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

June 13, 2023

Mr. Andrew Cook, Interim Reactor Facility Director
Radiation Sciences Department
Armed Forces Radiobiology Research Institute
4301 Jones Bridge Road, Building 42
Bethesda, MD 20889-5648

SUBJECT: EXAMINATION REPORT NO. 50-170/OL-23-01, ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE

Dear Mr. Cook:

During the week of May 22, 2023, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your Armed Forces Radiobiology Research Institute research reactor. The examinations were conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with Title 10 of the *Code of Federal Regulations,* Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC website 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 Amy Beasten at (301) 415-8341 or via email at Amy.Beasten@nrc.gov.

Sincerely,

Signed by Tate, Travis
on 08/10/23

Travis L. Tate, Chief
Non-Power Production and Utilization Facility
Oversight Branch
Division of Advanced Reactors and Non-Power
Production and Utilization Facilities
Office of Nuclear Reactor Regulation

Docket No. 50-170

Enclosures:
1. Examination Report No. 50-170/OL-23-01
2. Written examination

cc: w/o enclosures to GovDelivery Subscribers

SUBJECT: EXAMINATION REPORT NO. 50-170/OL-23-01, ARMED FORCES RADIOBIOLOGY RESEARCH INSTITUTE DATED: JUNE 13, 2023

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DATE	6/13/2023	6/13/2023	6/13/2023

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

REPORT NO.: 50-170/OL-23-01

FACILITY DOCKET NO.: 50-170

FACILITY LICENSE NO.: R-120

FACILITY: Armed Forces Radiobiology Research Institute

EXAMINATION DATES: May 22-24, 2023

SUBMITTED BY: *Amy E. Beasten* 05/31/2023
Amy E. Beasten, Chief Examiner Date

SUMMARY:
During the week of May 22, the NRC administered operator licensing examinations to three Senior Reactor Operating-Instant (SRO-I) and one Senior Reactor Operator Upgrade (SRO-U) candidates. One SRO-I failed the written examination and the remaining candidates passed all applicable portions of the examination.

REPORT DETAILS

1. Examiner: Amy Beasten, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:
Amy Beasten, Reactor Engineer, NRC
Andrew Cook, Head, Radiation Sciences Department
Mathieu Brener, Reactor Operations Supervisor

Prior to administration of the written examination, based on facility comments, adjustments were accepted. Comments provided corrections and additional clarity to questions/answers and identified where changes were appropriate based on current facility conditions. Upon completion of all operator licensing examinations, the NRC examiner met with facility staff representatives to discuss the results. At the conclusion of the meeting, the NRC examiner thanked the facility for their support in the administration of the examination.

U.S.NRC

UNITED STATES NUCLEAR REGULATORY COMMISSION

Protecting People and the Environment

Armed Forces Radiobiology Research Institute Reactor

Operator Licensing Examination

Week of May 22, 2023

Enclosure 2

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

FACILITY: AFRRI

REACTOR TYPE: TRIGA

DATE ADMINISTERED: May 22, 2023

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

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.

Category A: Reactor Theory, Thermodynamics, & 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 _____ (0.50 each)

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 ___

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

Category B: Normal/Emergency Operating 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 _____ (0.25 each)

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 _____ (0.25 each)

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 _____ (0.25 each)

B20 a b c d ___

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

Category 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 _____ (0.25 each)

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 _____ (0.25 each)

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 **********)

EQUATION SHEET

$$Q = mc_P\Delta T = m\Delta H = UA\Delta T$$

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 kg = 2.21 lb

1 Horsepower = 2.54 x 10^3 BTU/hr

1 Mw = 3.41 x 10^6 BTU/hr

1 BTU = 778 ft-lb

°F = 9/5 °C + 32

1 gal (H_2O) ≈ 8 lb

°C = 5/9 (°F - 32)

c_P = 1.0 BTU/hr/lb/°F

c_p = 1 cal/sec/gm/°C

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

QUESTION A.01 [1.0 point]
Which ONE of the following is defined as the balance between production of neutrons and their absorption and leakage in the core?

a. Effective Multiplication Factor.

b. Infinite Multiplication Factor.

c. Reproduction Factor.

d. Utilization Factor.

