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

January 16, 2019

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

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-19-01, UNIVERSITY OF MISSOURI - COLUMBIA

Dear Dr. Robertson:

During the week of December 17, 2018, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at the 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 Ms. Michele DeSouza at (301) 415-0747 or via internet e-mail Michele.DeSouza@nrc.gov.

Sincerely,

/RA/

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

Docket No. 50-186

Enclosures:
1. Examination Report No. 50-186/OL-19-01
2. Written examination

cc: w/o enclosures: See next page

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-19-01, UNIVERSITY OF MISSOURI – COLUMBIA DATED JANUARY 16, 2019

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ADAMS Accession No. ML19016A316 **NRR-079**

OFFICE	NRR/DLP/PROB/CE	NRR/DLP/IOLB/OLA	NRR/DLP/PROB/BC
NAME	MDeSouza	QLChen	AMendiola
DATE	01/08/2019	01/16/2019	01/16/2019

OFFICIAL RECORD COPY

cc:

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

REPORT NO.: 50-186/OL-19-01

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: Tank

EXAMINATION DATES: December 17-18, 2018

SUBMITTED BY: Michele DeSouza 01/08/2019
Michele DeSouza, Chief Examiner Date

SUMMARY:
During the week of December 17, 2018, the NRC administered an operator licensing examination to one Senior Reactor Operator Upgrade (SROU) and one Reactor Operator (RO) candidates. The SROU and RO candidates passed all applicable portions of the examination(s).

REPORT DETAILS

1. Examiner: Michele DeSouza, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:
Michele C. DeSouza, Chief Examiner, NRC
Ashley Ferguson, Reactor Inspector, NRC
Les Foyto, Associate Director, Reactor and Facilities Operations
Bruce Meffert, Facility Director, MURR Reactor
Sean Schaefer, Assistant Reactor Manager, MURR
Rob Hudson, Training Coordinator, MURR Reactor Operations
Ron Dobey, Health Physics Manager, MURR HP and Safety

Per discussion with the facility, prior to administration of the written examination, adjustments were accepted. Upon completion of the examination, the NRC Examiner met with facility staff representatives to discuss the results. NRC Inspector Follow-Up Items (IFI) were identified for Health Physics documentation issues and Visitor Electronic Personnel Device (EPD) issues. At the conclusion of the meeting, the NRC examiner thanked the facility for their support in the administration of the examination.

ENCLOSURE 1

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

FACILITY: University of Missouri - Columbia

REACTOR TYPE: Tank

DATE ADMINISTERED: 12/18/2018

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

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 **********)

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

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

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

4. Use black ink or dark pencil only to facilitate legible reproductions.

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

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

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

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

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

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

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

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

EQUATION SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 kg = 2.21 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]
The following shows part of a decay chain for the radioactive element Pa-234:
$_{91}Pa^{234} \rightarrow {}_{92}U^{234}$
This decay chain is an example of _____ decay.

a. Alpha

b. Beta

c. Gamma

d. Neutron

QUESTION A.02 [1.0 point]
Which ONE of the following is the MAJOR source of energy released during fission?

a. Fission fragments

b. Fission product decay

c. Prompt gamma rays

d. Fission neutrons

QUESTION A.03 [1.0 point]
The reactor is critical. What would be the corresponding k_{eff} when removing 0.06 $\Delta k/k$ from its criticality?

a. 0.9244

b. 0.9434

c. 0.9753

d. 1.0526

QUESTION A.04 [1.0 point]
What is the condition of the reactor when $k = \frac{1}{1-\beta_{\text{eff}}}$?

a. Subcritical

b. Critical

c. Super critical

d. Prompt critical

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

QUESTION A.05 [1.0 point]
Which ONE of the following conditions would INCREASE the shutdown margin of a reactor?

a. Inserting an experiment adding positive reactivity

b. Depletion of Uranium fuel

c. Depletion of a burnable poison

d. Lowering moderator temperature if the moderator temperature coefficient is negative

