July 12, 2017

Mr. Ralph A. Butler, Director
University of Missouri - Columbia
Research Reactor Center
1513 Research Park Drive
Columbia, MO 65211

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-17-02, UNIVERSITY OF MISSOURI – COLUMBIA

Dear Mr. Butler:

During the week of June 26, 2017, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your University of Missouri – Columbia reactor. The examination was conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. Examination questions and preliminary findings were discussed with you and those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with Title 10 of the *Code of Federal Regulations* Section 2.390, a copy of this letter and the enclosure will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Mrs. Paulette Torres at (301) 415-5656 or via e-mail Paulette.Torres@nrc.gov.

Sincerely,

/RA/

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

Docket No. 50-186

Enclosures:
1. Examination Report No. 50-186/OL-17-02
2. Facility Suggestions with NRC Resolution
3. Written Examination

cc: Bruce Meffert, Reactor Manager, MURR
cc w/o enclosure: See next page

SUBJECT: EXAMINATION REPORT NO. 50-186/OL-17-02, UNIVERSITY OF MISSOURI – COLUMBIA DATED JULY 12, 2017..

DISTRIBUTION w/ encl.

Public	PTorres	AMendiola	JEads
AAdams	GWertz		

ADAMS Accession No. ML **NRR-074**

OFFICE	NRR/DPR/PROB	NRR/DIRS/IOLB/OLA	NRR/DPR/PROB/BC
NAME	PTorres	ABaxter	AMendiola
DATE	7/05/2017	7/12/2017	7/12/2017

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cc:

Les Foyto, Associate Director
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Research Reactor Center
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Homeland Security Coordinator
Missouri Office of Homeland Security
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Jefferson City, MO 65102

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Jefferson City, MO 65102-0570

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Jefferson City, MO 65101

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

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

REPORT NO.: 50-186/OL-17-02

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: University of Missouri – Columbia Reactor

EXAMINATION DATE: June 26-27, 2017

SUBMITTED BY: /RA/ 7/5/17
Paulette Torres, Chief Examiner Date

SUMMARY:

During the week of June 26, 2017, the NRC administered a licensing examination to one Senior Reactor Operator Instant (SRO-I) applicant, and one Senior Reactor Operator Upgrade (SRO-U) applicant. The applicants passed all portions of the examination.

REPORT DETAILS

1. Examiner: Paulette Torres, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:
Paulette Torres, Chief Examiner, NRC
Robert Hudson, Training Coordinator, MURR
Bruce Meffert, Reactor Manager, MURR
Les Foyto, Associate Director, MURR

The facility licensee agreed to e-mail their comments/suggestions on the written examination that were incorporated into the examination report (see Enclosure 2).

FACILITY SUGGESTIONS ON THE WRITTEN EXAM WITH NRC RESOLUTION

QUESTION B.14 [1.0 point]
Which ONE of the following Emergency Action Levels provides notification to the NRC, the American Nuclear Insurers (ANI) and the State Emergency Management Agency (SEMA) during an emergency?

a. Assessment Actions

b. Corrective Actions

c. Specific Protective Actions

d. Subsequent Actions

Answer: d
REF: Emergency Plan, Section 5.1.5, 5.2.5, 5.3.5, pg. 13-15

Facility Suggestions &
Recommendations: Section 5.0 “Emergency Response” of the MURR Emergency Plan contains a multiple subsections titled “Emergency Action Levels” which direct an operator to utilizes Appendix B, if a specified threshold is met. None the these subsections direct the operator to perform any of the answers provided. Each of the answers provided are companion but independent subsections to the Emergency Action Levels subsection. Recommendation: Change the term “Emergency Action Levels” to “Emergency Responses” to encompass all answers provided. Reference: MURR Emergency Plan Procedures Manual, pages 12-15.

NRC Resolution: The NRC accepts the facility recommendation and understands that changing the term “Emergency Action Levels” to “Emergency Responses” will make the question correct to encompass all answers provided.

