UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

May 10, 2019

Dr. Melinda Krahenbuhl, Director
Reed College
Reed Research Reactor
3203 Southeast Woodstock Boulevard
Portland, OR 97202-8199

SUBJECT: EXAMINATION REPORT NO. 50-288/OL-19-01, REED COLLEGE

Dear Dr. Krahenbuhl:

During the weeks of March 25, and April 1, 2019, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your Reed College research reactor. The examinations were conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with Title 10 of the *Code of Federal Regulations,* Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Ms. Michele DeSouza at (301) 415-0747 or via internet e-mail Michele.DeSouza@nrc.gov.

Sincerely,

Anthony J. Mendiola, Chief
Research and Test Reactors Oversight Branch
Division of Licensing Projects
Office of Nuclear Reactor Regulation

Docket No. 50-288

Enclosures:
1. Examination Report No. 50-288/
   OL-19-01
2. Written examination

cc: w/o enclosures: See next page

Reed College Docket No. 50-288

cc:

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U.S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION REPORT

REPORT NO.: 50-288/OL-19-01

FACILITY DOCKET NO.: 50-288

FACILITY LICENSE NO.: R-112

FACILITY: TRIGA

EXAMINATION DATES: March 25, 2019 through April 1, 2019

SUBMITTED BY: ***/RA/*** April 18, 2019
Michele DeSouza, Chief Examiner Date

SUMMARY:
During the weeks of March 25, and April 1, 2019, the U.S. Nuclear Regulatory Commission (NRC) administered operator licensing examinations to twelve Reactor Operator (RO) and five Senior Reactor Operator Upgrade (SROU) candidates. One candidate failed the written exam. All other candidates passed all applicable portions of the examination.

REPORT DETAILS

1. Examiners: Michele DeSouza, Chief Examiner, NRC
Ashley Ferguson, Examiner Trainee, NRC
John Nguyen, Examiner, NRC

2. Results:

| | RO PASS/FAIL | SRO PASS/FAIL | TOTAL PASS/FAIL |
|---|---|---|---|
| Written | 11/1 | N/A | 11/1 |
| Operating Tests | 12/0 | 5/0 | 17/0 |
| Overall | 11/1 | 5/0 | 16/1 |

3. Exit Meeting:
Melinda Krahenbuhl, Director, Reed College
Ilana Novakoski, Reactor Operations Manager, Reed College
Michele DeSouza, Chief Examiner, NRC
Ashley Ferguson, Examiner Trainee, NRC [1]
John Nguyen, Examiner, NRC

At the conclusion of the meeting, the NRC Examiner thanked the facility for their support in the administration of the examinations. Comments from the facility licensee were incorporated prior to the administration of the written exam. The examiners discussed the general weaknesses observed during the operating tests. Specifically, the examiners observed that several of the candidates did not have a thorough understanding of the operation and air flow path of the

1 Attended via teleconference

Continuous Air Monitor (CAM) and initiating conditions of emergency procedures regarding personnel decontamination. In addition, the examiners observed inconsistencies with documentation and current facility orientation. Specifically, SOP 30, "Primary Cooling System and Reactor Pool," last revised December 12, 2018, was inconsistent with the current system alignment for adding water to the primary and several facility documents did not reflect that the logarithmic channel detector was changed from an ion chamber to a fission chamber. The facility acknowledged the documentation inconsistencies and informed the examiners that changes would be made accordingly.

U.S. NUCLEAR REGULATORY COMMISSION
NON-POWER REACTOR LICENSE EXAMINATION

FACILITY: Reed Research Reactor

REACTOR TYPE: TRIGA

DATE ADMINISTERED: 03/25/2019

CANDIDATE: _____

INSTRUCTIONS TO CANDIDATE:
Answers are to be written on the Answer sheet provided. Attach all Answer sheets to the examination. Point values are indicated in parentheses for each question. A 70% in each category is required to pass the examination. Examinations will be picked up three (3) hours after the examination starts.

| CATEGORY VALUE | % OF TOTAL | CANDIDATE'S SCORE | % OF CATEGORY VALUE | CATEGORY |
|---|---|---|---|---|
| 20.00 | 33.3 | _____ | _____ | A. REACTOR THEORY, THERMODYNAMICS AND FACILITY OPERATING CHARACTERISTICS |
| 20.00 | 33.3 | _____ | _____ | B. NORMAL AND EMERGENCY OPERATING PROCEDURES AND RADIOLOGICAL CONTROLS |
| 20.00 | 33.3 | _____ | _____ | C. FACILITY AND RADIATION MONITORING SYSTEMS |
| 60.00 | | _____ FINAL GRADE | _____ % | TOTALS |

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

_____
Candidate's Signature

Category A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

**ANSWER SHEET**

Multiple Choice (Circle or X your choice)
If you change your Answer, write your selection in the blank.

A01 a b c d ___

A02 a b c d ___

A03 a b c d ___

A04 a b c d ___

A05 a b c d ___

A06 a_____ b_____ c_____ d_____

A07 a b c d ___

A08 a b c d ___

A09 a b c d ___

A10 a b c d ___

A11 a b c d ___

A12 a b c d ___

A13 a b c d ___

A14 a b c d ___

A15 a b c d ___

A16 a b c d ___

A17 a b c d ___

A18 a b c d ___

A19 a b c d ___

A20 a b c d ___

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

Category B – Normal/Emergency Operating Procedures and Radiological Controls

**ANSWER SHEET**

Multiple Choice (Circle or X your choice)
If you change your Answer, write your selection in the blank.

