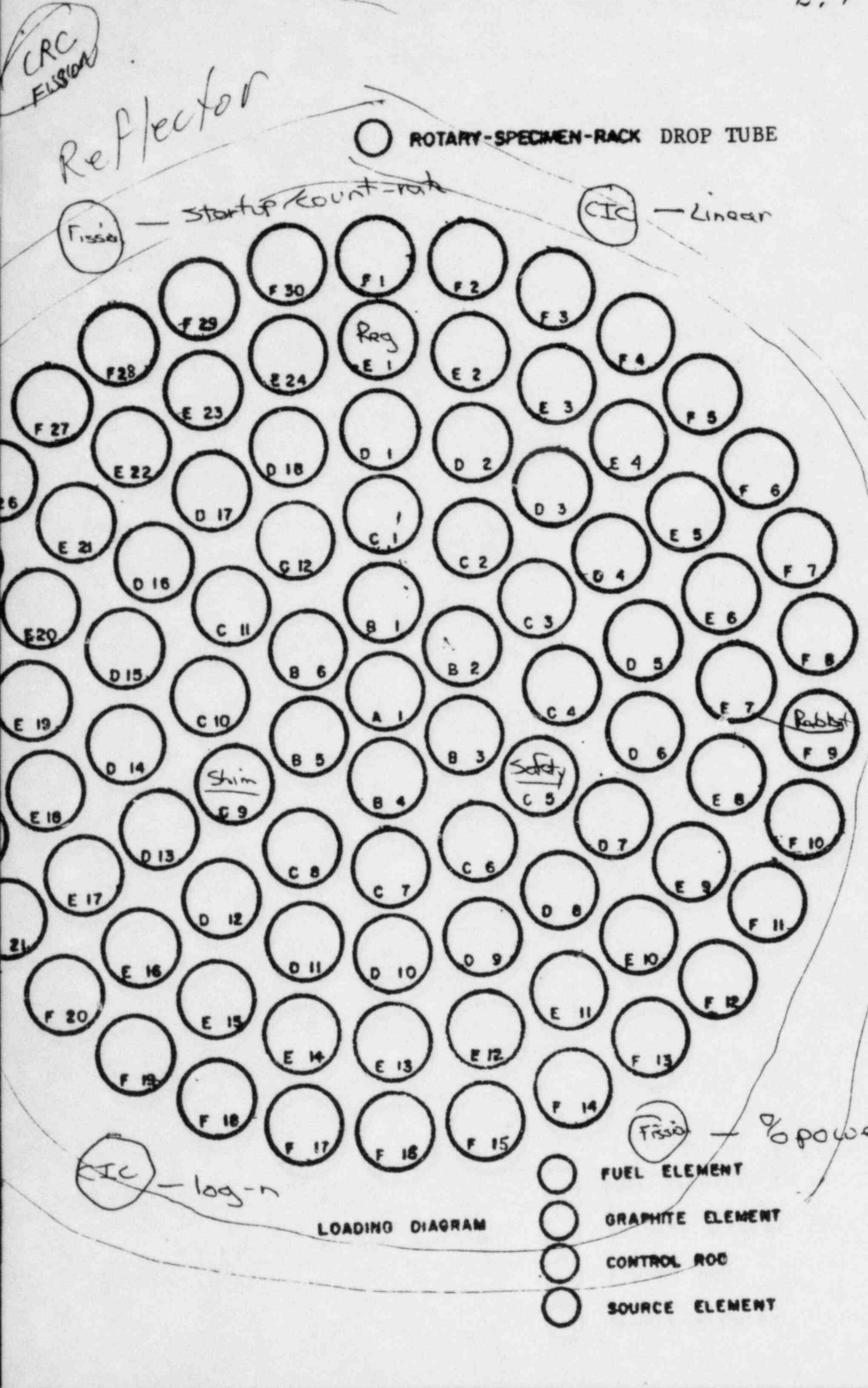
ANSWER B.1

See attached sketch.

Reference(s)

Reed SAR.