QUESTION B.15 [1.0 point]
The Emergency Organization consists of two groups: (1) the Facility Emergency Organization and (2) the Emergency Support Organizations. Which ONE of the following is part of the Emergency Support Organizations?

a. Reactor Operations

b. The UMC Radiation Safety Office

c. MURR staff in the Director's Office

d. The City of Columbia Fire Department

Answer: b
REF: Emergency Plan, Section 2.3, pg. 6 and Figure II, pg. 7

Facility Suggestions &
Recommendations: Answers 'B' and 'D' are both correct as the question is written. Both the UMC Radiation Safety Office and the City of Columbia Fire Department are members of the Emergency Support Organizations. However, the fire department is the only member not composed of University of Missouri staff. Recommendation: Change second sentence to "Which ONE of the following is part of the Emergency Support Organizations and composed of University of Missouri staff? Reference: MURR Emergency Plan Procedures Manual, page 6.

NRC Resolution: The NRC agrees with the facility suggestion and accepts answers 'B' and 'D' as both correct. The NRC also accepts the facility recommendation and understands that changing the sentence to "Which ONE of the following is part of the Emergency Support Organizations and composed of University of Missouri staff?" will make 'B' the only correct answer.

U. S. NUCLEAR REGULATORY COMMISSION

NON-POWER REACTOR LICENSE EXAMINATION

FACILITY: University Of Missouri – Columbia

REACTOR TYPE: TANK

DATE ADMINISTERED: 06/27/2017

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

A. Reactor Theory, Thermohydraulics & Facility Operating Characteristics

A N S W E R S H E E T

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

A01 a b c d ___

A02 a ___ b ___ c ___

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 ___

A11 a b c d ___

A12 a b c d ___

A13 a b c d ___

A14 a b c d ___

A15 a b c d ___

A16 a b c d ___

A17 a b c d ___

A18 a b c d ___

A19 a b c d ___

A20 a b c d ___

(***** END OF SECTION A *****)

B. Normal/Emergency Procedures and Radiological Controls

A N S W E R S H E E T

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

B01 a b c d ___

B02 a b c d ___

B03 a b c d ___

B04 a b c d ___

B05 a b c d ___

B06 a b c d ___

B07 a b c d ___

B08 a b c d ___

B09 a b c d ___

B10 a b c d ___

B11 a b c d ___

B12 a b c d ___

B13 a b c d ___

B14 a b c d ___

B15 a b c d ___

B16 a b c d ___

B17 a b c d ___

B18 a b c d ___

B19 a b c d ___

B20 a b c d ___

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

C. Facility and Radiation Monitoring Systems

A N S W E R S H E E T

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

C01 a b c d ___

C02 a b c d ___

C03 a b c d ___

C04 a b c d ___

C05 a b c d ___

C06 a ___ b ___ c ___ d ___

C07 a b c d ___

C08 a b c d ___

C09 a b c d ___

C10 a b c d ___

C11 a b c d ___

C12 a b c d ___

C13 a b c d ___

C14 a b c d ___

C15 a b c d ___

C16 a b c d ___

C17 a ___ b ___ c ___ d ___

C18 a b c d ___

C19 a b c d ___

C20 a b c d ___

(***** END OF SECTION C *****)
(********** END OF EXAMINATION **********)

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

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

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

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

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

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

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

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

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

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

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

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

EQUATION SHEET

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$T_{\frac{1}{2}} = \frac{0.693}{\lambda} \qquad \Delta\rho = \frac{K_{eff_2} - K_{eff_1}}{K_{eff_1} K_{eff_2}}$$

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

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

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

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

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

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

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

1 kg = 2.21 lbm

1 Horsepower = 2.54 x 10^3 BTU/hr

1 Mw = 3.41 x 10^6 BTU/hr

1 BTU = 778 ft-lbf

°F = 9/5 °C + 32

1 gal (H_2O) ≈ 8 lbm

°C = 5/9 (°F - 32)

c_P = 1.0 BTU/hr/lbm/°F

c_p = 1 cal/sec/gm/°C

UNIVERSITY OF MISSOURI – COLUMBIA

Operator Licensing Examination

Week of June 26, 2017

QUESTION A.01 [1.0 point]
During a Subcritical Multiplication "1/M" plot, data is required to be taken. What does the 1/M represent?

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

b. The inverse of the moderator coefficient of reactivity.

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

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

QUESTION A.02 [1.0 point, 0.33 each]
Match the best answer. If a reactor has values of k (multiplication factor) and ρ (reactivity) as follow (assume there is no neutron source present):

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

QUESTION A.03 [1.0 point]
Which ONE of the following factors is least affected by short term reactor transients?

a. Fast Non Leakage Probability (L_f)

b. Resonance Escape Probability (p)

c. Thermal Utilization Factor (f)

d. Reproduction Factor (η)

QUESTION A.04 [1.0 point]
Xenon-135 is formed directly by decay of _____.

a. Antimony-135

b. Cesium -135

c. Iodine-135

d. Tellurium-135

QUESTION A.05 [1.0 point, 0.25 each]
The following are various particles emitted in the radioactive process. Match the emission in Column A with its corresponding change in nucleus in Column B.

