April 21, 1988

Docket No. 50-288

Reed College
Portland, Oregon 97202

Attention: Dr. Paul Bragdon, President

Gentlemen:

SUBJECT: FXAMINATION REPORT

On March 25, 1988 the NRC administered a first retake examination to a member of your college who had applied for a license to operate your Reed Reactor Facility. At the conclusion of the examination on March 25, 1988, the examination process and associated licensing issues were discussed with those members of your staff identified in the enclosed report.

In accordance with 10 CFR 2.790(a), a copy of this letter and enclosures (1) and (2) will be placed in the NRC's Public Document Room. The results for the individual applicant are exempt from disclosure by 10 CFR 2.790(a)(6). Therefore, enclosure (3) will not placed the NRC's Public Document Room.

Should you have any questions concerning this examination, please contact Mr. Thomas Meadows at (415) 943-3867.

Sincerely,

/S/

Robert J. Pate, Chief
Operations Branch

Enclosures:
1. Examination Report No. 50-288/OL-88-01
2. Examinations and Answer Keys (SRO/RO)
3. Grade Summary Report

IE42
1/1

cc w/enclosures (1), (2) and (3):
Larry Ruby, Director, Reed Reactor Facility

cc w/enclosure (3) only:
Janet Lanning, Management Assistant, NRR/LOLB

cc w/enclosure (1) only:
J. Hannon, Branch Chief, OLB
J. Martin, RV
D. Kirsch, RV
R. Pate, RV
J. Elin, RV
T. Meadows, RV
H. Berkow, NRR/PDSNP
C. Thomas, NRR/PDISA
H. North, RV
M. Cillis, RV
R. Cross, RV (2 copies)

cc w/enclosures (1) and (2) only:
RSB/Document Control Desk (RIDS)

RV/jk

REQUEST COPY	REQUEST COPY	REQUEST COPY
YES / NO	YES / NO	YES / NO
		SEND TO PDR
		* YES / NO

SEE ENCLOSURE INSTRUCTIONS.
X DO NOT SEND ENCLOSURE 3 TO PDR!

MEADOWS	ELIN	PATE
4/15/88	4/14/88	4/18/88

MASTER KEY

KEY

U. S. NUCLEAR REGULATORY COMMISSION
REACTOR OPERATOR LICENSE EXAMINATION

Facility: Reed (Research)

Reactor Type: TRIGA

Date Administered: 3/25/88

Examiner: Thomas R. Meadows

Candidate: ______________________

INSTRUCTIONS TO CANDIDATE

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

Category Value	% of Total	Candidate's Score	% of Cat. Value	
____	____	____	____	A. Principles of Reactor Operation
____	____	____	____	B. Features of Facility Design
____	____	____	____	C. General Operating Characteristics
____	____	____	____	D. Instruments and Controls
____	____	____	____	E. Safety and Emergency Systems
____	____	____	____	F. Standard and Emergency Operating Procedures
15	100	____	____	G. Radiation Control and Safety
15	____			Final Grade ____%

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

____
Candidate's Signature

Time Begin 8:15 AM

ATTACHMENT 1 (continued)

Enclosure 2

REQUIREMENTS FOR ADMINISTRATION OF WRITTEN EXAMINATIONS

1. A single room shall be provided for completing the written examination. The location of this room and supporting restroom facilities shall be such as to prevent contact with all other facility and/or contractor personnel during the duration of the written examination. If necessary, the facility should make arrangements for the use of a suitable room at a local school, motel, or other building. Obtaining this room is the responsibility of the licensee.

2. Minimum spacing is required to ensure examination integrity as determined by the chief examiner. Minimum spacing should be one candidate per table, with a 3-ft space between tables. No wall charts, models, and/or other training materials shall be present in the examination room.

3. Suitable arrangements shall be made by the facility if the candidates are to have lunch, coffee, or other refreshments. These arrangements shall comply with Item 1 above. These arrangements shall be reviewed by the examiner and/or proctor.

4. The facility staff shall be provided a copy of the written examination and answer key after the last candidate has completed and handed in his written examination. The facility staff shall then have five working days to provide formal written comments with supporting documentation on the examination and answer key to the chief examiner or to the regional office section chief.

5. The facility licensee shall provide pads of 8-1/2 by 11 in. lined paper in unopened packages for each candidate's use in completing the examination. The examiner shall distribute these pads to the candidates. All reference material needed to complete the examination shall be furnished by the examiner. Candidates can bring pens, pencils, calculators, or slide rules into the examination room, and no other equipment or reference material shall be allowed.