QUESTION A.06 [1.0 point]
The reactor is on a CONSTANT positive period. Which ONE of the following power changes will take the SHORTEST time to complete?

a. From 100 kW to 150 kW

b. From 10 kW to 20 kW

c. From 10 W to 30 W

d. From 1 W to 5 W

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. Plutonium-239

b. Uranium-238

c. Uranium-235

d. Uranium-233

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

QUESTION A.09 [1.0 point]
What does the 1/M represent during a Subcritical Multiplication data plot?

a. Inverse of the moderator coefficient of reactivity

b. Inverse multiplication of the count rate between generations

c. Inverse of fuel elements presented in the core

d. Inverse migration length of neutrons of varying energies

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. Fission	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. Scattering	3. Nucleus absorbs neutron and splits into two similarly sized parts
d. Particle ejection	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]
Which ONE of the following isotopes will readily absorb neutrons when it interacts with neutrons?

a. Hydrogen-1

b. Oxygen-16

c. Boron-10

d. Iodine-131

QUESTION A.13 [1.0 point]
Which ONE of the following best describes the effects of moderator temperature DECREASE on neutron multiplication? L_f - Fast non-leakage probability L_t – Thermal non-leakage probability

a. $\downarrow L_f$, $\downarrow L_t$, $\downarrow$rod worth

b. $\uparrow L_f$, $\downarrow L_t$, $\uparrow$rod worth

c. $\downarrow L_f$, $\downarrow L_t$, $\uparrow$rod worth

d. $\uparrow L_f$, $\uparrow L_t$, $\downarrow$rod worth

QUESTION A.14 [1.0 point]
Which ONE of the following is a correct statement of how delayed neutrons enhance the ability to control reactor power?

a. Prompt neutrons can cause fissions in both U-235 and U-238 and delayed neutrons can only cause fissions in U-235

b. Delayed neutrons are born at higher energy levels than prompt neutrons

c. The average number of delayed neutrons produced per fission is higher than the average number of prompt neutrons

d. Delayed neutrons increase the average neutron lifetime that allows a reactor to be controlled

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

QUESTION A.15 [1.0 point]
Which ONE of the following statements correctly describes thermal neutrons?

a. A neutron that experiences an increase in energy levels after collisions with larger atoms of the moderator

b. A neutron that experiences a linear decrease in energy as the temperature of the moderator increases

c. A neutron that experiences no net change in energy after several collisions with atoms of the moderator

d. A neutron at resonant epithermal energy levels that causes fissions to occur in U-238

QUESTION A.16 [1.0 point]
How high will the reactor power get given the following: the lowest of the reactor high power scram set points is 120%, the scram delay time is 0.5 seconds, the reactor is operating at 100% power prior to the scram, and the reactor period is positive 20 second?

a. 113%

b. 119%

c. 123%

d. 125%

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. Fuel temperature

b. Flux shape

c. Reactor power

d. Rod speed

QUESTION A.18 [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.19 [1.0 point]
Given a source strength of 250 neutrons per second (N/sec) and a multiplication factor of 0.5, which ONE of the following is the expected stable neutron count rate?

a. 150 N/sec

b. 250 N/sec

c. 400 N/sec

d. 500 N/sec

QUESTION A.20 [1.0 point]
Which ONE of the following conditions will DECREASE the core excess reactivity?

a. Fuel depletion

b. Burnable poison burnout

c. Insertion of a positive reactivity worth experiment

d. Lowering moderator temperature (assume negative temperature coefficient)

(***** 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. Extremities	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. TEDE to a member of the public	4. 50.0 Rem

QUESTION B.02 [1.0 point]
A two curie source emits a 2MeV gamma 100% 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. Not required

b. 10.5 feet

c. 12.5 feet

d. 15.5 feet

QUESTION B.03 [1.0 point]
Which ONE of the following surveillance checks shall be tested at least quarterly?