QUESTION A.02 [1.0 point]
What is the fraction of thermal neutrons absorbed in U-235 by fission? Given Isotope $_{92}U^{235}$, σ_f = 577 barns, σ_c = 106 barns. Note: σ_f = fission cross section, σ_c = capture cross section

a. 0.84

b. 0.54

c. 0.18

d. 0.16

QUESTION A.03 [1.0 point]
The process in which a neutron strikes a nucleus leaving the nucleus in an excited state is referred to as:

a. Neutron annihilation

b. Photo electric effect

c. Inelastic scattering

d. Elastic scattering

QUESTION A.04 [1.0 point]
All of the following factors in the six-factor formula are affected by the enrichment of U-235 in the fuel EXCEPT:

a. Thermal Utilization Factor

b. Thermal Non-Leakage Probability

c. Reproduction Factor

d. Resonance Escape Probability

QUESTION A.05 [2.0 points, 0.50 points each]
Match the terms in Column A with the result in Column B to complete the following statements. Answers in Column B may be used once, more than once, or not at all:

As moderator temperature increases, [Column A] [Column B].

Column A	Column B
a. Resonance Escape Probability	Increases
b. Thermal Utilization Factor	Decreases
c. Fast Fission Factor	Stays the same
d. Control Rod Worth	

QUESTION A.06 [1.0 point]
While bringing the reactor critical, which ONE of the following describes how a subcritical reactor responds to equal insertions of positive reactivity?

a. Each reactivity insertion results in a smaller increase in neutron flux resulting in a longer time to stabilize.

b. Each reactivity insertion results in a smaller increase in neutron flux resulting in a shorter time to stabilize.

c. Each reactivity insertion results in a larger increase in neutron flux resulting in a longer time to stabilize.

d. Each reactivity insertion results in a larger increase in neutron flux resulting in a shorter time to stabilize.

QUESTION A.07 [1.0 point]
Which ONE of the following statements regarding fission product poisoning is true?

a. During normal reactor operation, Xe-135 is removed from the core only by radioactive decay.

b. Following a reactor shutdown, the concentration of Xe-135 reaches a peak based on the decay of I-135 in the core.

c. During normal reactor operation, Sm-149 is removed from the core by both radioactive decay and neutron absorption.

d. Following a reactor shutdown, the concentration of Sm-149 reaches a peak because some fission is still occurring in the core.

QUESTION A.08 [1.0 point]
Following a reactor scram from 500 kW, the reactor period has stabilized and power level is decreasing at a constant rate. What is the reactor power five minutes following the scram?

a. 823 W

b. 8.23 kW

c. 11.5 kW

d. 115.7 kW

QUESTION A.09 [1.0 point]
How long will it take reactor power to increase from 25kW to 500kW, if reactor period is 32 seconds?

a. 9.5 seconds

b. 22 seconds

c. 95 seconds

d. 170 seconds

QUESTION A.10 [1.0 point]
Which ONE of the following best describes alpha decay?

a. The emission of an alpha particle from an unstable nucleus. The daughter has an atomic number two more than the parent nuclide and a mass number four less than the parent nuclide.

b. The emission of an alpha particle from an unstable nucleus. The daughter has an atomic number two less than the parent nuclide and a mass number four more than the parent nuclide.

c. The emission of an alpha particle from an unstable nucleus. The daughter has an atomic number two more than the parent nuclide and a mass number four more than the parent nuclide.

d. The emission of an alpha particle from an unstable nucleus. The daughter has an atomic number two less than the parent nuclide and a mass number four less than the parent nuclide.

QUESTION A.11 [1.0 point]
An example of a FISSIONABLE NUCLEI is:

a. U-233

b. U-235

c. U-238

d. Pu-239

QUESTION A.12 [1.0 point]
The moderator temperature coefficient for a reactor is -0.00092 $\Delta k/k/°F$. What is the total reactivity change caused by a temperature decrease of 25°F?

a. 0.0230

b. 0.0178

c. 0.0690

d. 0.0980

QUESTION A.13 [1.0 point]
Following a reactor scram, the period meter will indicate _____ because _____.

a. Slightly positive; the neutron source is providing detectable neutron count rate to keep the reactor slightly supercritical.

b. -80 seconds; of the decay constant for the longest-lived neutron precursor.

c. -80 seconds; the fuel temperature coefficient adds positive reactivity as a result of the decrease in fuel temperature following a scram.

d. 0 seconds; the reactor is subcritical and reactor power is decreasing.

QUESTION A.14 [1.0 point]
Which ONE of the following best explains the importance of source neutrons?

a. Source neutrons are used to lengthen the neutron generation time to ensure the reactor does not go prompt critical.

b. Source neutrons ensure that there is a sufficient neutron population to provide visible indication of neutron level during start-up and shutdown.

c. Source neutrons ensure there is a sufficient neutron population to overcome the effects of fission product poisoning following a shutdown.

d. Source neutrons are essential to achieve and maintain criticality of the reactor.