6. Only black ink or dark pencils should be used for writing answers to questions.

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

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

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

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

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

6. Use only the paper provided for answers.

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

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

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

10. Skip at least three lines between each answer.

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

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

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

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

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

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

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

18. When you complete your examination, you shall:

    a. Assemble your examir on as follows:

        (1) Exam questions on top.

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

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

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

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

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

ATTACHMENT 1 (Continued)

Enclosure 3

Requirements for Facility Review of Written Examination

1. There shall be no review of the written examination by the facility staff before or during the administration of the examination. Following the administration of the written examination, the facility staff shall be provided a marked-up copy of the examination and the answer key.

2. The facility will have five (5) working days from the day of the written examination is given to provide formal comment submittal. The submittal will be made to the responsible Regional Office by the highest level of corporate management for plant operations, e.g., Vice President for Nuclear Operations. A copy of the submittal will beforwarded to the chief examiner, as appropriate. Comments not submitted within five (5) working days will be considered for inclusion in the grading process on a case by case basis by the Regional Office section leader. Should the comment submittal deadline not be met, a long delay for finalization of the examination results may occur.

3. The following format should be adhered to for submittal of specific comments:

   a. Listing of NRC Question, answer and reference.

   b. Facility comment & Evaluation

   c. Supporting documentation

NOTES:

1. No change to the examination will be made without submittal of complete, current, and approved reference material.

2. Comments made without a concise facility recommendation will not be addressed.

EQUATION SHEET

$f = ma$

$w = mg$

$E = mC^2$

$KE = \frac{1}{2}mv^2$

$PE = mgh$

$W = v\Delta P$

$\Delta E = 931\Delta m$

$\dot{Q} = \dot{m}C_p\Delta T$

$\dot{Q} = UA\Delta T$

$Pwr = W_f\,\dot{m}$

$P = P_o\,10^{SUR(t)}$

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

$SUR = 26.06/T$

$T = 1.44\ DT$

$SUR = 26\left(\frac{\lambda_{eff}\rho}{\bar{\beta} - \rho}\right)$

$T = (\ell^*/\rho) + [(\bar{\beta} - \rho)/\lambda_{eff}\rho]$

$T = \ell^*/(\rho - \bar{\beta})$

$T = (\bar{\beta} - \rho)/\lambda_{eff}\rho$

$\rho = (K_{eff}-1)/K_{eff} = \Delta K_{eff}/K_{eff}$

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

$P = \Sigma\phi V/(3 \times 10^{10})$

$\Sigma = N\sigma$

$v = s/t$

$s = v_o t + \frac{1}{2}at^2$

$a = (v_f - v_o)/t$

$v_f = v_o + at$

$\omega = \theta/t$

Cycle efficiency = $\frac{\text{Net Work (out)}}{\text{Energy (in)}}$

$A = \lambda N \qquad A = A_o e^{-\lambda t}$

$\lambda = \ln 2/t_{1/2} = 0.693/t_{1/2}$

$t_{1/2}(eff) = \frac{(t_{1/2})(t_b)}{(t_{1/2} + t_b)}$

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

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

$I = I_o\ 10^{-x/TVL}$

$TVL = 1.3/\mu$

$HVL = 0.693/\mu$

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

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

$CR_1(1 - K_{eff})_1 = CR_2(1 - K_{eff})_2$

$M = 1/(1 - K_{eff}) = CR_1/CR_0$

$M = (1 - K_{eff})_0/(1 - K_{eff})_1$

$SDM = (1 - K_{eff})/K_{eff} \approx 1 - K_{eff}$

$\ell^* = 1 \times 10^{-5}$ seconds

$\lambda_{eff} = 0.1$ seconds^{-1}

$I_1 d_1 = I_2 d_2$

$I_1 d_1^2 = I_2 d_2^2$

$R/hr = (0.5\ CE)/d^2$(meters)

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

WATER PARAMETERS

1 gal. = 8.345 lbm

1 gal. = 3.78 liters

1 ft^3 = 7.48 gal.

