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

November 6, 2019

Dr. J. David Robertson
Reactor Facility Director
University of Missouri-Columbia
Research Reactor Center
1513 Research Park Drive
Columbia, MO 65211

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-19-02, UNIVERSITY OF MISSOURI - COLUMBIA

Dear Dr. Robertson:

During the week of September 16, 2019, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your University of Missouri - Columbia research reactor. The examinations were conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with Title 10 of the *Code of Federal Regulations,* Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Mr. John Nguyen at (301) 415-4007 or via internet e-mail John.Nguyen@nrc.gov.

Sincerely,

Anthony J. Mendiola, 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. 50-186

Enclosures:
1. Examination Report No. 50-186/OL-19-02
2. Written examination

cc: w/o enclosures: See next page

cc:

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Reactor and Facilities Operations
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Test, Research and Training
Reactor Newsletter
Attention: Amber Johnson
Dept of Materials Science and Engineering
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4418 Stadium Drive
College Park, MD 20742-2115

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

REPORT NO.: 50-186/OL-19-02

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: Tank

EXAMINATION DATES: September 16 - 19, 2019

SUBMITTED BY: John Nguyen, Chief Examiner — 10/10/2019 Date

SUMMARY:
During the week of September 16, 2019, the NRC administered an operator licensing examination to three Reactor Operator (RO) candidates. The candidates passed all applicable portions of the examinations.

REPORT DETAILS

1. Examiner: John Nguyen, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:
John Nguyen, Chief Examiner, NRC
Bruce Meffert, Reactor Manager, MURR Reactor
Sean Schaefer, Assistant Reactor Manager, MURR
Rob Hudson, Training Coordinator, MURR Reactor Operations

At the conclusion of the meeting, the NRC examiner thanked the facility for their support in the administration of the examinations. The examiner discussed the facility comments of the written examination, the weaknesses observed during the operating test, and how to improve program performance in the training programs.

ENCLOSURE 1

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

FACILITY: University of Missouri - Columbia

REACTOR TYPE: Tank

DATE ADMINISTERED: 09/17/2019

CANDIDATE: _____

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

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

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

_____
Candidate's Signature

ENCLOSURE 2

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

ANSWER SHEET

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

A01 a b c d ___

A02 a b c d ___

A03 a b c d ___

A04 a b c d ___

A05 a b c d ___

A06 a b c d ___

A07 a b c d ___

A08 a ___ b ___ c ___ d ___ (0.25 each)

A09 a b c d ___

A10 a b c d ___

A11 a b c d ___

A12 a b c d ___

A13 a b c d ___

A14 a b c d ___

A15 a b c d ___

A16 a b c d ___

A17 a b c d ___

A18 a b c d ___

A19 a b c d ___

A20 a b c d ___

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

Category B – Normal/Emergency Operating Procedures and Radiological Controls

ANSWER SHEET

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

B01 a b c d ___

B02 a b c d ___

B03 a b c d ___

B04 a b c d ___

B05 a b c d ___

B06 a ___ b ___ c ___ d ___ (0.25 each)

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 ___ (0.25 each)

B12 a b c d ___

B13 a b c d ___

B14 a b c d ___

B15 a b c d ___

B16 a b c d ___

B17 a b c d ___

B18 a b c d ___

B19 a b c d ___

B20 a b c d ___

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

Category C – Facility and Radiation Monitoring Systems

ANSWER SHEET

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

C01 a ___ b ___ c ___ d ___ (0.25 each)

C02 a b c d ___

C03 a b c d ___

C04 a ___ b ___ c ___ (0.33 each)

C05 a b c d ___

C06 a b c d ___

C07 a b c d ___

C08 a b c d ___

C09 a b c d ___

C10 a b c d ___

C11 a ___ b ___ c ___ d ___ (0.25 each)

C12 a b c d ___

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

e ___ f ___ g ___ h ___

C14 a b c d ___

C15 a b c d ___

C16 a ___ b ___ c ___ d ___ (0.25 each)

C17 a b c d ___

C18 a b c d ___

C19 a b c d ___

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

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.

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

3. Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.

4. Use black ink or dark pencil <u>only</u> to facilitate legible reproductions.

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

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

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

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

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

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

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

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

EQUATION SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

---

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

1 Horsepower = 2.54 x 10^3 BTU/hr

1 BTU = 778 ft-lb

1 gal (H_2O) ≈ 8 lb

c_P = 1.0 BTU/hr/lb/°F

1 kg = 2.21 lb

1 Mw = 3.41 x 10^6 BTU/hr

°F = 9/5 °C + 32

°C = 5/9 (°F - 32)

c_p = 1 cal/sec/gm/°C

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

QUESTION A.01 [1.0 point]
If 0.156 %Δk/k of positive reactivity is suddenly inserted into a critical reactor core, what will be the steady reactor period?