QUESTION A.15 [1.0 point]
For the fast energy range, 100 keV – 10 MeV, the absorption cross section steadily decreases as the energy of the neutron increases. What is this region?

a. Fast neutron region

b. Resonance region

c. Thermal neutron region

d. Slow neutron region

QUESTION A.16 [1.0 point]
Which ONE of the following parameters is MOST significant in determining the differential rod worth of a control rod?

a. Fuel temperature

b. Reactor power

c. Rod speed

d. Flux shape

QUESTION A.17 [1.0 point]
A subcritical reactor has a k_{eff} of 0.826. How much reactivity is added to change the k_{eff} to 0.989?

a. 0.165

b. 0.197

c. 0.199

d. 0.218

QUESTION A.18 [1.0 point]
Which ONE of the following is the principal source of heat in the reactor after a shutdown from extended operation at full power?

a. Xe-135 peaking due to burnout.

b. Spontaneous fission of Uranium-238.

c. Continued production of delayed neutrons.

d. Decay of fission fragments.

QUESTION A.19 [1.0 point]
The average energy release per fission with a thermal neutron in U-235 is _____ with the majority of energy being released from _____.

a. 187 MeV; kinetic energy of fission products

b. 187 MeV; energy of fission neutrons

c. 200 MeV; kinetic energy of fission products

d. 200 MeV; energy of fission neutrons

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.01 [1.0 point]
In accordance with the AFRRI Emergency Plan, all of the following individuals can assume the role of Emergency Response Team Commander EXCEPT:

a. Reactor Facility Director.

b. Reactor Operations Supervisor.

c. Senior Reactor Operator.

d. Senior Health Physicist.

QUESTION B.02 [1.0 point]
In accordance with procedure 002, Reactor Operations, all of the following statements are true concerning the K-excess measurement EXCEPT:

a. K-excess is not required prior to fuel movement.

b. The recommended power level for k-excess measurements is 500 mW.

c. The reactor must be shut down if the k-excess exceeds $5.00.

d. K-excess is determined by summing the worths of all scrammable rods.

QUESTION B.03 [1.0 point]
A 30-mm thick sheet of lead placed at a certain location in a beam of gamma rays reduces the gamma radiation level from 400 mR/hr to 150 mR/hr. Approximately how much ADDITIONAL lead would be needed to reduce the gamma radiation level to 50 mR/hr?

a. 12 mm

b. 26 mm

c. 34 mm

d. 54 mm

QUESTION B.04 [1.0 point]
Which ONE of the following radiation monitors might first indicate a fuel cladding rupture?

a. Exposure Room Radiation Area Monitors

b. Stack Gas Radiation Monitor

c. Primary Reactor Room Continuous Air Monitor

d. Reactor Deck Radiation Area Monitors

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.05 [1.0 point, 0.25 points each]
Match the Reactor Safety System Setting in Column A with the appropriate mode of operation in Column B. Options in Column B may be used once, more than once, or not at all.

Column A	Column B
a. Percent power high flux scram	Steady State Mode
b. Control rod interlock if reactor period < 3 seconds	Pulse Mode
c. Fuel temperature ≤ 600 °C	Both
d. Withdrawal any control rod except the transient rod	

QUESTION B.06 [1.0 point]
In accordance with procedure 001, Reactor Startup Checklist, when is a Startup Checklist NOT required to be completed?

a. Between same day operations when the reactor has been secured.

b. Prior to restart following a loss of AC power.

c. Whenever more than one rod is being raised at a time from the bottom of the core.

d. Prior to the start of continuous operation.

QUESTION B.07 [1.0 point]
In accordance with procedure 004, which ONE of the following actions should NOT be taken in the event of a loss of commercial power?

a. Verify ventilation is isolated in the reactor room.

b. Secure the reactor.

c. Verify scram has occurred.

d. Shut down the CSS and UIT computers.

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.08 [1.0 point]
In accordance with procedure 215, Thermal Power Calibration and Power Coefficient, when must channel adjustment be performed following completion of thermal power coefficient?

a. If there is a discrepancy of greater than 1% of calculated reactor power.

b. If there is a discrepancy of greater than 3% of calculated reactor power.

c. If there is a discrepancy of greater than 1% between two or more power channels.

d. If there is a discrepancy of greater than 3% between two or more power channels.

QUESTION B.09 [1.0 point]
In accordance with AFRRI Technical Specifications, a Senior Reactor Operator is required to be present at the facility during all of the following conditions EXCEPT:

a. Recovery from an unplanned or unscheduled shutdown or significant power reduction.

b. Fuel or control rod movement within the reactor core or pool.

c. Initial startup and approach to power.

d. Recovery from an unplanned reactivity change greater than $0.25.

QUESTION B.10 [1.0 point, 0.25 points each]
Match the conditions or events in Column A to the appropriate level of classification in Column B. Options in Column B may be used once, more than once, or not at all.