B01 a b c d ___

B02 a b c d ___

B03 a b c d ___

B04 a b c d ___

B05 a b c d ___

B06 a b c d ___

B07 a b c d ___

B08 a b c d ___

B09 a b c d ___

B10 a b c d ___

B11 a b c d ___

B12 a b c d ___

B13 a b c d ___

B14 a b c d ___

B15 a b c d ___

B16 a___ b___ c___ d___

B17 a b c d ___

B18 a b c d ___

B19 a b c d ___

B20 a___ b___ c___ d___

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

Category C – Facility and Radiation Monitoring Systems

**ANSWER SHEET**

Multiple Choice (Circle or X your choice)
If you change your Answer, write your selection in the blank.

C01 a b c d ___

C02 a b c d ___

C03 a b c d ___

C04 a b c d ___

C05 a b c d ___

C06 a b c d ___

C07 a b c d ___

C08 a b c d ___

C09 a b c d ___

C10 a b c d ___

C11 a b c d ___

C12 a b c d ___

C13 a b c d ___

C14 a b c d ___

C15 a b c d ___

C16 a b c d ___

C17 a___ b___ c___ d___

C18 a b c d ___

C19 a b c d ___

C20 a b c d ___

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

# 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. After the examination has been completed, you must sign the statement on the cover sheet indicating that the work is your own and you have neither received nor given assistance in completing the examination. This must be done after you complete the examination.

3. 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.

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

5. Print your name in the blank provided in the upper right-hand corner of the examination cover sheet and each Answer sheet.

6. Mark your Answers on the Answer sheet provided. USE ONLY THE PAPER PROVIDED AND DO NOT WRITE ON THE BACK SIDE OF THE PAGE.

7. The point value for each question is indicated in [brackets] after the question.

8. If the intent of a question is unclear, ask questions of the examiner only.

9. When turning in your examination, assemble the completed examination with examination questions, examination aids and Answer sheets. In addition turn in all scrap paper.

10. Ensure all information you wish to have evaluated as part of your Answer is on your Answer sheet. Scrap paper will be disposed of immediately following the examination.

11. To pass the examination you must achieve a grade of 70 percent or greater in each category.

12. There is a time limit of three (3) hours for completion of the examination.

## EQUATION SHEET

$$\dot{Q} = \dot{m} c_P \Delta T = \dot{m} \Delta H = UA\Delta T$$

$$P = P_0 \, e^{t/\mathrm{T}}$$

$$SUR = 26.06\left[\frac{\lambda_{eff}\rho + \dot{\rho}}{\overline{\beta} - \rho}\right]$$

$$P = \frac{\beta(1-\rho)}{\beta - \rho} P_0$$

$$M = \frac{1 - K_{eff_1}}{1 - K_{eff\,2}}$$

$$\mathrm{T} = \frac{\ell^*}{\rho} + \left[\frac{\overline{\beta} - \rho}{\lambda_{eff}\rho + \dot{\rho}}\right]$$

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

$$DR = \frac{6 Ci\, E(n)}{R^2}$$

$$P_{\max} = \frac{(\beta - \rho)^2}{(2\alpha\ell)}$$

$$SCR = \frac{S}{-\rho} \cong \frac{S}{1 - K_{eff}}$$

$$CR_1(1 - K_{eff_1}) = CR_2(1 - K_{eff_2})$$

$$M = \frac{1}{1 - K_{eff}} = \frac{CR_2}{CR_1}$$

$$SDM = \frac{1 - K_{eff}}{K_{eff}}$$

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

$$DR = DR_0 \, e^{-\lambda t}$$

$$\frac{(\rho_2 - \beta)^2}{Peak_2} = \frac{(\rho_1 - \beta)^2}{Peak_1}$$

$$\lambda_{eff} = 0.1 \mathrm{sec}^{-1}$$

$$\ell^* = 1 \times 10^{-4} \mathrm{sec}$$

$$CR_1(-\rho_1) = CR_2(-\rho_2)$$

$$P = P_0 \, 10^{SUR(t)}$$

$$\mathrm{T} = \frac{\ell^*}{\rho - \overline{\beta}}$$

$$\Delta\rho = \frac{K_{eff_2} - K_{eff_1}}{K_{eff_1} K_{eff_2}}$$

$$DR_1 d_1^{\,2} = DR_2 d_2^{\,2}$$

DR – Rem, Ci – curies, E – Mev, R – feet

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**1 Curie = 3.7 x $10^{10}$ dis/sec**

**1 Horsepower = 2.54 x $10^3$ BTU/hr**

**1 BTU = 778 ft-lb**

**1 gal ($H_2O$) ≈ 8 lb**

**$c_P$ = 1.0 BTU/hr/lb/°F**

**1 kg = 2.21 lb**

**1 Mw = 3.41 x $10^6$ BTU/hr**

**°F = 9/5 °C + 32**

**°C = 5/9 (°F - 32)**

**$c_p$ = 1 cal/sec/gm/°C**

Category A: Reactor Theory, Thermodynamics, and Facility Operating Characteristics

**QUESTION A.01 [1.0 point]**
What is the difference between prompt and delayed neutrons?

a. Prompt neutrons are released during fast fission while delayed neutrons are released during thermal fissions.

b. Prompt neutrons are released directly from fission within ~$10^{-13}$ seconds, whereas delayed neutrons are emitted following the beta decay of a fission fragment.

c. Prompt neutrons are released virtually instantaneously, and delayed neutrons are a very small fraction of the total number of neutrons and do not have an important role in the control of the reactor.

d. Prompt neutrons are 99% of the neutron produced in fission and are therefore the dominating factor in determining the reactor period, whereas delayed neutrons account for less than 1% of the neutron population and have little effect on the reactor period.

