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

March 29, 2023

Matthew Sanford, Interim Reactor Facility Director
University of Missouri - Columbia
Research Reactor Center
1513 Research Park Drive
Columbia, MO 65211

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-23-01, UNIVERSITY OF MISSOURI - COLUMBIA

Dear Matthew Sanford:

During the week of February 20, 2023, the U.S. Nuclear Regulatory Commission (NRC) administered operator licensing examinations at the University of Missouri – Columbia Research Reactor (MURR). 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 you and 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 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. If you have any questions regarding the examination, please contact Michele DeSouza at (301) 415-0747 or via email at Michele.DeSouza@nrc.gov.

Sincerely,

Signed by Tate, Travis
on 03/29/23

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. 50-186

Enclosures:
1. Examination Report No. 50-186/OL-23-01
2. Written Examination

cc (w/o enclosures): See next page

cc:

Ronald Astrino, Reactor Manager
Reactor and Facilities Operations
University of Missouri – Columbia
Research Reactor Center
1513 Research Park Drive
Columbia, MO 65211

Homeland Security Coordinator
Missouri Office of Homeland Security
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Planner, Dept of Health and Senior Services
Section for Environmental Public Health
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Department of Natural Resources
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Commissioner's Office
Office of Administration
P.O. Box 809
State Capitol Building, Room 125
Jefferson City, MO 65101

Planning Coordinator
Missouri Department of Natural Resources
1101 Riverside Drive
Jefferson City, MO 65101

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

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-23-01, UNIVERSITY OF MISSOURI - COLUMBIA DATED: MARCH 29, 2023

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ADAMS ACCESSION No.: ML23087A113 **NRR-079**

Office	NRR/DANU/UNPO/CE	NRR/DANU/UNPO/OLA	NRR/DANU/UNPO/BC
Name	MDeSouza	NJones	TTate
Date	3/29/2023	3/29/2023	3/29/2023

OFFICIAL RECORD COPY

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

REPORT NO.: 50-186/OL-23-01

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: University of Missouri - Columbia

EXAMINATION DATES: February 20-22, 2023

SUBMITTED BY: _____ 02/23/2023
Michele C. DeSouza, Chief Examiner Date

SUMMARY:

During the week of February 20, 2023, the NRC administered operator licensing examinations to two Reactor Operator (RO) and three Senior Reactor Operators – Upgrade candidates. All candidates passed all applicable portions of the examinations and tests.

REPORT DETAILS

1. Examiner: Michele C. DeSouza, Chief Examiner, NRC

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	2/0	NA	2/0
Operating Tests	2/0	3/0	5/0
Overall	2/0	3/0	5/0

3. Exit Meeting:
Matthew Sanford, Interim Reactor Facility Director, MURR
Ronald Astrino, MURR Reactor Manager
Dan Doenges, MURR Health Physics & Safety Manager
Mike McDermit, MURR Associate Director
Rob Hudson, MURR Assistant Reactor Manager - Training
Michele C. DeSouza, Chief Examiner, NRC

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

University of Missouri - Columbia

Operator Licensing Examination

Week of February 20, 2023

Enclosure 2

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

FACILITY: University of Missouri-Columbia

REACTOR TYPE: TANK

DATE ADMINISTERED: 02/21/2023

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 ___

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 _____ (0.25 each)

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

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 _____ (0.25 each)

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 _____ (0.25 each)

B13 a b c d ___

B14 a b c d ___

B15 a _____ b _____ c _____ d _____ (0.25 each)

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

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 _____ (0.33 each)

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 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]
Which ONE of the following will DECREASE the core excess reactivity?

a. Fuel depletion

b. Burnable poison burnup

c. Insertion of a positive reactivity worth experiment

d. Lowering moderator temperature (assume negative temperature coefficient)

QUESTION A.02 [1.0 point]
Which ONE of the following best describes the difference between reflectors and moderators?