Column A	Column B
a. Fire within reactor facility not extinguished within 15 minutes	Class 0
b. Identification of fuel cladding rupture	Notification of Unusual Event
c. Personnel injury within operations boundary	Alert
d. Visual confirmation of a tornado in Bethesda	Site Area Emergency

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.11 [1.0 point]
In accordance with procedure 004, which ONE of the following is NOT an operator action if there is a loss of differential pressure to the reactor deck?

a. Check damper position indicators.

b. Investigate the cause of the loss of ΔP.

c. Scram the reactor.

d. Notify the Designated Senior Reactor Operator.

QUESTION B.12 [1.0 point, 0.25 points each]
Match the type of exposure in Column A to the Federal Annual Dose Limit in Column B. Answers in Column B may be used once, more than once, or not at all.

Column A	Column B
a. Extremities	0.1 rem
b. Total Effective Dose Equivalent for an occupational worker	5.0 rem
	15.0 rem
c. Total Effective Dose Equivalent for a member of the public	50.0 rem
d. Lens of the eye	

QUESTION B.13 [1.0 point]
A sample reads 135 mrem/hr at a distance of 4 meters from the source. How far away from the source will the reading be 50 mrem/hr?

a. 2.5 m

b. 4.8 m

c. 6.6 m

d. 8.6 m

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.14 [1.0 point]
In accordance with procedure 010, Conduct of Experiments, why might fuel elements need to be moved prior to determining the reactivity worth of an in-core experiment?

a. The absolute worth of materials would exceed $3.00.

b. The absolute worth of materials would exceed $5.00.

c. The maximum available excess reactivity above cold critical with or without all experiments in place would exceed $3.00.

d. The maximum available excess reactivity above reference core conditions with or without all experiments in place would exceed $3.00.

QUESTION B.15 [1.0 point]
A five-curie source emits a 5MeV gamma 65% of the time. The source will be placed in the reactor storage room. How far from the source should a high radiation area sign be posted?

a. 5.0 feet

b. 12.75 feet

c. 31.2 feet

d. 48.8 feet

QUESTION B.16 [1.0 point]
In order to ensure the health and safety of the public, 10 CFR 50 allows an operator to deviate from Technical Specifications. What is the MINIMUM level of authorization needed to deviate from Technical Specifications?

a. Reactor Supervisor

b. Licensed SRO

c. Licensed RO

d. Reactor Director

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.17 [1.0 point]
In accordance with the AFRRI Emergency Plan, which ONE of the following defines the Emergency Planning Zone?

a. The boundary that encompasses all areas of the reactor facility formed by the physical barriers of the reactor building, and within which emergency planning is performed to ensure that prompt and effective action can be taken to protect the public in the event of an accident.

b. The boundary that encompasses all areas within the AFRRI site boundary, and within which emergency planning is performed to ensure that prompt and effective action can be taken to protect the public in the event of an accident.

c. The area in which emergency planning is performed to ensure that prompt and effective action can be taken to protect the public in the event of an accident, established by the maximum distance within the AFRRI site bo.undary at which the protective action guide (PAG) is determined to be met

d. The area beyond the AFRRI site boundary, established by the maximum distance within the AFRRI site boundary at which the protective action guide (PAG) is determined to be met.

QUESTION B.18 [1.0 point]
Which ONE of the following modifications would NOT require a 50.59 evaluation?

a. Changing the frequency of the visual inspection of all fuel assemblies to every five years.

b. Adding a new limitation to the Startup Checklist Procedure.

c. Replacing the Continuous Air Particulate monitor with a like-for-like detector.

d. Removing the definition of Channel Check listed in the AFRRI Technical Specifications.

QUESTION B.19 [1.0 point, 0.25 points each]
Match surveillance requirements in Column A with the surveillance interval listed in Column B. Options in Column B may be used once, more than once, or not at all.

Column A	Column B
a. Control rod drop time verification	Monthly
b. Ventilation damper operation	Quarterly
c. Visual reactor pool level alarms	Semi-Annually
d. Continuous Air Particulate Monitor calibration	Annually

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.20 [1.0 point]
You are currently a licensed operator at the AFRRI reactor. Which ONE of the following is NOT a requirement of 10 CFR 55, “Operator’s Licenses”?

a. All licensed operators must have a medical examination by a physician every 2 years.

b. All licensed operators must actively perform the functions of an operator or senior operator for a minimum of 4 hours per quarter to maintain active status.

c. All licensed operators must pass a biennial operational requalification exam.

d. All licensed operators must successfully complete a continuous requalification program, not to exceed 24 months.