a. Reactor safety system channel

b. Reactor control interlocks

c. Total reactivity worth of each Shim Blade

d. Reactivity insertion rate of the Regulating Blade

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]
Which ONE of the following Emergency Action Levels requires notification of the Nuclear Regulatory Commission (NRC) and the State Emergency Management Agency (SEMA) during an emergency event?

a. Assessment

b. Corrective

c. Specific Protective

d. Subsequent

QUESTION B.06 [1.0 point]
Which ONE of the following is the 10CFR20 definition for “Annual Limit on Intake”?

a. The concentration of a radionuclide in air which, if inhaled by an adult worker for a year, results in a Total Effective Dose Equivalent of 100 mrem

b. The effluent concentration of a radionuclide in air which, if inhaled continuously over a year, would result in a Total Effective Dose Equivalent of 50 mrem for noble gases

c. The Committed Effective Dose Equivalent of 5 rem whole body or 50 rems to any individual organ, for the amount of radioactive material inhaled or ingested in a year by an adult worker

d. The projected Committed Effective Dose Equivalent commitment to individuals that warrants protective action following a release of radioactive material

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

a. Facility Director

b. Reactor Manager

c. Chief Operating Officer

d. RO with most experience at MURR

Category B – Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.08 [1.0 point]
Per MURR Technical Specifications, what is the MINIMUM shutdown margin with the most reactive shim blade and regulating rod fully withdrawn?

a. 0.01 Δk/k

b. 0.02 Δk/k

c. 0.1% Δk/k

d. 0.2% Δk/k

QUESTION B.9 [1.0 point]
How long will it take a 100 Curie source, with a half-life of 5.26 years, to decay to 2 Curie?

a. 15 years

b. 20 years

c. 30 years

d. 35 years

QUESTION B.10 [1.0 point]
The reactor shall not be operated in Modes I or II unless the following components or systems are operable EXCEPT_____.

a. Continuous primary coolant system fuel element failure monitor

b. In-Pool convective cooling system

c. Primary coolant isolation valves V507A and V507B

d. Anti-siphon system

QUESTION B.11 [1.0 point]
How many hours (MINIMUM) are Test and Research Reactors licensed operators 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 is the location personnel should evacuate and proceed to in the emergency event an ALERT has been declared?

a. Marx Building

b. Dalton Parking Lot

c. Research Park Development

d. USDA Biological Control of Insects Research Laboratory

QUESTION B.14 [1.0 point]
A radiation field is 330 mR/hr at 4 feet. What is your dose rate at 2 feet away from the source?

a. 499 mR/hr

b. 580 mR/hr

c. 660 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. 10CFR19	1. Technical information including the proposed maximum power level
b. 10CFR20	2. Individual radiation exposure data
c. 10CFR50	3. Postings of notices to workers
d. 10CFR55	4. Medical examination by a physician every two years

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

a. Emergency Director

b. Health Physics Manager

c. Emergency Coordinator

d. Emergency Director with concurrence of Health Physics Manager

QUESTION B.17 [1.0 point]
Calculate an individual's total whole body dose given the individual received the following doses: 20 mrad of alpha, 10 mrad of gamma, and 5 mrad of neutron (unknown energy)

a. 35 mrem

b. 415 mrem

c. 435 mrem

d. 460 mrem

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

Category B – Normal/Emergency Operating Procedures and Radiological Controls

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

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. Wide

b. Power

c. Source

d. Intermediate

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

Category C – Facility and Radiation Monitoring Systems

QUESTION C.01 [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.02 [1.0 point]
Which ONE of the following conditions does NOT warrant a reactor isolation?

a. Prolonged fire in containment

b. Radiation level reading ten times above normal background on the reactor bridge

c. Concentration of airborne reactivity in containment exceeds 40 AEC when averaged over 24 hours

d. Determination by the Lead Senior Reactor Operator that an abnormal condition requires Reactor Isolation

QUESTION C.03 [1.0 point]
In the event of a low primary coolant pressure condition, which ONE of the following actions occurs?

