January 7, 2014

Dr. Melinda Krahenbuhl, Director
Reed Reactor Facility
Reed College
3203 SE Woodstock Blvd.
Portland, OR 97202

SUBJECT: EXAMINATION REPORT NO. 50-288/OL-14-01, REED COLLEGE

Dear Dr. Krahenbuhl:

During the week of December 9, 2013, the U.S. Nuclear Regulatory Commission (NRC) administered operator licensing examination at your Reed Reactor Facility. The examination was conducted in accordance with NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2, published in June 2007. Examination questions and preliminary findings were discussed at the conclusion of the examination with those members of your staff identified in the enclosed report.

In accordance with Section 2.390 of Title 10 of the *Code of Federal Regulations*, 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 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 Public Electronic Reading Room). The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. If you have any questions concerning this examination, please contact John Nguyen at 301-415-4007 or via email at John.Nguyen@nrc.gov.

Sincerely,

/RA/

Gregory T. Bowman, Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-288

Enclosures:
1. Examination Report No. 50-288/OL-14-01
2. Written examination with
   facility comments incorporated

cc w/out enclosures:
See next page

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DISTRIBUTION w/ encls.:
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ADAMS ACCESSION #: ML13353A679		NRR-079

OFFICE	NRR/DPR/PROB	NRR/DPR/PROB	NRR/DPR/PROB
NAME	JNguyen	CRevelle	GBowman
DATE	12/18/2013	1/07/2014	1/07/2014

OFFICIAL RECORD COPY

cc:

Mayor of the City of Portland
1220 Southwest 5th Avenue
Portland, OR 97204

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Portland, OR 97202-8199

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Radiation Protection Services
Public Health Division
Oregon Health Authority
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Portland, OR 97232-2162

Test, Research, and Training
  Reactor Newsletter
University of Florida
202 Nuclear Sciences Center
Gainesville, FL 32611

EXAMINATION REPORT NO: 50-288/OL-14-01

FACILITY: Reed Reactor

FACILITY DOCKET NO.: 50-288

FACILITY LICENSE NO.: R-112

SUBMITTED BY: /RA/ 01/07/2014
John Nguyen, Chief Examiner Date

SUMMARY:

During the week of December 9, 2013, the NRC administered operator licensing examinations to one Senior Reactor Operator Instant (SROI), one retake Reactor Operator (written exam – part C), and two Senior Reactor Operator Upgrade (SROU) candidates. The candidates passed all portions of the examinations.

REPORT DETAILS

1. Examiner: John Nguyen, Chief Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	1/0	1/0	2/0
Operating Tests	N/A	3/0	3/0
Overall	1/0	3/0	4/0

3. Exit Meeting:

Dr. Melinda Krahenbuhl, Director, Reed Reactor
John Nguyen, NRC, Examiner

The NRC Examiner thanked the facility for their support in the administration of the examinations. The NRC examiners noted that the license candidates were well prepared for the examinations.

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

FACILITY:	Reed College
REACTOR TYPE:	TRIGA
DATE ADMINISTERED:	12/10/2013
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
18.00	33.3	________	_____	A. REACTOR THEORY, THERMODYNAMICS AND FACILITY OPERATING CHARACTERISTICS
18.00	33.3	________	_____	B. NORMAL AND EMERGENCY OPERATING PROCEDURES AND RADIOLOGICAL CONTROLS
18.00	33.3	________	_____	C. FACILITY AND RADIATION MONITORING SYSTEMS
54.00		________ FINAL GRADE	_____ %	TOTALS

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

____
Candidate's Signature

A. RX THEORY, THERMO & FAC OP CHARS

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 ___

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

B. NORMAL/EMERG PROCEDURES & RAD CON

A N S W E R   S H E E T

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 ___

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

C. PLANT AND RAD MONITORING SYSTEMS

A N S W E R   S H E E T

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 ___ (0.25 each)

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 ___ (0.33 each)

C11 a b c d ___

C12 a b c d ___

C13 a ___ b ___ c ___ d ___ (0.25 each)

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 ___

(***** 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 <u>only</u> 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

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

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

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

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

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

$$\ell^* = 1\times10^{-4}\sec$$

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

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

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

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

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

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

$$M = \frac{1 - K_{eff_1}}{1 - K_{eff_2}}$$

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

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

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

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

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

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

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

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

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

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

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

1 Curie = 3.7×10^{10} dis/sec

1 kg = 2.21 lbm

1 Horsepower = 2.54×10^3 BTU/hr

1 Mw = 3.41×10^6 BTU/hr

1 BTU = 778 ft-lbf

°F = 9/5 °C + 32

1 gal (H_2O) ≈ 8 lbm

°C = 5/9 (°F - 32)

c_P = 1.0 BTU/hr/lbm/°F

c_p = 1 cal/sec/gm/°C

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

REED RESEARCH REACTOR

Operator Licensing Examination

Week of December 9, 2013

ENCLOSURE 2

QUESTION A.1 [1.0 points]
A subcritical nuclear reactor has a count rate of 150 counts per second (cps) with a shutdown reactivity of -2.0% ΔK/K. Approximately how much positive reactivity must be added to establish a count rate of 600 cps?