**QUESTION A.02 [1.0 point]**
When a nucleus undergoes alpha decay, the atomic mass is reduced by _____ and the atomic number is reduced by _____.

a. 2, 2

b. 1, 2

c. 2, 4

d. 4, 2

**QUESTION A.03 [1.0 point]**
Which ONE of the following is the stable reactor period which will result in a power rise from 10% to 100% in one minute?

a. 6 seconds

b. 13 seconds

c. 26 seconds

d. 44 seconds

**QUESTION A.04 [1.0 point]**
Which ONE of the reactions below describes a method of production and removal of Xenon?

a. $^{53}I_{134} \rightarrow p + {}^{54}Xe_{135} \rightarrow \beta- + {}^{55}Cs_{135} \rightarrow \beta- + {}^{56}Ba_{135}$

b. $^{53}I_{135} \rightarrow \beta- + {}^{54}Xe_{135} \rightarrow \gamma + {}^{55}Cs_{135} \rightarrow \beta+ + {}^{56}Ba_{135}$

c. $^{53}I_{135} \rightarrow \beta- + {}^{54}Xe_{135} \rightarrow \gamma + {}^{54}Xe_{136} \rightarrow \beta- + {}^{56}Ba_{135}$

d. $^{53}I_{135} \rightarrow \beta- + {}^{54}Xe_{135} \rightarrow \beta- + {}^{55}Cs_{135} \rightarrow \beta- + {}^{56}Ba_{135}$

**QUESTION A.05 [1.0 point]**
Which ONE of the following factors in the "six factor formula" is the MOST affected by the MODERATOR?

a. Fast fission factor

b. Reproduction factor

c. Thermal utilization factor

d. Fast non leakage probability

**QUESTION A.06 [1.0 point, 0.25 each]**
Identify whether each of the following conditions will INCREASE or DECREASE the shutdown margin of a reactor.

a. Burnout of a burnable poison.

b. Insertion of boron graphite to the reactor core.

c. Moving one fuel element from reactor core to fuel storage.

d. Decreasing moderator temperature (Assume negative temperature coefficient.

**QUESTION A.07 [1.0 point]**
Which ONE of the following describes the general shape in determining the integral rod worth of a control rod?

a. S-shaped, with the net change in reactivity from bottom to top.

b. Cosine shaped, with the largest change in the middle of the core height.

c. Exponentially shaped, with the maximum at the bottom of the core height.

d. Parabolic shaped, with the maximum at the top and bottom of the core height.

**QUESTION A.08 [1.0 point]**
Calculate the shutdown margin. Given the following worth:

$\rho_{excess}$ = \$0.90
REG = \$1.05
SAFETY = \$1.55
SHIM = \$2.20

a. \$1.25

b. \$1.55

c. \$1.70

d. \$1.90

**QUESTION A.09 [1.0 point]**
The reactor is critical at 10 watts. A rod is moved to insert a positive reactivity of \$0.20. Which ONE of the following will be the stable reactor period as a result of this reactivity insertion? Given beta effective = 0.0075.

a. 4 seconds

b. 10 seconds

c. 40 seconds

d. 55 seconds

**QUESTION A.10 [1.0 point, 0.25 each]**
A reactor is slightly SUPERCRITICAL with the following values for each of the factors in the six-factor formula:

| | |
|---|---|
| Fast Fission Factor | 1.03 |
| Resonance Escape Probability | 0.94 |
| Thermal Utilization Factor | 0.73 |
| Thermal non-leakage probability | 0.90 |
| Reproduction Factor | 1.91 |
| Fast non-leakage probability | 0.85 |

A control rod is moved to bring the reactor back to critical. Assuming all other factors remain unchanged, the new value for the Thermal Utilization Factor is:

a. 0.703

b. 0.705

c. 0.707

d. 0.709

**QUESTION A.11 [1.0 point]**
Which ONE of the following is the reason for an installed neutron source within the reactor core? A startup without an installed neutron source _____.

a. Is impossible as no neutrons would be available to start up the reactor.

b. Would be very slow due to the buildup of xenon from the previous shutdown.

c. Can be compensated for by adjusting the compensating voltage on the Log Channel detector.

d. Could result in a very short period due to the reactor going critical before the neutron population is built up high enough to be read on nuclear instrumentation.