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

Category C: Facility and Radiation Monitoring Systems

QUESTION C.01 [1.0 point]
What is the main purpose of the atmospheric relief valves?

a. The atmospheric relief valves allow for controlled, monitored releases of air through the stack during events which include releases of airborne radioactivity.

b. The atmospheric relief valves are utilized during normal operation to divert a portion of the air exhausted from the reactor room for monitoring of radiological effluents.

c. The atmospheric relief valves permit air to enter or exit the stack in response to atmospheric changes in the reactor room which could otherwise result in structural damage.

d. The atmospheric relief valves permit for normal off-gassing during routine reactor operations.

QUESTION C.02 [1.0 point]
What is the purpose of the holes drilled into the primary coolant suction and return lines?

a. They impart a swirling motion to the water in the reactor pool causing the large gas bubbles to break into smaller ones and increasing the time for N-16 to escape the reactor pool.

b. They prevent the core from becoming uncovered in the event of a primary coolant leak or rupture.

c. They are the port locations for the thermometers used for the thermal power calibration.

d. They are sample ports for biological experiments.

QUESTION C.03 [1.0 point]
All of the following statements about the instrumented fuel element (IFE) are true EXCEPT:

a. Two IFEs are located in the C ring and one in the B ring of the core.

b. The IFEs have three chromel-alumel thermocouples embedded in the fuel moderator section at axial locations.

c. The thermocouples are located at the mid-plane of the fuel section and 1 inch above and below the center thermocouple.

d. All three IFEs are required to be operational per Technical Specifications.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.04 [1.0 point]
What could happen when the safety limit is exceeded?

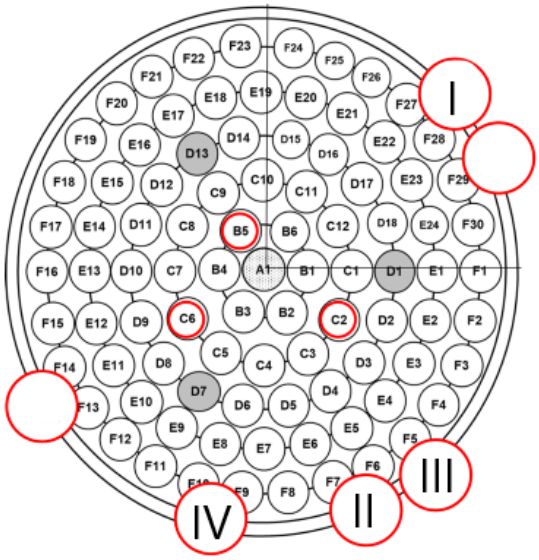
a. Loss of the integrity of the fuel element cladding due to build-up of excessive pressure between the fuel moderator and the cladding.

b. Loss of integrity of the fuel elements due to increased thermal expansion.

c. Loss of integrity of the fuel elements due to decreased cooling flow around the elements.

d. Loss of the integrity of the fuel elements due to increasing voids between the fuel elements as a result of increasing moderator temperature.

QUESTION C.05 [1.0 point, 0.25 points each]
Using the figure below, match the nuclear instrumentation in Column A to the correct location in the core in Column B.



Column A	Column B
a. Safety Channel 2 (NPP-1000)	I
b. Safety Channel 1 (NP-1000)	II
c. Linear Power Channel (NMP-1000)	III
d. Log Power Channel (NLW-1000)	IV

Category C: Facility and Radiation Monitoring Systems

QUESTION C.06 [1.0 point]
In accordance with Technical Specifications 3.3, the reactor shall not be operated if bulk water temperature exceeds _____ because _____.

a. 60 °C; sustained operations in excess of this temperature would violate the Limiting Safety System Setting.

b. 60 °F; sustained operations in excess of this temperature would violate the Limiting Safety System Setting.

c. 60 °C; sustained operations in excess of this temperature would cause the resins in the water purification system to break down.

d. 60 °F; sustained operations in excess of this temperature would cause the resins in the water purification system to break down.

QUESTION C.07 [1.0 point]
Which ONE of the following statements regarding operability of facility Radiation Monitors is true?

a. The reactor may be operated if one of the two RAMS on the reactor deck in the reactor room is inoperable, so long as the remaining RAM has audible and visual alarm indications.

b. Reactor operations may continue indefinitely with one or more Radiation monitors inoperable if they are replaced within one hour of discovery with an equivalent monitor with audible and visual alarm indications.

c. If a Radiation Monitor fails during reactor operations, operations may continue as planned, however the reactor may not restart until the monitor is returned to operable.

d. The reactor may not be operated if any of the required Radiation Monitors is inoperable.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.08 [1.0 point]
Which ONE of the following options correctly describes how primary coolant temperature is measured?

a. A semiconductor-based temperature sensor detects changes in pool temperature by utilizing two identical diodes with temperature-sensitive voltage vs current characteristics that are used to monitor changes in temperature.

b. A thermistor detects changes in pool temperature by using a thermally sensitive resistor that exhibits a continuous, small, incremental change in resistance correlated to variations in temperature.

c. A resistance temperature detector detects changes in pool temperature by measuring changes in resistance to the flow of electricity resulting from changes in temperature of the resistive metal element.

d. A thermocouple detects changes in pool temperature by measuring the voltage difference between two wires of dissimilar metals.

