November 12, 2014

Dr. Donald Wall, Director
Nuclear Radiation Center
Roundtop Drive
Washington State University
Pullman, WA 99164-1300

SUBJECT: EXAMINATION REPORT NO. 50-027/OL-15-01, WASHINGTON STATE UNIVERSITY

Dear Dr. Wall:

During the week of October 20, 2014, the U.S. Nuclear Regulatory Commission (NRC) administered operator licensing examinations at your Washington State University TRIGA 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 at the conclusion of the examination with those members of your staff identified in the enclosed report.

In accordance with Title 10, Section 2.390 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 (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 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 Mr. John T. Nguyen at (301) 415-4007 or via internet e-mail John.Nguyen@nrc.gov.

Sincerely,

/RA/

Kevin Hsueh, Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-027

Enclosures:
1. Examination Report No. 50-27/OL-15-01
2. Facility Comments with NRC Resolution
3. Written examination with facility comments incorporated

cc: Corey Hines, Reactor Supervisor, Washington State University
cc: w/o enclosures: See next page

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DISTRIBUTION w/ encls:
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OFFICE	NRR/DPR/PROB:CE		NRR/DPR/IOLB:LA	E	NRR/DPR/PROB:BC
NAME	JNguyen		CRevelle		KHsueh
DATE	11/4/2014		11/4/2014		11/12/2014

OFFICIAL RECORD COPY

cc:

Director
Division of Radiation Protection
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Mr. David Clark
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Washington State University
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Dr. Ken Nash
Chair, Reactor Safeguards Committee
Nuclear Radiation Center
Washington State University
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Test, Research and Training
Reactor Newsletter
P.O. Box 118300
University of Florida
Gainesville, FL 32611-8300

ENCLOSURE 1
U. S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION REPORT

REPORT NO.: 50-27/OL-15-01

FACILITY DOCKET NO.: 50-27

FACILITY LICENSE NO.: R-76

FACILITY: Washington State University TRIGA Reactor

EXAMINATION DATES: October 21 – October 22, 2014

SUBMITTED BY: **/RA/** **10/30/14**
John T. Nguyen, Chief Examiner Date

SUMMARY:

During the week of October 20, 2014, the NRC administered operator licensing examination to two Reactor Operator (RO) license candidates and one Senior Reactor Operator-Upgrade (SROU). The one RO candidate failed the written portion of the examination. The two other candidates passed all applicable portions of the examinations.

REPORT DETAILS

1. Examiners: John T. Nguyen, Chief Examiner, NRC

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	1/1	W	1/1
Operating Tests	1/0	1/0	2/0
Overall	1/1	1/0	2/1

3. Exit Meeting:
John T. Nguyen, Chief Examiner, NRC
Paulette Torres, Reactor Engineer, NRC
Corey Hines, Reactor Supervisor, Washington State University

At the conclusion of the site visit, the examiner met with representative of the facility staff to discuss the results of the examinations. The facility licensee had various comments on the written examination that were incorporated in the examination report (see Enclosure 2).

ENCLOSURE 2
FACILITY COMMENTS ON THE WRITTEN EXAM WITH NRC RESOLUTION

QUESTION A.02 [1.0 point]
The shutdown margin (SDM), upon full insertion of all control rods following a reactor scram after a 24 hours run at full power, is _____ the SDM immediately prior to the scram.

a. Less than

b. Equal to

c. Double

d. Higher than

Answer: d
REF: Burns, Section 6.2.3, pg. 6-4.

Facility comments: Answer (d) occurs in a power reactor when chemical shim is added to the coolant to provide additional negative reactivity to the SDM. In our reactor, the SDM is the amount of reactivity inserted into a core if all the rods were dropped from critical height (ref). Therefore the only effect on SDM is xenon which would be unchanged immediately before and after a scram.

It is also unclear as to if the shutdown margins in question are immediately following the scram at some longer (hours) interval thereafter.

Facility Recommendation: Since there is no chemical shim added to the pool, the SDM before and after a scram would be the same. Due to the vague nature of the SDM comparison times, we recommend the answer key be amended such that (b) and (d) are the correct answers.

Reference: Burn 6.2.3, pg. 6-6

NRC Resolution: The NRC agrees with the facility comment and accepts both B and D as correct answers.