Density = 62.4 lbm/ft^3

Density = 1 gm/cm^3

Heat of vaporization = 970 Btu/lbm

Heat of fusion = 144 Btu/lbm

1 Atm = 14.7 psi = 29.9 in. Hg

1 ft. H_2O = 0.4335 lbf/in^2

MISCELLANEOUS CONVERSIONS

1 Curie = 3.7×10^{10} dps = 3.7×10^{10} cps

1 kg = 2.21 lbm

1 hp = 2.54×10^3 BTU/hr

1 Mw = 3.41×10^6 Btu/hr

1 Btu = 778 ft-lbf

1 inch = 2.54 cm

$^oF = 9/5\,^oC + 32$

$^oC = 5/9\,(^oF - 32)$

SECTION G

Radiation Control and Safety

*QUESTION
G.01 (3.0)

You are operating the fuel handling tool over the reactor pool during refueling operations. Your shift SRO is with you by the pool, verifying the storage spent fuel. Both of you have just started the shift (time into shift is 0 seconds). Your shift SRO is 48 years old and has a total lifetime occupational dose of 100 Rem. You are 30 years old and have not received any occupational exposure to radiation over the present calendar quarter. Due to a management error, both of you took the shift without a shift turn over, and are the only persons in the reactor building. All area radiation monitoring equipment was placed out of service by gross calibration errors last shift. The background radiation level is a steady 10 Rem/hr. The 10CFR20 whole body quarterly exposure limit is 1.25 Rem.

a. How long can you remain (in hours) on the refueling platform without exceeding your 10CFR20 whole body quarterly exposure limit? (Show all work!) (0.5 for application) (0.25 for value) (0.75)

b. What is the 10CFR20 quarterly exposure limit (Rem) for the skin of your whole body? (0.5)

c. What is the 10CFR20 quarterly exposure limit (Rem) for your hands and forearms? (0.5)

d. How much radiation (Rem) can your Shift SRO receive before exceeding his 10CFR20 lifetime limit for occupational exposure? (Show all work!) (0.75 for application) (0.25 for value) (1.0)

e. What is the name of the program required by 10CFR20, to be implemented at Reed Reactor Facility, that would not have allowed you to work in the conditions described above? (0.25)

(see next page for answer key)

*ANSWER
G.01 (3.0)

a. Application:

time = 1.25 Rem/10 Rem per hr. (0.5)

Value:
time = 0.125 (+/- .01) hours (7.5 min.) (0.25)

b. 7.5 Rem (0.5)

c. 18.75 Rem (0.5)

d. Application:

exposure limit= 5 x (N - 18) Rem (0.25)
= 5 x (48 - 18) Rem (0.25)
exposure left = 150 - 100 Rem (0.25)

Value:
exposure left = 50 (+/- 2) Rem (0.25)

e. ALARA (As Low As Reasonably Achievable) (0.25)

*REFERENCE
10 CFR 20;

*QUESTION
G.02 (1.5)

The damaging effects of ionizing radiation on tissue, at the same given energy level, varies depending on the type radiation. Therefore, a Quality Factor (QF) must be applied to a given dosage in "Rads" to determine the equivalent biological damage in "Rem". The QF for (fast) neutron radiation is 10.

a. What is the QF for gamma type radiation? (0.5)

b. What is the QF for alpha type radiation? (0.5)

c. What is the QF for beta type radiation? (0.5)

*ANSWER
G.02 (1.5)

a. 1

b. 20

c. 1

*REFERENCE
Reed Training Manual, Chapter 2, pp. 2-3;

*QUESTION
G.03 (0.75)

MULTIPLE CHOICE (Select the correct response)

Which of the following correctly describes beta type radiation?

a. Radiation that has more penetrating power than fast neutron radiation.

b. Radiation that is usually classified as having a positive charge.

c. Radiation that has less penetrating power than gamma radiation.

d. Radiation that is usually classified as having a neutral charge.

*ANSWER
G.03 (0.75)

c.

*REFERENCE
Reed Training Manual, Chapter 1, pp. 7;

*QUESTION
G.04 (0.75)

MULTIPLE CHOICE (Select the correct response)

Which of the following correctly describes alpha type radiation?

a. Radiation that has more penetrating power than fast neutron radiation.

b. Radiation that is usually classified as having a positive charge.

c. Radiation that has more penetrating power than gamma radiation.

d. Radiation that is usually classified as having a neutral charge.

*ANSWER
G.04 (0.75)

b.

*REFERENCE
Reed Training Manual, Chapter 1, pp. 16-18;

*QUESTION
G.05 (1.0)

You are assisting with an experiment in the reactor room and must work on the RAM located 5 feet from a point source. The reading at the RAM is 100 Mrem/hr. from the point source alone. The point source is moved 2 feet further away.