QUESTION C.09 [1.0 point]
What happens when there is a loss of commercial power to the facility?

a. The reactor scrams automatically on loss-of-power scram, the Uninterruptible Power Supply provides immediate power to the console and radiation area monitoring equipment, and the loads transfer to the emergency generators approximately 10 minutes after the loss of power.

b. The reactor scrams automatically on loss-of-power scram, the Uninterruptible Power Supply provides immediate power to the console and radiation area monitoring equipment, and the loads transfer to the emergency generators approximately 1 minute after the loss of power.

c. The Uninterruptible Power Supply provides immediate power to the console and radiation area monitoring equipment allowing the operator to perform a normal reactor shutdown, and the loads transfer to the emergency generators approximately 1 minute after the loss of power.

d. The Uninterruptible Power Supply provides immediate power to the console and radiation area monitoring equipment allowing the operator to perform a normal reactor shutdown, and the loads transfer to the emergency generators approximately 10 minutes after the loss of power.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.10 [1.0 point]
Which ONE of the following best describes the flow of primary coolant?

a. The primary pump draws water from the reactor pool through the suction line, located approximately 4 feet below the surface. The water is cooled by the primary heat exchanger and then returns to the core through the return line located approximately 8 feet below the surface.

b. The primary pump draws water from the reactor pool through the suction line, located approximately 8 feet below the surface. The water is cooled by the primary heat exchanger and then returns to the core through the return line located approximately 4 feet below the surface.

c. The primary pump draws water downward from the reactor pool through the reactor core. The water is cooled by the primary heat exchanger, then returns to the core through the bottom of the reactor pool.

d. The primary pump draws water downward from the reactor pool through the reactor core. The water is cooled by the primary heat exchanger, then returns to the core through the top of the reactor pool.

QUESTION C.11 [1.0 point, 0.25 points each]
Match the radiation monitor instrumentation in Column A to the detector type in Column B. Answers in Column B may be used once, more than once, or not at all.

Column A	Column B
a. R-1 Radiation Area Monitor	1. NaI scintillation detector
b. Stack Gas Monitor	2. GM detector
c. Continuous Air Monitor	3. Energy-compensated GM Detector
d. E-5 Radiation Area Monitor	

QUESTION C.12 [1.0 point]
The purpose of the Pulse Initiation Interlock is _____.

a. To prevent pulse initiation above 1 kW to prevent a power level scram from occurring.

b. To prevent movement of standard control rods during a pulse to ensure reactor power level returns to a low level after pulsing.

c. To prevent movement of standard control rods in pulse mode to prevent inadvertent power increase prior to pulse initiation.

d. To prevent pulse initiation above 1kW to prevent the safety limit from being exceeded.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.13 [1.0 point]
All of the following facility interlock permits must be satisfied before the standard control rod magnet power circuits and transient control rod air circuits can be energized EXCEPT:

a. All emergency stop circuits in the exposure rooms and control system console must be energized.

b. The tank lead shield doors must be fully opened, AND both plug doors for the exposure rooms must be closed.

c. The tank lead shield doors must be fully closed, AND both plug doors for the exposure rooms must be closed.

d. The Key Switch must be in the ON position.

QUESTION C.14 [1.0 point]
All of the following initiate a scram EXCEPT:

a. Period < 3 seconds

b. Fuel temperature ≥ 600 °C

c. 20% loss of High Voltage to Safety Channel

d. Pool water level < 14 feet from the top of the core

QUESTION C.15 [1.0 point]
Which ONE of the following is NOT a purpose of the Primary Water Purification System?

a. Maintain optical clarity of the reactor pool.

b. Reduce activation in the primary coolant.

c. Minimize transport time of radionuclides.

d. Minimize corrosion of all reactor components.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.16 [1.0 point]
Which ONE of the following describes what happens to the transient rod when a scram signal is received?

a. The electromagnet is energized, interrupting magnet power and releasing the transient rod which falls into the core by gravity.

b. The electromagnet is de-energized, interrupting magnet power and releasing the transient rod which falls into the core by gravity.

c. The transient air solenoid valve is de-energized, interrupting the air supply so the transient rod falls into the core by gravity.

d. The transient air solenoid valve is energized, interrupting the air supply so the transient rod falls into the core by gravity.