a. Reflectors decrease thermal leakage while moderators decrease fast leakage

b. Reflectors thermalize neutrons while moderators decrease core leakage

c. Reflectors decrease core leakage while moderators thermalize neutrons

d. Reflectors shield against neutrons while moderators decrease core leakage

QUESTION A.03 [1.0 point]
Reactor power is rising on a 10 second period. Approximately how long will it take for power to quadruple?

a. 14 seconds

b. 29 seconds

c. 55 seconds

d. 72 seconds

QUESTION A.04 [1.0 point]
Which ONE of the following is defined as the balance between production of neutrons and their absorption in the core for which core leakage can be neglected?

a. Utilization Factor.

b. Reproduction Factor.

c. Infinite Multiplication Factor.

d. Effective Multiplication Factor.

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

QUESTION A.05 [1.0 point]
A fast neutron will lose the most energy in a collision with which ONE of the following atoms?

a. H^1.

b. H^2.

c. C^{12}.

d. U^{238}

QUESTION A.06 [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 the moderator coefficient of reactivity.

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

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

d. The inverse multiplication of the fuel elements presented in the core.

QUESTION A.07 [1.0 point]
What is β?

a. The fractional change in neutron population per generation

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

c. The time required for the reactor to change by power by a factor of e

d. The fraction of all delayed neutrons that reach thermal energy

QUESTION A.08 [1.0 point]
Which ONE of the following isotopes is an example of a fertile material?

a. Uranium-233

b. Uranium-235

c. Uranium-238

d. Plutonium-239

QUESTION A.09 [1.0 point]
Inelastic scattering can best be described as a process whereby:

a. A neutron is captured by the nucleus and the nucleus splits apart.

b. A neutron is captured by the nucleus and the nucleus emits one or more gamma rays.

c. A neutron enters a ground state nucleus. The neutron reappears, and the nucleus is left in its ground state.

d. A neutron enters a ground state nucleus, imparts kinetic energy to the nucleus, and leaves the nucleus in an excited state. The nucleus subsequently decays by gamma emission, called isomeric transition, to ground state.

QUESTION A.10 [1.0 point, 0.25 each]
Match the following Neutron Interactions in Column A with the appropriate definition in Column B (each used only once).

Column A	Column B
a. Scattering	1. Neutron enters nucleus, forms a compound nucleus, then decays by gamma emission
b. Radiative capture	2. Particle enters nucleus, forms a compound nucleus and is excited enough to eject a new particle with incident neutron remaining in nucleus
c. Particle ejection	3. Nucleus absorbs neutron and splits into two similarly sized parts
d. Fission	4. Nucleus is struck by a neutron and emits a single neutron

QUESTION A.11 [1.0 point]
A subcritical reactor, k_{eff} is increased from 0.917 to 0.966. Which ONE of the following is the amount of reactivity that was added to the core?

a. 3.64%Δk/k

b. 4.35%Δk/k

c. 5.53%Δk/k

d. 6.53%Δk/k

QUESTION A.12 [1.0 point]
The effective multiplication factor (K_{eff}) can be determined by dividing the number of neutrons produced from fission in the fourth generation by the number of neutrons produced from fission in the _____ generation.

a. first

b. second

c. third

d. fifth

QUESTION A.13 [1.0 point]
The reactor is on a constant period. Which ONE of the following changes in reactor power would take the SHORTEST time?

a. 5% — from 1% to 6%

b. 15% — from 20% to 35%

c. 20% — from 40% to 60%

d. 25% — from 75% to 100%

QUESTION A.14 [1.0 point]
A reactor is critical at 18.2 inches on a controlling blade. The controlling blade is inserted to a position of 17.9 inches. The reactivity removal during the insertion is 0.1%Δk/k. What is the differential rod worth?

a. 0.1%Δk/k /inch at 18.20 inches

b. 0.33%Δk/k /inch at 18.05 inches

c. 0.33%Δk/k /inch at 17.9 inches

d. 0.1%Δk/k /inch at 18.05 inches

QUESTION A.15 [1.0 point]
Which term is described by the following?
"The time from birth of a neutron to absorption and is the sum of slowing down time and diffusion time."

