March 21, 2016

Dr. Steven E. Reese, Director
Oregon State University
Radiation Center, A100
Corvallis, OR 97331-5903

SUBJECT: EXAMINATION REPORT NO. 50-243/OL-16-01, OREGON STATE UNIVERSITY

Dear Dr. Reese:

During the week of February 22, 2016, the NRC administered an operator licensing examination at your Oregon State University TRIGA reactor. The examination was conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with you and 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 enclosure 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 Mrs. Paulette Torres at (301) 415-5656 or via e-mail Paulette.Torres@nrc.gov.

Sincerely,

/RA/

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

Docket No. 50-243

Enclosures: 1. Examination Report No. 50-243/OL-16-01
2. Facility Comments with NRC Resolution
3. Written Examination

cc w/o enclosures: See next page

March 21, 2016

Dr. Steven E. Reese, Director
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SUBJECT: EXAMINATION REPORT NO. 50-243/OL-16-01, OREGON STATE UNIVERSITY

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DISTRIBUTION w/ encl.
Public RidsNrrDprPrtb RidsNrrDprPrta

ADAMS Accession No. ML16073A009 **NRR-079**

OFFICE	NRR/DPR/PROB/CE	NRR/DPR/PROB/OLA	NRR/DPR/PROB/BC
NAME	PTorres	CRevelle	AMendiola
DATE	3/01/2016	3/14/2016	3/21/2016

OFFICIAL RECORD COPY

cc:

Mayor of the City of Corvallis
Corvallis, OR 97331

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Corvallis, OR 97331-5904

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

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

REPORT NO.: 50-243/OL-16-01

FACILITY DOCKET NO.: 50-243

FACILITY LICENSE NO.: R-120

FACILITY: Oregon State University TRIGA Reactor

EXAMINATION DATE: February 23, 2016

SUBMITTED BY: **/RA/** **03/15/2016**
Paulette Torres, Chief Examiner Date

SUMMARY:

During the week of February 22, 2016 the NRC administered a licensing examination to one Reactor Operator (RO) applicant. The applicant passed all portions of the examination.

REPORT DETAILS

1. Examiner: Paulette Torres, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:

Paulette Torres, Chief Examiner, NRC
S. Todd Keller, SRO / Reactor Administrator, OSTR
Celia Oney, Reactor Supervisor, OSTR

The facility licensee agreed to email their comments on the written examination that were incorporated in the examination report (see Enclosure 2).

FACILITY COMMENTS ON THE WRITTEN EXAM WITH NRC RESOLUTION

We do not wish to challenge any of the exam (written) questions, but we would like to provide as much feedback as possible to improve future exams. In particular, we wish to point out that at the Oregon State TRIGA Reactor (OSTR) there is no line of succession that would result in a licensed RO taking on the duties of the Reactor Supervisor, an SRO licensed position. A licensed RO should certainly be aware of supervisor duties, and be able to provide advice. However, in accordance with our emergency plan, the RO may be required to take on duties of the Radiological Assessment Team and/or a hallway checker, but the RO will not rise to the level of responsibility of the Supervisor.

Please see below for specific comments on written exam questions. Note that we can only provide feedback on written questions since oral interactions were not specifically documented.

QUESTION A.06 [1.0 point, 0.33 each]
Match the best answer. If a reactor has values of k (multiplication factor) and ρ (reactivity) as follow:

Column A	Column B
a. $k = 1, \rho = 0$	1. The rate of fissioning is increasing.
b. $k < 1, \rho < 0$	2. The rate of fissioning is decreasing.
c. $k > 1, \rho > 0$	3. The rate of fissioning is constant.

Answer: a, 3 b,2 c,1
REF: OSU TRIGA Reactor Operator Training I, Neutron Flux and Multiplication Factor
OSU TRIGA Reactor Training Manual, Volume 3, pg. 12
Lamarsh, 3rd ed., Section 7.2, pg. 337
When $k = 1$, $\rho = 0$ and reactor is critical
When $k < 1$, $\rho < 0$ and reactor is subcritical
When $k > 1$, $\rho > 0$ and reactor is supercritical

Facility Comments &
Recommendations: It should be clarified that there is no neutron source present. Some of the answers change if a source is present in the reactor.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

QUESTION A.07 [1.0 point]
Which ONE of the following factors is not affected by the amount of moderator in the reactor?

a. Fast Fission Factor (ε)

b. Resonance Escape Probability (p)

c. Thermal Utilization Factor (f)

d. Reproduction Factor (η)

Answer: d
REF: The reproduction factor (also called the fuel utilization factor) is not affected by the moderator since it is purely a function of the nuclear characteristics of ^{235}U and other fissile nucleus.
OSU TRIGA Reactor Training Manual, Volume 3, pg. 11
DOE Fundamentals Handbook, NP-03, pg. 6-8

Facility Comments & Recommendations: The Reproduction Factor is slightly dependent on neutron spectrum and average neutron energy. This factor depends on the average number of neutrons released from fission, v, which is dependent on neutron energy. Average neutron energy is determined by the amount of moderator present. (See Duderstadt and Hamilton, Nuclear Reactor Analysis, p. 61, fig. 2-20.) We feel that this question has no correct answer. Changing the wording from “not affected” to “least affected” would make (d) the best answer.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