**QUESTION A.12 [1.0 point]**
Given a source strength of 250 neutrons per second (N/sec) and a multiplication factor of 0.75, which ONE of the following is the expected stable neutron count rate?

a. 250 N/sec

b. 500 N/sec

c. 750 N/sec

d. 1000 N/sec

**QUESTION A.13 [1.0 point]**
Which of the following is an example of a **FERTILE** material?

a. Th-232

b. U-233

c. U-235

d. Np-236

**QUESTION A.14 [1.0 point]**
Which ONE of the following physical characteristics of the TRIGA fuel is the main contributor for the prompt negative temperature coefficient?

a. As the fuel heats up, the resonance absorption peaks broaden and increases the likelihood of absorption in U-238 and/or Pu-240.

b. As the fuel heats up, a rapid increase in moderator temperature occurs through conduction and convection heat transfer mechanisms which adds negative reactivity.

c. As the fuel heats up, the oscillating hydrogen in the ZrH lattice imparts energy to a thermal neutron, thereby increasing its mean free path and probability of escape.

d. As the fuel heats up, fission product poisons (e.g., Xenon) increase in concentration within the fuel matrix and add negative reactivity via neutron absorption.

**QUESTION A.15 [1.0 point]**
Which ONE of the following best describes the relationship between power and fuel consumption?

a. The rate of fuel burn up is proportional to the reactor power level.

b. The rate of energy produced by the reactor is two times greater than the rate of total of fuel consumed per fission.

c. A reactor continuously operating at 1 MW for 24 hours will fission approximately 10 grams of fuel.

d. Reactor power can be calculated by subtracting the number of grams of fuel that fission per second by the number of grams of fuel at startup.

**QUESTION A.16 [1.0 point]**
Which ONE of the following describes the response of the subcritical reactor to equal insertions of positive reactivity as the reactor approaches critical? Each reactivity insertion causes:

a. A SMALLER increase in the neutron flux, resulting in a LONGER time to reach equilibrium.

b. A LARGER increase in the neutron flux, resulting in a LONGER time to reach equilibrium.

c. A SMALLER increase in the neutron flux, resulting in a SHORTER time to reach equilibrium.

d. A LARGER increase in the neutron flux, resulting in a SHORTER time to reach equilibrium.

**QUESTION A.17 [1.0 point]**

You're increasing reactor power on a steady +52 second period. How long will it take to increase power by a factor of 10?

a. 2 minute

b. 5 minutes

c. 12 minutes

d. 60 minutes

**QUESTION A.18 [1.0 point]**
What is the maximum power level a reactor will reach given the following: the lowest high power reactor scram set point is 120%, the scram delay time is 0.5 seconds, the reactor is operating at 100% power prior to the scram, and the reactor period is positive 20 seconds?

a. 113%

b. 119%

c. 123%

d. 125%

**QUESTION A.19 [1.0 point]**
Which ONE of the following is the MINIMUM amount of reactivity that makes the Reed Research Reactor **(finite)** to be a prompt critical reactor? This MINIMUM amount is equal to:

a. 1.0 % $\Delta K/K$

b. the factor of "e"

c. the $\beta$-effective value

d. the shutdown margin

**QUESTION A.20 [1.0 point]**
Which ONE of the following is not a desirable characteristic of a moderator?

a. Large scattering cross section

b. Small absorption cross section

c. Large energy loss per collision

d. Positive temperature coefficient

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B.01 [1.0 point]**
Which ONE of the following is NOT required to be performed prior to becoming the Operator of Record?

a. Review the Procedure Changes and Notices (PCN) Log for any changes.

b. Review all requests for authorization to use radiation or radioactive material for the day.

c. Review the day's Startup Checklist (even if you performed part of the Startup Checklist) and anything else on the Daily Clipboard.

d. Review the Main Logbook for changes during the last 30 days or back to the last time you reviewed the Main Logbook, whichever is more recent.

**QUESTION B.02 [1.0 point]**
Per the Reed Reactor Emergency Plan, which of the following are not always required to be on the Emergency Notification Call List?

a. Director

b. Radiation Safety Officer

c. Reactor Operations Manager

d. Senior Reactor Operator of Record

**QUESTION B.03 [1.0 point]**
Which ONE of the following activities does not require the use of personal dosimetry in accordance with the Reed Research Reactor dosimetry program?

a. An individual performing inventory of beta emitting sources.

b. An individual disposing of inorganic H-3 in single packages.

c. An individual conducting an experiment with milicurie level sources.

d. An individual performing janitorial services near a high radiation area.

**QUESTION B.04 [1.0 point]**
Which ONE of the following types of experiments are NOT permitted in the Reed Research Reactor?

a. A secured experiment containing 10 mg of nitroglycerin.

b. A movable experiment containing 25 mg of hydrochloric acid.

c. An unsecured experiment containing material with a reactivity worth $2.00

d. An in tank experiment containing material with a boiling point above 54.4°C.