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

QUESTION A.06 [1.0 point]
The term Excess Reactivity is defined as:

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

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

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

d. The amount of positive reactivity that would exist if all the control blades were moved to the fully withdrawn position from the point the reactor is exactly critical.

QUESTION A.07 [1.0 point]
Which of ONE the following does NOT affect the Effective Multiplication Factor (K_{eff})?

a. The moderator-to-fuel ratio.

b. The physical dimensions of the core.

c. The strength of the installed neutron source.

d. The current time in core life.

QUESTION A.08 [1.0 point]
The reactor has been operating at 100% power for the past 20 days. Which ONE of the following is the PRIMARY SOURCE of heat generation in the core 30 seconds following a reactor scram from 100% power?

a. Fission resulting from spent fuel.

b. Fission resulting from installed neutrons sources.

c. Beta and gamma heating from fission decay products.

d. Beta and gamma heating from fission generated by installed neutron sources.

QUESTION A.09 [1.0 point]
The amount of reactivity necessary to make a reactor prompt critical is _____.

a. $\rho = \beta$

b. $(1-\beta)k < 1$

c. $\rho < \beta$

d. $\beta_{eff} = 0.00738$

QUESTION A.10 [1.0 point]
Which ONE of the following describes the difference between reflectors and moderators?

a. Reflectors decrease core leakage while moderators thermalize neutrons.

b. Reflectors thermalize neutrons while moderators decrease core leakage.

c. Reflectors shield against neutrons while moderators decrease core leakage.

d. Reflectors decrease thermal leakage while moderators decrease fast leakage.

QUESTION A.11 [1.0 point]
What is the K_{eff} for a reactor shutdown by 0.0455 $\Delta K/K$?

a. 0.957

b. 0.855

c. 0.786

d. 0.0455

QUESTION A.12 [1.0 point]
Which ONE of the following changes to the core will most strongly affect the Thermal Utilization Factor?

a. Going from High Enrichment fuel to Low Enrichment fuel.

b. Removal of moderator (Thermal expansion).

c. Buildup of fission products in the fuel.

d. Removal of a control rod.

QUESTION A.13 [1.0 point]
For U-235, the thermal fission cross-section is σ_f = 582 barns, and the capture cross-section is σ_γ = 99 barns. When a thermal neutron is absorbed by U-235, what is the relative probability that fission will occur?

a. 14.6 %

b. 17.0 %

c. 83.0 %

d. 85.5 %

QUESTION A.14 [1.0 point]
Which ONE of the following statements describes the difference between the Integral Rod Worth (IRW) curves and the Differential Rod Worth (DRW) curves?

a. IRW relates the worth of the rod per increment of movement to rod position. DRW relates the total reactivity added by the rod to the rod position.

b. IRW relates the total reactivity added by the rod to the rod position. DRW relates the worth of the rod per increment of movement to rod position.

c. IRW relates the total reactivity in the core to the time rate of reactivity change. DRW relates the time rate of reactivity change to rod position.

d. IRW is the slope of the DRW at a given rod position.

QUESTION A.15 [1.0 point]
During the minutes following a reactor scram, reactor power decreases on a negative 80 second period, corresponding to the half-life of the longest lived delayed neutron precursor, which is approximately _____.

a. 20 seconds

b. 40 seconds

c. 55 seconds

d. 80 seconds

QUESTION A.16 [1.0 point]
A reactor with an initial population of 1 x 10^8 neutrons is operating with K_{eff} = 1.001. Considering only the increase in neutron population, how many neutrons (of the increase) will be prompt when the neutron population changes from the current generation to the next? Assume β = 0.007.

a. 700

b. 7,000

c. 99,300

d. 100,000

QUESTION A.17 [1.0 point]
Inelastic Scattering can be described as a process whereby a neutron collides with a nucleus and:

a. Recoils with the same kinetic energy it had prior to the collision.

b. Is absorbed by the nucleus, with the nucleus emitting a gamma ray.

c. Recoils with a lower kinetic energy, with the nucleus emitting a gamma ray.

d. Recoils with a higher kinetic energy, with the nucleus absorbing a gamma ray.