QUESTION B.04 [1.0 point]
Which ONE of the following Radiation Monitoring Channels is NOT required to measure gaseous airborne radionuclide concentration?

a. Reactor Top Area Radiation Monitor

b. Continuous Air Particulate Radiation Monitor

c. Exhaust Gas Radiation Monitor

d. Exhaust Particulate Radiation Monitor

Answer: b

REF: OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, pg. 20

Facility Comments &
Recommendations: This question is a bit confusing and may have no correct answer from the options provided. All four of the possible answers are required by Tech Specs. (TS 3.7.1, Table 4). The reference in the answer key refers to the OSU TRIGA Reactor Training Manual, Vol. 4, pg. 20. This page states: "The CAM is also capable of measuring the gaseous airborne radionuclide concentration using a G-M detector; however, this feature is not required by technical specifications." This sentence refers to the Continuous Air Gas Radiation Monitor, which would be the correct answer to the question as written.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

QUESTION C.03 [1.0 point]
Which ONE of the following Safety Channels operates in all effective modes?

a. High Voltage

b. Fuel Element Temperature

c. Power Level

d. Preset Timer

Answer: a
REF: TS 3.2.3, Table 2, pg. 14

Facility Comments &
Recommendations: As stated in the answer key, the correct answer is (a) per TS 3.2.3 Table 2, "Minimum Reactor Safety Channels". However, some of the items in this table, including the High Voltage scram, do not fit the Technical Specification definition of a Safety Channel (TS 1.27, "a measuring channel in the reactor safety system"). We are currently undergoing revisions to our Technical Specifications and this will be corrected in the future. For this question, changing "Safety Channels" to "Safety Systems" or "SCRAMs" would make the intent of the question more clear.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

QUESTION C.05 [1.0 point]
Which ONE of the following Interlocks operates only in the steady state and square wave mode?

a. 1 kW Pulse Interlock

b. Shim, Safety, and Regulating Rod Drive Circuit Interlock

c. Wide Range Log Power Level Channel Interlock

d. Transient Rod Cylinder Interlock

Answer: b
REF: TS 3.2.3 Table 3, pg. 14

Facility Comments &
Recommendations: This question is a bit confusing and may have no correct answer from the options provided. The answer key gives (b) as the correct answer, "Shim, Safety, and Regulating Rod Drive Circuit Interlock". TS 3.2.3, Table 3, lists this interlock twice, with one function in steady state and square wave mode and a different function in pulse mode. None of the interlocks in this table operate only in steady state and square wave mode.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

QUESTION C.16 [1.0 point]
Per Technical Specifications, activities such as changing out of the NORMAL core, moving away from the reference state or adding negative worth experiments will make core excess __________ and shutdown margin __________.

a. Less Negative, More Positive

b. More Positive, Less Negative

c. More Negative, Less Positive

d. Less Positive, More Negative

Answer: c
REF: TS 3.1.3 Basis, pg. 10

Facility Comments &

Recommendations: The stated basis of this Technical Specification is incorrect. Core Excess should never be a negative quantity and Shutdown Margin should never be a positive quantity. We believe that (d) is the most correct option. We are currently undergoing revisions to our Technical Specifications and this will be corrected in the future.

NRC Resolution: Thank you for the comment.

QUESTION C.17 [1.0 point]

Which ONE of the following Reactor Measuring Channels may not be inoperable while the reactor is operating?

a. Fuel Element Temperature

b. Linear Power Level

c. Log Power Level

d. Power Level

Answer: a

REF: TS 3.2.2 Footnote (1), pg. 12
TS 3.2.3 Footnote (1), pg. 14

Facility Comments &
Recommendations: The answer key gives (a), Fuel Element Temperature as the correct answer on the basis of TS 3.2.2 Footnote (1) and 3.2.3 Footnote (1). However, these footnotes apply if a channel is inoperable while performing a channel check, test, or experiment. TS 3.2.2 Footnote (2) states that if any of the required measuring channels (including Fuel Element Temperature) becomes inoperable for other reasons (i.e., channel failure), the channel shall be restored within five minutes or the reactor shall be shutdown.

NRC Resolution: Thank you for the comment. We will consider writing the question differently in the future.

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

FACILITY: Oregon State University

REACTOR TYPE: TRIGA

DATE ADMINISTERED: 02/23/2016

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

ENCLOSURE 3

A. Reactor Theory, Thermohydraulics & Facility Operating Characteristics

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 ___

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 SECTION A *****)

B. Normal/Emergency Procedures and Radiological Controls

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 ___

B19 a b c d ___

B20 a b c d ___

(***** END OF SECTION B *****)

C. Facility and Radiation 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 ___

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 SECTION 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$T = \frac{\lambda^*}{\rho - \bar{\beta}}$$

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

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

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

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

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

$$DR_1 d_1^2 = DR_2 d_2^2$$

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

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

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

U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

OREGON STATE UNIVERSITY

Operator Licensing Examination

Week of February 22, 2016

QUESTION A.01 [1.0 point, 0.25 each]
The following are various particles emitted in the radioactive process. Match the emission with its corresponding change in nucleus.