QUESTION A.20 [1.0 point]
During the time when reactor power increases, the delayed neutron fraction, β:

a. Remains unchanged.

b. Increases because prompt neutrons are being produced at a faster rate.

c. Increases because delayed neutron precursors are being produced at a faster rate.

d. Decreases because delayed neutrons are being produced from precursors that were formed at a lower power level.

Answer: d
REF: Burns, Section 4.4, pg. 4-8

Facility comments: "When reactor power increases" could mean delayed supercritical or immediately following a reactivity insertion. In either case, the beta fraction is not actually affected. The *effective* beta fraction, that is, the apparent effect on the beta fraction is unchanged. Burn says that the beta fraction is "**effectively decreased** due to the faster rate of production of prompt neutrons during control rod withdrawal." So the prompt neutrons dominate the delayed neutrons, but the actual fraction of delayed neutrons remains unchanged.

Facility Recommendation: Due to the vague nature of the question the recommendation is to throw out the exam question.

Reference: Burn 4.4.1, page 4-11.

NRC Resolution: The NRC agrees with the facility comment and accepts deleting question A.20.

QUESTION B.04 [1.0 point]
When the reactor is in Steady State mode, which ONE interlock prevents the rapid insertion of reactivity?

a. Control element selector

b. Transient rod control

c. 1 kW pulse

d. Pulse-mode switch

Answer: b
REF: TS, Table 3.3, pg. 19 and TS 3.2.3 Basis, pg. 20

Facility comments: Both (a) control element selector and (b) transient rod control prevents rapid insertion of reactivity. Both (a) and (b) are correct.

Recommendation: Answer key should reflect that both answers (a) and (b) should be accepted as correct.

Reference: Tech Spec 3.2.3 basis for control element selector switch AND transient rod control.

NRC Resolution: The NRC agrees with the facility comment and accepts both A and B as correct answers.

QUESTION C.04 [1.0 point]
Which ONE of the following channels is not linked to a safety function?

a. Pulse Power channel

b. Log Power channel

c. Linear Power channel

d. Fuel Temperature Monitoring channel

Answer: c
REF: SAR 7.3.3, pg.7-9

Facility comments: Change answer key to reflect log channel. However, log channel has LCRI, pulse power inhibit, and period scram. All are safety functions. The given correct answer (c) linear power channel has a high power scram and is listed in table 3.2 of the TS. All three power channels and the fuel temperature channel are listed in the SAR as having safety functions.

Facility Recommendation: No correct answer is provided, so the question should be thrown out.

Reference: SAR pg 7-9, Technical Specifications 3.2.3 table 3.2.

NRC Resolution: The NRC agrees with the facility comment and accepts deleting question C.04.

ENCLOSURE 3
U. S. NUCLEAR REGULATORY COMMISSION
NON-POWER REACTOR LICENSE EXAMINATION

FACILITY: Washington State University

REACTOR TYPE: TRIGA

DATE ADMINISTERED: 10/20/2014

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
19.00 ~~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
19.00 ~~20.00~~	33.3	_____	_____	C. FACILITY AND RADIATION MONITORING SYSTEMS
58.00 ~~60.00~~		_____ 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

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.

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 ___~~ deleted per facility comment

(***** 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 ___ (0.25 each)

B09 a b c d ___

B10 a b c d ___

B11 a b c d ___

B12 a ___ b ___ c ___ d ___ (0.25 each)

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 *****)

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 ___~~ deleted per facility comment

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 kg = 2.21 lbm

1 Horsepower = 2.54 x 10^3 BTU/hr

1 Mw = 3.41 x 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

WASHINGTON STATE UNIVERSITY
TRIGA REACTOR

Operator Licensing Examination

Week of October 20, 2014

QUESTION A.01 [1.0 point]
Which ONE is true about "subcritical multiplication"? As the reactor approaches criticality, the parameter

a. k_{eff} approaches zero

b. 1/M approaches zero

c. M approaches one

d. ρ approaches infinity

QUESTION A.02 [1.0 point]
The shutdown margin (SDM), upon full insertion of all control rods following a reactor scram after a 24 hours run at full power, is _____ the SDM immediately prior to the scram.

d. Less than

e. Equal to

f. Double

d. Higher than

QUESTION A.03 [1.0 point]
The reactor is shutdown with a k_{eff} of 0.952. Initial power is 250 mW. The operator withdraws a safety blade to its required position; thereby adding 110 cents of reactivity. What would be the new power level?