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

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

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

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

QUESTION C.04 [1.0 point]
Domestic water enters the facility in which ONE of the following locations?

a. Laboratory basement

b. Missouri University Research Reactor (MURR) industrial building

c. Area outside mechanical equipment room 114

d. Southwest corner of the cooling tower basement

Category C – Facility and Radiation Monitoring Systems

QUESTION C.05 [1.0 point]
The stack radiation monitor may be placed out of service for up to _____ hours for calibration and maintenance.

a. 2

b. 4

c. 12

d. 24

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. Radon-222

d. Xenon-135

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 – Facility and Radiation Monitoring Systems

QUESTION C.08 [1.0 point]
How many charcoal filters are required to be operable when processing Iodine-131 in the Iodine-131 processing hot cell?

a. 1

b. 2

c. 3

d. 4

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. 1 second
b.	2. 7 seconds
c.	3. 5 minutes
	4. 7 minutes
	5. 10 minutes

QUESTION C.10 [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

Category C – Facility and Radiation Monitoring Systems

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
	5. 12,000 cpm

QUESTION C.12 [1.0 point]
In accordance with MURR Technical Specification, which ONE of the following is approximately the MINIMUM amount of water required to provide shielding from direct core radiation with the reactor at full power?

a. 26 feet

b. 27 feet

c. 28 feet

d. 29 feet

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

Category C – Facility and Radiation Monitoring Systems

QUESTION C.14 [1.0 point]
A decrease in pressurizer level in conjunction with an increase in pool water is an indication of which ONE of the following?

a. Failure of isolation valves V546A and V546B

b. Overspeed of the primary coolant charging pump

c. Overpressurization of the primary coolant system

d. Primary coolant system leak within the reactor pool

QUESTION C.15 [1.0 point]
The Uncompensated Ion Chamber signal is fed directly to which ONE of the following?

a. Source Range 1

b. Power Range 6

c. Intermediate Range 2

d. Wide Range Monitor

QUESTION C.16 [1.0 point]
Which ONE of the following reactor regions contains flow nozzles that function to restrict flow so that changes in experiments do NOT significantly alter the pool cooling flow through the rod gaps?

a. Active Fuel Region

b. Beryllium Reflector

c. Center Test Hole

d. Graphite Reflector Region

QUESTION C.17 [1.0 point]
When the reactor is operating above 100kW, sufficient cooling of the control blades is provided by which ONE of the following?

a. Forced convection flow

b. In-pool heat exchanger

c. Natural circulation of pool water

d. DCW supplied from the After Cooler

Category C – Facility and Radiation Monitoring Systems

QUESTION C.18 [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. Reactor Pool→Pool Demin Pump→Pool Inlet Filter→DI Tank→Pool Outlet Filters

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

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

QUESTION C.19 [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 P501A and P501B

d. Off/On indication for P508A and P508B

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 A – Reactor Theory, Thermodynamics, & Facility Operating Characteristics

A.01
Answer: b
Reference: Chart of the Nuclides

A.02
Answer: a
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Table 3.2, Page 3-5b
$\rho=(k-1)/k-0.05\rightarrow 1=k-(-0.05k)=k(1+0.05)\rightarrow k=1/1.05=0.9524$

A.03
Answer: b
Reference: $\rho=(k-1)/k-0.06\rightarrow 1=k-(-0.06k)=k(1+0.06)\rightarrow k=1/1.06=0.943$

A.04
Answer: d
Reference: LaMarsh, *Introduction to Nuclear Engineering*, Page 340-341
$(1-\beta)k=1$ manipulated reads $k=1/(1-\beta)$

A.05
Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 6.2.3

A.06
Answer: a
Reference: $P=P_o e^{t/T}\rightarrow t=T*\ln(P/P_o)$ assume constant period=1
The smallest ratio of P/P_o is the shortest time to complete

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

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

A.09
Answer: b
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 4, Page 1-9

A.10
Answer: a(3), b(1), c(4), d(2)
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
$\Delta\rho=(k_{eff2}-k_{eff1})/(k_{eff1}*k_{eff2}) = (0.966-0.917)/(0.966*0.917) = 0.0553\Delta k/k=5.53\%\Delta k/k$