a. 10 seconds

b. 26 seconds

c. 37 seconds

d. 80 seconds

QUESTION A.02 [1.0 point]
K_{eff} of reactor A is 0.1 and K_{eff} of reactor B is 0.8. Assume that both K_{eff} increases by 0.1, the amount of reactivity added in reactor A is _____ in comparing with reactor B for the same increment.

a. less than

b. same

c. eight times

d. thirty-six times

QUESTION A.03 [1.0 point]
K_{eff} is K_∞ times ...

a. the fast fission factor (ε)

b. the reproduction factor (η)

c. the resonance escape probability (p)

d. the total non-leakage probability ($L_f \times L_{th}$)

QUESTION A.04 [1.0 point]
Which type of neutron interaction (light nuclei) is most important in moderating fast neutrons to thermal neutrons?

a. Radioactive Capture

b. Elastic scattering

c. Inelastic scattering

d. Fission

QUESTION A.05 [1.0 point]
The Reactor is critical at 100 watts. A reactor operator makes a mistake by inserting a sample worth of 0.008 $\Delta k/k$ into the reactor core. Which ONE of the following best describes the reactor kinetic when inserting this amount?

a. Critical, $K_{eff} = 1$ and $\rho = 0$

b. Super critical, $K_{eff} = 1$ and $\rho = \beta$-eff

c. Prompt critical, $K_{eff} > 1$ and $\rho > \beta$-eff

d. Prompt critical, $K_{eff} > 1$ and $\rho = \beta$-eff

QUESTION A.06 [1.0 point]
A reactor contains a neutron source of 1000 neutrons/second. If the stable total neutron production rate is 5000 neutrons/seconds, what is a value of k_{eff}?

a. 0.60

b. 0.70

c. 0.80

d. 0.90

QUESTION A.07 [1.0 point]
Delayed neutrons are born at _____ energies than prompt neutrons which leads to the effective delayed neutron fraction being _____ than the delayed neutron fraction.

a. higher; higher

b. higher; lower

c. lower; lower

d. lower; higher

QUESTION A.08 [1.0 point, 0.25 each]
A fissile material is one that will fission upon absorption of a thermal neutron. A fertile material is one that absorbs a neutron and becomes a fissile material. Identify each of the listed isotopes as either fissile or fertile.

a. U-238

b. Pu-241

c. Th-232

d. U-235

QUESTION A.09 [1.0 point]
What is a typical value of prompt neutron generation time?

a. 12 seconds

b. 1 second

c. 0.1 second

d. 1×10^{-4} second

QUESTION A.10 [1.0 point]
Reactor is in an automatic mode of 10 MW. How will the regulating blade behave if boron in the Shim blade is replaced with void (air)?

a. Drive out to compensate a positive reactivity added.

b. Drive out to compensate a negative reactivity added.

c. Drive in to compensate a positive reactivity added.

d. Drive in to compensate a negative reactivity added.

QUESTION A.11 [1.0 point]
Which ONE of the following statements is true regarding to Xe-135 poison in the MURR reactor?

a. There are two methods forming Xe-135 poison: by decay of I-135 and decay of Cs-135.

b. As Xe-135 is formed in the reactor, the thermal utilization factor will increase.

c. Xe-135 is never reach equilibrium during reactor operation.

d. Xe-135 can be formed directly as a fission product.

QUESTION A.12 [1.0 point]
Which ONE of the following will require the control blades INSERTION to maintain the same power level following the change?

a. Adding of a Pu-241 material into the core experiment.

b. Insertion of an experiment containing cadmium.

c. Primary coolant water temperature increase.

d. Samarium-149 is formed in the core.

QUESTION A.13 [1.0 point]
Which ONE of the following is the stable reactor period which will result in a power rise from 1% to 100% power in 25 seconds?

a. 5 seconds

b. 16 seconds

c. 24 seconds

d. 43 seconds

QUESTION A.14 [1.0 point]
Which term is described by the following?
"The increase in neutron population by providing a positive additional reactivity while the reactor is subcritical"

a. Inverse Multiplication

b. Subcritical Multiplication

c. Neutron Production

d. Source Strength

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

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

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

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

d. Neutron cross sections of U-235 and U-238 are independent from the neutron energy levels.

QUESTION A.16 [1.0 point]
Shortly after a reactor shutdown, you note that reactor period is a stable with negative value. By what factor has reactor power level decreased three minutes later?

a. 2

b. 2.718 (e)

c. 5

d. 10

QUESTION A.17 [1.0 point]
Reactor A increases power from 10% to 30% with a period of 25 seconds. Reactor B increases power from 70% to 100% with a period of also 25 seconds. Compared to Reactor A, the time required for the power increase of Reactor B is:

a. longer than A

b. exactly the same as A

c. twice that of A

d. shorter than A

QUESTION A.18 [1.0 point]
A reactor is critical at 18.1 inches on a controlling blade. The controlling blade is withdrawn to 18.4 inches. The reactivity inserted is 0.1%Δk/k. What is the differential rod worth?

a. 0.1%Δk/k /inch at 18.25 inches.

b. 0.33%Δk/k /inch at 18.40 inches.

c. 0.33%Δk/k /inch at 18.25 inches.

d. 0.1%Δk/k /inch at 18.1 inches.