Column A: Emission	Column B: Mass #, Atomic #
a. Beta	1. No change, No change
b. Gamma	2. No change, Decreases by 1
c. Positron	3. Decreases by 1, No change
d. Neutron	4. No change, Increases by 1

QUESTION A.02 [1.0 point]
Xenon-135 is formed directly by decay of __________.

a. Antimony-135

b. Cesium -135

c. Iodine-135

d. Tellurium-135

QUESTION A.03 [1.0 point]
The term Core Excess is defined as:

a. The negative reactivity inserted by an increase in moderator temperature within the core when the reactor is brought from zero to full power.

b. Provides a measure of excess reactivity available to overcome fission product buildup, fuel burnup, and power defect.

c. The amount of negative reactivity that would be added to a core if the rods in a critical, cold, clean reactor were fully inserted.

d. The positive reactivity available which is above that necessary to achieve criticality.

QUESTION A.04 [1.0 point]
The count rate is 100 cps. An experimenter inserts an experiment into the core, and the count rate decreases to 60 cps. Given the initial K_{eff} of the reactor was 0.92, what is the worth of the experiment?

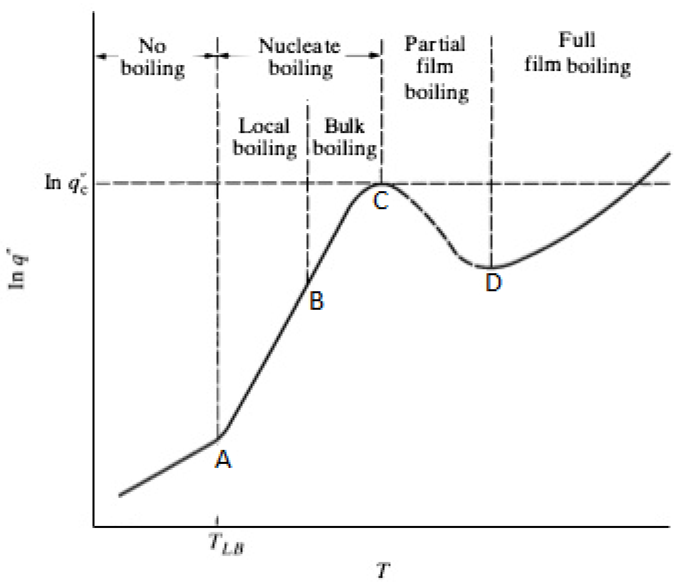
a. $\Delta\rho$ = - 0.07

b. $\Delta\rho$ = + 0.07

c. $\Delta\rho$ = - 0.02

d. $\Delta\rho$ = + 0.02

QUESTION A.05 [1.0 point]
From the figure below, which ONE of the following points corresponds to a condition leading to a Departure from Nucleate Boiling (DNB)?



a. Point A

b. Point B

c. Point C

d. Point D

QUESTION A.06 [1.0 point, 0.33 each]
Match the best answer. If a reactor has values of k (multiplication factor) and ρ (reactivity) as follow:

Column A	Column B
a. $k = 1, \rho = 0$	1. The rate of fissioning is increasing.
b. $k < 1, \rho < 0$	2. The rate of fissioning is decreasing.
c. $k > 1, \rho > 0$	3. The rate of fissioning is constant.

QUESTION A.07 [1.0 point]
Which ONE of the following factors is not affected by the amount of moderator in the reactor?

a. Fast Fission Factor (ε)

b. Resonance Escape Probability (p)

c. Thermal Utilization Factor (f)

d. Reproduction Factor (η)

QUESTION A.08 [1.0 point]
Which ONE of the following statements correctly describes the term neutron lifetime?

a. The mean time required for fission neutrons to slow down to thermal energies.

b. The average time that thermal neutrons diffuse before being lost in some way.

c. The time between succeeding neutron generations and is the sum of fission time, slowing down time, and diffusion time.

d. The average time elapsing between the release of a neutron in a fission reaction and its loss from the system by absorption or escape.

QUESTION A.09 [1.0 point]
Most text books list β for a U^{235} fueled reactor as 0.0065 ΔK/K and β_{eff} as being 0.0075 ΔK/K. Why is β_{eff} larger than β?

a. Delayed neutrons are born at lower energies than prompt neutrons resulting in less loss due to leakage for these neutrons.

b. Delayed neutrons are born at higher energies than prompt neutrons resulting in a greater worth for these neutrons.

c. The fuel includes U^{238} which has a relatively large for fast fission.

d. Some U^{238} in the core becomes Pu^{239} (by neutron absorption) which has a larger for fission.

QUESTION A.10 [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.11 [1.0 point]
During a Subcritical Multiplication "1/M" plot, data is required to be taken. What does the 1/M represent?

a. The inverse of fuel elements presented in the core.

b. The inverse of the moderator coefficient of reactivity.

c. The inverse migration length of neutrons of varying energies.

d. The inverse multiplication of the count rate between generations.