What is the new dose rate (Mrem/hr.) at the RAM?
(0.75 pts for application)
(0.25 pts. for value) (1.0)

*ANSWER
G.05 (1.0)

Application:

R2 = R1 (D1/D2)^2 (0.5)
R2 = 100Mrem/hr x (5/7)^2 (0.25)

Value:

R2 = 51 (+/- 1) Mrem/hr at 7 ft. (0.25)

*REFERENCE
Reed Training Manual, Chapter 2, pp. 20-28;

*QUESTION
G.06 (2.0)

You are irradiating a specimen in the Chemistry lab. The radiation source that you are using is a sample from the reactor, that is kept in a shielded container mechanism fitted with an open window. The source is transmitting a narrow beam of 0.1 Mev gamma radiation at a negligible distance from the specimen. You would like to reduce the beam's intensity by 10% using an Aluminum shield. Using the equation sheet provided with this examination, and Figure G.06 (Attached):

a. What is the thickness (cm) of the required aluminum shielding? (Show all work!)
(1.0 pts. for correct application)
(0.25 pts. for correct value) (1.25)

b. Which one(1) of the substances listed on Figure G.06 would make the most effective radiation shielding (in terms of reducing personal exposure) for 0.1 Mev gamma? (0.75)

*ANSWER
G.06 (2.0)

a. Application:

I = Io e^-ux (0.25)
.9 ~~1/10~~ = e^-(0.435 cm^-1)(x cm) (0.25)
ln~~1~~9- ln10 = ln[e^-0.435(x)] (0.25)
2.2 ~~0~~ - 2.3 = -.435x (0.25)

Value:

t = ~~5.3~~ 0.23 (+/- 0.1) cm (0.25)

b. Pb (lead) (0.75)

(relationship between density and attenuation)

*REFERENCE
Reed Training Manual, Chapter 2, pp. 20-28;

Linear Attenuation Coefficients, CM^{-1}

Quantum Energy, MeV				
	ρ, g/cm^3	0.1	0.15	0.2
C	2.25	0.335	0.301	0.274
Al	2.7	0.435	0.362	0.324
Fe	7.9	2.72	1.445	1.090
Cu	8.9	3.80	1.830	1.309
Pb	11.3	59.7	20.8	10.15
Air	1.29×10^{-3}	1.95×10^{-4}	1.73×10^{-4}	1.59×10^{-4}
H_2O	1	0.167	0.149	0.136
Concrete	2.35	0.397	0.326	0.291

FIGURE G.06

*QUESTION
G.07 (0.75)

You have counted an air sample filter that was just obtained from the Reactor room. You are using the Ludlum MODEL 177 ratemeter with the hand monitor attachment to obtain your data. To be conservative, the Reactor Director wants you to assume that all of the airborne contamination in the Reactor room is due to insoluble Iodine 131 (I-131) isotope. Using the attached Figure G.07 (10CFR20 Appendix B):

a. What is the 10CFR20 airborne contamination limit for insoluble I-131? (0.25)

b. How many hours per week working period does 10CFR20 assume for the airborne contamination limits specified on Figure G.07? (0.5)

*ANSWER
* G.07 (0.75)

a. 3 x 10^-7 uCi/ml
(from Figure G.07, 10CFR20 Appendix B Table I) (0.25)

b. 40 hours (0.5)

*REFERENCE
Reed Training Manual, Chapter 1, pp. 13-14;
10CFR20

* ALSO ACCEPT:

a. 1x10^-8 uCi/ml.
(from 10CFR20 App B, Table II) (0.25)

b. 168 hours (one week) (0.5)

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope [1]		Table I Col. 1—Air (μCi/ml)	Table I Col. 2—Water (μCi/ml)	Table II Col. 1—Air (μCi/ml)	Table II Col. 2—Water (μCi/ml)
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}
		I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}		1×10^{-7}	
	Kr 85	Sub	1×10^{-5}		3×10^{-7}	
	Kr 87	Sub	1×10^{-6}		2×10^{-8}	
	Kr 88	Sub	1×10^{-6}		2×10^{-8}	
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}

FIGURE G.07

*QUESTION
G.08 (1.5)

The types of radiation detectors can be characterized by the mode of the interaction with radiation. For example, one(1) of the two(2) types of detectors that the Ludlum Model 177 ratemeter was designed to be used with is the scintillation type. Using this type of detector the Ludlum can reach up to 100% detection efficiency for gamma radiation.

a. What is the other detector type designed to be used with the Ludlum Model 177 ratemeter? (0.5)

b. What are the other two(2) kinds of radiation that can be counted by the Ludlum? (0.5 pts. each) (1.0)