a. Reactor period

b. Neutron lifetime

c. Multiplication time

d. Delayed generation Time

QUESTION A.16 [1.0 point]
A reactor contains a neutron source of 1200 neutrons/second. If the stable total neutron production rate is 4800 neutrons/second, what is the value of k_{eff}?

a. 0.60

b. 0.75

c. 0.80

d. 0.95

QUESTION A.17 [1.0 point]
Which ONE of the following parameters is MOST significant in determining the differential rod worth of a control rod?

a. Flux shape

b. Rod speed

c. Reactor power

d. Fuel temperature

QUESTION A.18 [1.0 point]
Which ONE of the following isotopes has the largest microscopic absorption cross-section for thermal neutrons?

a. Xenon-135

b. Boron-10

c. Samarium-149

d. Uranium-235

QUESTION A.19 [1.0 point]
If 0.156% Δk/k of positive reactivity is suddenly inserted into a critical reactor core, what will be the steady state reactor period?

a. 37 seconds

b. 52 seconds

c. 31 seconds

d. 80 seconds

QUESTION A.20 [1.0 point]
What is the typical value of prompt neutron generation time?

a. 15 seconds

b. 1 second

c. 0.1 second

d. 1 E-4 seconds

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.01 [1.0 point, 0.25 each]
Match the Federal Annual Dose Limit in Column B to the type of exposure in Column B. Answers can be used once, more than once or not at all.

Column A	Column B
a. TEDE to a member of the public	1. 0.1 Rem
b. Lens of the Eye	2. 5.0 Rem
c. Occupational Total Effective Dose Equivalent (TEDE)	3. 15.0 Rem
d. Extremities	4. 50.0 Rem

QUESTION B.02 [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. 10.25 feet

c. 12.75 feet

d. 15.50 feet

QUESTION B.03 [1.0 point]
Per MURR Emergency Plan, which ONE of the following is an ALERT event?

a. Bomb threat directed to the reactor facility

b. Tornado impacting the reactor facility

c. Radioactive spill involving personnel contamination

d. Failure of an experiment that results in a significant release of radioactive materials

QUESTION B.04 [1.0 point]
Which ONE of the following is the radiation dose limit for the public in an unrestricted area?

a. No limit

b. 2 rem in a year

c. 2 rem in any one hour

d. 2 mrem in any one hour

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.05 [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 SRO

d. Licensed RO

QUESTION B.06 [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 operational 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 actins 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 the protective action to preclude reaching the LSSS.

QUESTION B.07 [1.0 point]
In accordance with MURR emergency plan, which ONE of the following is NOT a '*person authorized to assume the Emergency Director responsibilities"*?

a. MURR RO with most experience

b. Facility Director

c. Chief Operating Officer

d. Reactor Manager

Category B: Normal/Emergency Operating Procedures and Radiological Controls

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 Δk/k

b. 0.098 Δk/k

c. 0.060 %Δk/k

d. 0.980 %Δk/k

QUESTION B.9 [1.0 point]
How long will it take a 300 Curie source, with a half-life of 5.26 years, to decay to 2 Curie?

a. 18.5 years

b. 26.2 years

c. 31.3 years

d. 38.1 years

QUESTION B.10 [1.0 point]
Which ONE of the following is NOT considered an abnormal occurrence?

a. During reactor operation, the operator noted the pool water level indicates 29 feet.

b. During reactor operation, the operator could not withdraw the regulating rod from 6 inch position.

c. During reactor operation, a student inserted an experiment that causes a short period scram.

d. During reactor training, a student lets the power drift up to the 120% of full power and a rod run-in occurs.