QUESTION C.17 [1.0 point]
What is the purpose of the > $1x10^{-5}$ W control rod withdrawal inhibit on NMP-1000?

a. This inhibit ensures that there is sufficient voltage to the NMP-1000 as indicated by the CSC to operate the reactor.

b. This inhibit ensures there is sufficient indication of source neutrons to approach criticality in a controlled manner.

c. This inhibit ensures that the reactor period reading is on scale prior to continuing power ascension.

d. This inhibit ensures that there is accurate multi-range percent linear power indication prior to reactor startup.

QUESTION C.18 [1.0 point]
A gaseous effluent commonly produced from reactor operation is _____ which is _____:

a. Rn-222; a naturally occurring isotope.

b. I-135; produced as a byproduct of fission.

c. H^3; produced from irradiation of water.

d. Ar-41; produced from irradiation of air.

Category C: Facility and Radiation Monitoring Systems

QUESTION C.19 [1.0 point]
With the reactor in Automatic Mode, which of the following statements regarding rod motion is NOT true?

a. The transient rod will not move in Automatic Mode.

b. Rods will not move if the reactor is within ± 5% of demand power (dead band).

c. All rod UP buttons are disabled in Automatic Mode.

d. A 3 second period will always mandate max rod speed, unless in the dead band.

QUESTION C.20 [1.0 point]
Which ONE of the following describes the AFRRI fuel?

a. $UZrH_{1.7}$ fuel enriched to < 20% U-235.

b. $UZrH_{1.5}$ fuel enriched to < 20% U-235.

c. $UZrH_{1.7}$ fuel enriched to < 20% U-238.

d. $UZrH_{1.5}$ fuel enriched to < 20% U-238.

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

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

A.01
Answer: a.
Reference: DOE Fundamentals Handbook, Volume 2, Module 3, p. 15

A.02
Answer: a.
Reference: Burn, Introduction to Nuclear Reactor Operations, Section 3.2, page 3-2.
U-235 Fission Capture = $\sigma_f / (\sigma_f + \sigma_c)$ = 577/(577+106) = 0.84

A.03
Answer: c.
Reference: Burn, Introduction to Nuclear Reactor Operations, Section 2.4.5, page 2-7-1

A.04
Answer: b.
Reference: DOE Fundamentals Handbook, Volume 2, Module 3, p. 16

A.05
Answer: a. Decreases; b. Increases; c. Stays the same; d. Increases
Reference: DOE Fundamentals Handbook, Volume 1, Module 1, p. 3-16

A.06
Answer: c.
Reference: Burn, R., Introduction to Nuclear Reactor Operation, Section 5.3, p. 5-12

A.07
Answer: b.
Reference: DOE Fundamentals Handbook, Volume 2, Module 3, p. 30-47

A.08
Answer: a.
Reference: $P = P_0 e^{-t/T}$
$P = 500*0.07$ (prompt drop) kW * $e^{(300s/-80s)}$
$P = 35$ kW * $e^{(-3.75)}$
$P = 823$ W

A.09
Answer: c.
Reference: $P(t) = P(0)e^{t/T}$
$500kW = 25kW*e^{t/32}$
$500kW / 25kW = e^{t/32}$
$\ln(20) = \ln(e^{t/32})$
$2.9957 = t/32$
$t = 95$ s

A.10
Answer: d.
Reference: DOE Fundamentals Handbook, Volume 1, Module 1, p. 29

A.11
Answer: c.
Reference: DOE Fundamentals Handbook, Volume 1, Module 1, p. 50-55

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

A.12
Answer: a.
Reference: DOE Fundamentals Handbook, Volume 2, Module 3, p. 21,
$\Delta\rho = \alpha T * \Delta T$
$\Delta\rho = (-0.00092\ \Delta k/k\ /°F) * (-25°F)$
$\Delta\rho = 0.023\ \Delta k/k$

A.13
Answer: b.
Reference: DOE Handbook Nuclear Physics & Reactor Theory, Volume 1, Module 2, p. 7

A.14
Answer: b.
Reference: DOE Fundamentals Handbook, Volume 1, Module 2, p. 1

A.15
Answer: a.
Reference: DOE Fundamentals Handbook Nuclear Physics and Reactor Theory, Volume 1, Module 2, page 10

A.16
Answer: d.
Reference: Burn, Introduction to Nuclear Reactor Operations, Section 7.2

A.17
Answer: c.
Reference: Burn, Section 3.3.4, p 3-20-21
$\Delta\rho = (k_{eff2}-k_{eff1})/(k_{eff1}*k_{eff2})$
$\Delta\rho = (0.989-0.826)/(0.989*0.826)$
$\Delta\rho = 0.199\ \Delta k/k$