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B.05 [1.0 point]**
Which ONE of the following NRC regulations requires a medical examination for operator licensees to be completed biennially?

a. 10 CFR 19

b. 10 CFR 20

c. 10 CFR 50

d. 10 CFR 55

**QUESTION B.06 [1.0 point]**
According to the Reed Emergency Plan, which role is responsible for establishing reentry requirements after evacuating due to an emergency condition?

a. Facility Director

b. Emergency Coordinator

c. Radiation Safety Officer

d. Reactor Operations Manager

**QUESTION B.07 [1.0 point]**
A radioactive source reads 50 mRem/hr on contact. Thirty minutes later, the same source reads 40 mrem/hr. How long is the time for the source to decay from a reading of 50 mrem/hr to 5 mrem/hr?

a. 2.5 hours

b. 3 hours

c. 5 hours

d. 7 hours

**QUESTION B.08 [1.0 point]**
If a licensee has not been actively preforming the functions of an operator or senior operator, the licensee may not resume licensed activities until a minimum of ____ hours has been completed under the instruction of an operator or senior operator, as appropriate.

a. 4

b. 6

c. 8

d. 10

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B.09 [1.0 point]**
How often are licensed reactor operators required to pass a comprehensive requalification operating test, in accordance with the Reed Research Reactor Requalification Plan?

a. Only for initial qualification

b. Each academic year

c. Every six years

d. Biennially

**QUESTION B.10 [1.0 point]**
Which ONE of the following indicates posting requirements for the bridge area any time the beam is open with reactor power above 5 watts?

a. Radiation Area

b. Radioactive Material

c. High Radiation Area

d. No posting is required

**QUESTION B.11 [1.0 point]**
Which ONE of the following meets the MINIMUM staffing requirement when the reactor is NOT secured?

a. 1 SRO in the control room, 1 SRO on call, and a second person to summon help.

b. 1 RO in the control room, 1 SRO on call, and a second person to summon help.

c. 1 SRO in the control room and the Reactor Operations Manager on call.

d. 1 RO in the control room, and the Reactor Operations Manager on call.

**QUESTION B.12 [1.0 point]**
Argon-41 is produced by neutron absorption of argon-40. Argon-41 decays by:

a. 1.3 Mev beta with a half-life of 7 seconds

b. 6.1 Mev gamma with a half-life of 7 seconds

c. 1.3 Mev gamma with a half-life of 1.8 hours

d. neutron emission with a half-life of 1.8 hours

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B.13 [1.0 point]**
A radiation field is 270 mR/hr at 5 feet. What is the dose rate at 2 feet away from the source?

a. 580 mR/hr

b. 675 mR/hr

c. 1320 mR/hr

d. 1688 mR/hr

**QUESTION B.14 [1.0 point]**
An individual receives 75 mRem of Beta (ß), 25 mRem of gamma (γ), and 5 mRem of neutron radiation (unknown source). What is the total dose the individual received?

a. 105 mRem

b. 130 mRem

c. 150 mRem

d. 210 mRem

**QUESTION B.15 [1.0 point]**
A radioactive source currently has an activity of 5 Curies. The activity of the source 25 years ago was 300 Curies. What is the half-life of the radioactive source?

a. 4.2 years

b. 5 years

c. 7.5 years

d. 8 years

**QUESTION B.16 [1.0 point, 0.25 each]**
Identify each of the following as either a Safety Limit (SL), a Limiting Safety System Setting (LSSS) or a Limiting Condition for Operation (LCO).

a. Control rod scram times shall not exceed 1 second.

b. The maximum fuel temperature shall not exceed 1000°C.

c. The steady-state reactor power level shall not exceed 300 kW.

d. The maximum available excess reactivity based on the reference core condition shall not exceed $3.00.

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B.17 [1.0 point]**
Which ONE of the following is not an action that should occur if an area in the reactor bay exceeds 100 mrem/hour at 30 cm?

a. Evacuate the area.

b. Notify the Radiation Safety officer.

c. Post it as a very high radiation area.

d. If the radiation area is caused by sample, shield the sample.

**QUESTION B.18 [1.0 point]**
A survey instrument with a window probe is used to measure the beta-gamma dose rate from an irradiated experiment. The dose rate is 170 mrem/hr with the window opened and 60 mrem/hr with the window closed. The gamma dose rate is:

a. 60 mrem/hr

b. 110 mrem/hr

c. 170 mrem/hr

d. 230 mrem/hr

**QUESTION B.19 [1.0 point]**
Which ONE of the following is counted as part of the 50 rem annual limit to any individual organ or tissue other than the lens of the eye, per 10 CFR 20?

a. Shallow dose equivalent

b. Effective dose equivalent

c. Committed dose equivalent

d. Total effective dose equivalent

Category B: Normal/Emergency Operating Procedures and Radiological Controls

**QUESTION B. 20 [1.0 point, 0.25 each]**

Match the event in column A with the proper emergency classification in Column B. Answers may be used once, more than once, or not at all.

| Column A | Column B |
|---|---|
| a. Failure of an in-core experiment with a minor release of radioactivity in the reactor pool | 1. No NRC Classification |
| b. The RO of duty falling into the reactor pool | 2. Notification of Unusual Event |
| c. An intruder entering the reactor facility | 3. Alert |
| d. A fire in the electrical panel that is extinguished within 10 minutes | |

(***** End of Category B *****)

Category C: Facility and Radiation Monitoring Systems

**QUESTION C.01 [1.0 point]**
Which ONE of the following components measures the bulk pool temperature of the primary system?

a. Orifice

b. Thermometer

c. Thermocouple

d. Conductivity Probe

**QUESTION C.02 [1.0 point]**
Which ONE of the following is NOT a function of the primary coolant system?

a. Maintain core reactivity

b. Dissipate heat from the reactor core

c. Prevent corrosion of reactor systems

d. Provide radiation shielding from the reactor core

**QUESTION C.03 [1.0 point]**
Which ONE of the following is true when the ventilation system is operating in NORMAL mode?

a. Air is recirculated to the control room through a HEPA filter.

b. Air is drawn from the reactor room by an exhaust fan to the exhaust stack.

c. Input fans are shut down to maintain the reactor bay at negative pressure in respect to the control room.

d. Airflow is moved through the reactor room, the control room, and the mechanical equipment room at 1,200 cubic feet per minute.