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

A.12
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 2.5.1, Pages 2-38-43

A.13
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 3.3.2

A.14
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 3.3.2, Page 3-7

A.15
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 1, Module 2

A.16
Answer: c
Reference: $P/P_o = 120\%$, T = 20 seconds, t = 0.5, $P/P_o = 120\ e^{\wedge 0.5/20} = 123\%$

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

A.18
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 5.4

A.19
Answer: d
Reference: $CR=S/(1-k) \rightarrow 250/(1-0.5) = 500$ N/sec

A.20
Answer: a
Reference: NRC standard question; decreasing core reactivity worth will decrease the core excess

Category B: Normal/Emergency Operating Procedures and Radiological Controls

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

B.2
Answer: d
Reference: I=6CEn=R/hr@ft.→2Ci x 2Mev x 100% = 24 R/hr@ $(1ft)^2$ =
24 R/hr = 0.1 R/hr@ D^2 = √240 R/hr = 15.5 ft.

B.3
Answer: a
Reference: MURR TS 4.2

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

B.5
Answer: d
Reference: MURR Emergency Plan, Section 5.1.2, 5.1.3, 5.1.4 and 5.1.5

B.6
Answer: c
Reference: 10CFR20.1003

B.7
Answer: d
Reference: MURR EP 2.1

B.8
Answer: b
Reference: MURR TS 3.1.b.

B.9
Answer: c
Reference: $T A = A_{\circ} * e^{-\lambda t}$
$2Ci = 100Ci * e^{-\lambda(t)}$ Note: $\lambda = -\ln 2/t^{1/2} = -0.1315$
Ln(2/100) = -ln2/5.27 yr*(t) --> -3.912/-0.1315 →
solve for t: 29.75 years

B.10
Answer: a
Reference: MURR TS 3.3(a)

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

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.13
Answer: b
Reference: MURR EP-RO-14 Page 2

B.14
Answer: d
Reference: $I_1D_1^2=I_2D_2^2 \rightarrow 330mR/hr@(4ft)^2=I_2@(2ft)^2 \rightarrow 1320mR/hr$

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

B.16
Answer: a
Reference: MURR Emergency Plan, Section 2.1

B.17
Answer: d
Reference: 20mrad Alpha x 20 = 400mrem, 10mrad Gamma x 1 = 10mrem, 5mrad neutron x 10 = 50mrem → 400mrem + 10mrem + 50mrem = 460mrem

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

B.19
Answer: b
Reference: MURR Emergency Procedures 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 3-2A

C.02
Answer: c
Reference: EP-RO-012, Section 1.0, Page 2

C.03
Answer: d
Reference: MURR Operations Training Manual, Page 2-4C

C.04
Answer: d
Reference: MURR Operations Training Manual, Page 1-1A

C.05
Answer: a
Reference: MURR TS 3.7, Page 35

C.06
Answer: a
Reference: MURR TS 3.7, Page 31

C.07
Answer: b
Reference: MURR SAR 7.6.5, Page 307

C.08
Answer: c
Reference: MURR TS 3.10, Page A-38

C.09
Answer: a (2), b (3), c (5)
Reference: MURR Operations Training Manual, Page 2-2B

C.10
Answer: c
Reference: MURR Operations Training Manual, Page 8-9A

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 TS 3.2.f, Basis

C.13
Answer: a
Reference: MURR SAR 5.2.5, Page 5-5

Category C: Facility and Radiation Monitoring Systems

C.14
Answer: d
Reference: MURR SAR 3.1.5, Page 3-15

C.15
Answer: b
Reference: MURR Operations Training Manual, Page 3-9A

C.16
Answer: d
Reference: MURR Operations Training Manual, Page 4-8A

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

C.18
Answer: b
Reference: MURR Operations Training Manual, Page 1-5E

C.19
Answer: d
Reference: MURR Operations Training Manual, Page 3-4A

C.20
Answer: a
Reference: MURR TS Section 3.4, Page A-24