- Section B continued on next page -

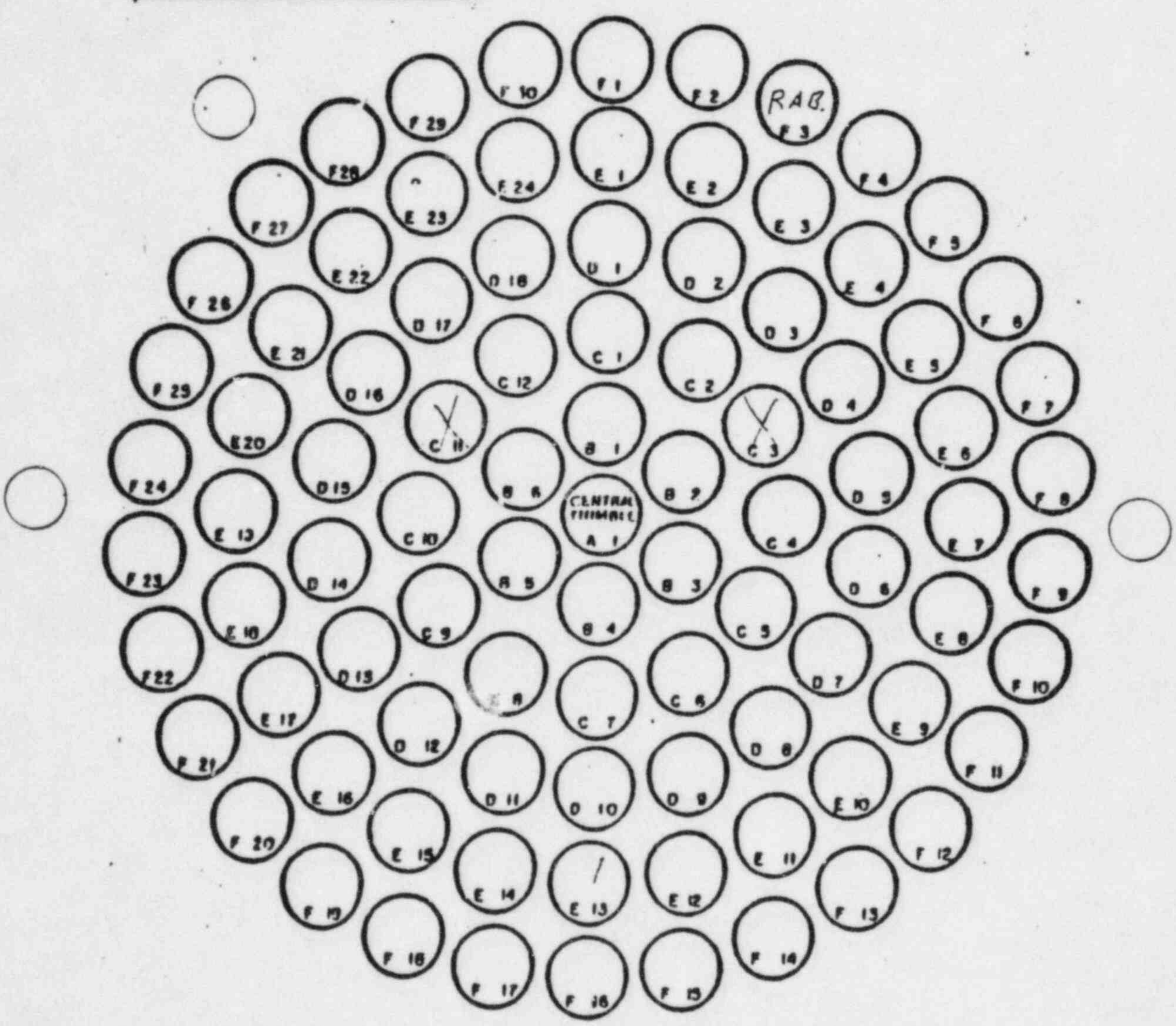

CRC FISSION
Reflector
ROTARY-SPECIMEN-RACK DROP TUBE
Fission — Startup/count-rate
CIC — Linear
F 1
F 2
F 3
F 4
F 5
F 6
F 7
F 8
F 9
F 10
F 11
F 12
F 13
F 14
F 15
F 16
F 17
F 18
F 19
F 20
F 27
F 28
F 29
F 30
Reg
E 1
E 2
E 3
E 4
E 5
E 6
E 7
Rabbit
E 8
E 9
E 10
E 11
E 12
E 13
E 14
E 15
E 16
E 17
E 18
E 19
E20
E 21
E 22
E 23
E 24
D 1
D 2
D 3
D 4
D 5
D 6
D 7
D 8
D 9
D 10
D 11
D 12
D 13
D 14
D 15
D 16
D 17
D 18
C 1
C 2
C 3
C 4
Safety
C 5
C 6
C 7
C 8
Shim
C 9
C 10
C 11
C 12
B 1
B 2
B 3
B 4
B 5
B 6
A 1
Fission — % power
CIC — log-n
FUEL ELEMENT
GRAPHITE ELEMENT
CONTROL ROD
SOURCE ELEMENT
LOADING DIAGRAM

Points Available

Sketch for Question B.1

Type of Control Rod	Control Rod Location Steady-State Reactors
Regulating	E-13
Shim	C-3
Safety	C-11

ROTARY-SPECIMEN-RACK DRIVE SHAFT



- Section B continued on next page -

Points Available

QUESTION B.2

Which one of the following statements about the Rabbit System is correct? (1.0)

a. This system is used to convey the Rabbit to a central core location of maximum flux.

b. There is no contact with the reactor coolant; therefore, flooding is impossible.

c. The Rabbit is a hollow plastic cylinder containing about 50 g of cadmium to insure it will never insert positive reactivity.

d. Argon gas is used to operate the Rabbit in order to minimize corrosion in the tube.

ANSWER B.2

b.

Reference(s)

SOP-51.

- Section B continued on next page -

Points
Available

QUESTION B.3

A portion of the oxygen in the pool water is activated to nitrogen-16 by a fast neutron reaction as the water passes upward through the core. What design feature helps reduce the dose rate at the top of the pool from N-16? (2.0)

ANSWER B.3

Downward slanted discharge of water into the tank through a diffuser nozzle.

Reference(s)

Reed SAR, pp. 7-8.

- Section B continued on next page -

Points Available

QUESTION B.4

The Reed Reactor Ventilation System is shown in the figure attached. List the position (status) only of dampers 10, 11, 12, 13, 14, 15, 16 and 17 during isolation operation. (3.0)

ANSWER B.4

See attached figure.

(0.4 ea) (3.0 max)