QUESTION A.18 [1.0 point]
During a startup you increase reactor power from 50 watts to 1000 watts in 100 seconds. What is the reactor period?

a. 25

b. 33

c. 41

d. 50

QUESTION A.19 [1.0 point]
Which ONE of the following is the correct reason that delayed neutrons enhance control of the reactor?

a. There are more delayed neutrons than prompt neutrons.

b. Delayed neutrons take longer to reach thermal equilibrium.

c. Delayed neutrons increase the average neutron generation time.

d. Delayed neutrons are born at higher energies than prompt neutrons and therefore have a greater effect.

QUESTION A.20 [1.0 point]
A fissile material is one which will fission upon absorption of a thermal neutron. A fertile material is one which upon absorption of a neutron becomes a fissile material. Which ONE of the following isotopes is an example of a fertile material?

a. U-233

b. U-235

c. U-238

d. Pu-239

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

QUESTION B.01 [1.0 point, 0.25 each]
Based on 10 CFR 55, which ONE of the following is the MINIMUM requirement that must be met to retain an active Reactor Operator license? Must perform license duties:

a. A minimum of 8 hours per month.

b. At least 40 hours per calendar year.

c. A minimum of 4 hours per calendar quarter.

d. A minimum of 5 eight-hour shifts per calendar quarter.

QUESTION B.02 [1.0 point]
Per Technical Specifications, the average reactor core temperature coefficient of reactivity shall be more negative than _____.

a. -6.0×10^{-5} Δk/k/°F

b. -2.0×10^{-3} Δk/k/°F

c. -5.0×10^{-5} Δk/k/°F

d. -20.0×10^{-3} Δk/k/°F

QUESTION B.03 [1.0 point]
In accordance with the Technical Specifications, a SAFETY LIMIT is:

a. The actuating level for an automatic protective device related to those variables having significant safety functions.

b. A system which is designed to initiate automatic reactor protection or to provide information for initiation of manual protective action.

c. An administratively established constraint on equipment and operational characteristics which shall be adhered to during operation of the reactor.

d. A limit on an important process variable which is found to be necessary to reasonably protect the integrity of physical barriers which guard against the uncontrolled release of radioactivity.

QUESTION B.04 [1.0 point]
Temporary changes may be made to a procedure with the approval of the _____.

a. Reactor Manager Supervisor

b. Lead Senior Reactor Operator (LSRO)

c. LSRO and another licensed operator

d. Reactor Procedure Review Subcommittee (RPRS)

QUESTION B.05 [1.0 point]
How would an accessible area be posted if the radiation level in the area is 65 mR/hr?

a. CAUTION - RADIATION AREA

b. CAUTION - RESTRICTED AREA

c. CAUTION - HIGH RADIATION AREA

d. CAUTION - RADIOACTIVE MATERIALS AREA

QUESTION B.06 [1.0 point]
Which ONE of the following records need NOT be retained for the lifetime of the reactor facility?

a. Radiation Exposures for All Monitored Personnel

b. Off-Site Environmental Monitoring Surveys

c. Updated Drawings of the Reactor Facility

d. Reportable Occurrences

QUESTION B.07 [1.0 point]
"Area for which emergency planning is performed to assure that prompt and effective actions can be taken to protect the public in the event of an accident" defines a (an):

a. Site Boundary

b. Operations Boundary

c. Emergency Planning Zone

d. Emergency Control Center

QUESTION B.08 [1.0 point]
In accordance with Technical Specifications, a REACTOR SHUTDOWN condition requires all four (4) of the shim blades are fully inserted and:

a. The console key removed.

b. Power is unavailable to the shim rod drive mechanism electromagnets.

c. No operations are in progress which involve control rod maintenance.

d. No operations are in progress which involve moving fuel elements in the reactor vessel.

QUESTION B.09 [1.0 point]
10 CFR 20 requires that dose equivalent to the embryo/fetus during the entire pregnancy, due to the occupational exposure of a declared pregnant woman, does not exceed _____.

a. 0.5 rem

b. 5.0 rem

c. 0.1 rem

d. 1.0 rem

QUESTION B.10 [1.0 point]
An individual is accidentally exposed to a mixed gamma and neutron radiation field for 20 minutes. The radiation field from gamma is 30 R/hr, and the radiation field from neutrons of unknown energy is 9 R/hr. What is the individual's total absorbed dose? Refer to the table below.