QUESTION A.19 [1.0 point]
Which ONE of the following isotopes has the largest microscopic absorption cross-section for thermal neutrons?

a. B-10

b. Xe-135

c. Sm-149

d. U-235

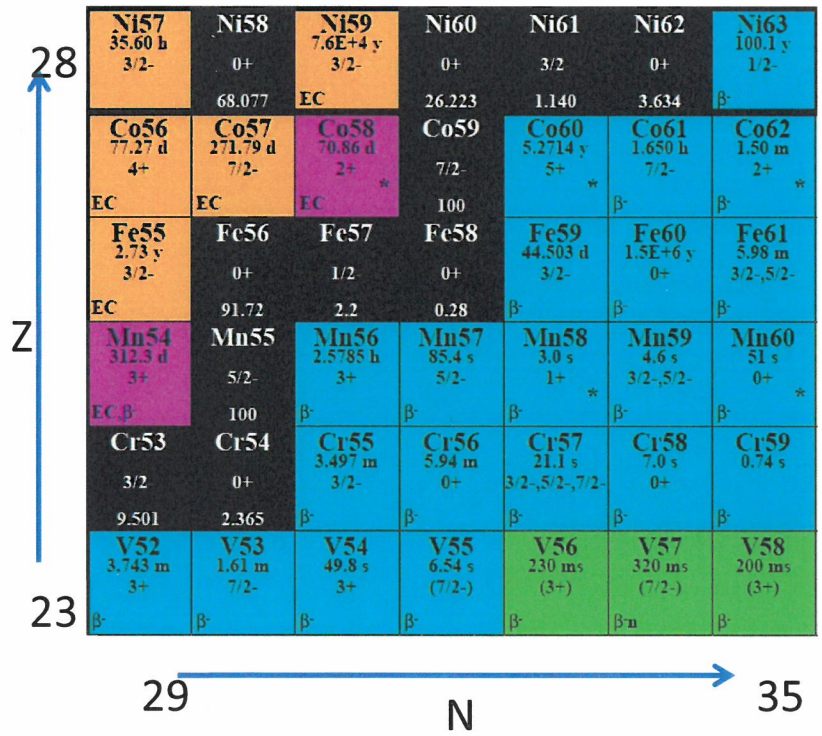
QUESTION A.20 [1.0 point]
Attached is the applicable portion from the chart of the nuclides, what will Mn-57 decay into?

a. Fe-57

b. Mn-58

c. Cr-57

d. V-53



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

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.01 [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 SL is a maximum operationally limiting value that prevents exceeding the LSSS during normal operations.

b. The SL is a parameter that assures the integrity of the fuel cladding. The LSSS initiates protective actions to preclude reaching the SL.

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

d. The LSSS is a parameter that assures the integrity of the fuel cladding. The SL initiates protective action to preclude reaching the LSSS.

QUESTION B.02 [1.0 point]
In order to ensure the health and safety of the public, 10CFR50 allows the operator to deviate from Technical Specifications. What is the minimum level of authorization needed to deviate from Technical Specifications?

a. Reactor Director

b. Reactor Supervisor

c. Licensed Senior Reactor Operator

d. Licensed Reactor Operator

QUESTION B.03 [1.0 point]
Per MURR Technical Specifications, the reactor is considered "Secured" when: (provide best answer)

a. The reactor is shut down which means subcritical by at least 0.7% $\Delta k/k$.

b. The core has been unloaded such that there is not enough fuel in the reactor to attain criticality in the most optimum conditions of moderation and reflection with all control elements in the full out position.

c. No involving the transfer of fuel in or out of the reactor core. The console key switch in the "OFF" position and the key is removed from the console and under the control of a licensed operator or stored in a locked storage area.

d. All four shim rods are fully inserted. No work is in progress involving core fuel, core structures, control elements, or control element drives unless the work on the drive cannot move the control element.

QUESTION B.04 [1.0 point]
A five-curie source, emitted 70% of 500 Kev gamma, is to be stored in the reactor building. Approximately how far from the source will it read 100 mrem/hr?

a. 2 feet

b. 10 feet

c. 132 feet

d. 324 feet

QUESTION B.05 [1.0 point]
Which One of the following changes must be submitted to NRC for approval prior to implementation?

a. Add a low enriched fuel element to the reactor core.

b. Add new limit to the pre-startup checklist procedure.

c. Replace a primary cooling pump with an identical pump.

d. Add more responsibilities to the Radiation Protection Officer listed in the health physics procedure.

QUESTION B.06 [1.0 point, 0.25 each]
Match type of radiation listed in column A with their quality factor listed in column B. Items in column B can be used once, more than once or not at all.