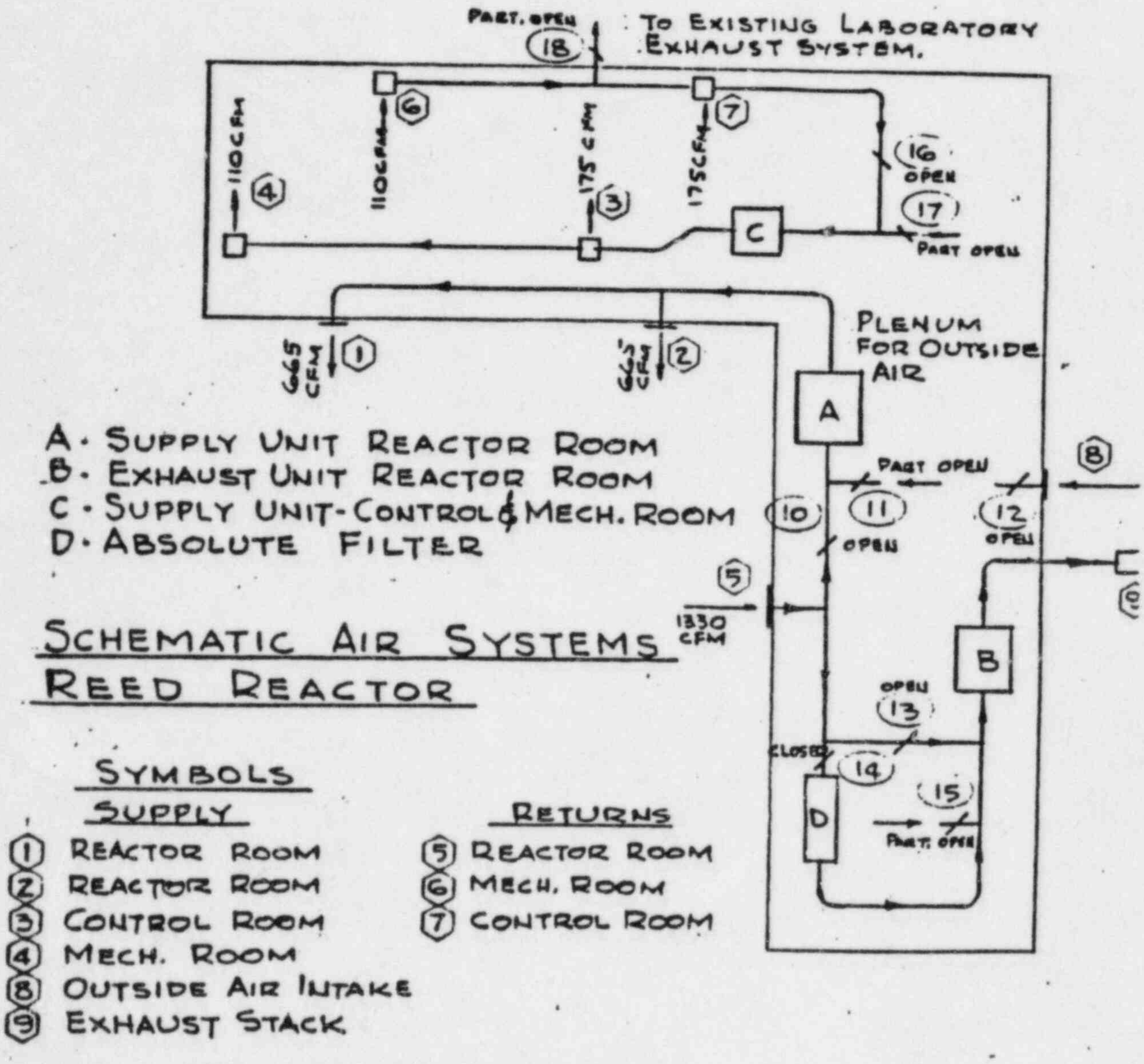
Reference(s)

SAR, pp. 4-7.