QUESTION B.11 [1.0 point]
What is the MINIMUM number of hours a Research and Test Reactor licensed operator is required to perform the functions of a licensed operator to maintain an active operator's license?

a. 4 hours per month

b. 6 hours per month

c. 4 hours per quarter

d. 6 hours per quarter

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.12 [1.0 point, 0.25 each]
Identify each of the following surveillances as a channel check (CHECK), a channel test (TEST), or a channel calibration (CAL). Write the correct answer on your answer sheet next to the space given for each example listed below.

a. During performance of the daily checklist, you compare the readings of radiation area monitor one and radiation monitor two

b. During performance of the daily checklist, you press the scram button to verify a scram on the safety system channel

c. Adjustment of the wide range monitor channel in accordance with recent data collected during a reactor power calibration

d. You expose a 2 mCi check source to the continuous air monitor detector to verify that its output is operable

QUESTION B.13 [1.0 point]
Which ONE of the following reactor emergencies would require an immediate action of inserting a manual rod run-in to reduce power to an acceptable level?

a. Failure of experimental apparatus

b. Nuclear instrumentation failure

c. High radiation levels

d. Single phasing or low line voltage

QUESTION B.14 [1.0 point]
A radiation field is 421 mR/hr at 6 feet. What is the dose rate at 2 feet away from the source?

a. 6499 mR/hr

b. 3789 mR/hr

c. 2660 mR/hr

d. 1320 mR/hr

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.15 [1.0 point, 0.25 each]
Match the appropriate 10CFR part in Column A with the requirements in Column B.

Column A	Column B
a. 19	1. Medical examination by a physician every two years
b. 20	2. Individual radiation exposure data
c. 50	3. Postings of notices to workers
d. 55	4. Technical information including the proposed maximum power level

QUESTION B.16 [1.0 point]
What is the emergency term associated with the definition, '*area where emergency planning is performed and bounded by a 150-meter radius from the MURR exhaust stack and lies within the site boundary*'?

a. Operations Boundary

b. Emergency Planning Zone

c. Emergency Control Center

d. Emergency Site Zone

QUESTION B.17 [1.0 point]
A reactor operator (RO) works in a dose rate area of 100 mrem/hour (high radiation area) for 8 hours a day. Which ONE of the following is the MAXIMUM number of days the RO can perform their duties WITHOUT exceeding their 10CFR20 limits?

a. 4 days

b. 5 days

c. 6 days

d. 7 days

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.18 [1.0 point]
Which ONE of the following experimental facilities/research projects conducts experiments that are classified as Neutron Beam Experiments?

a. Graphite Reflector Region

b. Pneumatic Tube System

c. Center Test Hole

d. Thermal Column

QUESTION B. 19 [1.0 point]
In accordance with MURR Emergency Plan, which ONE of the following may be a Notification of Unusual Events (NOUE)?

a. Individual Injury

b. Bomb Threat to the reactor facility

c. Experiment failure releasing significant radioactive materials

d. Fuel element failure releasing significant radioactive materials to containment

QUESTION B.20 [1.0 point]
Which ONE of the following Nuclear Range Monitors is required for startup only?

a. Intermediate

b. Power

c. Source

d. Wide

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

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

QUESTION C.01 [1.0 point]
Which ONE of the following best describes the flow path of the pool coolant demineralizer loop?

a. DI tank→Demin Pump→Pool Inlet Filter→Reactor Pool→Pool Outlet Filter

b. Pool Inlet Filter→DI Tank→Pool Outlet Filters→Pool Demin Pump→Reactor Pool

c. Reactor Pool→Pool Outlet Filters→Pool Demin Pump→Pool Inlet Filter→DI Tank

d. Reactor Pool→Pool Demin Pump→Pool Inlet Filter→DI Tank→Pool Outlet Filters

QUESTION C.02 [1.0 point]
Which ONE of the following best describes the signal path for the Power Range Monitor #5 instrument loop?