a. 127 mW

b. 214 mW

c. 293 mW

d. 525 mW

QUESTION A.04 [1.0 point]
Which ONE is true about "excess reactivity"?

a. Ensures that the reactor can be shut down from any condition of operation

b. Ensures that the fuel temperature safety limit will not be exceeded

c. Is the change in reactivity caused by control rod motion

d. Is the amount of reactivity in excess of the amount of reactivity needed to make the reactor critical

QUESTION A.05 [1.0 point]
A glass contains 25 gram of H_2O. How many Deuterium atoms are in the water? Atomic Weight of Hydrogen is 1.00797 and Atomic Weight of Oxygen is 15.9994. Deuterium is 0.015% of Hydrogen.

a. 2.508×10^{20}

b. 5.014×10^{20}

c. 1.672×10^{24}

d. 3.343×10^{24}

QUESTION A.06 [1.0 point]
The ideal moderator has _____ atomic mass for large fractional energy loss per collision; _____ neutron scattering cross section, so the distance between collisions is small; and a _____ absorption cross section so that the thermal utilization of the neutrons is dependent primarily on the characteristics of the fuel.

a. Low, low, high

b. Low, high, low

c. High, low, high

d. High, high, low

QUESTION A.07 [1.0 point]
Which ONE is true about “reflectors”?

a. Produces neutrons

b. Have a high neutron absorption cross section

c. Limit the chain reaction by absorbing neutrons

d. Flatten the neutron flux profile of a reactor core

QUESTION A.08 [1.0 point]
The term “macroscopic cross section” is defined as

a. The average distance travelled by a neutron between interactions in a material.

b. An indication of energy loss per collision.

c. The probability of neutron interaction per centimeter of travel in a material.

d. The effective cross sectional area of a single nucleus presented to an oncoming neutron.

QUESTION A.09 [1.0 point]
The reactor is operating at a constant power of 300kW. The reactor is scrammed by the sudden insertion of control rods worth 7% Δk/k in reactivity. What is the prompt drop power (immediate power dropped after scram the control rods?

a. 100 kW

b. 60 kW

c. 30 kW

d. 10 kW

QUESTION A.10 [1.0 point]
Which one of the following is the MAJOR source of energy released during fission?

a. Kinetic energy of the fission neutrons.

b. Kinetic energy of the fission fragments.

c. Decay of the fission fragments.

d. Prompt gamma rays.

QUESTION A.11 [1.0 point]
You start with a cold critical reactor and you insert a control rod to change the reactivity to k_{eff}=0.994. How much reactivity was inserted by the control rods in units of cents? Given β=0.007.

a. -86.2 ¢

b. -60.4 ¢

c. -0.862 ¢

d. -0.604 ¢

QUESTION A.12 [1.0 point]
Which ONE of the following factors is not affected by the amount of moderator in the reactor?

a. Thermal non-leakage probability

b. Resonance escape probability

c. Thermal utilization factor

d. Reproduction factor

QUESTION A.13 [1.0 point]
You start with 10^{10} atoms of ^{60}Co ($t_{1/2}$ = 1,925.1 days). How many years will it take for the number of atoms to decay to 5 x 10^{8} atoms?

a. 4.32 years

b. 11.5 years

c. 22.9 years

d. 34.6 years

QUESTION A.14 [1.0 point]
Reactor period is defined as:

a. The time required for a reactor to change by a factor of *e*

b. The time required for the reactor power to double

c. The number of factors of ten that reactor power changes in one minute

d. The fraction of all neutrons that are born as delayed neutrons

QUESTION A.15 [1.0 point]
Which ONE of the following has the lowest thermal neutron cross section?

a. Cd-113

b. Xe-135

c. Sm-149

d. U-235

QUESTION A.16 [1.0 point]
Which ONE is true about the four factor formula?

a. Neutron leakages can be reduced by increasing the size of the core.

b. Neutron leakages can be reduced by using a reflector.

c. Neutron leakages can be reduced by increasing moderator temperature.

d. There is no leakage term. The reactor is considered to be infinite in size.

QUESTION A.17 [1.0 point]
Which ONE defines an integral rod worth curve?

a. Conforms to an axial flux shape.

b. Represents the cumulative area under the differential curve starting from the bottom of the core.

c. Any point on the curve represents the amount of reactivity that one inch of rod motion would insert at that position in the core.

d. Reactivity is highest at the top of the core and lowest at bottom of the core.