- Section B continued on next page -

Points
Available

Figure for Question B.4

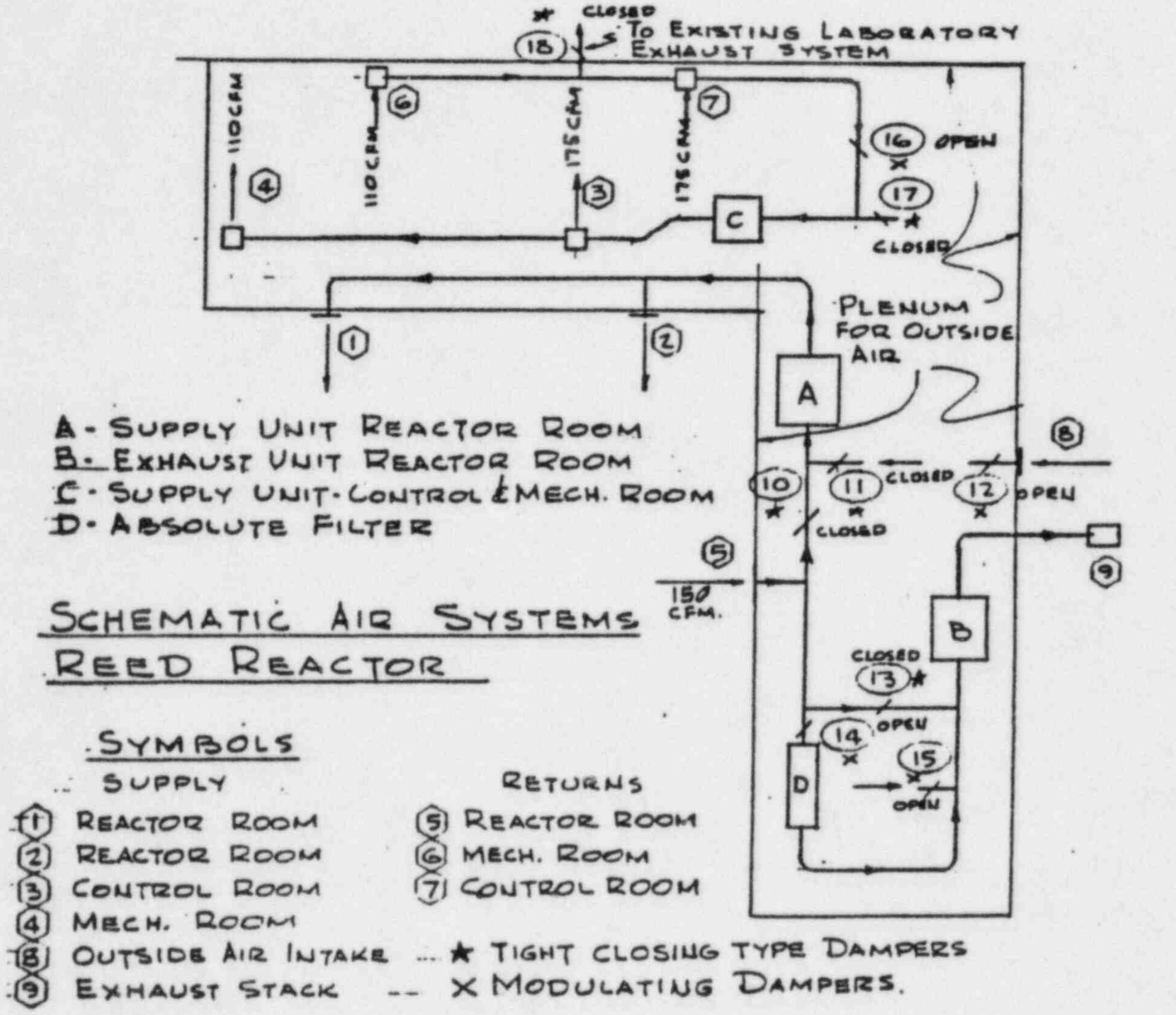


NORMAL HEATING & VENTILATING CYCLE

- Section B continued on next page -

Points
Available

Figure for Answer B.4



ISOLATION OPERATING CYCLE

SUPPLY UNIT A SHUT DOWN, SUPPLY UNIT C AND EXHAUST FAN B OPERATING, DAMPER (18) CLOSED TO LABORATORY AREA. DAMPERS (10) (11) (13) (17) CLOSED. DAMPERS (12) (14) (15) (16) OPEN. 150 CFM OF AIR EXHAUSTED THROUGH RETURN GRILLE 5, DAMPERS (14)(15) OPEN AND POSITIONED TO ALLOW ALL OF THIS EXHAUST AIR FROM REACTOR ROOM TO GO THROUGH THE ABSOLUTE FILTER D, DAMPER(15) PARTIALLY OPEN TO PLENUM TO MAKE UP FULL CAPACITY OF EXHAUST UNIT B AND EXHAUSTING THROUGH EXHAUST STACK 9. A SLIGHT NEGATIVE PRESSURE IS TO BE MAINTAINED IN REACTOR ROOM. ALL DAMPERS ARE OF THE POSITIVE SHUT-OFF TYPE AND ARE TO BE OPERATED BY PNEUMATIC DAMPER OPERATORS.

- Section B continued on next page -

Points Available

QUESTION B.5

Explain how the pool water is prevented from mixing with the secondary water during reactor operation if a leak should occur in the heat exchanger. (2.0)

ANSWER B.5

Secondary side is maintained at higher pressure during operation.

Reference(s)

SAR 5.2.6.

- Section B continued on next page -

Points Available

QUESTION B.6

List the five (5) functions of the Reactor Cooling and Purification System. (3.0)

ANSWER B.6

1. Maintains low conductivity of the water to minimize corrosion of all reactor components, particularly the fuel elements.

2. Reduces radioactivity in the water by removing nearly all particulate and soluble impurities.

3. Maintains the optical clarity of the water.

4. Provides a means of dissipating the heat generated in the reactor.

5. Reduces the radiation level due to nitrogen-16 at the top of the reactor because the vertical convective core water currents are deflected by the downward slanted discharge of water through a diffuser nozzle on the water system tank inlet. **(+0.6 ea)**

Reference(s)

Reed SAR 5.2.6, pp. 5-7.

- Section B continued on next page -

Points Available

QUESTION B.7

Explain the purpose of the graphite plugs at the top and bottom of the fuel-moderator elements. (2.0)

ANSWER B.7

Provide top and bottom reflector for each element.

Reference(s)

Reed SAR 5.2.2.

- End of Section B -

C. GENERAL OPERATING CHARACTERISTICS (14.0)

Points Available

QUESTION C.1

After a long period of full power operation a scram occurs.

a. What would you expect to see while monitoring the nuclear instrumentation for the first five (5) minutes? Explain. (2.0)

b. What difficulties would you expect associated with a reactor startup eight (8) to twelve (12) hours after the scram? Explain. (2.0)

ANSWER C.1

a. Prompt drop followed by an ~80 second negative period.

b. Xenon will peak, then decay adding positive reactivity over the next sixty (60) to seventy (70) hours.

Reference(s)

Stephenson, R., McGraw Hill.

- Section C continued on next page -

Points Available

QUESTION C.2

If the Reed Reactor is critical at one (1) watt and power is increasing on a constant ten (10) second period, how long will it take the reactor to reach a power level of four-hundred (400) watts? Show work. (2.0)

ANSWER C.2

$P_{(final)} = P_{(initial)} e^{t/TAU}$ TAU = 10 Sec

$(400) = (1 \text{ watt}) e^{t/TAU}$

$\ln 400 = t/10 \text{ sec}$

$t = 10 \ln 400$

$t = 10 \times 5.99$

$= 59.9 \text{ seconds}$

Reference(s)

Stephenson, R., McGraw-Hill.

- Section C continued on next page -

Points Available

QUESTION C.3

What is the maximum excess reactivity allowed by the Reed Operating License (including) experiments. (1.5)

ANSWER C.3

2.25% $\Delta k/k$ ($3.00)

Reference(s)

Reed SAR, p. 1-1.

QUESTION C.4

What is the maximum steady state thermal power level allowable by the technical specifications? (1.5)

ANSWER C.4

250 kW.

Reference(s)

Reed SAR, p. 1-1.

- Section C continued on next page -

Points Available

QUESTION C.5

The regulating rod is worth about (1.0)

a. $2.73
b. $3.73
c. $1.33
d. $1.73.

ANSWER C.5

d.

Reference(s)

Reed SAR 5.2.7, p. 5-8.

QUESTION C.6

If the reactivity addition rate of a regulating rod is adjusted as per the technical specifications, how long would it take to insert one (1) dollars worth (~0.7% $\Delta k/k$) of reactivity? Select one. (1.0)

a. 5 seconds
b. 7 seconds
c. 15 seconds
d. 1 minute

ANSWER C.6

b. ACCEPT EITHER a. OR b. DEPENDING ON WHETHER THEY USE .007 OR .0075 FOR β

Reference(s)

Reed SAR 5.2.7, p. 5-8.

- Section C continued on next page -

Points Available

QUESTION C.7

Describe the LAZY SUSAN system. Include in the discussion how specimens are loaded and unloaded. (3.0)

ANSWER C.7

A rotary specimen rack, **located in a well in the top of the graphite reflector**, provides for the large-scale production of radioisotopes and for the activation and irradiation of small specimens in a dry atmosphere. All **40 positions** in this rack are exposed to neutron fluxes of comparable intensity. **(+1.0)** Samples are loaded from the top of the reactor through a water-tight tube into the rotary rack using a specimen lifting device (essentially a fishing pole with a grapple mechanism on the end of a power cord). (+1.0) [The rotary rack can be turned manually or by using a motor drive at the top of the reactor.] [+1.0]

Reference(s) SAMPLES LOADED BY DROPPING

Reed SAR 5.2.5, pp. 5-5/7.

- End of Section C -

D. INSTRUMENTS AND CONTROLS (14.0)

Points Available

QUESTION D.1

Explain the functions of the upper and lower limit switches on each of the rod assemblies. (3.0)

ANSWER D.1

Show:

1. When magnet is in up position.
2. When magnet is in down position.
3. When magnet is in contact with control rod armature.