*ANSWER
G.08 (1.5)

a. Geiger-Muller (GM) (0.5)

b. 1. alpha (ALSO ACCEPT: GAMMA) (0.5)
   2. beta (0.5)

*REFERENCE
Reed Training Manual, Chapter 2, pp. 34-38;
Instruction Manual, Model 177

*QUESTION
G.09 (1.75)

Attached Figure G.09 is a drawing of the Model E-140 counter used at Reed College. The "probe connection" is usually connected to an Eberline HP-270 or HP-190 detector ("frisker") when being used for personal contamination monitoring. Notice that the "Range" switch is marked off in three(3) multipliers 1, 10, and 100, yielding 600, 6k, or 60k counts per minute (cpm) full scale on the indicator face. These three(3) full scale readings also correspond to an equivalent exposure reading in mR/hr. There are two(2) specific functions for the "Reset" pushbutton.

a. What are the three(3) equivalent exposure readings (mR/hr) that correspond to the full scale indications? (0.25 pts. each) (0.75)

b. What does the indicator label marked "xx" on Figure G.09 actually say on the E-140's used at Reed College? (0.5)

c. What are the two(2) specific functions of the "Reset" pushbutton? (0.25 pts. each) (0.5)

*ANSWER
G.09 (1.75)

a. (any order, 0.25 pts. each) (0.75)