**QUESTION C.04 [1.0 point]**
Which ONE of the following is the purpose for primary water returning to the pool through a diffuser nozzle?

a. To allow for the decay of Nirogen-16.

b. To reduce the probability of radioactive ion build up.

c. To filter particulate in the water before entering the core.

d. To accelerate the flow of water being returned to the pool.

Category C: Facility and Radiation Monitoring Systems

**QUESTION C.05 [1.0 point]**
The Safety Rod is in which core position?

a. C5

b. C9

c. E1

d. F5

**QUESTION C.06 [1.0 point]**
A signal from which ONE of the following is used by the compensated ion chamber to calculate reactor power?

a. Source Range Channel

b. Multi-Range Linear Channel

c. Wide Range Logarithmic Channel

d. Full-Scale-Percent Power Channel

**QUESTION C.07 [1.0 point]**
Which ONE of the following locations within the Reed Research Reactor facility is a MOST likely site of contamination?

a. Control room

b. Lazy Susan sample port

c. Floor near entrance to reactor bay

d. Table for rabbit sample preparation

**QUESTION C.08 [1.0 point]**
Which ONE of the following is a safety related feature of the Logarithmic Channel?

a. Source Interlock

b. High Power Scram

c. Power Level Interlock

d. Reactor Period Scram

Category C: Facility and Radiation Monitoring Systems

**QUESTION C.09 [1.0 point]**
What IMMEDIATE action should be taken if linear power changes by more than 10% of the range when an experiment is leaving the reactor via the rabbit system?

a. Scram the reactor.

b. Return the experiment to reactor.

c. Evacuate the glovebox lab room.

d. None, reactivity worth of experiments are verified prior to insertion.

**QUESTION C.10 [1.0 point]**
A fire in the material handling area of the reactor bay has the possibility of releasing RADIOACTIVE MATERIALS in the form of which ONE of the following?

a. A vapor

b. An aerosol

c. Radioactive flames

d. An undetectable gas

**QUESTION C.11 [1.0 point]**
Fixed area dosimetry is required to be exchanged and evaluated at which ONE of the following intervals?

a. Monthly

b. Quarterly

c. Annually

d. Biannually

Category C: Facility and Radiation Monitoring Systems

**QUESTION C.12 [1.0 point]**
Which ONE of the following best describes how background radiation is subtracted on the Continuous Air Monitor (CAM)?

a. Subtracting the preset calculated background radiation from detector readout.

b. Subtracting the readout from one detector sampling background and another detector sampling air near the filter.

c. A pulse discriminator distinguishes the alpha particles produced from radon, which is subtracted from the total readout.

d. Subtracting the interactions caused by alpha particle in the outer chamber from the total interactions in the inner chamber of the detector.

**QUESTION C.13 [1.0 point]**
When in Automatic Rod Control mode, overshoot of the regulating rod is modulated by which ONE of the following?

a. Linear Channel

b. Pulse Height Analyzer

c. Control Rod Drive Circuit

d. Log Channel Wide Range Period Signal

**QUESTION C.14 [1.0 point]**
When the reactor is at full power, which ONE of the following experimental facilities provides for an average thermal neutron flux of approximately $1.4 \times 10^{13}$ n/cm$^2$s?

a. In-pool

b. Central thimble

c. Rotating specimen rack

d. Pneumatic transfer system

**QUESTION C.15 [1.0 point]**
Which ONE of the following is an indication that the motors on the Safety and Shim Rods need to be rebalanced?

a. Sparking from the rod down limit switch.

b. Control Rod Indication light is on in the control room.

c. A clicking noise is heard when rods are being withdrawn.

d. The motor creeping up and down without a demand signal.

**QUESTION C.16 [1.0 point]**
Which ONE of the following represents the maximum drop time of the control rods form the fully withdrawn to the fully inserted position?

a. 0.5 seconds

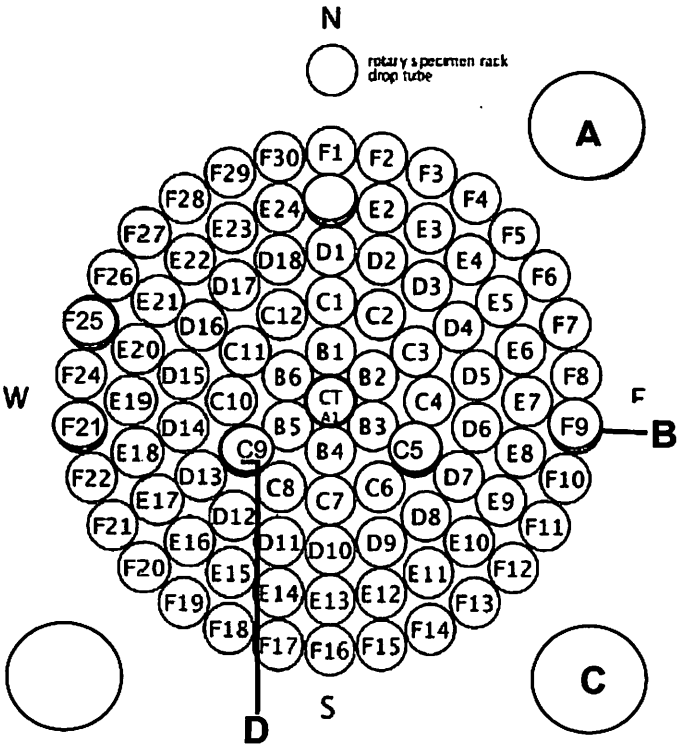
b. 1 second

c. 30 seconds

d. 1 minute

**QUESTION C.17 [1.0 point, 0.25 each]**

Match the following components in Column A with the corresponding core position in Column B, as indicated in the figure below. Answers may be used once, more than once, or not at all.