Limit upper and lower travel.

Reference(s)

Reed SAR 5.2.8, pp. 5-11.

QUESTION D.2

Explain what type of detector is used for the count-rate channel. (1.0)

ANSWER D.2

Fission chamber.

Reference(s)

Reed SAR 5.3.2, pp. 5-14.

- Section D continued on next page -

Points Available

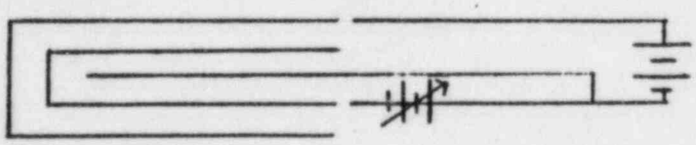
QUESTION D.3

a. How and why is gamma radiation compensated for in a compensated ion chamber (CIC)? (3.0)

b. How would the output of a CIC be affected if it was significantly under-compensated? (2.0)

ANSWER D.3

a. Neutron countrate is sensed in the outer can by interaction with boron paint. Gamma radiation is sensed in both the outer can and inner can. The lack of boron paint in the inner can causes only gamma interations to take place. A compensating voltage is applied to the inner can to exactly balance the gamma current being sensed in the outer can:



b. At low powers and for extended periods after shutdown, the detector output would read high. At ~~low~~ High powers the effect would not be noticeable because the gamma flux is proportional to power and is overwhelmed by the neutron flux.

Reference(s)

G.A. Triga Training Manual 2.5.2, pp. 2-39/40.

- Section D continued on next page -

Points Available

QUESTION D.4

List six (6) functions that scram the reactor. (3.0)

ANSWER D.4

1. Power level channel, compensated ion chamber, micromicroammeter.
2. Power level channel, ion chamber, adjustable by operator, from 20 to 110% of full power.
3. Reactor period channel, adjustable period scram between ∞ and +3 sec.
4. Manual.
5. Ion-chamber power supply failure.
6. Console power circuit failure.

Reference(s)

Reed SAR 5.3.4, pp. 5-16.

- Section D continued on next page -

Points Available

QUESTION D.5

Describe the control rod inhibits at the reed reactor. (2.0)

ANSWER D.5

Interlocks are provided to:

1. Assure minimum source strength before control rods can be withdrawn.

2. Prevent withdrawal of two control rods simultaneously on manual control.

Reference(s)

Reed SAR 5.3.4, pp. 5-16.

- End of Section D -

E. SAFETY AND EMERGENCY SYSTEMS (14.0)

QUESTION E.1

List the location of the buttons for manually activating the evacuation alarm. (2.0)

ANSWER E.1

One each in the Reactor Room and the Console Room.

Reference(s)

1. Reed Emergency Plan, p. 2.

QUESTION E.2

Answer the following TRUE or FALSE. An amber failsafe light and a red alarm light for the continuous air monitor are located on the cam and on the console. (0.5)

ANSWER E.2

False.

Reference(s)

1. Reed Emergency Plan, p. 2.

- Section E continued on next page -

Points Available

QUESTION E.3

The following statement is from the Tech-Specs. "The reactor, with fixed experiments in place, shall be considered to be shut-down (not in operation) whenever all of the following conditions have been met: (a) ...; (b) ...; (c) ..." Provide these three (3) conditions. (3.0)

ANSWER E.3

"(a) the console key switch is in the "off" position and the key is removed from the console and under the control of a licensed operator (or stored in a locked storage area);

(b) sufficient control rods are inserted so as to assure the reactor is subcritical by a margin greater than 0.7% $\Delta k/k$ cold, without xenon;

(c) no work is in progress involving fuel handling or refueling operations or maintenance of its control mechanisms."

(+1.0 each)

Reference(s)

1. Reed: Technical Specifications for the Reed College Triga Mark I Reactor, July 2, 1968, p. 1.

- Section E continued on next page -

Points Available

QUESTION E.4

Provide a description of the operation of the following instruments.

a. Pencil dosimeter
b. Film badge
c. Cutie pie

Specify the type of radiation for which each instrument is designed to monitor (3.0)

ANSWER E.4

a. The pocket dosimeter used at the Reed Reactor Facility is direct reading and operates on the principle of the gold-leaf electroscope. The detection system consists of a small quartz-fiber electroscope, which forms part of the collecting electrode. The instrument case, which is insulated from the fiber system, serves as the other electrode. The collection volume is small (2 cm^3) and most often contains air at ambient pressure. The quartz fiber is displaced electrostatically by charging it to a potential of about 200 volts. By adjusting the voltage on the charger, we can bring the image to zero-scale reading. The scale may be measured in terms of image movement. The light for viewing enters through a window at the end of the device. An image of the fiber is focused on the scale and is viewed through a lens at the other end of the instrument. Exposure of the dosimeter to radiation discharges the fiber, thereby allowing it to return to its original position. The amount discharged, and consequently the change in position of the fiber, is proportional to the radiation exposure. (Commonly-used direct reading dosimeters that are commercially availably have a range of 0-200 mR, and read within about 15% of the true exposure for gamma-ray energies from about 50 keV to 2 MeV.) **(+1.0)**

- Question E.4 continued on next page -

Points Available

b. Film badge dosimetry is based on the fact that ionizing radiation exposes the silver halide in the photographic emulsion, which results in a darkening of the film. The degree of darkening, which is called the optical density of the film, can be precisely measured with a photoelectric densitometer whose reading is expressed as the logarithm of the intensity of the light transmitted through the film. A typical film badge consists of a packet of dental-sized film wrapped in light-tight paper and worn in a suitable plastic or metal container. The film for X and gamma-radiation includes a sensitive emulsion and a relative insensitive emulsion. Such a film pack is useful over an exposure range of about 10 mR to about 1800 R of gamma rays. The film is also sensitive to beta-radiation if the beta energy exceeds 400 keV. **(+1.0)**

c. For beta and gamma radiation levels of between 5 mrem/hr and 500 mrem/hr, ionization chambers are generally used for both detection and measurement. A commonly used instrument is called the cutie pie meter. An ionization chamber is a gas-filled detector that is operating in the Ionization Region. Such detectors are accurate but low in sensitivity. **(+1.0)**

Reference(s)

1. Reed: Reed Training Document, Technical Education Research Center-Southwest, "Nuclear Technology," pp. 2-38f.

- Section E continued on next page -

Points Available

QUESTION E.5

Specify the letter designation of the most correct statement from those listed below.