QUESTION A.12 [1.0 point]
Which ONE defines an integral rod worth curve?

a. A plot of incremental reactivity (ΔK/K/in) as a function of the axial rod position (in) in the core.

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

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

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

QUESTION A.13 [1.0 point]
Which ONE of the following is the correct reason for the 80 second negative period following a reactor scram?

a. The fuel temperature coefficient adding positive reactivity due to the fuel temperature decrease following a scram.

b. The ability of U-235 to fission with source neutrons.

c. The decay constant for the longest lived precursor.

d. The amount of negative reactivity added on a cram being greater that the shutdown margin.

QUESTION A.14 [1.0 point]
The reactor is operating at a power of 1 MW. The reactor shutdown adding a reactivity of \$1.10. To what fission power level has the reactor fallen 5 minutes later? (Assume β_{eff} = 0.0065)

a. 0.01 MW

b. 0.02 MW

c. 0.11 MW

d. 0.48 MW

QUESTION A.15 [1.0 point]
By reducing neutron leakage, the __________ increases k_{eff} and reduces the amount of fuel necessary to make the reactor critical.

a. Reflector

b. Control Rods

c. Moderator

d. Source

QUESTION A.16 [1.0 point]
The reactor is critical at 5 watts. Which ONE of the following correctly describes the reactor behavior when a reactivity worth of 0.50% ΔK/K is IMMEDIATELY inserted to the reactor core?

a. Subcritical

b. Critical

c. Supercritical

d. Delayed Critical

QUESTION A.17 [1.0 point]
Which one of the following has the highest thermal neutron cross section?

a. Cd-113

b. Gd-157

c. Xe-135

d. Sm-149

QUESTION A.18 [1.0 point]
Which ONE is true about the four factor formula, $k_\infty = \varepsilon\ p\ f\ \eta$?

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.19 [1.0 point]
Reactor period is defined as __________.

a. The time required to change reactor power 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.20 [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.

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

QUESTION B.01 [1.0 point]
Per 10 CFR 20.1003, a __________ is defined as an area, access to which is limited by the licensee for the purpose of protecting individuals against undue risk from exposure to radiation and radioactive materials.

a. Restricted Area

b. Radiation Area

c. High Radiation Area

d. Airborne Radioactivity Area

QUESTION B.02 [1.0 point]
What is the Occupation Dose Limit for Total Effective Dose Equivalent?

a. 0.5 rem

b. 5 rem

c. 15 rem

d. 50 rem

QUESTION B.03 [1.0 point]
Which ONE of the following Area Radiation Monitors (ARMs) has an intermediate alarm setting of 10 mR/h?

a. Beam Port # 4

b. Fuel Storage Pits

c. Sample Handling

d. Demineralizer Column

QUESTION B.04 [1.0 point]
Which ONE of the following Radiation Monitoring Channels is NOT required to measure gaseous airborne radionuclide concentration?

a. Reactor Top Area Radiation Monitor

b. Continuous Air Particulate Radiation Monitor

c. Exhaust Gas Radiation Monitor

d. Exhaust Particulate Radiation Monitor

QUESTION B.05 [1.0 point]
If the Nitrogen-16 control system was not in use, what type of dose would increase?

a. Alpha

b. Beta

c. Gamma

d. Neutron

QUESTION B.06 [1.0 point]
Which ONE of the following dosimeters measures ONLY gamma dose and gives real-time dose information, but not dose rate?

a. Thermoluminescent Dosimeter (TLD)

b. Electronic Dosimeter

c. Pocket Ion Chamber (PIC)

d. Finger Rings

QUESTION B.07 [1.0 point]
The OSTR shall notify the NRC within 30 days when finding that the licensed operator is convicted for a felony. 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 73

QUESTION B.08 [1.0 point]
Which ONE of the following statements correctly describes the relationship between the Safety Limit (SL) and the Limiting Safety System Setting (LSSS)?

a. The LSSS is a limit on important process variables that assures the integrity of the fuel cladding. The SL initiates protective action to preclude reaching the LSSS.

b. The SL is a limit on important process variables that assures the integrity of the fuel cladding. The LSSS initiates protective actions to preclude reaching the SL.

c. The SL is a maximum operationally limiting value that prevents exceeding the LSSS during normal operations.

d. The SL is a maximum setpoint for instrumentation response. The LSSS is the minimum number of channels required to be operable.

QUESTION B.09 [1.0 point]
Which ONE of following types of radiation has the LOWEST Quality Factor specified in 10 CFR 20?

a. Alpha Particles, Heavy Recoil Nuclei

b. Gamma/X-Ray/Beta

c. Fast Neutrons/Protons

d. Thermal Neutrons

QUESTION B.10 [1.0 point]
An applicant for a license shall have a medical examination by a physician every __________.

a. Six Months

b. One Year

c. Two Years

d. Four Years

QUESTION B.11 [1.0 point]
In accordance with 10 CFR Part 50.47(b)(11), under what conditions a radiation worker can have exposure in excess of 10 CFR 20 limits?

a. During any emergency.

b. For lifesaving situations, a total effective dose equivalent of up to 25 rem is permissible, due to the urgency of the situation.

c. As long as the radiation worker does not exceed 50 Rem whole body for life saving.

d. In an emergency declared by the Emergency Director with concurrence of the OSU Radiation Safety Officer if available.