a. 0.53% ΔK/K

b. 1.02% ΔK/K

c. 1.54% ΔK/K

d. 2.00% ΔK/K

QUESTION A.2 [1.0 point]
Which of the following is the definition for reactivity (ρ)?

a. The measure of a reactor's departure from criticality.

b. The time required for power to change by a factor of "e".

c. The fraction of all fission neutrons that are born as delayed neutrons.

d. The faction of number of neutrons at a current generation and number of neutrons at a previous generation.

QUESTION A.3 [1.0 point]
Few minutes following shutdown, reactor power is at 3×10^6 counts per minute (cpm). Which ONE of the following is the count rate three minutes later?

a. 2×10^6 cpm

b. 8×10^5 cpm

c. 5×10^5 cpm

d. 3×10^5 cpm

QUESTION A.4 [1.0 point]
The reactor is at full power. The operator immediately scrams all control rods into the core. This IMMEDIATE insertion of all control rods will cause:
Given:
T: reactor period, ℓ^*: Prompt neutron lifetime; ρ: reactivity insertion; β: beta fraction

a. The delayed period equals to POSITIVE 80 seconds.

b. A number of prompt neutrons equals to a number of delayed neutrons.

c. The delayed period to be a function of the prompt neutron lifetime ($T=\ell^*/\rho$).

d. A sudden change of power that equals to the initial power multiplied by $\beta(1-\rho)/(\beta-\rho)$.

QUESTION A.5 [1.0 point]
The reactor is on a CONSTANT positive period. Which ONE of the following power changes will take the SHORTEST time to complete?

a. From 1 W to 5 W

b. From 10 W to 30 W

c. From 10 kW to 20 kW

d. From 100 kW to 150 kW

QUESTION A.6 [1.0 point]
The reactor is critical at 5 W. K_{eff} and Δρ respectively are:

a. 0 and 0

b. 0 and 1

c. 1 and 0

d. 1 and 1

QUESTION A.7 [1.0 point]
Given the following Core Reactivity Data during startup:

Control Rod	Total Rod Worth ($)	Rod Worth removed at 5 watts critical ($)	Rod excess at 5 watts critical ($)
Rod #1	1.50	1.50	0.00
Rod # 2	1.80	1.50	0.30
Rod # 3	2.20	2.00	0.20
Rod # 4	3.50	2.50	1.00
Total Worth	9.00	7.50	1.50

Assume all rods are scrammable; the **MINIMUM SHUTDOWN MARGIN** in accordance with the Technical Specifications for this core is:

a. $1.5

b. $4.0

c. $5.5

d. $6.0

QUESTION A.8 [1.0 point]
Which ONE of the following is the MOST reason that Xenon peaks after a shutdown?

a. Iodine decays faster than Xenon decays.

b. Xenon decays faster than Iodine decays.

c. Xenon is depleted only with fast neutron flux.

d. The reactor core produces more thermal neutrons than fast neutrons after a shutdown. With the increase of thermal neutrons, the fission yields are higher and directly generates the more fission products such as xenon.

QUESTION A.9 [1.0 point]
Which ONE of the following correctly describes the SIX - FACTOR FORMULA?

a. $K_{eff} = K_\infty$ * the reproduction factor (η)

b. $K_\infty = K_{eff}$ * the fast non-leakage probability (L_f) * the fast leakage probability

c. $K_{eff} = K_\infty$ * the total non-leakage probability (L_f x L_{th})

d. $K_{eff} = K_\infty$ * (the resonance escape probability (p) x fast fission factor (ε))

QUESTION A.10 [1.0 point]
The reactor is subcritical with a K_{eff} of 0.945. If you add 5.5% $\Delta k/k$ of positive reactivity into the core, the reactor will be …

a. subcritical

b. exactly critical

c. supercritical

d. prompt critical

QUESTION A.11 [1.0 point]
The following shows part of a decay chain for the radioactive element Pa-234:
$_{91}Pa^{234} \rightarrow {}_{92}U^{234}$

This decay chain is a good example of ___ decay.

a. Alpha

b. Beta

c. Gamma

d. Neutron

QUESTION A.12 [1.0 point]
Given a reactor period of 22 seconds, approximately how long will it take for power to triple?

a. 10 seconds

b. 24 seconds

c. 36 seconds

d. 66 seconds

QUESTION A.13 [1.0 point]
Which ONE of the following isotopes will absorb neutrons quickly when it interacts with neutrons?

a. Uranium-235

b. Oxygen-16

c. Boron-10

d. Hydrogen-1

QUESTION A.14 [1.0 point]
Inelastic scattering can be described as a process whereby a neutron collides with a nucleus and a neutron:

a. is absorbed by the nucleus; the nucleus will emit an alpha particle.

b. reappears with the same kinetic energy that had prior to the collision.

c. reappears with a lower kinetic energy; the nucleus will emit gamma after the neutron has left.

d. reappears with a lower kinetic energy, the nucleus will emit beta after the neutron has left.