(a.) Maintenance work cannot be carried out on more than two rods at a time.

(b.) The core excess shall be measured and recorded in the Log Book after any change which might affect reactivity.

(c.) All unexplained scrams must be reported to a Senior Reactor Operator.

(d.) The pressure of the lake water in the secondary water system of the heat exchanger must at all times be less than the pressure of the reactor pool water in the heat exchanger.

ANSWER E.5

(b.). **(+1.0)**

Reference(s)

1. Reed College Reactor Facility, Administrative Procedures, pp. 2-74f.

- Section E continued on next page -

Points Available

QUESTION E.6

a. What two (2) conditions will automatically isolate the ventilation systems? (2.0)

b. On isolation, which of the following will occur?

1. Fan A starts, damper 13 and 14 close
2. Fan A shuts down, damper 11 and 15 open
3. Fan A starts, damper 13 and 11 close
4. Fan A shuts down, damper 13 and 11 close (1.0)

ANSWER E.6

a. (1.) The radioactivity in the control room exceeds the alarm setpoint of the CAM. (2.) The radioactivity of the air purged through the exhaust stack of the ventilation system exceeds the trip point of the gaseous stack monitor.

b. #4.

Reference(s)

1. Reed: Reed SOP - 65.1, 65.5.

- Section E continued on next page -

Points Available

QUESTION E.7

The reactor cannot be operated if the compressor is not operable. Why? (1.5)

ANSWER E.7

A low line pressure can render the dampers useless which put the ventilation system in isolation.

Reference(s)

1. Reed: Reed SOP 1.5.

- End of Section E -

F. STANDARD AND EMERGENCY OPERATING PROCEDURES (14.0)

Points Available

QUESTION F.1

List six (6) of the eight (8) Reed facility emergency signals and alarms, their location and their meaning. (3.0)

Example

Name	Location	Meaning of Alarm
1. Security alarm	Bell on south wall of Reactor Room	Possible illegal entry into the facility

ANSWER F.1

EMERGENCY SIGNALS AND ALARMS

Name	Location	Meaning of Alarm
1. Radiation Area Monitor (RAM)	NW corner of pool	Source of high radiation near the reactor pool
2. Continuous Air Monitor (CAM)	East side of reactor room	Air above pool contains excessive amount of [illegible]activity
3. Stack Monitors Gaseous Particulate	Console room	Air leaving the reactor room contains excessive radioactivity
4. Hi/Low Water Alarm	Lights in west hall and on roof	Water in pool has dropped 4 in. below normal
5. Evacuate Alarm	Siren in reactor room Light in Radiochem Lab	Manually operated from console or reactor room
6. Security Alarm	Bell on south wall of reactor room	Possible illegal entry into the facility
7. Secondary Water	High-pitched alarm in reactor room	Secondary water pressure is low, pump is on
8. Secondary Water Pump Motor	Green light on south wall of reactor room	Not an alarm; may be on or off

Reference(s)

Reed Emergency Plan.

- Section F continued on next page -

Points Available

QUESTION F.2

Information associated with wipe tests is to be recorded in the Health Physics Log Book in a five-column format. List the headings of these five (5) columns. (2.5)

ANSWER F.2

1. Wipe position
2. Count length (min)
3. Counts
4. Gross CPM
5. Contaminated?

Reference(s)

SOP-02.

QUESTION F.3

Explain why it is required that the reactor control be placed in the automatic mode when reactor power is greater than 90%. (2.0)

ANSWER F.3

Because of frequent and unexpected power fluctuations.

Reference(s)

SOP-04.

- Section F continued on next page -

Points Available

QUESTION F.4

List three (3) of the five (5) conditions that would be considered to be major contamination. (3.0)

ANSWER F.4

1. Any area showing a greater than 1000 times background count rate when a wipe test is taken.

2. The rupture of a fuel element.

3. Any accident involving unsealed sources of alpha particles.

4. The venting or rupturing of an experiment involving fission products.

5. Any contamination requiring notification of the NRC. this includes contamination which

   a. results in the release of radioactive material in excess of the standards set forth in Appendix B of 10 CFR 20

   b. results in the loss of one working day to the facility

   c. results in damage to the facility of greater than $2000.

Reference(s)

SOP-19, p. 19.9.

- Section F continued on next page -

Points Available

QUESTION F.5

The problem log is maintained in a three-column format. Explain what information is contained in these three (3) columns. (1.5)

ANSWER F.5

a. Date
b. Problem description
c. Page number indicating location of detailed information

Reference(s)

SOP-11.

QUESTION F.6

Explain how rod drop time is measured. (2.0)

ANSWER F.6

This is a visual test of the rod drop times. One operator remains at the console while two other timers position themselves in the console room so that they can see the control rod lights. The operator raises one, and only one, rod to its maximum height. The other two control rods are to remain fully inserted into the core. The console operator then manually scrams the rod; the timers start their watches when the yellow magnet goes off and stop their watches when the blue "cont" light goes off. The yellow light indicates that the rod has been released, the blue "cont" light indicates when the rod down switch has been closed indicating that the rod is fully back into the core. The times for each rod should be averaged. Then the procedure should be repeated for the other two rods, one at a time.

Reference(s)

SOP-42.