QUESTION A.18 [1.0 point]
Which ONE of the following describes the term prompt jump?

a. A rapid rise in power level due to an increase in the production of prompt neutrons.

b. A reactor which has attained criticality on prompt neutrons alone.

c. A reactor which is critical using both prompt and delayed neutrons.

d. A negative reactivity insertion which is less than k_{eff}.

QUESTION A.19 [1.0 point]
Xenon-135 is formed directly by decay of _____.

a. Iodine-135

b. Tellurium-135

c. Cesium -135

d. Barium-135

~~**QUESTION A.20 [1.0 point]**~~
~~During the time when reactor power increases, the delayed neutron fraction, β:~~

~~e. Remains unchanged.~~

~~f. Increases because prompt neutrons are being produced at a faster rate.~~

~~g. Increases because delayed neutron precursors are being produced at a faster rate.~~

~~h. Decreases because delayed neutrons are being produced from precursors that were formed at a lower power level.~~

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

QUESTION B.01 [1.0 point]
Per Technical Specifications, which ONE of the following Measuring Channels has to be operable for both steady-state and pulsing modes of operation?

a. Integrated pulse power

b. Fuel element temperature

c. Log power level

d. Linear power level

QUESTION B.02 [1.0 point]
Continuous Air Monitor is capable of all EXCEPT:

a. Particulate collection

b. Detection of beta and gamma radiation

c. Monitor ^{41}Ar

d. Monitor particulate radioactivity in the pool room air

QUESTION B.03 [1.0 point]
In accordance with 10 CFR 20, the "Annual Limit on Intake (ALI)" refers to:

a. The concentration of a given radionuclide in air which, if breathed for a working year of 2000 hours, would result in a committed effective dose equivalent of 5 rems.

b. The dose equivalent to organs that will be received from an intake of radioactive material by an individual during the 50-year period following the intake.

c. The amount of radioactive material taken into the body by inhalation or ingestion in one year which would result in a committed effective dose equivalent of 5 rems.

d. Limits on the release of effluents to an unrestricted environment.

QUESTION B.04 [1.0 point]
When the reactor is in Steady State mode, which ONE interlock prevents the rapid insertion of reactivity?

e. Control element selector

f. Transient rod control

g. 1 kW pulse

h. Pulse-mode switch

QUESTION B.05 [1.0 point]
According to Technical Specifications, the Core Excess Reactivity is limited to _____.

a. $0.26

b. $2.25

c. $4.50

d. $7.47

QUESTION B.06 [1.0 point]
_____ are thresholds for establishing emergency classes and initiating appropriate emergency measures.

a. Emergency Action Levels

b. Emergency Planning Zones

c. Emergency Procedures

d. Protection Action Guides

QUESTION B.07 [1.0 point]
A _____ of the fuel rod temperature measuring channel shall be made each time the reactor is operated in the steady state mode by comparing the indicated instrumented fuel rod temperature with previous indicated temperature values for the same core configuration and power level.

a. Channel Calibration

b. Channel Check

c. Channel Test

d. Visual Inspection

QUESTION B.08 [1.0 point, 0.25 point each]
Match the 10CFR55 requirements for maintaining an active operator license in column A with the corresponding time period from column B (answers can be used more than once).

Column A	Column B
a. Renewal Application of Existing License	1 year
b. Medical Exam	2 years
c. Pass Requalification Written Examination	4 years
d. Pass Requalification Operating Test	6 years

QUESTION B.09 [1.0 point]
A GM detector with window open reads a radiation source as 200 mR/hr. The new reading is 50 mR/hr with the window close. What would be the gamma and beta doses?

a. The gamma dose rate is 20 mR/hr and the beta rate is 180 mR/hr

b. The gamma dose rate is 50 mR/hr and the beta rate is 150 mR/hr

c. The dose rate from gammas is half of the betas

d. Gamma and beta dose rates are the same

QUESTION B.10 [1.0 point]
Following an evacuation of the facility during an emergency, who by title, shall authorize reentry into the Nuclear Radiation Center building (according to the Emergency Plan)?

a. Emergency Director

b. Emergency Coordinator

c. WSU emergency management

d. Radiation Safety Officer

QUESTION B.11 [1.0 point]
Which ONE of the following BNC facility actions shall be done pursuant to the requirements of 10 CFR 50.59? _____ of the BNC room radiation monitor.