Radiation	Q
Alpha; heavy recoil nuclei	20
Neutron (fast)	11
Neutron (unknown energy)	10
Neutron (slow)	2
Beta	1
X-ray; gamma	1

a. 10 rem

b. 13 rem

c. 40 rem

d. 39 rem/hr

QUESTION B.11 [1.0 point]
The intensity of radiation from a point source is 100 mR/hr at a distance of 12 meters. What is the intensity at 4 meters?

a. 1,800 mR/hr

b. 900 mR/hr

c. 33 mR/hr

d. 11.1 mR/hr

QUESTION B.12 [1.0 point]
Which ONE of the following listed experiments is NOT allowed per Technical Specifications?

a. A double encapsulated experiment containing corrosive materials.

b. A fueled experiment generating 300 curies of Iodine-131 through Iodine-135.

c. An experiment containing 20 milligrams of explosive material.

d. A movable experiment with a maximum absolute reactivity worth of 0.001ΔK/K.

QUESTION B.13 [1.0 point]
During an emergency, who has the responsibility for authorizing volunteer emergency workers to incur radiation exposure in excess of normal occupational limits?

a. The Emergency Director.

b. The Health Physics Manager.

c. The Emergency Coordinator.

d. The Emergency Coordinator, with concurrence of Health Physics Manager.

QUESTION B.14 [1.0 point]
Which ONE of the following Emergency Action Levels provides notification to the NRC, the American Nuclear Insurers (ANI) and the State Emergency Management Agency (SEMA) during an emergency event?

a. Assessment Actions

b. Corrective Actions

c. Specific Protective Actions

d. Subsequent Actions

QUESTION B.15 [1.0 point]
The Emergency Organization consist of two groups: (1) the Facility Emergency Organization, and (2) the Emergency Support Organizations. Which ONE of the following is part of the Emergency Support Organizations?

a. Reactor Operations

b. The UMC Radiation Safety Office

c. MURR staff in the Director's Office

d. The City of Columbia Fire Department

QUESTION B.16 [1.0 point]
Which ONE of the following Action Levels corresponds to an ALERT Emergency Class?

a. Loss of physical control of the facility.

b. Prolonged fire or explosion within the facility.

c. Concentration of airborne radioactivity at the stack monitor exceeding 20,000 Air Effluent Concentration averaged over 24 hours.

d. Radiation levels at the distance corresponding to the nearest site boundary of 100 mrem/hr for 1 hour whole-body of 500 mem thyroid dose.

QUESTION B.17 [1.0 point]
Which ONE of the following nuclear instruments is required for Startup only?

a. The Source Range Monitor (SRM)

b. The Intermediate Range Monitor (IRM)

c. The Power Range Monitor (PRM)

d. The Wide Range Monitor (WRM)

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. The Thermal Column

b. The Pneumatic Tube System

c. The Graphite Reflector Region

d. The Center Test Hole (Flux Trap)

QUESTION B.19 [1.0 point]
Which ONE of the following is NOT part of the Reactor Shutdown Checklist?

a. VERIFY core free of debris and abnormalities.

b. VERIFY all key box keys inventoried and key box locked.

c. VERIFY area radiation monitoring system trip levels set as specified on form FM-21.

d. VERIFY all control blades are bottomed and all control rod drive mechanism are fully inserted.

QUESTION B.20 [1.0 point]
FM-57 and FM 58 corresponds to the Long and Short Form Startup Checksheet respectively. In both forms, an asterisk (*) denotes an item that is a corrective action commitment resulting from a:

a. Reactor Utilization Request (RUR)

b. Radiation Work Permit (RWP)

c. Licensee Event Report (LER)

d. Safety Analysis (SA)

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

QUESTION C.01 [1.0 point]
The neutron source consists of a homogeneous mixture of _____, double encapsulated in stainless steel.

a. Am-Li

b. Am-Be

c. Sb-Be

d. Pu-Be

QUESTION C.02 [1.0 point]
The Anti-Siphon System is connected to the primary coolant loop, at the high point of the inverted loop, by valves:

a. 507A and 507B

b. 527E and 527F

c. 543A and 543B

d. 546A and 546B

QUESTION C.03 [1.0 point]
A containment building isolation is initiated when a high radiation level condition is detected by the _____ channel.