- End of Section F -

G. RADIATION CONTROL AND SAFETY (14.0)

Points Available

QUESTION G.1

A target has been irradiated in the Triga Reactor in the Lazy Susan.

a. You anticipate that the target contains only one stable isotope of one low-Z element that has undergone a neutron absorption [an (n,γ) reaction]; you anticipate that the radioactive decay of the resulting radioactive isotope is a one-step decay to a new stable isotope. What type(s) of emissions would you anticipate would come from the radioactive target after it is removed from the reactor? Justify your answer. (2.0)

b. If, after you have removed the target from the reactor, you record over a period of time the countrate from from a detector placed next to this target, how would you determine the half-life of the radioactivity. (2.0)

ANSWER G.1

a. If a stable isotope of an element absorbs a neutron, it will form a new isotope that is above the line of stability. **(+1.0)** Isotopes of low-Z materials which are above this "line" usually decay toward the "line" by β^- emission. Such β^- emissions may be preceded by or may include the emission of one or several γs. **(+1.0)**

- Answer G-1 continued on next page -

Points
Available

b. The radioactive decay of a single radioactive isotope will follow the exponential decay law.

$$A_1 = A_o e^{-\lambda t_1} \qquad \textbf{(+0.5)}$$

$$A_2 = A_o e^{-\lambda t_2}$$

$$\frac{A_1}{A_2} = e^{-\lambda(t_1 - t_2)}$$

$$\ln A_1 - \ln A_2 = -\lambda(t_1 - t_2)$$

$$\lambda = \frac{\ln A_1 - \ln A_2}{t_1 - t_2} \qquad \textbf{(+2.0)}$$

then,

$$t_{1/2} = \frac{.693}{\lambda} .$$

Graphically, you can plot ln A(t) versus t and the slope of the graph is $-\lambda$. **(+2.0)**

(+2.0 max)

Reference(s)

1. Reed: Reed Training Document, Technical Education Research Center-Southwest, pp. 1-7 to 1-12.

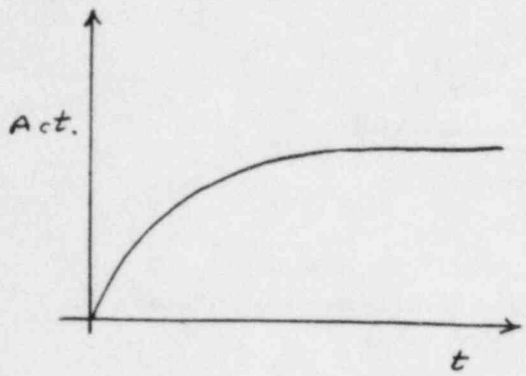
- Section G continued on next page -

Points Available

QUESTION G.2

If the target of Question G.1 had been placed in the Triga Reactor and the reactor brought to 100% of full power, sketch the activity of the target as a function of time. (2.0)

ANSWER G.2



$$A = \Sigma\Phi(1-e^{-\lambda t})$$

(+2.0 for shape or equation)

Reference(s)

1. Reed: Reed Training Document, Technical Education Researcn Center-Southwest, pp. 1-15.

- Section G continued on next page -

Points Available

QUESTION G.3

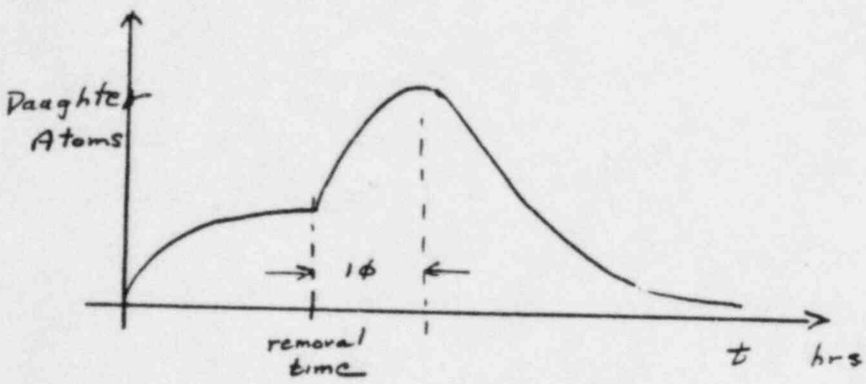
If the target of Question G.1 had produced the following:

- a single radioactive isotope from the (n,λ) reaction
- a half-life for the n-produced isotope of 10 min
- a radioactive daughter from the n-produced isotope
- a half-life for the daughter of 10-hr,

then, after the target is taken out of the reactor, how does the concentration of daughter atoms vary with time? (2.0)

ANSWER G.3

The situation within this target is essentially the same as that of Xe-135 concentration within the reactor after a trip. Hence



(+2.0 for shape)

Reference(s)

1. Reed: Reed Training Document, Technical Education Research Center-Southwest, pp. 1-12, 12-7-22, 23, 24, 25.

- Section G continued on next page -

Points Available

QUESTION G.4

If two centimeters of lead placed at a certain location in a beam of gamma rays would reduce the gamma radiation level from 100 mR/hr to 50 mR/hr, what thickness of lead placed in this beam would reduce the gamma radiation level from

a. 400 mR/hr to 50 mR/hr (0.5)
b. 50 mR/hr to 25 mR/hr? (0.5)

ANSWER G.4

a. 6 cm **(+0.5)**
b. 2 cm **(+0.5)**

Reference(s)

Reed: Reed Training Document, Technical Education Research Center-Southwest, pp. 1-24, 1-25, 2-1, 2-2.

QUESTION G.5

If the gamma-ray radiation level from a pump (point source) had been 30 mR/hr 1 foot from the pump, what would be the radiation level 10 feet from the pump? (1.0)

ANSWER G.5

Neglecting gamma-ray absorption by the air,

distance factor = $\left(\frac{10}{1}\right)^2 = \frac{1}{100}$ **(+0.5)**

rad level (10) = rad level (1)/100

= 0.30 mR/hr. **(+0.5)**

Reference(s)

1. Generic: Nuclear Energy Training, Module 5, "Radiation Protection," pp. 3.3-1 to 3.3-4.

- Section G continued on next page -

Points Available

QUESTION G.6

If a man had been exposed to 0.01 R gamma radiation, 0.04 rad of beta radiation and 0.02 rad of fast neutrons, what is his total biological dose in rems? Show your work. (2.0)

ANSWER G.6

0.01 R of gamma	x 1 QF	=	0.01	rem
0.04 rad of beta	x 1 QF	=	0.04	rem
0.02 rad of fast react	x 10 QF	=	0.20	rem
	Total dose	=	0.25	rem

(+0.25 for dose equation, +2.0 for answer, +2.0 max)

Reference(s)

1. Generic: Nuclear Energy Training, Module 5, "Radiation Protection," pp. 2.1-1 to 2.1-3.

2. Reed: Reed Training Document, Technical Education Research Center-Southwest, pp. 2-3.

QUESTION G.07

Explain the procedures to be used at the Reed Triga facility to prepare radioactive material for shipment. (2.0)

ANSWER G.7

The essence of SOP-52 (Radioactive Materials Transfer) will be accepted for an answer. **(+2.0)**

Reference(s)

1. Reed: SOP-52, "Radioactive Materials Transfer."

- Section G continued on next page -

G.7 RADIOACTIVE MATERIALS TRANSFER: sop52

52.1 PURPOSE:
To comply with Federal and State Regulations requiring RRF to keep track of all radioactive materials leaving the reactor facility such as irradiated samples, produced isotopes, and sources of all types.