a. Maintenance

b. Repair

c. Modification

d. Operation

QUESTION B.12 [1.0 point, 0.25 each]
Match the surveillance requirements for control rod operability (answers can be used more than once):

Column A	Column B
a. The Regulating Rod shall be visually inspected _____.	1. monthly
b. The Standard Control Rod shall be visually inspected _____.	2. semiannually
c. The scram time shall be measured _____.	3. annually
d. The transient rod drive cylinder and associated air supply system shall be inspected, cleaned, and lubricated _____.	4. biennially

QUESTION B.13 [1.0 point]
Minor modifications that do not change the original intent to a reviewed and approved experiment may be made at the discretion of the _____.

a. Reactor Supervisor

b. Facility Director

c. Nuclear Regulatory Commission

d. Reactor Safeguards Committee

QUESTION B.14 [1.0 point]
Per Technical Specifications, the reactivity worth of moveable experiments shall be shown by measurement, testing, calculation, or comparison to other experiments, to be less than _____, and, the sum of absolute values of all individual experiments shall be shown to be less than _____.

a. $1.00 and $2.00

b. $1.00 and $5.00

c. $2.00 and $5.00

d. $5.00 and $8.00

QUESTION B.15 [1.0 point]
Per 10 CFR 55.53 “Conditions of Operator Licenses”, which ONE of the following is a condition of your reactor operating license?

a. Transferrable between facilities

b. Subject to all NRC rules and regulations

c. Subject to an annual medical examination

d. Must be exercised for at least 8 hours per quarter

QUESTION B.16 [1.0 point]
Which ONE is an example of a safety event described in the Emergency Plan?

a. Bomb threat directed at the facility.

b. Personal injury with radiological complications.

c. Exceeding a Safety Limit.

d. Failure of an in-core reactor experiment.

QUESTION B.17 [1.0 point]
Which ONE of the following describes a Radiation Area?

a. Any area to which access is limited for any reason.

b. Any area to which access is limited for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

c. Area where radiation exposure rates would result in a dose equivalent in excess of 5 mrem (0.05 mSv) in one hour at 30 centimeters from the radiation source.

d. Area where radiation exposure rates would result in a dose equivalent in excess of 0.1 rem (1 mSv) in one hour at 30 centimeters from the radiation source.

QUESTION B.18 [1.0 point]
If a gamma source measures 425 mR/hr at one foot, what will it measure at three feet?

a. 0.021 mR/hr

b. 47 mR/hr

c. 142 mR/hr

d. 207 mR/hr

QUESTION B.19 [1.0 point]
The ventilation system shall automatically switch to dilute mode upon a high activity alarm from the _____.

a. Reactor bridge radiation monitor

b. Beam room radiation monitor

c. Continuous air monitor

d. Exhaust gas monitor

QUESTION B.20 [1.0 point]
Which ONE of the following requires NRC approval for changes?

a. Operator Requalification Program

b. Reactor Startup Checkout Form

c. Radiation Protection Program

d. Standard Operating Procedures

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

QUESTION C.01 [1.0 point]
A system of limit switches is used to indicate the position of the air cylinder and the transient rod. Which ONE is the switch actuated when the piston reaches its lower limit of travel?

a. The Drive Up switch

b. The Drive Down switch

c. The Rod Up switch

d. The Rod Down switch

QUESTION C.02 [1.0 point]
After the performance of Thermal Power Calibration, the Linear Power Channel indicates 98% of full power calculated on the power calibration. The SOP #13: Standard Procedure for Performing Power Calibrations recommends doing the following:

a. Raise the Fission Chamber position to increase channel indication

b. Lower the Fission Chamber position to increase channel indication

c. Increase the H.V. CIC of the NMP 1000 to increase channel indication

d. No adjustment of detectors is required

QUESTION C.03 [1.0 point]
The facility is designed so that the ventilation system will normally maintain a negative pressure with respect to the atmosphere. This is done to _____.

a. Minimize uncontrollable leakage to the environment.

b. Prevent the generation of Argon-41.

c. Keep personnel exposures ALARA.

d. Expedite reactor cooling by natural convection.