a. Fission Chamber #2→ Isolator→Pre-Amplifier→Annunciator

b. Fission Chamber #2→Pre-Amplifier→Local Level Display→Auto Control Interlock

c. Fission Chamber #2→Pre-Amplifier→Isolator→Remote Chart Recorder

d. Fission Chamber #2→Isolator→Power Down Scale→Annunciator

QUESTION C.03 [1.0 point]
Which ONE of the following is NOT a primary coolant system indication located on the control room instrument panel?

a. HX503A Out Temperature

b. Reactor Core Inlet Temperature

c. Off/On indication for P508A and P508B

d. Off/On indication for P501A and P501B

QUESTION C.04 [1.0 point]
Which ONE of the following is an indication of a decrease in pressurizer level in conjunction with an increase in pool water?

a. Failure of isolation valves V546A and V546B

b. Primary coolant system leak within the reactor pool

c. Overpressurization of the primary coolant system

d. Overspeed of the primary coolant charging pump

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

QUESTION C.05 [1.0 point]
Which ONE of the following is directly fed from the Uncompensated Ion Chamber signal?

a. Power Range 6

b. Source Range 1

c. Wide Range Monitor

d. Intermediate Range 2

QUESTION C.06 [1.0 point]
Which ONE of the following is the primary air effluent from MURR?

a. Argon-41

b. Iodine-131

c. Xenon-135

d. Radon-222

QUESTION C.07 [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, LC 936 signals water addition valve V527B to open and start coolant charging pump 533, adding water to the pressurizer.

b. At approximately 11 inches (27.94 cm) below center line LC 937 initiates a “pressurizer water lo 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.

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

QUESTION C.08 [1.0 point]
Which ONE of the following receives signal input from the Compensated Ion Chamber ?

a. Power Range Monitor (PRM 4)

b. Source Range Monitor (SRM 1)

c. Wide Range Monitor (WRM)

d. Intermediate Range Monitor (IRM 2)

QUESTION C.09 [1.0 point, 0.33 each]
Following a loss of power, the emergency power generator will assume all emergency loads within (a) _____ and continue to run for an additional (b) _____ once the normal source has been restored and remained stable for (c) _____.
Fill out the blanks in Column A with the timeframes in Column B. Answers may be used once, more than once or not all.

Column A	Column B
a.	1. 5 minutes
b.	2. 10 minutes
c.	3. 7 seconds

QUESTION C.10 [1.0 point]
Which ONE of the following radiation monitor channels contains a charcoal cartridge?

a. Gas channel

b. Iodine channel

c. Particulate channel

d. Air plenum #1 channel

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

QUESTION C.11 [1.0 point, 0.25 each]
Match the Area Radiation Monitors in Column A with its current set point in Column B. Answers may be used once, more than once or not at all.

Column A	Column B
a. Bridge	1. 3 mR/hr
b. Fuel Vault	2. 4 mR/hr
c. Air Plenum #1	3. 6 mR/hr
d. North Beamport Wall	4. 50 mR/hr

QUESTION C.12 [1.0 point]
Which ONE of the following temperature detectors will provide a reactor scram in the event of high reactor coolant temperature?

a. PT 844B

b. TE 980A/B

c. FT 912H

d. TE 901A

QUESTION C.13 [1.0 point]
Which ONE of the following set of valves actuates to isolate the in-pool portions of the primary coolant system from the remainder of the system?

a. V507A and V507B

b. V527A and V527B

c. V543A and V543B

d. V546A and V546B

QUESTION C.14 [1.0 point]
Which ONE of the following provide the low count rate signal?

a. Wide Range Monitor

b. Power Range Monitor 6

c. Source Range Monitor 1

d. Intermediate Range Monitor

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

QUESTION C.15 [1.0 point]
Up to how many hours may the stack radiation monitor may be placed out of service to perform calibration and maintenance.

a. 2

b. 4

c. 12

d. 24

QUESTION C.16 [1.0 point]
Which ONE of the following Area Radiation Monitoring System (ARMs) channels does NOT cause a building isolation?