QUESTION A.15 [1.0 point]
Which ONE of the following best describes the likelihood of fission reactions occurring in U-235 and U-238?

a. Neutron cross sections of U-235 and U-238 are independent from the neutron velocity.

b. Neutron cross section of U-235 increases with increasing neutron energy, whereas neutron cross section of U-238 decreases with increasing neutron energy.

c. Neutrons at low energy levels (eV) are more likely to cause fission with U-238 than neutrons at higher energy levels (MeV).

d. Neutrons at low energy levels (eV) are more likely to cause fission with U-235 than neutrons at higher energy levels (MeV).

QUESTION A.16 [1.0 point]
Which ONE of the following is the principle source of heat in the reactor after a shutdown from extended operation at 100 kW?

a. Decay of fission products

b. Spontaneous fission of U^{238}

c. Production of delayed neutrons

d. Production of prompt gamma rays

QUESTION A.17 [1.0 point]
During the time following a reactor scram, reactor power decreases on a negative 80 second period. Which ONE of the following is the correspondence of the half-life of the longest-lived delayed neutron precursors?

a. 80 seconds

b. 55 seconds

c. 40 seconds

d. 20 seconds

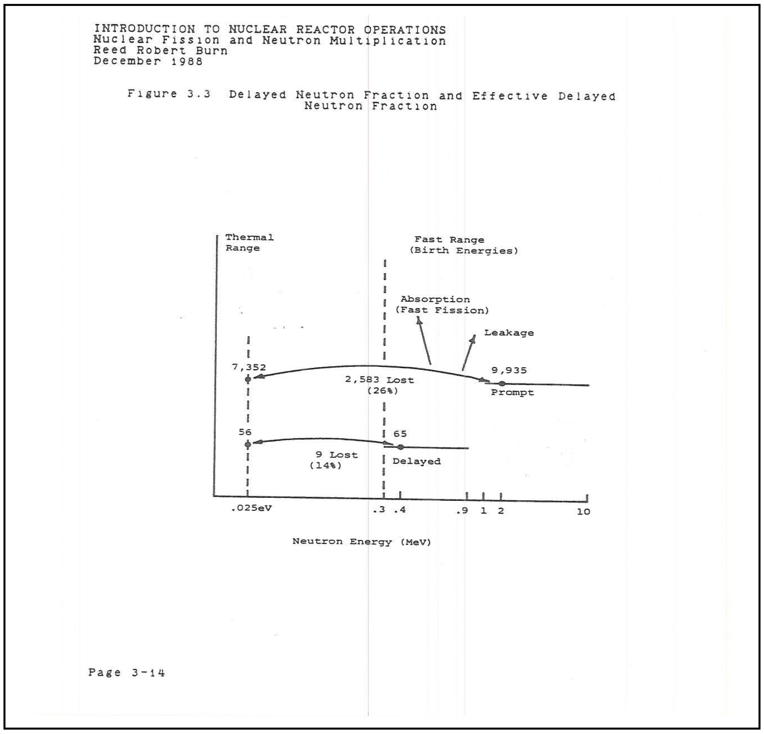
QUESTION A.18 [1.0 point]
Use Figure 3.3 attached. Calculate the effective delayed neutron fraction (β-effective). At birth energies, there are 65 delayed neutrons and 9935 prompt neutrons. In the process of slowing down, there are only 56 delayed neutrons and 7352 prompt neutrons at the thermal range. The resultant β-effective of Figure 3.3 is:

a. 0.00654

b. 0.00756

c. 0.00762

d. 0.00348



***************** End of Section A *********************

QUESTION B.1 [1.0 point]
The following measurements are made from a beta-gamma point source:
At one foot, it measures 1 R/hr
At ten feet, it measures 0.5 mR/hr
Betas and gammas emitted at one foot respectively are:

a. 950 mR/hr and 50 mR/hr

b. 995 mR/hr and 5 mR/hr

c. 1000 mR/hr and 50 mR/hr

d. 1000 mR/hr and 5 mR/hr

QUESTION B.2 [1.0 point]
Per 10 CFR 20, a radiation worker can receive an annual limit of ________ to the skin of whole body.