	Column A	Column B	
a.	X-ray	1.	1
b.	Gamma	2.	5
c.	Alpha particles	3.	10
d.	High-energy neutron	4.	20

QUESTION B.07 [1.0 point]
Which parts in 10CFR states that the licensed operator shall not consume or ingest alcoholic beverage within the controlled access area; and shall not use, possess, or sell any illegal drugs?

a. 10CFR19

b. 10CFR20

c. 10CFR50

d. 10CFR55

QUESTION B.08 [1.0 point]
Per MURR Technical Specifications, what is the MAXIMUM reactor core excess reactivity above cold, clean, and critical?

a. 0.006 $\Delta k/k$

b. 0.098 $\Delta k/k$

c. 0.060 $\%\Delta k/k$

d. 0.980 $\%\Delta k/k$

QUESTION B.09 [1.0 point]
How long will it take a 5 Curie source, with a half-life of 5 months, to decay to 10 millicurie?

a. 2.4 years

b. 3.7 years

c. 28.8 years

d. 44.8 years

QUESTION B.10 [1.0 point]
An unshielded source reads 300 mr/hr at 100 cm. You store it in a lead pig and perform a survey. It reads 200 mr/hr on contact, and 10 mr/hr at 100 cm. If a shielded source is stored in a lead pig, which of the following is a correct statement for posting requirement?

a. Very High Radiation Area because an unshielded source reads 3333 mr/hr at 30 cm

b. High Radiation Area because a shielded source reads 200 mr/hr on contact.

c. High Radiation Area because a shielded source reads 111 mr/hr at 30 cm from the lead pig.

d. Radiation Area because a shielded source reads 10 mr/hr at 100 cm from the lead pig.

QUESTION B.11 [1.0 point, 0.25 each]
Per MURR Technical Specifications, fill out the blank in column B with appropriate LSSS for the Mode I Operation listed in column A.

	Column A	Column B
a.	Power Level	_____ MW (10/12.5/14.5) Maximum
b.	Primary Coolant Flow	_____ gpm (1625/1685/16250) Minimum
c.	Inlet Water Temperature	_____ °F (135/155/175) Maximum
d.	Pressurizer Pressure	_____ Psia (55/65/75) Minimum

QUESTION B.12 [1.0 point]
Prior to reactor startup,per OP-RO-210, if the difference in indication of the shim blade #1 and Shim blade #2 at "Full in" position is 0.05 inch, then you should:

a. continue in operation because it is a normal condition.

b. adjust a Shim blade micro limit switch for same position.

c. Adjust the RPI indication according to the Rod Position Indication- Zero Setting.

d. secured reactor, then inform the LSRO that the Shim plate position is inoperable.

QUESTION B.13 [1.0 point]
You follow the Standing Order (SO) Guidance related to the new Mirion Stack Monitor testing. This Standing Order will remain in effect until:

a. you complete verifying the Mirion Stack Monitor testing is complete.

b. Mirion Stack Monitor testing is complete, and the SO is cancelled by the Lead Senior Reactor Operator.

c. Mirion Stack Monitor testing is complete, and the SO is cancelled by the Reactor Manager.

d. annual calibration of the Mirion Stack Monitor is complete.

QUESTION B.14 [1.0 point]
An unshielded source has a dose rate of 1 Rem/hr. What is the actual dose rate if shielded by 3-cm lead?
Given:
Lead density: 11.35 g/cm^3
Lead Mass Attenuation Coefficient: 0.0708 cm^2/g

a. 907 mrem/hr

b. 656 mrem/hr

c. 91 mrem/hr

d. 11 mrem/hr

QUESTION B.15 [1.0 point]
Each fuel experiment shall be limited such that the total inventory of iodine-131 through iodine-135 in the experiment is not greater than _____?

a. 150 millicuries

b. 300 millicuries

c. 150 curies

d. 300 curies

QUESTION B.16 [1.0 point]
During an emergency, who has the responsibility for authorizing volunteer emergency workers to incur radiation exposure in excess of normal occupation limits?

a. US NRC Project Manager

b. MURR Health Physics Manager

c. MURR Emergency Coordinator

d. MURR Emergency Director

QUESTION B.17 [1.0 point]
The siphon break system pressure will be verified, recorded, and readjusted as required every _____ as part of the facility routine patrol.

a. 1 hour

b. 2 hours

c. 4 hours

d. 6 hours

QUESTION B.18 [1.0 point]
Per MURR Technical Specifications, the Power Range Nuclear Instrument channel shall be calibrated:

a. Monthly.

b. Semiannually.

c. Annually.

d. Biennially.

QUESTION B. 19 [1.0 point]
Per MURR Emergency Plan, which ONE of the following is an Alert Event?

a. Personnel radioactive contamination.

b. Tornadoes directed toward the reactor.

c. Bomb threat directed toward the reactor facility.

d. Experiment failure releasing significant radioactive materials

QUESTION B.20 [1.0 point]
Which One of the following is a prerequisite and initial condition for the Reactor Startup-Hot procedure?

a. Ensure ventilation system closed.

b. Reactor Manager is in the facility.

c. An estimated critical position (ECP) has been provided by the LSRO.

d. Ensure the Wide Range Monitor Level Recorder Auto Prohibit Set point is 75%.