a. Room 114

b. South Wall

c. Secondary Coolant monitor

d. Air Plenum #2

QUESTION C.04 [1.0 point]
The neutron-absorbing material in the MURR shim blades is:

a. Beryllium

b. Boral Plate

c. Aluminum Oxide

d. Zirconium Hydride

QUESTION C.05 [1.0 point]
The alarm modules are segregated by their illumination color. Which ONE of the following color corresponds to an abnormal condition or event?

a. Blue

b. White

c. Green

d. Yellow

QUESTION C.06 [1.0 point, 0.25 each]
Match the following pH ranges in Colum A with their corresponding function in Column B.

Column A	Column B
a. 5 to 6	1. The pH of the water in the primary coolant system shall be maintained between _____ when averaged over a period of one (1) quarter.
b. 5.0 and 7.0	2. Waste Tank Sample release pH must be between _____.
c. 8.0 to 8.4	3. The primary and pool coolant ion-exchange systems maintain the pH in a range around _____.
d. 5.5 and 9.5	4. Secondary Coolant System Chemistry pH level is maintained in the normal range of _____ by the addition of sulfuric acid.

QUESTION C.07 [1.0 point]
Per the Reactor Startup – Normal Operation Procedure, the _____ low pressure alarm may cause electrical noise at lower reactor powers during reactor start up.

a. Firemain

b. Pressurizer

c. Anti-Siphon Tank

d. Primary Coolant System

QUESTION C.08 [1.0 point]
High Voltage Panel # _____ provide power to Distribution Center-1 and Distribution Center-2.

a. HVP #1

b. HVP #2

c. HVP #3

d. HVP #4

QUESTION C.09 [1.0 point]
The _____ houses the sensing and control devices to ensure emergency electrical distribution is powered from either the normal or emergency source.

a. Automatic Transfer Switch (ATS)

b. Emergency Distribution Center (EDC)

c. Emergency Power Generator (EPG)

d. Uninterruptible Power Supply (UPS)

QUESTION C.10 [1.0 point]
Air produced by the Emergency Air Compressor is stored in the _____.

a. Air Tank

b. Vent Tank

c. Holdup Tank

d. Receiver Tank

QUESTION C.11 [1.0 point]
Which ONE of the following actions will NOT occur upon actuation of the Reactor Isolation –Manual Initiation?

a. Reactor scram is initiated by the Reactor Safety System.

b. “Evacuation or Isolation Scram” alarm annunciation.

c. Containment building ventilation exhaust plenum backup doors close.

d. Reactor Isolation relays R2A and R2B are tripped.

QUESTION C.12 [1.0 point]
The primary coolant system fuel element failure monitor shall be _____ on a semiannual basis.

a. Channel-Checked

b. Channel-Calibrated

c. Channel-Replaced

d. Channel-Tested

QUESTION C.13 [1.0 point]
The major flow path for the Primary Coolant Loop, beginning at the reactor core, is as follows:

a. First V502, second V507A, Third V507B, Fourth P501A, Fifth HX503A.

b. First 507A, second P501A&B, Third HX503A&B, Fourth V507B, Fifth V502.

c. First HX503A&B, second V502, Third P501A&B, Fourth 507A, Fifth V507B.

d. First 507A, second V507B, Third HX503B, Fourth V502, Fifth P501B.

QUESTION C.14 [1.0 point]
When the pressurizer pressure falls below the lower limit of the normal operating band, V526 will automatically open. Which ONE of the following gases supplies the volume above the water surface to maintain the necessary operating pressure?

a. CO_2

b. Hydrogen

c. Nitrogen

d. Oxygen

QUESTION C.15 [1.0 point]
Which ONE of the following systems provides a means of heat removal from in-pool components such as control blade gaps, the center test hole and the reflector region?

a. Pool Coolant System

b. Primary Coolant System

c. Reactor Coolant Clean Up System

d. Secondary Coolant System

QUESTION C.16 [1.0 point]
The pool skimmer system may be arranged to perform any of three operations EXCEPT:

a. Remove debris from the reactor pool surface.