a. the shallow-dose equivalent of 50 Rems

b. the deep-dose equivalent of 5 Rems

c. the committed-dose equivalent of 5 Rems

d. the sum of deep-dose equivalent and the committed-dose equivalent of 50 Rems

QUESTION B.3 [1.0 point]
Per Technical Specification, what is the MINIMUM level of management who may direct relocation of any in-core experiment with reactivity worth greater than one dollar?

a. Senior Reactor Operator on call

b. Senior Reactor Operator at the facility

c. Operations Supervisor

d. Reactor Director

QUESTION B.4 [1.0 point]
Which ONE of the following does NOT require the NRC approval for changes?

a. Change an unsecured experiment from less than $1.00 to less than $1.50 in the Technical Specifications.

b. Drop the written examination described in the Requalification Plan.

c. Delete Alert Emergency Class described in the Emergency Plan.

d. Delete Section 3 listed in SOP 20, Startup Checklist.

QUESTION B.5 [1.0 point]
A point source reads 1 mRem/hr at one (1) meter. Which ONE of the following defines the posting requirements in accordance with 10 CFR 20?

a. Public Area

b. Radiation Area

c. High Radiation Area

d. Grave Danger, Very High Radiation Area

QUESTION B.6 [1.0 point]
A radioactive source reads 10 Rem/hr on contact. Five hours later, the same source reads 1.0 Rem/hr. How long is the time for the source to decay from a reading of 10 Rem/hr to 10 mRem/hr?

a. 10 hours

b. 15 hours

c. 20 hours

d. 25 hours

QUESTION B.7 [1.0 point]
The operator licensing candidate requires submitting the NRC Form 396, Certification of Medical Examination by Facility Licensee, to the NRC Chief Examiner before the start date of the examination. This requirement can be found in:

a. 10 CFR Part 26

b. 10 CFR Part 50.59

c. 10 CFR Part 55

d. 10 CFR Part 20

QUESTION B.8 [1.0 point]
Per Technical Specification, temporary deviations from the procedures may be made by the responsible ______ when the procedure contains errors or in order to deal with special conditions. Such deviation shall be documented and reported by ______ to _________.

a. RO / the next working day / SRO on duty

b. SRO / the next working day / Director (or Associate Director)

c. SRO / the five working days / Director (or Associate Director)

d. Director (or Associate Director) / within 14 days / NRC

QUESTION B.9 [1.0 point]
Per Technical Specifications, the reactor pool water radioactivity shall be measured _________.

a. weekly

b. monthly

c. quarterly

d. annually

QUESTION B.10 [1.0 point]
Which ONE of the following would be an initiating condition for a Notification of Unusual Event?

a. Staff injury

b. Staff contamination

c. A Deep Dose Equivalent of 20 mRem/hr for 1 hour

d. Radiological effluents from the Reactor Laboratory exceed 15 mRem whole-body dose equivalent accumulated in 24 hours

QUESTION B.11 [1.0 point]
Per Technical Specifications, which ONE of following reactivity values is NOT permissible for reactor operations?

a. TS Shutdown margin = $1.0

b. Excess reactivity = $3.0

c. Reactivity addition rate = $0.10 per second

d. Reactivity worth of all secured experiment = $1.50

QUESTION B.12 [1.0 point]
The radiation from an unshielded source is 1 Rem/hr. When a 60 mm thickness of lead sheet is inserted; the radiation level reduces to 125 mRem/hr. What is the half-value-layer of lead? (HVL: thickness of lead required so that the original intensity will be reduced by half)?

a. 10 mm

b. 20 mm

c. 30 mm

d. 40 mm

QUESTION B.13 [1.0 point]
A radioactive source contains 10 curies and emits 100% of 110-Kev gamma. Assuming no shielding used, how far is a distant that reads 100 mrem/hr?

a. 8 feet

b. 24 feet

c. 75 feet

d. 257 feet

QUESTION B.14 [1.0 point]
Which ONE of the following types of experiments shall NOT be irradiated at Reed Research Reactor?

a. Any experiment contains gunpowder.

b. Any experiment contains nitroglycerin.

c. Any experiment contains corrosive materials.

d. Single unsecured experiment has a reactivity worth of $1.0.

QUESTION B.15 [1.0 point]
Which ONE of the following is the correct statement when the Radiation Area Monitor (RAM) required by Tech Specs becomes inoperable? Operations may continue:

a. within one hour if Continuous Air Monitor is still operable.

b. within two hours if Continuous Air Monitor is still operable.

c. only if portable instruments are substituted for the normally installed monitor within one hour of discovery for periods not to exceed one month.

d. only if portable instruments are substituted for the normally installed monitor within one day of discovery for periods not to exceed one month.

QUESTION B.16 [1.0 point]
Which ONE of the following is the definition of Total Effective Dose Equivalent (TEDE) specified in 10 CFR 20?

a. The sum of thyroid dose and external dose.

b. The sum of the external deep dose and the organ dose.

c. The sum of the deep dose equivalent and the committed effective dose equivalent.

d. The dose that your whole body is received from the source, but excluded from the deep dose.