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

Category C – Facility and Radiation Monitoring Systems

QUESTION C.01 [1.0 point, 0.25 each]
Fill out the position (Open/Close) in accordance with Emergency Air System Valve Line Up Checklist for the Emergency Air System.

a. A-149, 16-inch "B" valve compressor outlet.

b. A-115, Vent.

c. A-137, Door-504 inlet.

d. A-164, Backup door isolation.

QUESTION C.02 [1.0 point]
You work on lowering the pool level using the skimmer system. If a pool level is lowered to less than the lower limit of normal operating range (29'4"), you need to _____

a. open both Lower Skimmer Suction Valve 548B and Upper Skimmer Suction Valve 548A.

b. close both Lower Skimmer Suction Valve 548B and Upper Skimmer Suction Valve 548A.

c. obtain a Radiation Work Permit (RWP).

d. complete a "50.59" screening sheet.

QUESTION C.03 [1.0 point]
Which of the following statements best describes the operation of three-way solenoid control valve (529 Series)? When the solenoid valve is de-energized:

a. Supply port: OPEN. Exhaust port: OPEN. Air on the Actuator port is vented through the Exhaust port.

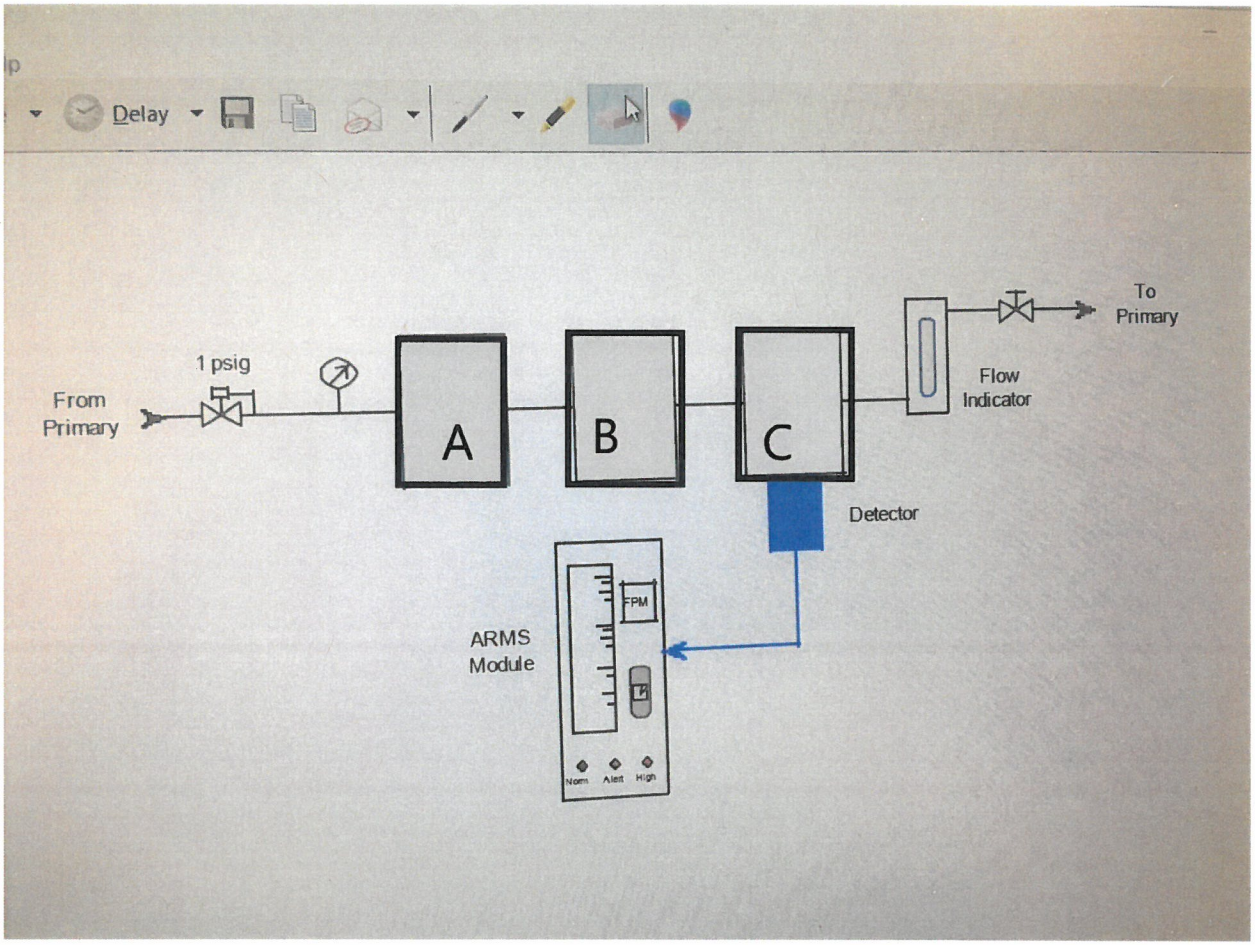
b. Supply port: OPEN. Exhaust port: OPEN. Air on the Actuator port is vented through the Supply port.

c. Supply port: CLOSED. Exhaust port: OPEN. Air on the Actuator port is vented through the Exhaust port.

d. Supply port: OPEN. Exhaust port: CLOSED. Air on the Exhaust port is vented through the Supply port.