52.2 FREQUENCY:
Whenever any radioactive materials are shipped or removed from RRF or transferred to the Reed College licence.

52.3 SPECIAL EQUIPMENT:
Two RADIOACTIVE MATERIALS TRANSFER forms separated by a sheet of carbon paper.
A completed IR form (for irradiated samples).
A portable GM monitor.
The low background GM counter.
One Kimwipe
Methanol

52.4 PERSONNEL:
One RRF staff member.
The person(s) removing/shipping the radioactive materials.
(These may and have, at times, been one and the same)

52.5 PRELIMINARY ACTIONS:
Set up the low background counter in the reactor room and start a five minute background count.

52.6 PROCEDURE:
Fill out the first two sections of the RADIOACTIVE MATERIALS TRANSFER form obtaining the transfer number by adding one to the latest transfer number posted on the blackboard. Check the appropriate box for materials shipped or removed (materials removed are those taken away by the experimenters themselves rather than being shipped via a public carrier. Indicate the means of transport used in the box provided ie. private auto, UPS, etc. The recipients license number must be found on a copy of their current licence in the console room file cabinet. No material shall be released without a copy of the recipient's licence on file. Indicate the general type of material being transferred, whether geological samples, physiological saline, etc. and the estimated activity in millicuries.

Before packaging, monitor the material itself at one foot from its surface with the GM portable monitor and record this reading on the transfer form. After packaging, monitor the package at its surface and at one meter from its surface. Next, moisten a Kimwipe with methanol and wipe a representative area,usually a bottom edge and corner and the top and closure of the container and place the kimwipe in the low background counter for a one minute count and determine the net beta-gamma counts above back- ground, record all of this monitoring information on the trandsfer form and applicable parts in the appropriate blanks of the IR form. In the blank for remarks record the type of packaging, la-

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belling, and any other useful information about the package and shipping procedure. See the appendix to this sop and the Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials to be found on file in the console room under "shipping information" for further information.

52.7 ADJUSTMENTS:
Insure that all labelling on the packages to be shipped or removed is correct and that the materials are not in violation of the applicable state and/or federal regulations by adding more shielding or packaging, or by breaking a large shipment up into smaller ones.

52.8 CLEANUP:
Check to see that all blanks have been filled in and that all signatures have been obtained on the transfer form and IR form. Make sure the package has a seal such as tape or wire. Give the carbon of the transfer form and the orange sheet of the IR to the experimenter/shipper with the materials involved and file the originals in the console room filing cabinet. Turn off the low background counter and the portable monitors.

52.9 LOGGING IN:
Log the shipment in the console log book and update the "latest transfer" number on the blackboard.

52.10 APPENDIX:
Useful information from the Summary of Federal Regulations for Packaging and Transportation of Radioactive Materials:

I. Removable contamination is considered insignificant if the net beta-gamma count is < 2,200 dps/100sq.cm.

II. Labelling:

A. white radioactive I label:	< 0.5 mR/hr at surface
B. yellow radioactive II label:	< 10 mR/hr at surface < 0.5 mR/hr at 1 meter or Transport Index < 0.5
C. yellow radioactive III label:	> 10 mR/Hr fissile class III see Federal Regs.

III. Packaging:
Package must have a seal over opening to ensure contents arrive undisturbed ie. tape or lead wire.
No dimension of the package may be less than 4" for shipping by public carrier.
No package may read > 200 mR/hr at its surface or > 10 mR/hr at 1 meter for postal shipping.

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END OF EXAMINATION

EQUATION SHEET

Where $\dot{m}_1 = \dot{m}_2$

$(density)_1(velocity)_1(area)_1 = (density)_2(velocity)_2(area)_2$

$KE = \frac{mv^2}{2}$ $PE = mgh$ $PE_1+KE_1+P_1V_1 = PE_2+KE_2+P_2V_2$ where V = specific volume, P = Pressure

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$Q = \dot{m}c_p(T_{out}-T_{in})$ $Q = UA\ (T_{ave}-T_{stm})$ $Q = \dot{m}(h_1-h_2)$

$P = P_o 10^{(SUR)(t)}$ $P = P_o e^{t/T}$ $SUR = \frac{26.06}{T}$ $T = 1/\text{Delta k}$

$\text{delta K} = (K_{eff}-1)/K_{eff}$ $CR_1(1-K_{eff1}) = CR_2(1-K_{eff2})$ $CR = S/(1-K_{eff})$

$M = \frac{(1-K_{eff1})}{(1-K_{eff2})}$ $SDM = \frac{(1-K_{eff}) \times 100\%}{K_{eff}}$

$\text{decay constant} = \frac{\ln(2)}{t_{1/2}} = \frac{0.693}{t_{1/2}}$ $A_1 = A_o e^{-(\text{decay constant})x(t)}$

Water Parameters

1 gallon = 8.345 lbs
1 gallon = 3.78 liters

1 ft^3 = 7.48 gallons

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 psia = 29.9 in Hg

Miscellaneous Conversions

1 Curie = 3.7 x 10^{10} dps
1 kg = 2.21 lbs

1 hp = 2.54 x 10^3 Btu/hr

1 MW = 3.41 x 10^6 Btu/hr
1 Btu = 778 ft-lbf

Degrees F = (1.8 x Degrees C) + 32
1 inch = 2.54 centimeters
g = 32.174 ft-lbm/lbf-sec^2