QUESTION B.17 [1.0 point]
How often is a status stamp required to be completed in the log book during operations at constant power?

a. 15 minutes

b. 30 minutes

c. 60 minutes

d. 90 minutes

QUESTION B.18 [1.0 point]
Significant amounts of secondary radiation may increase the dose rate on the other side of a shield. This increase in the amount of radiation is called:

a. Buildup

b. Backscattering

c. Photoelectric Effect

d. Pair Production

****************************** End of Section B ********************************

QUESTION C.1 [1.0 point]
The Reed Technical Specifications specify that the maximum fuel temperature shall not exceed 1000 °C. Which ONE of the following is a correct method used to prevent the fuel temperature from exceeding 1000 °C? The Reed Reactor:

a. has an instrumented fuel element. The scram is based on a set point of the instrumented fuel temperature.

b. conducts the thermal power calibration. The scram is based on a set point of the pool water temperature.

c. analyzes the thermal hydraulic behavior. The scram is based on a set point of the steady state power.

d. conducts the pool water level calculation. The scram is based on a set point of the pool water level.

QUESTION C.2 [1.0 point]
To reduce neutron leakage, which ONE of the following materials is inserted in the top and bottom of the active fuel portion of each fuel element?

a. Aluminum

b. Boron

c. Cadmium

d. Graphite

QUESTION C.3 [1.0 point]
Per SOP 30, the primary water filter on the purification water system will be replaced when :

a. the pH of the reactor pool water is between 6 and 7.

b. the flow rate of the purification system is higher than 10 gpm.

c. the conductivity of the reactor tank water is less than 5 μmhos/cm.

d. The differential pressure on the purification water system exceeds 8 psi.

QUESTION C.4 [1.0 point, 0.25 each]
Match the inputs listed in column A with their responses listed in column B. (Items in column B may be used more than once or not at all). Assume the reactor is in operation.

Column A	Column B
a. High Voltage to CIC = 500 V	1. Indicate only
b. Percent power level=104 %	2. Interlock
c. Pool water conductivity = 1 µsiemen/cm	3. Scram
d. Withdrawal of Shim and Reg rods simultaneously	

QUESTION C.5 [1.0 point]
During the thermal power calibration, if the Percent Power Channel output is about 5% HIGHER than the calculated thermal power calibration, the reactor operator:

a. no needs to adjust the Percent Power Channel output.

b. needs to adjust the Percent Power Channel output by adjusting the Percent Power Channel gain.

c. needs to adjust the Percent Power Channel output by physically LOWER the height of the detectors in the support assembly.

d. needs to adjust the Percent Power Channel output by physically RAISE the height of the detectors in the support assembly.

QUESTION C.6 [1.0 point]
The reactor is at 5 watts. Which ONE of the following will result in a reactor scram?

a. Move the source out of the reactor core.

b. Press the Percent Power Ramp Test button and watch the percent Power Channel exceeding 106 %.

c. Insert the test source to the RAM, verify the alarm.

d. The inlet conductivity approaches the TS limit of 2 µS/cm.

QUESTION C.7 [1.0 point]
Which ONE of the following materials is used as the neutron absorber in the Shim-Safety rods?

a. Hafnium

b. Cadmium

c. Samarium

d. Boron Carbide

QUESTION C.8 [1.0 point]
Half-way through a 6-hour reactor operation at full power, you discover that the exhaust fans haven't been operating. You try to turn ON, but they do not. Which ONE of the following actions should you take?

a. Immediately secure reactor operations. This event is a Technical Specification (TS) violation.

b. Immediately secure reactor. This event is NOT a TS violation because the supply fans are still operating.

c. Continue with reactor operations. Up to the next working day is allowed to repair the exhaust fans.

d. Continue with reactor operations. Technical Specifications specify the exhaust fans shall turn OFF during full power.

QUESTION C.9 [1.0 point]
The Reed Research Reactor uses the Compensated Ion Chamber (CIC) for:

a. Startup Channel

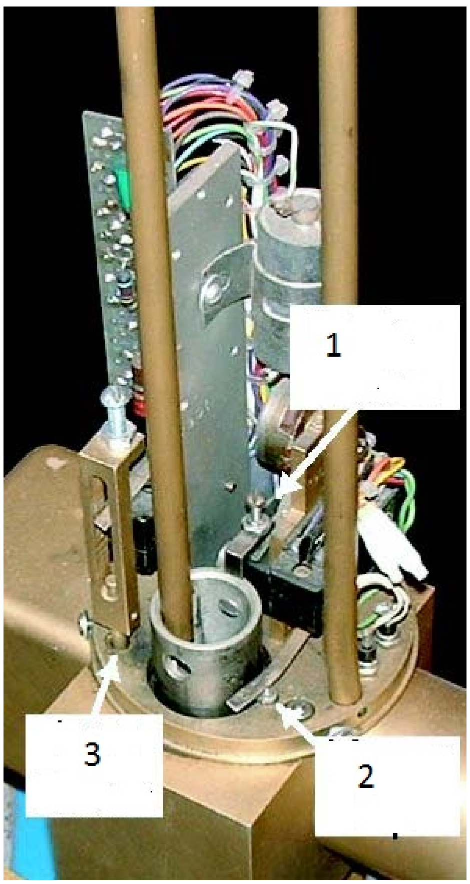
b. Percent Power Channel

c. Log Power Channel

d. Linear Power Channel

QUESTION C.10 [1.0 point, 1/3 each]
Use the following diagram of the control rod. Match the three limit switches listed in Column A to the appropriate labels in Column B?

Column A	Column B
a. Motor Down	1
b. Rod Down	2
c. Motor Up	3



QUESTION C.11 [1.0 point]
During reactor operation, a leak develops in the SECONDARY to PRIMARY heat exchanger. Which ONE of the following correctly explains the reactor pool level?

a. Pool level will increase because the Primary pressure is HIGHER than the Secondary pressure

b. Pool Level will increase because the Primary pressure is LOWER than the Secondary pressure

c. Pool Level will be the same because the Primary pressure is EQUAL to the Secondary pressure

d. Pool Level will decrease because the Primary pressure is HIGHER than Secondary pressure

QUESTION C.12 [1.0 point]
You as a Reactor Operator perform a fuel element inspection. In measuring the transverse bend, you find the bend of one fuel element exceeds the original bend by 0.10 inches. For this measurement, you will:

a. continue the fuel inspection because this bend is within TS limit.

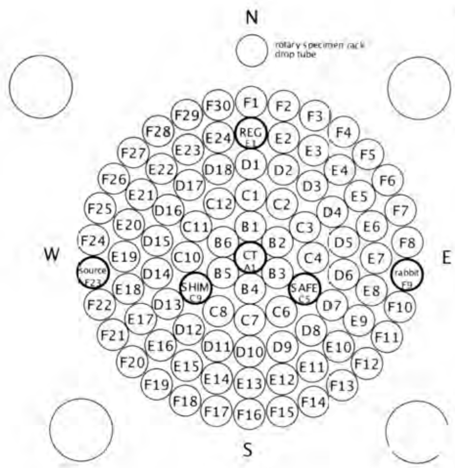
b. continue the fuel inspection because the Technical Specifications require the elongation measurement only.

c. stop the fuel inspection; you immediately report the result to the supervisor because it is considered a damaged fuel element.

d stop the fuel inspection, you immediately report the result to the U.S. NRC since it is a reportable occurrence.

QUESTION C.13 [1.0 point]
Use the following diagram of the reactor core. Match the nuclear detectors (Column A) to the respective locations (Column B)?

Column A	Column B
a. Linear	1
b. % Power	2
c. Log-n	3
d. Unused	4


N
rotary specimen rack
drop tube
W
E
S
REG
E1
CT
A1
SHIM
C9
SAFE
C5
source
F23
rabbit
F9
F1 F2 F3 F4 F5 F6 F7 F8 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F24 F25 F26 F27 F28 F29 F30
E2 E3 E4 E5 E6 E7 E8 E9 E10 E11 E12 E13 E14 E15 E16 E17 E18 E19 E20 E21 E22 E23 E24
D1 D2 D3 D4 D5 D6 D7 D8 D9 D10 D11 D12 D13 D14 D15 D16 D17 D18
C1 C2 C3 C4 C6 C7 C8 C10 C11 C12
B1 B2 B3 B4 B5 B6

QUESTION C.14 [1.0 point]
Which ONE of the following best describes on how the compensated Ion Chamber (CIC) and the Fission Chamber (FC) operate?

a. The CIC has two chambers, both can sense gamma rays but only one is coated with boron-10 for (n,α) reaction; whereas the FC is coated with U-235 for fission reaction.

b. The CIC has two chambers, one is coated with U-235 for fission reaction and the other is coated with boron-10 for (n,α) reaction; whereas the FC has only one chamber coated with U-235 for fission reaction.

c. The CIC has only one chamber coated with boron-10 for (n,α) reaction; whereas the FC is coated with U-235 for fission reaction.

d. The CIC has only one chamber coated with U-235 for fission reaction, whereas the FC has two chambers, both can sense gamma rays but only one is coated with U-235 for fission reaction.