Category C – Facility and Radiation Monitoring Systems

QUESTION C.04 [1.0 point, 0.33 each]
Figure below depicts the Fission Product Monitor that utilizes a NaI thallium activated scintillation detector to measure the gross gamma activity of the primary coolant water. Match each label with appropriate function column (Cation resin column, Anion resin column, and Filter column).



a. _____

b. _____

c. _____

Category C – Facility and Radiation Monitoring Systems

QUESTION C.05 [1.0 point]
Domestic Cold Water (DCW) enters the facility in which ONE of the following locations?

a. Fire Suppression system

b. Basement chiller unit

c. Domestic hot water heater system

d. Southeast corner of the cooling tower basement

QUESTION C.06 [1.0 point]
If the RED leg relay contact for the Power Level Interlock (PLI) of the Safety System opens, it will:

a. energize only 1K8 relay; and cause rod run-in A/ B

b. de-energize only 2K21 relay; and scram rod C/ rod D

c. de-energize 2K20 and 2K21 relays; and scram rod A / B/ C/ D

d. energize 1K8 and 2K21 relays; and cause rod run-in A / B /C/ D

QUESTION C.07 [1.0 point]
Which ONE of the following conditions will NOT allow the Regulating blade to be placed in automatic control?

a. IRM2 period indication is 40 seconds.

b. Range Switch selected to 10 kW red scale position.

c. "Regulating Blade 60% Withdrawn" annunciation is lit.

d. WRM recorder indication is lesser than Auto Prohibit set point by 10%.

QUESTION C.08 [1.0 point]
If pressurizer liquid level decreases below the normal operating level, which ONE of the following actions does NOT occur?

a. At approximately 7 inches (17.78 cm) below centerline, the LC 936 initiates a water valve V527B to open and start adding water to the pressurizer.

b. At approximately 11 inches (27.94 cm) below center line, the LC 937 initiates a "Pressurizer Water Low Level" annunciator alarm and signals valve V527A to close.

c. At approximately 13 inches (33.0 cm) below center line, the surge line isolation valve V527C closes to prevent an introduction of nitrogen gas into the primary coolant system.

d. At approximately 13 inches (33.0 cm) below center line, LC 935 initiates a reactor scram by opening a contact (K28-2) in the process input string to E3B of the Reactor Safety System NCLUs.

QUESTION C.09 [1.0 point]
The function of an INVERTER in the Uninterruptible Power Supply (UPS) system is to:

a. Convert alternating current (AC) from the Emergency Distribution to direct current (DC). This DC signal is then sent in parallel to the inverter and a float charge of the battery bank.

b. Convert DC from the battery bank to a step-like AC. This AC signal is then sent to the Static Switch for distribution of the UPS loads during a loss of electrical power.

c. Step down 480-V three-phase AC to 120-V single phase AC. This 120-V AC signal is sent to the Static Switch for distribution of the UPS loads during a loss of electrical power.

d. Switch the electrical power from the normal source to the Emergency Power source during a loss of electrical power.

QUESTION C.10 [1.0 point]
Just prior to withdrawing control rods with all process control systems on line, the Master Control Switch (1S1) is taken from the **ON** position to the **OFF** position. This action will cause:

a. All systems will shut down.

b. All systems will remain running, but without automatic operation.

c. All systems will remain running with all automatic functions operable.

d. The system is mechanically interlocked, and you cannot move 1S1 to the off position with all systems running.

Category C – Facility and Radiation Monitoring Systems

QUESTION C.11 [1.0 point, 0.25 each]
Fill out the current set point of the Area Radiation Monitors listed below:

Column A

a. Room 114 _____ mR/hr (50/300/1300)

b. Fuel Vault _____ mR/hr (3/6/10)

c. Bridge (not ALARA) _____ mR/hr (6/50/300)

d. South Beam Port Wall _____ mR/hr (3/6/50)

QUESTION C.12 [1.0 point]
The Low Count Rate signal is coming from:

a. Source Range Monitor 1.

b. Power Range Monitor 6.

c. Intermediate Range Monitor 2.

d. Wide Range Monitor

QUESTION C.13 [2.0 points,0.25 each]
Fill out the blank in accordance with MURR Technical Specifications.