~~**QUESTION C.04 [1.0 point]**~~
~~Which ONE of the following channels is not linked to a safety function?~~

~~e. Pulse Power channel~~

~~f. Log Power channel~~

~~g. Linear Power channel~~

~~h. Fuel Temperature Monitoring channel~~

QUESTION C.05 [1.0 point]
Which ONE of the following materials is used for the Transient Control Rod?

a. Hafnium

b. Cadmium

c. Borated graphite

d. Stainless steel

QUESTION C.06 [1.0 point]
Which ONE of the following is classified as an Operational Experiment?

a. Irradiations with a dose rate greater than 10 rem/hr at 30 cm upon removal from the reactor shielding.

b. Reactivity worth of the device or material greater than $0.25.

c. In-core residence time of greater than 15 days.

d. Argon-41 effluent measurement.

QUESTION C.07 [1.0 point]
What kind of detector feeds the Linear Power channel?

a. Fission chamber

b. Compensated ion chamber

c. Geiger-Mueller

d. Scintillation

QUESTION C.08 [1.0 point]
A Senior Reactor Operator shall be present at the facility during the following EXCEPT:

a. Any significant increases in power level changes

b. A recovery from an unplanned shutdown

c. All fuel movement or relocation

d. Fuel temperature calibration

QUESTION C.09 [1.0 point]
The lowest level conductivity alarm, occurs when the conductivity of the ion exchanger bed rises to _____.

a. 0.1 μmhos

b. 0.5 μmhos

c. 1.0 μmhos

d. 1.25 μmhos

QUESTION C.10 [1.0 point]
Which ONE of the following Reactor Safety Channels ensures that the reactor power level will return to a low level after pulsing?

a. Primary coolant temperature

b. Power level

c. Manual scram

d. Preset timer

QUESTION C.11 [1.0 point]
Per the Technical Specifications, the pH of the pool water is required to be checked _____.

a. Daily

b. Every two weeks

c. Quarterly

d. Every year

QUESTION C.12 [1.0 point]
Which ONE of the following control rod components is used to reduce the drive speed?

a. Magnet leads

b. Worm-gear assembly

c. Mechanical slip clutch

d. Ball-bearing screw and nut system

QUESTION C.13 [1.0 point]
You perform a fuel element inspection. In measuring the transverse bend, you find the bend of one fuel element to be 0.120 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 WSU Tech Spec requires the elongation measurement only.

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

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

QUESTION C.14 [1.0 point]
Which ONE of the following Area Radiation Monitors has a setpoint of 50 mR/hr?

a. Beam Room 2 South ARM

b. Beam Room 2 North ARM

c. Beam Room 2A Cave ARM

d. Radio Chem Lab Room 101 ARM

QUESTION C.15 [1.0 point]
Fuel temperature must be limited in the Standard TRIGA fuel rods in order to avoid fuel element failure due to which of the following mechanisms?

a. Distortion of the fuel element due to a phase change of the natural erbium.

b. Fission product built up.

c. Excessive pressure from expansion of Argon-41.

d. Excessive pressure caused by air, fission product gases, and zirconium hydride hydrogen dissociation.

QUESTION C.16 [1.0 point]
Per Technical Specifications, the radiation shielding requirements of the Reactor Pool Water System are fulfilled by keeping at least _____ of water directly above the top of the core.

a. 12 ft

b. 14 ft

c. 16 ft

d. 20 ft

QUESTION C.17 [1.0 point]
Which ONE of the following correctly describes the characteristic of the unirradiated 30/20 fuel rods used at the WSU reactor?

a. The maximum uranium content is 30% by weight uranium, enriched to less than 20% U-235; and the erbium content is homogeneously distributed with a nominal 0.90% by weight.

b. The maximum uranium content is 30% by weight uranium, enriched to less than 20% U-235, and NO erbium content.

c. The hydrogen to zirconium atom ratio (in the ZrHx) shall be between 1.5 and 1.8.

d. The maximum uranium content is 30% by weight uranium, enriched to less than 20% U-235; and the erbium content is homogeneously distributed with a nominal 0.50% by weight.

QUESTION C.18 [1.0 point]
Which ONE of the following systems obtains emergency power in the event of a power loss by the Auxiliary Reactor Emergency Supply (ARIES)?

a. Pool Level Alarm

b. Primary Coolant Pump

c. Control Rods

d. Pneumatic Transfer System

QUESTION C.19 [1.0 point]
Which ONE of the following will result in a reactor scram?

a. Bulk primary coolant temperature exceeds 40°C.

b. Instrumented fuel element temperature to exceed 180°C.

c. Withdrawing two control rods at the same time.

d. Loss of high voltage to power channels.