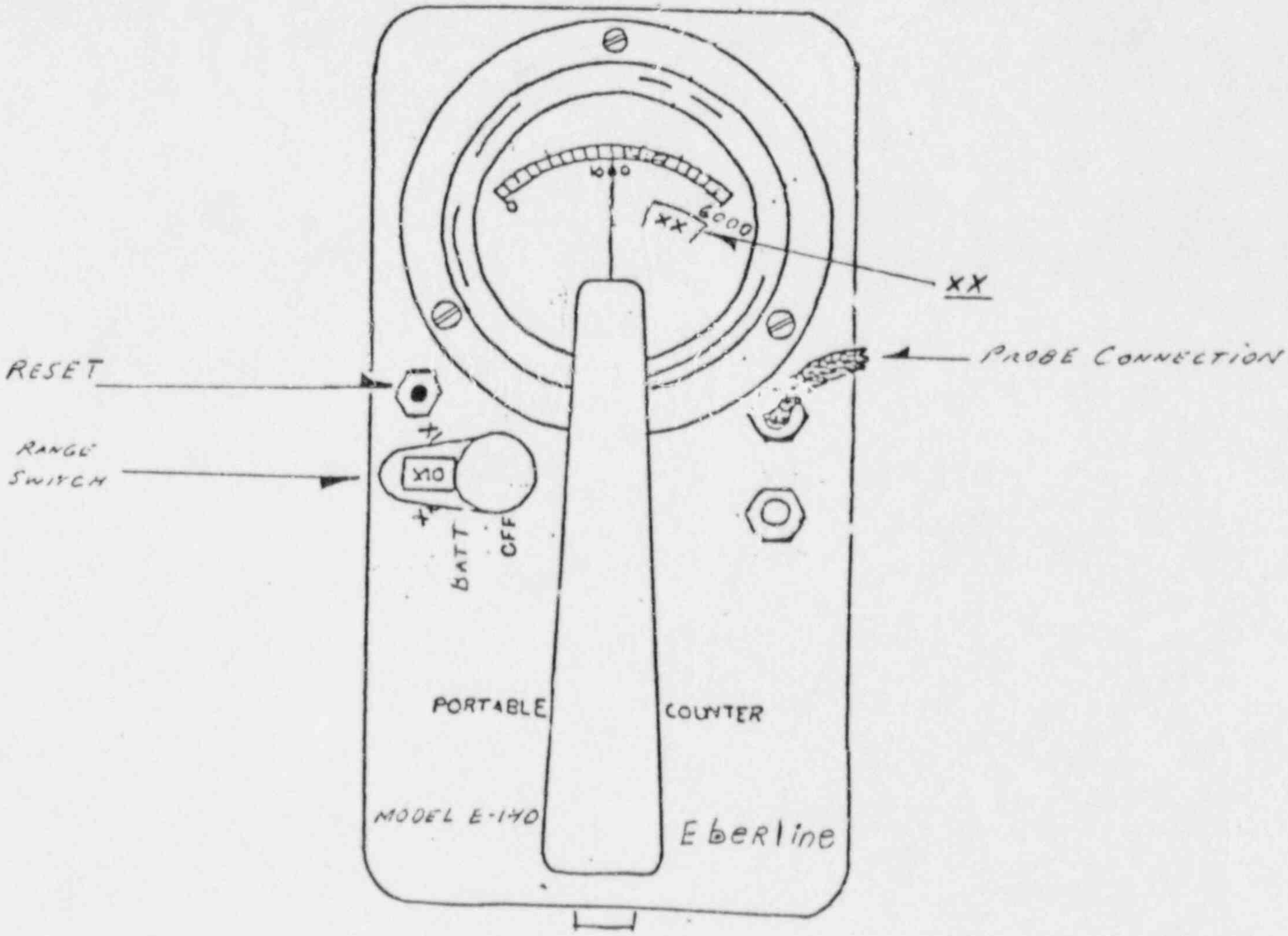
1. 0.5 mR/hr
2. 5 mR/hr
3. 50 mR/hr

b. BATT OK (battery OK) (0.5)

c. (any order, 0.25 pts. each) (0.5)

1. Reset after full scale (alarm)
2. Operational checks (calibration)

*REFERENCE
Instruction Manual, Model E-140



RESET
RANGE SWITCH
PROBE CONNECTION
XX
6000
X10
BATT
OFF
PORTABLE
COUNTER
MODEL E-140
Eberline

FIGURE G.09

*QUESTION
G.10 (2.0)

Attached Figure G.10 is an illustration of the floor plan of the Reed Reactor Facility. The general background radiation levels are indicated for the Reactor room, the Laboratory, the Mechanical room, and the Counting room. Radioactive sources are kept in the Laboratory for instrument calibration and certain experiments. 10CFR20 requires specific types of "CAUTION" signs for each of these four(4) areas, for the specific conditions identified on Figure G.10. Using Figure G.10 and the previous Figure G.07 (10CFR20 Appendix B):

a. What must the "CAUTION" sign read that is hung over the counting room? (0.5)

b. What must the "CAUTION" sign read that is posted on the reactor room door? (0.5)

c. What must the "CAUTION" sign read that is posted on the cabinet containing radioactive sources in the lab? (0.5)

d. What must the "CAUTION" sign read that is posted on the mechanical room door? (0.5)

*ANSWER
G.10 (2.0)

a. (CAUTION/DANGER) RADIATION AREA (0.5)

b. (CAUTION/DANGER) HIGH RADIATION AREA (0.5)

c. (CAUTION/DANGER) RADIOACTIVE MATERIAL(S) (0.5)

d. (CAUTION/DANGER) AIRBORNE (RADIOACTIVITY AREA) (0.5)