a. Air Plenum 2

b. Bridge ALARA

c. Reactor Bridge

d. Room 114

QUESTION C.17 [1.0 point]
Which ONE of the following airborne concentrations is NOT measured in the Lab Impex stack monitor?

a. Iodine

b. Nitrogen-16

c. Noble gases

d. Radioactive Particulates

QUESTION C.18 [1.0 point]
Which ONE of the following Motor Control Centers (MCC) supplies 480V power to the reactor load equipment?

a. MCC-2

b. MCC-3

c. MCC-4

d. MCC-5

QUESTION C.19 [1.0 point]
In the event of a low primary coolant pressure condition, which ONE of the following actions occurs?

a. Flow path is provided from the anti-siphon tank to the primary coolant system

b. Nitrogen gas is vented to the Room 114 exhaust line

c. Coolant flow is redirected to bypass the pool coolant heat exchanger

d. Water is drained from the pressurizer to the drain collection tank

QUESTION C.20 [1.0 point]
For containment integrity to exist, the reactor containment building must be at a negative pressure of at least _____ of water with respect to the surrounding areas.

a. 0.25 inches

b. 1 inch

c. 1.5 feet

d. 3 feet

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

A.01
Answer: a
Reference: NRC standard question; decreasing core reactivity worth will decrease the core excess

A.02
Answer: c
Reference: Burn*, Introduction to Nuclear Reactor Operations*, Section 5.4

A.03
Answer: a
Reference: $P = P_0 e^{t/T}$ —> ln(4) = time ÷ 10 seconds –> time = ln (4) x 10 sec. 1.386 x 10 ≈ 13.8 seconds

A.04
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory,* NP-03, page 2

A.05
Answer: a
Reference: NRC standard question

A.06
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory,* NP-01, page 24

A.07
Answer: b
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 4

A.08
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 3.2(a), Page 3-2

A.09
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 2.4.5.2, page 2-28

A.10
Answer: a. 4; b. 1; c. 2; d. 3
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 1, Module 1, Page 43-46

A.11
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 3.3.4, page 3-20&21
$\Delta\rho=(k_{eff2}-k_{eff1})/(k_{eff1}*k_{eff2})$ = (0.966-0.917)/(0.966*0.917) = 0.0553Δk/k=5.53%Δk/k

A.12
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 3.3.1, page 3-16

A.13
Answer: d
Reference: $P = P0\ e^{t/\tau}$ $Ln(P/P0) = t/\tau$ Since you are looking for which would take the SHORTEST time, the ratio P/P0 must be the smallest value.

A.14
Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 7.3
Differential position is at the midpoint (18.05)
$\Delta\rho = 0.1\%\Delta k/k$
$\Delta x = 18.2 – 17.9 = 0.3$ inches
Differential rod worth ($\Delta\rho$/in) = $(\Delta\rho)/(\Delta x)$
$= 0.1\%\Delta k/k / 0.3 = 0.33\%\Delta k/k$ at midpoint (18.05 inches)

A.15
Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 5.1

A.16
Answer: b
Reference: Source CR = (S) / (1 – k_{eff}); (1200) / (1 - k_{eff}) = 4800; $k_{eff} = 0.75$
DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 4, page 4

A.17
Answer: a
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 7.2

A.18
Answer: a
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 8.1

A.19
Answer: a
Reference:

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

$\rho = 0.00156$; T = (0.0074 – 0.00156) / (0.1 * 0.00156) T = 37.4 seconds

A.20
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 5.4

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.1
Answer: a. 1; b. 3; c. 2; d. 4
Reference: 10CFR20

B.2
Answer: c
Reference: I=6CEn=R/hr@ft.→5Ci x 5Mev x 65% = 16.25 R/hr@ $(1ft)^2$ = 16.25 R/hr = 0.1 R/hr@ D^2 = √162.5 R/hr = 12.75 ft.