QUESTION C.20 [1.0 point]
Upon initiation of a high fuel temperature reactor scram, the ventilation system:

a. Shall be switched to the isolate mode

b. Shall automatically switch into the dilute mode

c. Is operating normally

d. Shut down

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

A.01
Answer: b
REF: Burns, Table 5.5, pg. 5-15

A.02
Answer: b and d are correct per facility comment
REF: Burns, Section 6.2.3, pg. 6-4 and 6-6.

A.03
Answer: c
REF: Given: $\Delta k/k_{(1)} = (keff_1 - 1)/keff_1 = (0.952 - 1) / 0.952 = -0.0504$
$\Delta k/k$ safety blade = \$ * β = (\$1.1) (0.0070) = \$0.0077
$\Delta k/k_{(2)} = \Delta k/k_{(1)} + \Delta k/k$ safety blade = - 0.0504 + 0.0077 = - 0.0427
$keff_2 = 1 / (1 - \Delta k/k_{(2)}) = 1 / (1 - (- 0.0427)) = 0.959$
$(1 - keff_1)(CR_1) = (1 - keff_2)(CR_2) = (1 - 0.952)(250mW) = (1 - 0.959)(CR_2)$
$CR_2 = 293$ mW

A.04
Answer: d
REF: TS Section 3.1.4, pg. 15 (Answer for a and b is shutdown margin)
DOE Handbook part 2, module 3, p. 50 (Answer for c is control rod worth)

A.05
Answer: a
REF: Molecular weight $H_2O = (2)(1.00797) + 15.9994 = 18.01537$ amu
moles H_2O = 25 g/18.01534 g/mole = 1.388
H atoms = (1.388)(6.023 x 10^{23} molecules per mole) (2 H atoms per molecule)
H atoms = 1.672 x 10^{24}
H-2 atoms = (0.00015)(1.672 x 10^{24}) = 2.508 x 10^{20}

A.06
Answer: b
REF: Reed Training Manual (September 2009), Section 7.4, pg. 113

A.07
Answer: d
REF: Reed Training Manual (September 2009), pg. 116

A.08
Answer: c
REF: Burns, Section 2.5, pg. 2-36 to 2-47

A.09
Answer: c
REF: Given P_0 = 300 kW, then $P_1 = \frac{\beta(1-\rho)}{\beta-\rho} P_0 = \frac{0.007(1-(-0.07))}{0.007-(-0.07)} 300 = 29.18$ kW

A.10
Answer: b
REF: Burns, Section 3.2.1, and Table 3.2, pg. 3-4 and 3-5

A.11
Answer: a
REF: Given k_{eff}=1, then $\rho = \frac{k_{eff}-1}{k_{eff}} = \frac{0.994-1}{0.994} = -0.006\frac{\Delta k}{k}$

$\Delta\rho(\$) = \frac{\Delta\rho\left(\frac{\Delta k}{k}\right)}{\beta} = \frac{-0.006\left(\frac{\Delta k}{k}\right)}{0.007} = -\$0.862$

$\Delta\rho(¢) = \Delta\rho(\$) * 100 = -\$0.862(100) = -86.2¢$

A.12
Answer: d
REF: Reed Training Manual (September 2009), Section 10.5, pg. 167. The fuel utilization factor (also called the reproduction factor) is not affected by the moderator since it is purely a function of the nuclear characteristics of ^{235}U.

A.13
Answer: c
REF: $N(t)=N_0e^{-\lambda t} \rightarrow N(t)/N_0=e^{-\lambda t} \rightarrow \ln(N(t)/N_0)=-\lambda t$
$\lambda = \ln(2)/t_{1/2}$

$t = \frac{ln\frac{N(t)}{N_0}}{-\lambda} = \frac{\ln\left(\frac{5x10^8}{10^{10}}\right)}{\frac{\ln(2)}{-(1925.1\ days)/(365 days/years)}}$

t=22.9 years

A.14
Answer: a
REF: DOE Handbook part 2, module 4, pg. 21

A.15
Answer: d
REF: Burns, Table 2.5, pg. 2-59. Also, Table 8.1, pg. 8-2

A.16
Answer: d
REF: Reed Training Manual (September 2009), equation 8.13, pg. 125

A.17
Answer: b
REF: Burn, Section 7.3, pg. 7-5 to 7-7

A.18
Answer: a
REF: Burns, Section 4.7, pg. 4-21

A.19

Answer: a
REF: Burns, Figure 8.1, pg. 8-6

~~**A.20**~~
~~Answer: d~~
~~REF: Burns, Section 4.4, pg. 4-8~~ deleted per facility comment