Rod Run-in Function	Number Required (N)			Trip Set Point
	Mode I	Mode II	Mode III	
High Power Level	a_____ (1/2/3)	b_____ (2/3/4)	c_____ (3/4/5)	d_____ %of full power (Max) (110/115/120)
Reactor Period	e_____ (1/2/3)	f_____ (2/3/4)	g_____ (2/3/4)	h_____ seconds (5/10/15) (Min)

Category C – Facility and Radiation Monitoring Systems

QUESTION C.14 [1.0 point]
Which ONE of the following Area Radiation Monitoring System (ARMS) channels does NOT cause a building isolation?

a. Air Plenum 1

b. Air Plenum 2

c. Fuel vault

d. Bridge

QUESTION C.15 [1.0 point]
When Low Pressure from PT 944A activated, which of the following occurs?

a. Valve 507A & 507 B: Shut. Valve 543 A & 543 B: Open

b. Valve 507A & 507 B: Open. Valve 543 A & 543 B: Shut

c. Valve 507A & 543 B: Shut. Valve 543 A & 507 B: Open

d. Valve 507A & Valve 543 A: Shut. 507 B & 543 B: Open

QUESTION C.16 [1.0 point]
Match the types of radiation detectors in column A with its detection in column B. Items in column B can be used once, more than once or not at all.

Column A	Column B
a. Particulate (Phosphor Scintillation Detector)	1. alpha
b. Particulate (ZnS Detector)	2. beta
c. Iodine (NaI Detector)	3. gamma
d. Gas (Phosphor Scintillation Detector)	4. neutron

QUESTION C.17 [1.0 point]
Sufficient cooling of the control blades is provided by _____ when the reactor is in Mode III operation.

a. Forced convection flow

b. Xenon build-up in the reactor core

c. Natural circulation of pool water

d. DCW supplied from the After Cooler

QUESTION C.18 [1.0 point]
Temperature detectors TE 980A/B will provide a reactor scram in the event of high reactor coolant temperature. If they fail to initiate a scram, a backup scram signal is provided by:

a. PT 944B.

b. TE901B.

c. FT 912H.

d. DPS 929.

QUESTION C.19 [1.0 point]
Reactor is in operation. The BRIDGE Radiation Monitor System (ARMS) changes from normal to a failure mode. This failure mode will cause:

a. Rod run in.

b. Evacuation Relays (R3A & R3B) tripped.

c. Containment building exhaust isolation valves 16A and 16B changing from Open to Close.

d. Isolation doors 504 and 505 Open.

(***** END OF CATEGORY C *****)
((***** END OF EXAM *****))

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

A.01
Answer: c
Reference:

$$T = \left[\frac{\overline{\beta} - \rho}{\lambda_{eff}\,\rho} \right]$$

ρ = 0.00156
T = (0.0078 – 0.00156)/(0.1*.00156)
T = 40 seconds

A.02
Answer: d
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.3, page 3-21.
$\Delta\rho$ reactor A = $(Keff_1-Keff_2)/(Keff_1*Keff_2)$. (0.2-0.1)/(0.2*0.1) = 5 Δk/k
$\Delta\rho$ reactor B = $(Keff_1-Keff_2)/(Keff_1*Keff_2)$. (0.9-0.8)/(0.9*0.8) = 0.139 Δk/k
5/0.139 = 36

A.03
Answer: d
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Section 3.3

A.04
Answer: b
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Section 2.4.5

A.05
Answer: c
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 4.2

A.06
Answer: c
Reference: SCR = (S)/ (1-Keff)
(1000)/(1-Keff) = 5000
Keff = 0.80
DOE Fundamentals Handbook, NPRT, Vol. 2, Module 4, EO 1.2, p 4

A.07
Answer: d
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 3.2.4

A.08
Answer: a. = fertile; b. = fissile; c. = fertile; d. = fissile (0.25 each)
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 3.2

A.09
Answer: d
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Section 3.3.6

A.10
Answer: c
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 7.7.6

A.11
Answer: d
Reference: Burn, R., *Introduction of Nuclear Reactor Operations*, © 1988, Sec 8.3

A.12
Answer: a
Reference: Pu-241 is a fissile

A.13
Answer: a
Reference: P = P0 e t/T —> T= t/Ln(P/ P0)
T= 25/Ln(100/1); T = 25/4.61=5.4 sec.

A.14
Answer: b
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Section 5.1, Subcritical Multiplication

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

A.16
Answer: d
Reference: $P = P_0\, e^{t/\beta}$, where t = 180 seconds and β = -80 seconds, $P/P_0 = e^{-180/80} = 0.1054$
1/0.1054 = 9.49

A.17
Answer: d
Reference: The power of reactor A increases by a factor of 3, while the power of reactor B increases by a factor of 1.43. Since the periods are the same (rate of change is the same), power increase of reactor B takes a shorter time.