*REFERENCE
10 CFR 20

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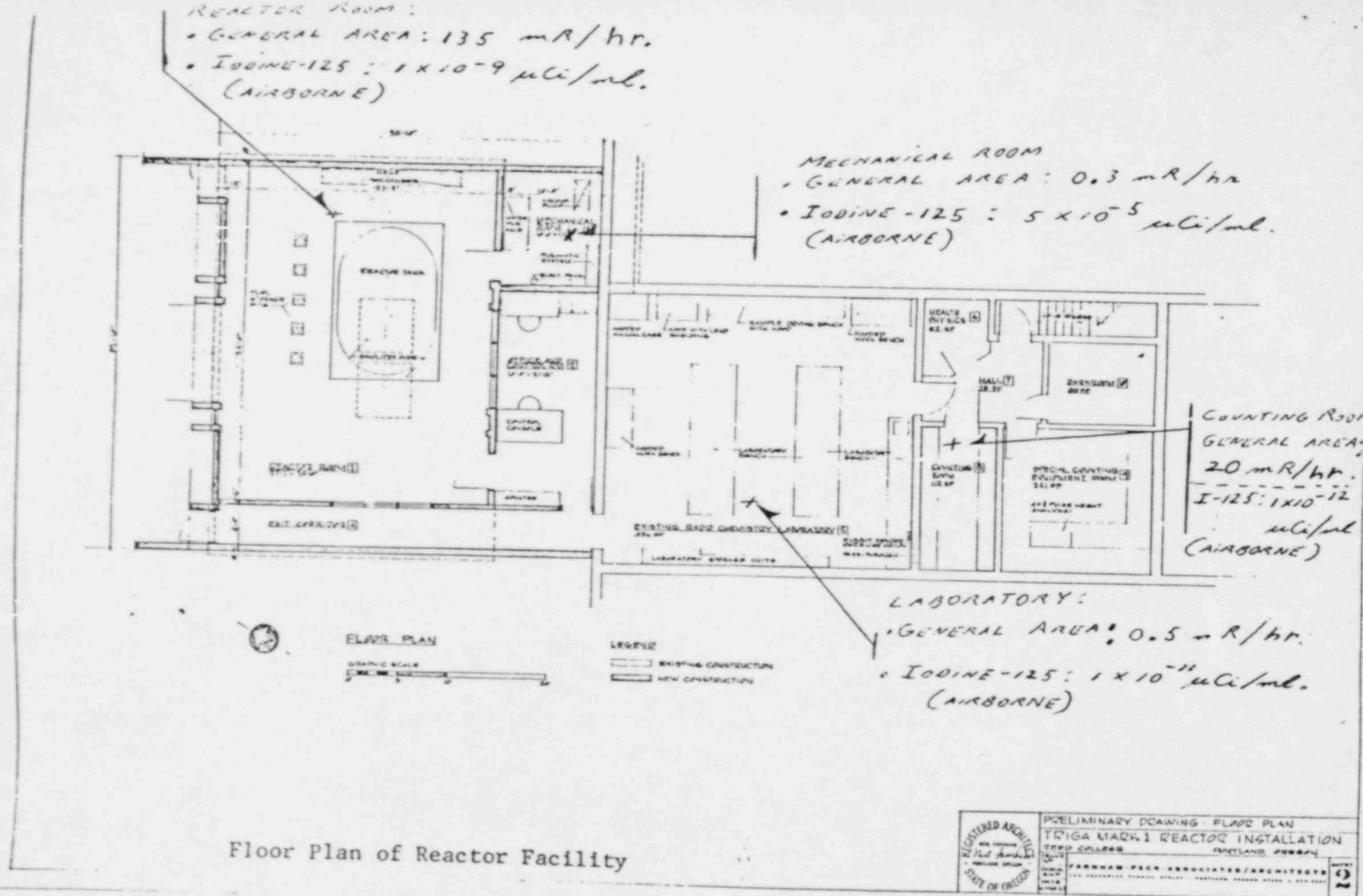
END OF SECTION G

END OF EXAM



Floor Plan of Reactor Facility

FIGURE G.10

APPENDIX B—CONCENTRATIONS IN AIR AND WATER ABOVE NATURAL BACKGROUND—Continued

[See footnotes at end of Appendix B]