| Column A | Column B |
|---|---|
| a. A | 1. % Power |
| b. B | 2. Linear |
| c. C | 3. Safety Rod |
| d. D | 4. Shim |
| | 5. Rabbit |
| | 6. Log-n |

Category C: Facility and Radiation Monitoring Systems

**Question C.18 [1.0 point]**
Which ONE of the following best describes the reason that fuel elements are spaced so that 33% of the core volume is occupied by water?

a. To prevent boiling in the core.

b. To accommodate future fuel additions.

c. To compensate for excess reactivity during transients.

d. To protect the aluminum cladding from heat produced in the core.

**QUESTION C.19 [1.0 point]**
Which ONE of the follow represents the flow path of the primary coolant system?

a. Core → Heat Exchanger → Primary Pump → Flow Meter → Orifice → Filter

b. Core → Filter →Demineralizer → Heat Exchanger → Orifice → Primary Pump

c. Core → Deflector → Primary Pump→ Filter → Heat Exchanger → Demineralizer

d. Core → Primary Pump → Heat Exchanger → Filter → Demineralizer → Flow Meter

**QUESTION C.20 [1.0 point]**
What are all piping and fittings in the primary coolant system are made of?

a. Aluminum Alloy

b. Stainless Steel

c. Carbon Steel

d. Nickel Alloy

(***** End of Category C *****)
(***** END OF EXAM *****)

## Section A: Reactor Theory, Thermohydraulics & Facility Operating Characteristics

**A.01**
Answer: b
Reference: DOE Fundamentals Handbook, NPRT, Vol.1, Module 2, EO 3.1, p. 29

**A.02**
Answer: d
Reference: Reed Research Reactor Training Manual Chapter 2, pg. 18

**A.03**
Answer: c
Reference: $P = P_0 e^{t/T}$

$$T = \frac{t}{\ell n(P/P_0)} = \frac{60}{\ell n(10)} = 26\ seconds$$

**A.04**
Answer: d
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 3, EO 4.1, p.35

**A.05**
Answer: c
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 3, EO 2.3, p.25

**A.06**
Answer: a, DECREASE; b, INCREASE; c, INCREASE; d, DECREASE
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 4, EO 3.6, p.28

**A.07**
Answer: a
Reference: Reed Research Reactor Training Manual Chapter 12, Figure 12.6, pg. 191

**A.08**
Answer: c
Reference: Reed Research Reactor TS 3.1.2; $SDM = \$_{CR} - \$_{HWR} - CE = 4.80 - 2.20 - 0.90 = \$1.7($

**A.09**
Answer: c
Reference: Reactivity Added$= \$0.20\ x\ 0.0075 = 0.0015$

$$T = \frac{(\beta - \rho)}{\lambda_{eff}\ \rho} = \frac{.0075 - .0015}{.1(.0015)} = 40\ seconds$$

**A.10**
Answer: c
Reference: 1.03 x 0.94 x 0.73 x 0.85 x 0.90x 1.91 = 1.03
1 / (1.03 x 0.94 x 0.85 x 0.90 x 1.91) = 0.707

**A.11**
Answer: d
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 4, EO 3.1, p.24

**A.12**
Answer: d
Reference: $CR = \frac{S}{(1-k)} = \frac{250}{(1-0.75)} = 1000\ N/sec$

**A,13**
Answer: a
Reference: DOE Fundamentals Handbook, NPRT, Vol. 1, Module 1, EO 4.3,p. 51

**A.14**
Answer: c
Reference: TRIGA Fuel Design

**A.15**
Answer: a
Reference: Reed Research Reactor Training Manual Chapter 12, pg. 188

**A.16**
Answer: b
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 4, EO 1.2, p. 7

**A.17**
Answer: a
Reference: $P = P_0 e^{t/T}$
$t = \ell n(P/P_0) * T = \ell n(10) * 52 = 119.7\ seconds \approx 120\ seconds = 2\ minutes$