B.3
Answer: d
Reference: MURR Emergency Plan, Section 3.2 and 3.3

B.4
Answer: d
Reference: 10CFR20.1301(a)(2)

B.5
Answer: c
Reference: 10CFR50.54(y)

B.6
Answer: b
Reference: NRC standard question

B.7
Answer: a
Reference: MURR Emergency Plan, Section 2.1

B.8
Answer: b
Reference: MURR Technical Specification 3.1.f.

B.9
Answer: c
Reference: $T A = A_o * e^{-\lambda t}$
$2Ci = 300Ci * e^{-\lambda(t)}$ Note: $\lambda = -\ln 2/t^{1/2} = -0.1315$
$\ln(2/100) = -\ln 2/5.27\ yr * (t)$ --> -5.011/-0.1315 →
solve for t: 38.1 years

B.10
Answer: a
Reference: MURR Technical Specification 1.1 and 3.2

B.11
Answer: c
Reference: 10CFR55.53(e)

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.12
Answer: a. check; b. test; c. cal; d. test
Reference: MURR TS definitions 1.4, 1.5 and 1.6

B.13
Answer: a
Reference: MURR Emergency Procedures, REP 12

B.14
Answer: b
Reference: $I_1D_1^2=I_2D_2^2 \rightarrow$ 421mR/hr@$(6ft)^2=I_2$@$(2ft)^2 \rightarrow$3789mR/hr

B.15
Answer: a. 3; b. 2; c. 4; d. 1
Reference: 10CFR19.11, 10CFR20.1501(2)(i), 10CFR50.34(1)(ii)(A), 10CFR55.21

B.16
Answer: b
Reference: MURR Emergency Plan, Section 9.8

B.17
Answer: c
Reference: 10CFR20.1201(a)(1); [5000mR * 1hr * day / 100mR * 8hours] = 6.25 days

B.18
Answer: d
Reference: MURR AP-RO-135

B.19
Answer: b
Reference: MURR Emergency Plan, Section 3.2

B.20
Answer: c
Reference: MURR REP-RO-100, Rev 20, REP-5, page 9

Category C: Facility and Radiation Monitoring Systems

C.01
Answer: d
Reference: MURR Operations Training Manual, page 5.5-2

C.02
Answer: c
Reference: MURR Operations Training Manual, page 9.1-8

C.03
Answer: c
Reference: MURR Operations Training Manual, page 4.1-2, 4.1-3, 5.1-1, 6.1-3

C.04
Answer: b
Reference: MURR SAR 3.1.5, page 3-15

C.05
Answer: a
Reference: MURR Operations Training Manual, page 9.1-6

C.06
Answer: a
Reference: MURR Technical Specification 3.7, page 31

C.07
Answer: b
Reference: MURR SAR 7.6.5

C.08
Answer: c
Reference: MURR Operations Training Manual, page 9.1-3

C.09
Answer: a. 3; b. 1; c. 2
Reference: MURR Operations Training Manual, page 2.2-2

C.10
Answer: b
Reference: MURR Operations Training Manual, page 9.3-2

C.11
Answer: a(4), b(2), c(1), d(2)
Reference: MURR Operations Training Manual, page 1-9B

C.12
Answer: b
Reference: MURR Operations Training Manual, page 4.1-5

C.13
Answer: a
Reference: MURR Operations Training Manual, page 4.1-3

Category C: Facility and Radiation Monitoring Systems

C.14
Answer: c
Reference: MURR Operations Training Manual, page 9.1-4

C.15
Answer: a
Reference: MURR Technical Specification 3.7, page A-29

C.16
Answer: d
Reference: MURR Operations Training Manual, page 9.2-3

C.17
Answer: b
Reference: MURR Operations Training Manual, page 9.4-1

C.18
Answer: d
Reference: MURR Operations Training Manual, page 2.1-3

C.19
Answer: a
Reference: MURR Operations Training Manual, page 4.3-2

C.20
Answer: a
Reference: MURR Technical Specification Section 3.4, page A-24