QUESTION C.15 [1.0 point]
The demineralizer is a mixed-bed type that removes both positive and negative ions from the circulating water. Which ONE of the following best describes on how these ions are replaced?

a. Both negative and positive ions are replaced by hydroxyl (OH) ions.

b. Both negative and positive ions are replaced by hydrogen (H) ions.

c. The positive ions are replaced by hydrogen (H) ions and the negative ions are replaced by hydroxyl (OH) ions.

d. The positive ions are replaced by hydroxyl (OH) ions and the negative ions are replaced by hydrogen (H) ions.

QUESTION C.16 [1.0 point]
Which ONE of the following correctly describes the Shim and Regulating rod drive motors at Reed Research Reactor?

a. The Shim and Regulating rod drive motors are non-synchronous, single-phase, and electrically-reversible.

b. The Shim and Regulating rod drive motors are synchronous, three-phase, and electrically-reversible.

c. The Shim rod drive motor is non-synchronous, single-phase, and electrically-reversible whereas the Regulating rod drive motor is a stepper motor.

d. The Regulating rod drive motor is non-synchronous, single-phase, and electrically-reversible whereas the Shim rod drive motor is a stepper motor.

QUESTION C.17 [1.0 point]
The reactor is at 100 kW. Which **ONE** of the following Experimental Facilities provides the **HIGHEST** neutron flux?

a. Central Thimble Facility

b. Pneumatic Transfer System

c. Rotary Specimen Rack

d. Single-element Replacement located at C-ring

QUESTION C.18 [1.0 point]
Which ONE of the following is the MAIN purpose to have a neutrons source in the reactor core?

a. To ensure the reactor change from subcritical to critical by using neutron source ONLY.

b. To provide a reference point where all instruments undergo a check before the reactor is brought to a critical position.

c. To provide enough delayed neutrons for all nuclear instrumentations before the reactor can go to a critical position.

d. To prevent the period becoming very short and resulting in an inadvertent power excursion.

******************* End of Section C *****************************
****************** End of the Exam ***************************

A.1
Answer: c
Reference: First, find K_{eff1} with ρ = -2.0% ΔK/K

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

$-0.02\ K_{eff1} = K_{eff1} - 1$ so $1.02\ K_{eff1} = 1$ $K_{eff1} = 0.980$
$CR_2/CR_1 = (1 - K_{eff1})/(1 - K_{eff2})$ $600/150 = (1 - 0.980)/(1 - K_{eff2})$
Then find: $K_{eff2} = 0.995$
$\Delta\rho = (Keff_2 - Keff_1)/(Keff_1 * Keff_2) = (0.995-0.980)/(0.995*0.98) = 1.54\%$ ΔK/K

A.2
Answer: a
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.3
Answer: d
Reference: $P=P_o e^{t/\tau}$ x $=3 \times 10^6 * e^{180/-80}$
$3 \times 10^6 * 0.105 = 3.15 \times 10^5$ cpm

A.4
Answer d
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1988, Sec 4.6, page 4-17

A.5
Answer: d
Reference: $P = P_0\ e^{t/T}$ —> $t= T*Ln(P/ P_0)$ assume constant period = 1
$t= Ln(P/ P_0)$ —> the smallest ratio of P/ P_0 is the shortest time to complete; so it is 150kW/100kW.

A.6
Answer: c
Reference: Burn, R., *Introduction of Nuclear Reactor Operations*, © 1988, Sec 4.2

A.7
Answer: b
Reference: Tech Spec SDM = total rod worth removed at critical – most reactivity control rod worth= $7.5 -$3.5 = $4.0
or
Tech Spec SDM = total rod worth –((rod excesses) + most reactivity control rod worth)= $9.0 – ($1.5+$3.5) = $4.0

A.8
Answer: a
Reference: Introduction to Nuclear Operation, Reed Burn, 1988, Figure 8.1
Decay of I-135 produces xenon, and decay of Xe-135 produces Cs-135 where t1/2 of I-135 = 6.7 hour, t1/2 of Xe-135 = 9.2 hours

A.9
Answer: c
Reference: DOE Handbook Vol 2, Theory (Nuclear Parameters), E.O. 1.1 a&b, pg. 9

A.10
Answer: a
Reference: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4
SDM = (1- keff)/keff = (1-0.945)/0.945 = 0.0582 Δk/k, it means you need 0.0582 Δk/k to get criticality. Adding 0.055 Δk/k, the reactor is still subcritical.
Another method:
Keff2=1 (critical) and Keff1=0.945, Δρ requires to reach criticality:
$\Delta\rho = (Keff_2 - Keff_1)/(Keff_1 * Keff_2) = (1-0.945)/(1*0.945) = 0.0582 > 0.055$, so the reactor is still subcritical.

A.11
Answer b
Reference: Chart of the Nuclides

A.12
Answer: b
Reference: $P=P_o e^{t/\tau}$ $3=1* e^{t/22}$ $t = 22$ sec*ln(3) = 24.2 sec

A.13
Answer: c
Reference: DOE Handbook Vol. 1 Section 3.0

A.14
Answer: c
Reference: DOE Fundamentals Handbook, Module 1, Neutron Interactions, page 45.