QUESTION B.12 [1.0 point]
The __________ ensures proper evacuation of the reactor facility when evacuation is required during an emergency.

a. Emergency Director

b. Radiation Center Director

c. Emergency Coordinator

d. Senior Reactor Operator

QUESTION B.13 [1.0 point]
Which ONE of the following is denoted as a Class O Emergency event?

a. Personnel and Operational Events

b. Notification of Unusual Events

c. Alert

d. Site Area Emergency

QUESTION B.14 [1.0 point]
If background radiation levels permit, direct surface contamination levels will be monitored using a __________ detector.

a. Geiger-Müeller

b. Plastic Scintillator

c. Ionization Chamber

d. High-Purity Germanium (HPGe)

QUESTION B.15 [1.0 point]
Which ONE of the following correctly defines the term “Emergency Action Levels”?

a. Projected radiation doses or dose commitments to individuals in the general population that warrant protective action following a release of radioactive material.

b. Radiological dose rates, specific concentrations of airborne, waterborne or surface-deposited radioactive materials, specific observations, or specific instrument readings that may be used as thresholds for initiating specific emergency measures.

c. Actions taken during or after an accident to obtain and process information that is necessary when deciding whether to implement specific emergency measures.

d. Measures taken in anticipation of an uncontrolled release of radioactive material, or after an uncontrolled release of radioactive material has occurred, for the purpose of preventing or minimizing personnel radiation doses or dose commitments that would otherwise be likely to occur if the actions were not taken.

QUESTION B.16 [1.0 point]
Beam Port 3 abnormal operations is an example of a __________.

a. High Voltage Scram

b. Safety Scram

c. Experiment Scram

d. External Scram

QUESTION B.17 [1.0 point]
All of the following items are audited by the Reactor Operations Committee (ROC) on an annual basis EXCEPT:

a. The Emergency Plan

b. The Physical Security Plan

c. The Technical Specifications

d. The Reactor Operator Requalification Program

QUESTION B.18 [1.0 point]
The water temperature shall not be permitted to rise above 49°C. This is a Technical Specification Requirement:

a. To minimize the degradation of the aluminum tank.

b. To maintain the usefulness of the demineralizer resin.

c. For best operation of the skimmer and for proper shielding.

d. For effective cooling of the fuel.

QUESTION B.19 [1.0 point]
If the reactor is to be operated at greater than 100 kW, then the __________ purge must be in service.

a. Nitrogen

b. Argon

c. Xenon

d. Radon

QUESTION B.20 [1.0 point]
While operating the pneumatic-transfer "rabbit" system, the remote area monitor indicates greater than 10 mR h^{-1}, but less than 50 mR h^{-1}. Per the radiation monitoring procedure for the rabbit system you are required to:

a. Stand back. Do not handle the sample. Wait for a reactor operations or health physics staff member to monitor the sample.

b. Quickly remove the rabbit capsule using remote handling tongs and place the rabbit at the bottom of the hood within the lead brick shielded area.

c. Grasp the rabbit capsule with remote handling tongs and place it in the round lead holder/shield.

d. Evacuate D102 and proceed to the east end of the controlled hallway. Wait there for instructions from the Reactor Operations staff or health physics personnel.

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

QUESTION C.01 [1.0 point]
The instrumented fuel element shall be located in the __________.

a. B-ring

b. C-ring

c. E-ring

d. G-ring

QUESTION C.02 [1.0 point]
Which ONE of the following correctly describes the characteristic of the unirradiated 30/20 fuel rods used at the OSTR?

a. The uranium content is a nominal 30 wt%, enriched to less than 20% U-235; and the natural erbium content is homogeneously distributed with a nominal 1.1 wt%.

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

QUESTION C.03 [1.0 point]
Which ONE of the following Safety Channels operates in all effective modes?

a. High Voltage

b. Fuel Element Temperature

c. Power Level

d. Preset Timer

QUESTION C.04 [1.0 point]
Which ONE of the following systems is located on the first floor, mechanical equipment room of the reactor building?

a. The Reactor Cooling System Components

b. The Pneumatic Transfer System Receiver Sender Stations

c. The Reactor Building Pressure Regulating Systems

d. The Fuel Storage Pits

QUESTION C.05 [1.0 point]
Which ONE of the following Interlocks operates only in the steady state and square wave mode?

a. 1 kW Pulse Interlock

b. Shim, Safety, and Regulating Rod Drive Circuit Interlock

c. Wide Range Log Power Level Channel Interlock

d. Transient Rod Cylinder Interlock

QUESTION C.06 [1.0 point, 0.25 points each]
Match the possible combination of standard control rod indicating lights UP, DOWN and CONT/ON in Column A with the possible meaning of each combination for Control Rod and Drive Normal Condition in Column B.