A.18
Answer: c
Reference: Burn, R., Introduction of Nuclear Reactor Operations, © 1988, Sec 7.3
Differential position is at the midpoint (18.25)
$\Delta\rho = 0.1\%\Delta k/k$
$\Delta x = 18.4 - 18.1 = 0.3$ inche
Differential rod worth ($\Delta\rho$/in) = $(\Delta\rho)/(\Delta x)$
= $0.1\%\Delta k/k / 0.3 = 0.33\%\Delta k/k$ at midpoint (18.25 inches)

A.19

Answer b

Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, Sec 8.1

A.20

Answer: a

Reference: β^- decay ($n \rightarrow p + \beta^-$) Fe57 (N-1, Z+1)
Chart of the Nuclides

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.01
Answer: b
Reference: Standard NRC question on Safety Limits

B.02
Answer: c
Reference: 10CFR50.54(y)

B.03
Answer: b
Reference: MURR TS 1.23

B.04
Answer: b
Reference: 6CEN = R/hr @ 1 ft. -> 6 x 5 x 0.7 x 0.5 = 10.5 R/hr at 1ft.
$I0D0^2 = I*D^2$
$10.5\ R/hr*(1\ ft)^2 = 0.1\ R/hr\ *D^2$
D= sqrt(10.5/0.1) = 10.3 ft.

B.05
Answer: a
Reference: 10CFR50.59

B.06
Answer: a(1) b(1) c(4) d(3)
Reference: 10 CFR 20

B.07
Answer: d
Reference: 10 CFR 55.53

B.08
Answer: b
Reference: MURR TS 3.1.f

B.09
Answer: b
Reference: $T\ A = A_o*e^{-\lambda t}$
$0.01Ci = 5Ci*\ e^{-\lambda(t)}$ Note: $\lambda = -\ln 2/t^{1/2} = -0.1386$
Ln(0.01/5) = -0.1386 yr*(t) --> -6.21/-0.1386 →
solve for t: 44.8 months or 3.7 years

B.10
Answer: c
Reference: $10\ mR/hr\ (100\ cm)^2 = X * (30\ cm)^2$
X = 111 mR/hr at 30 cm

B.11
Answer: a(12.5) b(1625) c(155) d(75)
Reference: MURR TS 2.2.a

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.12
Answer: c
Reference: OP-RO-210, Section 5.1

B.13
Answer: c
Reference: Standing Order 19-04

B.14
Answer: c
Reference: $I = I_{oe}{-\mu x}$ and $\mu_m = \frac{\mu}{\rho}$
Solving for $\mu = \mu_m * \rho = (0.0708\ cm^2/g) * (11.35\ g/cm^3) = 0.8\ cm^{-1}$
$I = 1\ Rem/hr * \exp(-3*0.8) = 90.7 mRem/hr$

B.15
Answer: c
Reference: MURR TS 3.6

B.16
Answer: d
Reference: MURR EP 2.1

B.17
Answer: c
Reference: MURR TS 3.9

B.18
Answer: b
Reference: MURR TS 4.5.a

B.19
Answer: d
Reference: MURR EP 3.2 and 3.3

B.20
Answer: c
Reference: MURR OP-RO-211, Section 4.2

Category C: Facility and Radiation Monitoring Systems

C.01
Answer: a (Open) b(Close) c(Open) d(Open)
References: OP-RO-515

C.02
Answer: c
Reference: OP-RO-465

C.03
Answer: c
Reference: MURR Reactor Operations Training Manual, Valve Operating System (10A)

C.04
Answer: a (Filter) b (Cation) c (Anion)
Reference: MURR Operations Training Manual, Fission Product Monitor (9C)

C.05
Answer: d
Reference: MURR Operations Training Manual, Page 1-1A

C.06
Answer: c
Reference: MURR Reactor Operations Training Manual, Safety System and Rod Run-In System, 1-10D

C.07
Answer: d
Reference: MURR Reactor Operations Training Manual, Rod Control – Regulating Blade, 2-10 C

C.08
Answer: b
Reference: MURR SAR 7.6.5, Page 307

C.09
Answer: b
Reference: MURR Reactor Operations Training Manual, UPS System, 2-2C

C.10
Answer: c
Reference: SAR, Chapter 7 -Instrumentation and Control Systems

C.11
Answer: a(1300), b(3), c(50), d(3)
Reference: MURR Operations Training Manual, Area Radiation Monitor System, Page 1-9B

C.12
Answer: a
Reference: MURR Operations Training Manual, Page 4-9A

Category C: Facility and Radiation Monitoring Systems

C.13
Answer: a (3) b(3) c(3) d(115)
e(2) f(2) g(2) h(10)
Reference: MURR TS 3.2.f

C.14
Answer: c
Reference: MURR Operations Training Manual, Page 3-9B

C.15
Answer: a
Reference: MURR Operations Training Manual, Page 4-4A

C.16
Answer: a, 2 b,1 c,3 d,2
Reference: MURR Reactor Operations Training Manual, Page 1-9F

C.17
Answer: c
Reference: MURR Operations Training Manual, Page 2-8C

C.18
Answer: b
Reference: MURR Operations Training Manual, Page 1-4A

C.19
Answer: c
Reference: MURR Reactor Operations Training Manual, page 3-3B

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