B.1
Answer: b
REF: TS, Table 3.1, pg. 18

B.2
Answer: c
REF: TS 5.6, pg. 56-57

B.3
Answer: c
REF: 10CFR20.1003

B.4
Answer: a and b are correct per facility comment
REF: TS, Table 3.3, pg. 19 and TS 3.2.3 Basis, pg. 20

B.5
Answer: d
REF: TS 4.1.4, pg. 37.
The core excess reactivity is limited to 5.6% Δk/k.
$\Delta\rho(\$) = \frac{\Delta\rho\left(\frac{\Delta k}{k}\right)}{\beta} = \frac{0.056(\frac{\Delta k}{k})}{0.0075} = \$7.47$

B.6
Answer: a
REF: EP 2.2, pg.7

B.7
Answer: b
REF: TS 4.2.2, pg. 40

B.8
Answer: a, 6 years (10 CFR 55.55)
b, 2 years (10 CFR 55.53)
c, 2 years (10 CFR 55.59)
d, 1 years (10 CFR 55.59)

REF: 10 CFR 55.53 “Conditions of Operator Licenses”
10 CFR 55.55 “Expiration”
10 CFR 55.59 “Requalification”

B.9
Answer: b
REF: With the aluminum shield in place, with the shield in place, only gammas are measured, so the gamma dose rate is 50 mR/hr. Without the shield, both gamma and beta are measured, so the beta dose rate must be 200 mR/hr - 50 mR/hr =150 mR/hr.

B.10
Answer: a
REF: EP 3.4, pg. 15

B.11
Answer: c
REF: TS 3.8(11), pg. 31

B.12
Answer: (a,4), (b,4), (c,3), (d,2)
REF: TS 4.2.1, pg. 39 and TS 1 "Control Rod definition", pg. 5-6

B.13
Answer: a
REF: TS 4.6 (9), pg. 46

B.14
Answer: b
REF: TS 4.6, pg. 45

B.15
Answer: b
REF: 10 CFR 55.53

B.16
Answer: b
REF: SOP #6, pg. 2-3

B.17
Answer: c
REF: 10 CFR20.1003 "Definitions"

B.18
Answer: b
REF: Given $DR_1(d_1)^2 = DR_2 (d_2)^2$
Then $DR_2 = \frac{DR_1}{(d_2/d_1)^2}$

$DR_2 = \frac{425 \text{ mR}}{(3/1)^2}$

$DR_2 = 47.2$ mR/hr

B.19
Answer: c
REF: TS 3.4 (3), pg. 22

B.20
Answer: a
REF: 10 CFR 50.54

C.01
Answer: d
REF: SAR 4.2.2, pg. 4-29

C.02
Answer: d
REF: SOP #13, pg. 5

C.03
Answer: a
REF: TS 5.6 Basis, pg. 36

~~**C.04**~~
~~Answer: c~~
~~REF: SAR 7.3.3, pg.7-9~~ deleted per facility comment

C.05
Answer: c
REF: TS 5.4, pg. 55

C.06
Answer: d
REF: SOP #3, pg. 1-2 and TS 3.11, pg. 16-17

C.07
Answer: b
REF: SAR 7.3.3, pg. 7-9

C.08
Answer: d
REF: TS 6.2.3 pg. 62 and SOP#14

C.09
Answer: b
REF: ~~SAR 5.4, pg. 5-13~~ To be provided by licensee

C.10
Answer: d
REF: TS Table 3.2, pg. 19

C.11
Answer: b
REF: TS 4.3, pg. 42 and SOP#5, section Q

C.12
Answer: b
REF: SAR 4.2.2, pg. 4-23

C.13
Answer: a
REF: TS 3.1.6, pg. 16

C.14
Answer: c
REF: Reactor Start-up Checkoff (WSUNRC Form No. 34) pg. 2

C.15
Answer: d
REF: TS 2.1 basis, pg. 12

C.16
Answer: c
REF: TS 5.8, pg.59

C.17
Answer: a
REF: TS 5.2, pg. 53

C.18
Answer: a
REF: SAR 7.4.6, pg. 7-17

C.19
Answer: d
REF: TS Table 3.2, pg. 19

C.20
Answer: a
REF: TS 3.4 (4), pg. 22