Column A: UP, DOWN, CONT/ON	Column B: Control Rod and Drive Normal Condition
a. ON, OFF, ON	1. After scram, control rod down.
b. OFF, ON, ON	2. Rod drive completely withdrawn, magnet making contact.
c. OFF, OFF, ON	3. Rod and drive between either limit, magnet making contact.
d. OFF, OFF, OFF	4. Rod and drive at their lower limits, magnet making contact.

QUESTION C.07 [1.0 point]
The Uncompensated Ion Chamber __________.

a. Is able to discriminate between Neutrons and Beta Radiation.

b. Is able to discriminate between Neutrons and Fission Fragments.

c. Is able to discriminate between Neutrons and Gamma Radiation.

d. Lacks Gamma Compensation.

QUESTION C.08 [1.0 point]
The __________ is grounded in square-wave and pulse modes.

a. Linear Channel

b. Log-N Channel

c. Safety Channel

d. Period Channel

QUESTION C.09 [1.0 point]
Which ONE of the following reactor power indicator monitors DOES NOT operates off the Fission Chamber?

a. Linear Power Recorder

b. Log Power Recorder

c. Safety Power Meter

d. Log Power Meter

QUESTION C.10 [1.0 point]
Fuel element temperature must be limited in the TRIGA fuel element in order to avoid fuel element cladding failure due to which of the following mechanisms:

a. Distortion of the fuel element due to a phase change of the 304 stainless steel.

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.11 [1.0 point]
Which ONE of the following design features prevents the accidental siphoning of reactor pool water?

a. The action of the coolant diffuser nozzle.

b. The capacity of the primary coolant makeup water tank.

c. A positive pressure difference between the shells inside the heat exchanger.

d. Holes located in the in-tank system piping at 22 inches below normal tank level.

QUESTION C.12 [1.0 point]
Which ONE of the following Standard Control Rod Drive components provides rod position indication?

a. Limit Switches

b. Potentiometer

c. Electromagnet

d. Armature

QUESTION C.13 [1.0 point]
Which ONE of the following Beam Ports is the piercing Beam Port that penetrates the graphite reflector?

a. B.P. # 1

b. B.P. # 2

c. B.P. # 3

d. B.P. # 4

QUESTION C.14 [1.0 point]
Which ONE of the following will result in a reactor scram?

a. Bulk tank water temperature exceeds 40°C.

b. Instrumented fuel element temperature exceeds 500°C.

c. Simultaneous withdrawal of two control rods.

d. Loss of high voltage to the power measuring channels.

QUESTION C.15 [1.0 point]
The ventilation system shall be shut down upon a high activity alarm from:

a. Reactor Top Area Radiation Monitor

b. Continuous Air Particulate Radiation Monitor

c. Exhaust Gas Radiation Monitor

d. Exhaust Particulate Radiation Monitor

QUESTION C.16 [1.0 point]
Per Technical Specifications, activities such as changing out of the NORMAL core, moving away from the reference state or adding negative worth experiments will make core excess __________ and shutdown margin __________.

a. Less Negative, More Positive

b. More Positive, Less Negative

c. More Negative, Less Positive

d. Less Positive, More Negative

QUESTION C.17 [1.0 point]
Which ONE of the following Reactor Measuring Channels may not be inoperable while the reactor is operating?

a. Fuel Element Temperature

b. Linear Power Level

c. Log Power Level

d. Power Level

QUESTION C.18 [1.0 point]
Which ONE of the following OSTR Control Rods is equipped with a pneumatic system?

a. Regulating Rod

b. Shim Rod

c. Safety Rod

d. Transient Rod

QUESTION C.19 [1.0 point]
The reactor bay is maintained at a negative pressure with respect to outside atmosphere to:

a. Minimize uncontrollable leakage to the unrestricted environment.

b. Prevent the generation of Argon-41.

c. Keep personnel exposures ALARA.

d. Expedite reactor cooling by natural convection.

QUESTION C.20 [1.0 point]
Per Technical Specifications, to guarantee the radiation levels at the top of the reactor are within acceptable levels, the Reactor Primary Tank Water level shall be greater than __________ of water above the top of the core.

a. 12 feet

b. 14 feet

c. 16 feet

d. 20 feet

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

A.01

Answer: a, 4 b,1 c,2 d,3

REF: Shultis and Faw, Fundamentals of Nuclear Science and Engineering, Section 5.4, pg. 93-101

Beta decay: ${}^{A}_{Z}P \rightarrow \left[{}^{A}_{Z+1}D^{+}\right] + {}^{0}_{-1}e + \overline{\nu}_e$

Gamma decay: ${}^{A}_{Z}P^{*} = {}^{A}_{Z}P + \gamma$

Positron decay: ${}^{A}_{Z}P \rightarrow \left[{}^{A}_{Z-1}D^{-}\right] + {}^{0}_{+1}e + \overline{\nu}_e$