A.15
Answer: d
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Section 3.2

A.16
Answer: a
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, page 4-33

A.17
Answer: b
Reference: Group 1 is the longest-lived delayed neutron precursor for thermal fission in U-235, with a half-life of 55.72 sec. Lamarsh, J. “Introduction to Nuclear Engineering” p. 88

A.18
Answer: b
Reference: β-effective =56/(56+7352) =0.00756
Burn, R., *Introduction of Nuclear Reactor Operations*, © 1988, Figure 3.3

B.1
Answer: a
Reference: Assume beta cannot travel to 10 feet in air, therefore 0.5 mR is only gamma.
Gamma dose at 1 ft is: $(DR1)(R1^2) = (DR2)(R2^2) \rightarrow DR2 = (DR1)(R1^2) / R2^2 = 0.5$ mr x $(10\text{ ft})^2$ / $(1\text{ ft})^2$ = 50 mr/hr
Therefore, beta contribution at 1 ft. is 1000 - 50 = 950 mr/hr.

B.2
Answer: a
Reference: 10 CFR 20 (the committed-dose equivalent and the deep-dose equivalent used for individual organ)

B.3
Answer: b
Reference: Technical Specifications 6.1.2

B.4
Answer: d
Reference: Standard NRC Question

B.5
Answer: b
Reference: 1 mrem/hr at 1 meter (100 cm) = 11.1 mrem/hr. at 30 cm

B.6
Answer: b
Reference: $DR = DR_{\circ} {*} e^{-\lambda t}$
1.0 rem/hr =10 rem/hr* $e^{-\lambda(5hr)}$
Ln(1.0/10) = -λ*5 --> λ=0.4605; solve for t: Ln(.01/10)=-0.4605 (t) → t=15 hours
or
Reduce from 10 Rem to 1 Rem: 5 hours
From 1 Rem to 0.1 Rem: 5 hours
From 0.1 Rem to 0.01 Rem: 5 hours
Total: 15 hours

B.7
Answer: c
Reference: 10 CFR 55.21

B.8
Answer: b
Reference: TS 6.4

B.9
Answer: c
Reference: TS 4.3

B.10
Answer: d
Reference: EP 4.1, 4.2, and 4.3

B.11
Answer: b
Reference: TS 3.1 and 3.6

B.12
Answer: b
Reference: $DR = DR_o * e^{-\mu X}$
Find μ : $125 = 1000 * e^{-\mu * 60}$; $\mu = 0.03466$
If insertion of an HVL (thickness of lead), the original intensity will be reduced by half.
Find X: $1 = 2 * e^{-0.03466 * X}$; X= 20 mm
Find HVL by shortcut:
1000mR- 500 mR is the 1st HVL
500 mR – 250 mR is the 2nd HVL
500mR-125 mR is the 3rd HVL
So HVL=60mm/3 = 20 mm

B.13
Answer: a

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

Dose rate at 1 ft = 6CEN = 6 x 10Ci x 0.110 Mev x 1 =6.6 Rem/hr
Distant at 100 mrem/hr = R= sqrt(6600 mR/100 mR) = 8.12 ft

B.14
Answer: d
Reference: TS 3.6.1

B.15
Answer: c
Reference: TS 3.5

B.16
Answer: c
Reference: 10 CFR 20.

B.17
Answer: c
Reference: SOP 1

B.18
Answer: a
Reference: RRR Training Manual 3.4.6

C.1
Answer: c
Reference: TS 2.1

C.2
Answer: d
Reference: Reed Training Manual, Section 11.2

C.3
Answer: d
Reference: SOP 30

C.4 Key changed during the administration of the examination
Answer: a(3) b~~(1)~~ (3) c(1) d(2)
Reference: TSs 3.2.3 and 3.3

C.5
Answer: d
Reference: SOP 33

C.6
Answer: b
Reference: SOP 20 and SOP 30

C.7
Answer: d
Reference: Reed Training Manual, Section 11.3

C.8
Answer: a
Reference: TS 3.4

C.9
Answer: d
Reference: Reed Training Manual, Figure 11.10

C.10
Answer: a(1) b(3) c(2)
Reference: Reed Training Manual

C.11
Answer: b
Reference: Information got from site visit

C.12
Answer: c
Reference: TS 3.1.4

C.13
Answer: a(2) b(4) c(3) d(1)
Reference: Reed Training Manual

C.14
Answer: a
Reference: Information during a walkthrough

C.15
Answer: c
Reference: RRR Facility Reference Manual 2.2.4

C.16
Answer: c
Reference: RRR Facility Reference Manual 3.3

C.17
Answer: a
Reference: Highest flux due to its location (center of the reactor core)

C.18
Answer: d
Reference: TS 3.2.3