A.18
Answer: d.
Reference: DOE Fundamentals Handbook, Volume 1, Module 1, p. 61

A.19
Answer: c.
Reference: DOE Fundamentals Handbook, Volume 1, Module 1, page 61

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.01
Answer: d.
Reference: AFRRI Emergency Plan, p. 3-6

B.02
Answer: b.
Reference: 002, Reactor Operations

B.03
Answer: c.
Reference: $DR = DR \cdot e^{-\mu x}$; Find μ
$150 = 400 \cdot e^{-30\mu}$
$0.375 = e^{-30\mu}$
$\ln(0.375) = \ln(e^{-30\mu})$
$-0.9808 = -30\mu$
$\mu = 0.03269$

Find X:
$50 = 150 \cdot e^{-0.03269X}$
$\ln(0.333) = \ln(e^{-0.03269X})$
$-1.0986 = -0.03269X$
$X = 34$ mm

B.04
Answer: c.
Reference: 004, Response to SCRAMS, Alarms and Abnormal Conditions

B.05
Answer: a. Steady State; b. Steady State; c. Both; d. Pulse
Reference: AFRRI Technical Specifications 3.2.2

B.06
Answer: a.
Reference: 002, Reactor Startup Checklist

B.07
Answer: a.
Reference: 004, Response to SCRAMS, Alarms, and Abnormal Conditions

B.08
Answer: b.
Reference: 215, Thermal Power Calibration and Power Coefficient

B.09
Answer: d.
Reference: AFRRI Technical Specifications 6.1.4

B.10
Answer: a. Notification of Unusual Event; b. Alert; c. Class 0;
d. Notification of Unusual Event
Reference: AFRRI Emergency Plan, Section 4

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.11
Answer: c.
Reference: 004, Response to SCRAMS, Alarms, and Abnormal Conditions

B.12
Answer: a. 50 rem; b. 5 rem; c. 0.1 rem; d. 15 rem
Reference: 10 CFR 20.1003

B.13
Answer: c.
Reference: $DR_1*(D_1)^2 = DR_2*(D_2)^2$;
135 mrem*(4 m)^2 = 50 mrem(d)^2
2160 mrem-m^2 = 50 mrem(d)^2
43.2 m^2 = d^2
d = 6.6 m

B.14
Answer: a.
Reference: 010, Conduct of Experiments

B.15
Answer: c.
Reference: I=6CEn=R/hr@ft.
6*5Ci x 5Mev x 65% = 97.5 R/hr@ (1ft)^2 =
97.5 R/hr = 0.1 R/hr@ D2 = √975 R/hr = 31.2 ft.

B.16
Answer: b.
Reference: 10 CFR 50.54(y)

B.17
Answer: c.
Reference: AFRRI Emergency Plan, Section 2

B.18
Answer: c.
Reference: 10 CFR 50.59

B.19
Answer: a. Semi-annually; b. Monthly; c. Quarterly; d. Annually
Reference: AFRRI Technical Specifications 4.2.1, 4.3, 4.4, 4.5.1

B.20
Answer: c.
Reference: 10 CFR Part 55

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

C.01
Answer: c.
Reference: AFRRI SAR 6.2.1

C.02
Answer: b.
Reference: AFRRI SAR 5.2

C.03
Answer: d.
Reference: AFRRI SAR 4.2.1

C.04
Answer: a.
Reference: AFRRI Technical Specifications 2.1

C.05
Answer: a. IV; b. II; c. III; d. I
Reference: AFRRI SAR 7.2.2.1

C.06
Answer: c.
Reference: AFRRI Technical Specifications 3.3

C.07
Answer: d.
Reference: AFRRI Technical Specifications 3.5.1

C.08
Answer: c.
Reference: AFRRI SAR 7.7.2

C.09
Answer: b.
Reference: AFRRI SAR 8.2

C.10
Answer: a.
Reference: AFRRI SAR 5.2

C.11
Answer: a. 3.; b. 1; c. 2; d. 3
Reference: AFRRI SAR 7.8.1,

C.12
Answer: d.
Reference: AFRRI Technical Specifications 3.2

C.13
Answer: c.

Reference: AFRRI SAR 7.3.5

C.14
Answer: a.
Reference: AFRRI Technical Specifications 3.2

C.15
Answer: c.
Reference: AFRRI SAR 5.4

C.16
Answer: c.
Reference: AFRRI SAR 7.3.2

C.17
Answer: b.
Reference: AFRRI SAR 7.2.2.1.2

C.18
Answer: d.
Reference: AFRRI SAR 11.1.1.1

C.19
Answer: b.
Reference: 002, Reactor Operations

C.20
Answer: a.
Reference: AFRRI SAR 4.1

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