Neutron decay: ${}^{A}_{Z}P = {}^{A-1}_{Z}P^{*} + {}^{1}_{0}n$

Where A=Mass#, Z=Atomic#, P=parent atom, D=daughter atom

A.02

Answer: c

REF: Burns, Figure 8.1, pg. 8-6
OSU TRIGA Reactor Operator Training I, Decay and Build-up of Nuclides
OSU TRIGA Reactor Training Manual, Volume 3, pg. 19

A.03

Answer: d

REF: OSU TRIGA Reactor Training Manual, Volume 3, pg. 22
OSU TRIGA Reactor Operator Training I, Steady Reactor Physics

A.04

Answer: a

REF: $CR1 / CR2 = (1 - K_{eff2}) / (1 - K_{eff}1)$
$100 / 60 = (1 - K_{eff}2) / (1 - 0.92)$
Therefore $K_{eff}2 = 0.867$
$\Delta\rho = (K_{eff}2 - K_{eff}1) / (K_{eff}2 * K_{eff}1)$
$\Delta\rho = (0.867 - 0.92) / (0.867 * 0.92)$
$\Delta\rho = - 0.0664$

A.05

Answer: c

REF: Lamarsh, 3rd ed., Figure 8.10, pg. 442 and section 8.5, pg. 446
OSU TRIGA Reactor Operator Training I, Steady State Fundamental Thermal Hydraulics, Steady State Analysis

A.06
Answer: a, 3 b,2 c,1
REF: OSU TRIGA Reactor Operator Training I, Neutron Flux and Multiplication Factor
OSU TRIGA Reactor Training Manual, Volume 3, pg. 12
Lamarsh, 3rd ed., Section 7.2, pg. 337
When k = 1, ρ= 0 and reactor is critical
When k < 1, ρ< 0 and reactor is subcritical
When k > 1, ρ > 0 and reactor is supercritical

A.07
Answer: d
REF: The reproduction factor (also called the fuel utilization factor) is not affected by the moderator since it is purely a function of the nuclear characteristics of ^{235}U and other fissile nucleus.
OSU TRIGA Reactor Training Manual, Volume 3, pg. 11
DOE Fundamentals Handbook, NP-03, pg. 6-8

A.08
Answer: d
REF: Burns, section 3.3.5, pg. 3-23
OSU TRIGA Reactor Training Manual, Volume 3, pg. 24

A.09
Answer: a
REF: Burns, Section 3.2.4, pg. 3-12
OSU TRIGA Reactor Training Manual, Volume 3, pg. 24

A.10
Answer: c
REF: Burns, Section 2.5.2, pg. 2-43
OSU TRIGA Reactor Training Manual, Volume 3, pg. 25

A.11
Answer: d
REF: DOE Fundamentals Handbook, NP-04, pg. 6-8
OSU TRIGA Reactor Operator Training I, Neutron Flux and Multiplication Factor
OSU TRIGA Reactor Training Manual, Volume 3, pg. 33-35

A.12
Answer: c
REF: Burns, Section 7.3, pg. 7-5 to 7-7
OSU TRIGA Reactor Training Manual, Volume 3, Figure 3.6, pg. 17-7

A.13
Answer: c
REF: Lamarsh, 3rd ed., pg. 345
OSU TRIGA Reactor Training Manual, Volume 3, pg. 29

A.14
Answer: a

$$\rho = \$\beta_{eff}$$
$$\rho = -1.1 \times 0.0065 = -0.00715$$
$$P_1 = \frac{\beta(1-\rho)P_0}{\beta-\rho} = \frac{0.0065(1+0.00715)\times 1}{0.0065+0.00715} = 0.4796MW$$
$$P(t) = P_1 e^{\frac{-t}{T}} = 0.4796e^{-\left(\frac{5\times 60}{80}\right)}$$
$$P(5\min) = 0.0113MW$$

REF: Lamarsh, 3rd ed., Example 7.6, pg. 345-346
OSU TRIGA Reactor Training Manual, Volume 3, pg. 30

A.15
Answer: a
REF: OSU TRIGA Reactor Training Manual, Volume 3, pg. 15

A.16
Answer: c
REF: Burn, Section 4.2, Figure 4-1, pg. 4-2
0.5 % ΔK/K = 0.005 ΔK/K = ρ, ρ > 0
$\rho = (k_{eff} - 1) / k_{eff}$, then $k_{eff} = 1.005$
When k > 1, ρ > 0 and reactor is supercritical

A.17
Answer: c
REF: Lamarsh, 3rd ed., pg. 377, 387
OSU TRIGA Reactor Training Manual, Volume 3, pg. 19

A.18
Answer: d
REF: OSU TRIGA Reactor Training Manual, Volume 3, pg. 9
Lamarsh, 3rd ed., Section 6.5, pg. 287

A.19

Answer: a

REF: DOE Handbook part 2, module 4, pg. 21
OSU TRIGA Reactor Training Manual, Volume 2, pg. 22
OSU TRIGA Reactor Training Manual, Volume 3, pg. 26

A.20

Answer: b

REF: Burns, Table 3.2, pg. 3-5
Lamarsh, 3rd ed., Table 3.6, pg. 88

B.01
Answer: a
REF: OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, pg. 14
10 CFR 20.1003