Element (atomic number)	Isotope[1]		Table I Col. 1—Air (μCi/ml)	Table I Col. 2—Water (μCi/ml)	Table II Col. 1—Air (μCi/ml)	Table II Col. 2—Water (μCi/ml)
Iodine (53)	I 125	S	5×10^{-9}	4×10^{-5}	8×10^{-11}	2×10^{-7}
		I	2×10^{-7}	6×10^{-3}	6×10^{-9}	2×10^{-4}
	I 126	S	8×10^{-9}	5×10^{-5}	9×10^{-11}	3×10^{-7}
		I	3×10^{-7}	3×10^{-3}	1×10^{-8}	9×10^{-5}
	I 129	S	2×10^{-9}	1×10^{-5}	2×10^{-11}	6×10^{-8}
		I	7×10^{-8}	6×10^{-3}	2×10^{-9}	2×10^{-4}
	I 131	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
		I	3×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
	I 132	S	2×10^{-7}	2×10^{-3}	3×10^{-9}	8×10^{-6}
		I	9×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	I 133	S	3×10^{-8}	2×10^{-4}	4×10^{-10}	1×10^{-6}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
	I 134	S	5×10^{-7}	4×10^{-3}	6×10^{-9}	2×10^{-5}
		I	3×10^{-6}	2×10^{-2}	1×10^{-7}	6×10^{-4}
	I 135	S	1×10^{-7}	7×10^{-4}	1×10^{-9}	4×10^{-6}
		I	4×10^{-7}	2×10^{-3}	1×10^{-8}	7×10^{-5}
Iridium (77)	Ir 190	S	1×10^{-6}	6×10^{-3}	4×10^{-8}	2×10^{-4}
		I	4×10^{-7}	5×10^{-3}	1×10^{-8}	2×10^{-4}
	Ir 192	S	1×10^{-7}	1×10^{-3}	4×10^{-9}	4×10^{-5}
		I	3×10^{-8}	1×10^{-3}	9×10^{-10}	4×10^{-5}
	Ir 194	S	2×10^{-7}	1×10^{-3}	8×10^{-9}	3×10^{-5}
		I	2×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
Iron (26)	Fe 55	S	9×10^{-7}	2×10^{-2}	3×10^{-8}	8×10^{-4}
		I	1×10^{-6}	7×10^{-2}	3×10^{-8}	2×10^{-3}
	Fe 59	S	1×10^{-7}	2×10^{-3}	5×10^{-9}	6×10^{-5}
		I	5×10^{-8}	2×10^{-3}	2×10^{-9}	5×10^{-5}
Krypton (36)	Kr 85m	Sub	6×10^{-6}	—	1×10^{-7}	—
	Kr 85	Sub	1×10^{-5}	—	3×10^{-7}	—
	Kr 87	Sub	1×10^{-6}	—	2×10^{-8}	—
	Kr 88	Sub	1×10^{-6}	—	2×10^{-8}	—
Lanthanum (57)	La 140	S	2×10^{-7}	7×10^{-4}	5×10^{-9}	2×10^{-5}
		I	1×10^{-7}	7×10^{-4}	4×10^{-9}	2×10^{-5}
Lead (82)	Pb 203	S	3×10^{-6}	1×10^{-2}	9×10^{-8}	4×10^{-4}
		I	2×10^{-6}	1×10^{-2}	6×10^{-8}	4×10^{-4}
	Pb 210	S	1×10^{-10}	4×10^{-6}	4×10^{-12}	1×10^{-7}
		I	2×10^{-10}	5×10^{-3}	8×10^{-12}	2×10^{-4}
	Pb 212	S	2×10^{-8}	6×10^{-4}	6×10^{-10}	2×10^{-5}
		I	2×10^{-8}	5×10^{-4}	7×10^{-10}	2×10^{-5}
Lutetium (71)	Lu 177	S	6×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Manganese (25)	Mn 52	S	2×10^{-7}	1×10^{-3}	7×10^{-9}	3×10^{-5}
		I	1×10^{-7}	9×10^{-4}	5×10^{-9}	3×10^{-5}
	Mn 54	S	4×10^{-7}	4×10^{-3}	1×10^{-8}	1×10^{-4}
		I	4×10^{-8}	3×10^{-3}	1×10^{-9}	1×10^{-4}
	Mn 56	S	8×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	5×10^{-7}	3×10^{-3}	2×10^{-8}	1×10^{-4}
Mercury (80)	Hg 197m	S	7×10^{-7}	6×10^{-3}	3×10^{-8}	2×10^{-4}
		I	8×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
	Hg 197	S	1×10^{-6}	9×10^{-3}	4×10^{-8}	3×10^{-4}
		I	3×10^{-6}	1×10^{-2}	9×10^{-8}	5×10^{-4}
	Hg 203	S	7×10^{-8}	5×10^{-4}	2×10^{-9}	2×10^{-5}
		I	1×10^{-7}	3×10^{-3}	4×10^{-9}	1×10^{-4}
Molybdenum (42)	Mo 99	S	7×10^{-7}	5×10^{-3}	3×10^{-8}	2×10^{-4}
		I	2×10^{-7}	1×10^{-3}	7×10^{-9}	4×10^{-5}
Neodymium (60)	Nd 144	S	8×10^{-11}	2×10^{-3}	3×10^{-12}	7×10^{-5}
		I	3×10^{-10}	2×10^{-3}	1×10^{-11}	8×10^{-5}
	Nd 147	S	4×10^{-7}	2×10^{-3}	1×10^{-8}	6×10^{-5}
		I	2×10^{-7}	2×10^{-3}	8×10^{-9}	6×10^{-5}
	Nd 149	S	2×10^{-6}	8×10^{-3}	6×10^{-8}	3×10^{-4}
		I	1×10^{-6}	8×10^{-3}	5×10^{-8}	3×10^{-4}
Neptunium (93)	Np 237	S	4×10^{-12}	9×10^{-5}	1×10^{-13}	3×10^{-6}
		I	1×10^{-10}	9×10^{-4}	4×10^{-12}	3×10^{-5}
	Np 239	S	[illegible]	4×10^{-3}	3×10^{-8}	1×10^{-4}
		I	7×10^{-7}	4×10^{-3}	2×10^{-8}	1×10^{-4}
Nickel (28)	Ni 59	S	5×10^{-7}	6×10^{-3}	2×10^{-8}	2×10^{-4}

FIGURE G.07