**A.18**
Answer: c
Reference: $P = P_0 e^{t/T}$
$\frac{P}{P_0} = 120e^{0.5/20} = 123\%$

**A.19**
Answer: c
Reference: DOE Fundamentals Handbook, NPRT, Vol. 2, Module 4, EO 2.9, pg. 15

**A.20**
Answer d
Reference: DOE Fundamentals Handbook, NPRT, Vol. 1, Module 2, EO 2.12, p.24

## Section B: Normal/Emergency Operating Procedures and Radiological Controls

**B.01**
Answer: b
Reference: Reed SOP 1, dated August 15, 2017, Section 1.5, pg. 6

**B.02**
Answer: d
Reference: Read Research Reactor Emergency Plan, dated January 2016, Section 3.1.2, pg 5

**B.03**
Answer: d
Reference: Radioactive Materials Policy and Procedures Manual, dated February 2016, Section 3, pg. 10

**B.04**
Answer: c
Reference: Reed Research Reactor TS 3.6

**B.05**
Answer: d
Reference: 10 CFR 55

**B.06**
Answer: b
Reference: Read Research Reactor Emergency Plan, dated January 2016, Section 3.1.2, pg 5

**B.07**
Answer: c
Reference:

$$DR = DR_0 e^{-\lambda t}$$

$$\lambda = \frac{-\left(\ell n \frac{DR}{DR_0}\right)}{t} = \frac{0.223}{0.5} = 0.446$$

$$t = -\frac{\ell n \frac{DR}{DR_0}}{-\lambda} = \frac{-2.303}{-0.446} \approx 5\ hrs$$

**B.08**
Answer: b
Reference: 10 CFR 55.53

**B.09**
Answer: b
Reference: Reed Research Reactor Requalification Plan, dated 2010, Section 5.2

**B.10**
Answer: c
Reference: Reed SOP 15, dated March 21, 2016, Section 15.4, pg. 2

**B.11**
Answer: b
Reference: Reed Research Reactor TS 6.1.3

**B.12**
Answer: c
Reference: Chart of Nuclides

**B.13**
Answer: d
Reference: $DR_1 d_1^2 = DR_2 d_2^2$

$$DR_2 = \frac{DR_1 d_1^2}{d_2^2} = \frac{270(5^2)}{2^2} = 1687.5 mR/hr$$

**B.14**
Answer: a
Reference: 10 CFR 20.1004, Units of radiation dose

**B.15**
Answer: a
Reference: $A = A_0 e^{-\lambda t}$; $\lambda = -\ell n 2/t_{1/2}$

$$\ell n\left(\frac{5Ci}{300\,Ci}\right) = \frac{-\ell n(2)}{t_{\frac{1}{2}}}(25\,years)$$

$$t_{1/2} = \frac{-\ell n(2)}{-.16377} = 4.232\,years$$

**B.16**
Answer: a, LCO b, SL c, LSSS d, LCO
Reference: Reed Research Reactor TS 2.1, 2.2, 3.1

**B.17**
Answer: c
Reference: Read Research Reactor EIP G

**B.18**
Answer: a
Reference: DOE Fundamentals Handbook, NPRT, Vol.1, Module 1, EO 5.1, pg. 65

**B.19**
Answer: c
Reference: 10 CFR 20.1003, Definitions

**B.20**
Answer: a,1 b,1 c,3 d,1
Reference: Read Research Reactor Emergency Plan, dated January 2016, Section 4, pg. 9-10

Section C: Facility and Radiation Monitoring Systems

**C.01**
Answer: c
Reference: Reed Research Reactor Training Manual Chapter 13, pg. 222

**C.02**
Answer: a
Reference: Reed Research Reactor SAR, Chapter 5, pg. 5-1

**C.03**
Answer: b
Reference: Reed Research Reactor SAR, Chapter 9, pg. 9-1

**C.04**
Answer: a
Reference: Reed Research Reactor SAR, Chapter 5, pg. 5-7

**C.05**
Answer: a
Reference: Reed Research Reactor Training Manual Chapter 13, pg. 214

**C.06**
Answer: b
Reference: Reed Research Reactor SAR, Chapter 7, pg. 7-2

**C.07**
Answer: b
Reference: Reed Research Reactor SAR, Chapter 11, pg. 11-18

**C.08**
Answer: a
Reference: Reed Research Reactor SAR, Chapter 7, pg. 7-3

**C.09**
Answer: a
Reference: Reed SOP 12, dated August 26, 2016, Section 13.4, pg. 3

**C.10**
Answer: b
Reference: Reed Research Reactor SAR, Chapter 20, pg. 4

**C.11**
Answer: b
Reference: Reed Research Reactor TS 4.5

**C.12**
Answer: b
Reference: Reed Research Reactor Training Manual Chapter 6, pg. 102

**C.13**
Answer: d
Reference: Reed SOP 1, dated August 15, 2017, Section 1.13, pg. 15

Section C: Facility and Radiation Monitoring Systems

**C.14**
Answer: b
Reference: Reed Research Reactor Training Manual Chapter 13, pg. 219

**C.15**
Answer: d
Reference: Reed SOP 34, dated December 8, 2017, Section 34.6.2 pg. 7

**C.16**
Answer: b
Reference: Reed Research Reactor SAR, Chapter 3, pg. 3-3

**C.17**
Answer: a, 2 b, 5 c,1 d,4
Reference: Reed Research Reactor Training Manual, Chapter 1, pg. 213

**C.18**
Answer: a
Reference: Reed Research Reactor SAR, Chapter 4, pg. 4-19

**C.19**
Answer: d
Reference: Reed Research Reactor SAR, Chapter 5, pg. 5-2

**C.20**
Answer: a
Reference: Reed Research Reactor SAR, Chapter 5, pg. 5-6

SUBJECT: EXAMINATION REPORT NO. 50-288/OL-19-01, REED COLLEGE DATED MAY 10, 2019

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