B.02
Answer: b
REF: OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, Table 4.4, pg. 17
10 CFR 20.1201(a)(1)(i)

B.03
Answer: b
REF: OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, Table 4.6, pg. 19

B.04
Answer: b
REF: OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, pg. 20

B.05
Answer: c
REF: OSU TRIGA Reactor Training Manual, Volume 4, pg. 12
SAR 5.6, pg. 5
SAR 11.1.1.2.1, pg. 9
Nitrogen-16 is produced by (n,p) reaction of Oxygen-16 (due to neutron interactions with oxygen-16 in the primary coolant and neutron-activated dust particulates). The hazard is due to high energy gamma (6.13 MeV and 7.11 MeV). N-16 is produced within the coolant passing through the core of the reactor. To decrease the N-16 gas that becomes airborne, water above the core may be over stirred using diffuser pumps. This increases the transport time of the short-lived (t1/2 = 7.13 sec) N-16 from the core to the surface of the pool and allows additional decay time.

B.06
Answer: c
REF: OSU TRIGA Reactor Training Manual, Volume 4, pg. 17
TLDs and finger rings all provide information on accumulated dose. These have to be processed. They do not tell you the dose rate. Pocket ion chambers provide immediate visual information on your accumulated dose, but not dose rates. Electronic dosimeters give real time reading of the dose received by the wearer but not the gamma dose.

B.07
Answer: c
REF: 10 CFR 55.53 (g)
OSU TRIGA Reactor Operator Training II, Operators' Licenses

B.08
Answer: b
Reference: TS 2.1 and 2.2

B.09
Answer: b
REF: 10 CFR 20.1004
OSU TRIGA Reactor Operator Training I & II, Radiological Protection
OSU TRIGA Reactor Training Manual, Volume 4, pg. 8

B.10
Answer: c
REF: 10 CFR 55.21
OSU TRIGA Reactor Operator Training II, Operators' Licenses

B.11
Answer: b
REF: ERP 7.4.1, pg. 7-13

B.12
Answer: c
REF: ERP 3.3.2, pg. 3-6

B.13
Answer: a
REF: ERP 4.1, pg. 4-1

B.14
Answer: a
REF: ERP 7.1.2 6) a), pg. 7-3
OSU TRIGA Reactor Training Manual, Volume 4, pg. 25

B.15
Answer: b
REF: ERP 2.0, pg. 2-1

B.16
Answer: d
REF: OSTROP 1, II.A.6, pg. 4
SAR 7.4.1, pg. 11

B.17
Answer: c
REF: OSTROP 6, IV.C.1.c., pg. 11

B.18
Answer: a
REF: OSTROP 7, I.D., pg. 5
TS 3.3.b and 3.3 Basis, pg. 16

B.19
Answer: a
REF: OSTROP 2, V.D., pg. 23

B.20
Answer: b
REF: OSTROP 10, II.B.4.a.(1)(b), pg. 12

C.01
Answer: a
REF: OSU TRIGA Reactor Operator Training I
TS 2.2, pg. 8

C.02
Answer: a
REF: TS 5.3.3, pg. 31

C.03
Answer: a
REF: TS 3.2.3, Table 2, pg. 14

C.04
Answer: c
REF: SAR 9.1.1, pg. 1

C.05
Answer: b
REF: TS 3.2.3 Table 3, pg. 14

C.06
Answer: a,2 b,4 c,3 d,1
REF: OSU TRIGA Reactor Operator Training II, Instrumentation & Control System
OSU TRIGA Reactor Training Manual, Volume 2, Table 2.1, pg. 12

C.07
Answer: d
REF: OSU TRIGA Reactor Training Manual, Volume 2, pg. 21

C.08
Answer: d
REF: OSU TRIGA Reactor Training Manual, Volume 2, pg. 22

C.09
Answer: c
REF: ERP 8.2.5 1) a), pg. 8-3
OSU TRIGA Reactor Training Manual, Volume 2, Figure 2.17 & 2.19
SAR 7.2.3.1, pg. 2

C.10
Answer: d
REF: TS 2.1 Basis, pg. 6

C.11
Answer: d

REF: SAR 5.2, pg. 1

C.12
Answer: b
REF: SAR 7.3.1, pg. 6

C.13
Answer: d
REF: SAR 10.2.1, pg. 1-2

C.14
Answer: d
REF: TS 3.2.3 Table 2, pg. 14
SAR 7.4.1, pg. 11

C.15
Answer: d
REF: TS 3.5.b, pg. 17

C.16
Answer: c
REF: TS 3.1.3 Basis, pg. 10

C.17
Answer: a
REF: TS 3.2.2 Footnote (1), pg. 12
TS 3.2.3 Footnote (1), pg. 14

C.18
Answer: d
REF: SAR 3.5.1, pg. 4
SAR 4.2.2, pg. 24
OSU TRIGA Reactor Training Manual, Volume 1, pg. 28, 29, 37

C.19
Answer: a
REF: TS 4.5, pg. 25
TS 5.1 Basis, pg. 27

C.20
Answer: b
REF: TS 3.3.a, pg. 16