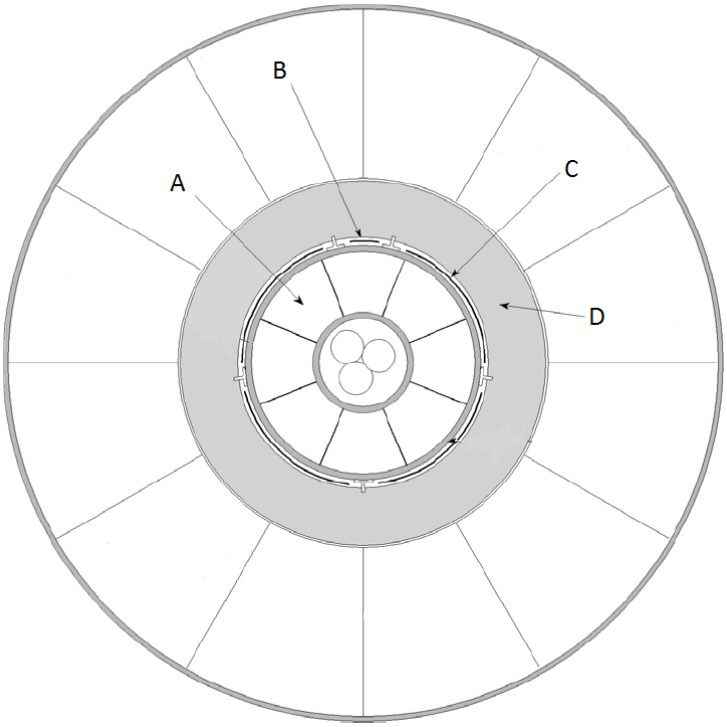
b. Provide a path for make-up water to the reactor pool.

c. Lower reactor pool water level to the elevation of the lower bridge.

d. Purifies pool coolant water, thereby, reducing the radioactive nuclide inventory.

QUESTION C.17 [1.0 point, 0.25 each]
The figure below is a simplified system drawing of the reactor. Match the corresponding regions in Column A with the reactor system in Column B.

Column A



Column B

1. Graphite Reflector Wedges
2. Fuel Elements
3. Beryllium Reflector
4. Inner pressure Vessel
5. Outer Pressure Vessel
6. Control Blade
7. Regulating Blade

QUESTION C.18 [1.0 point]
Which ONE of the following Reactor Core Assembly Support Structure is composed of a single component named the island tube?

a. Outer Pressure Vessel

b. Inner Pressure Vessel

c. Upper Reflector Tank

d. Lower Reflector Plenum

QUESTION C.19 [1.0 point]
The regulating blade is driven at a speed of _____ per minute.

a. 2 inches

b. 15 inches

c. 26 inches

d. 40 inches

QUESTION C.20 [1.0 point]
Which ONE of the following detector signal is fed directly to the Wide Range Monitor (WRM) drawer in the Control Room Instrument Panel?

a. Fission Chamber #1

b. Fission Chamber #2

c. Compensated Ion Chamber

d. Uncompensated Ion Chamber

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

A.01
Answer: d
REF: DOE Handbook, Volume 2, Module 4, "Subcritical Multiplication", pg. 1-9

A.02
Answer: a, 3; b,2; c,1
REF: Lamarsh, 3rd ed., Section 7.2, pg. 337
When k = 1, ρ= 0 and reactor is critical
When k < 1, ρ< 0 and reactor is subcritical
When k > 1, ρ > 0 and reactor is supercritical

A.03
Answer: d
REF: Burns, Example 3.3.1 (c), pg. 3-18

A.04
Answer: c
REF: Burns, Figure 8.1, pg. 8-6

A.05
Answer: a, 4; b,1; c,2; d,3
REF: Shultis and Faw, Fundamentals of Nuclear Science and Engineering, Section 5.4, pg. 93-101

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

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

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

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

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

A.06
Answer: d
REF: Technical Specifications, Definitions 1.9, pg. A-2

A.07
Answer: c
REF: Burns, Section 3.3.2, pg. 3-18

A.08
Answer: c
REF: Glasstone and Sesonske, 1967, Section 2.178-2.188

A.09
Answer: a
REF: Lamarsh 3rd ed., pg. 340-341

A.10
Answer: a
REF: Lamarsh, 3rd ed., pg. 71, 297

A.11
Answer: a
REF:

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

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

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

$$K_{eff} = \frac{1}{1 - (-0.455)}$$

$$k_{eff} = 0.9565$$

A.12
Answer: d
REF: Burns, Section 3.3.2, pg. 3-19

A.13
Answer: d
REF: Lamarsh, 3rd ed., Example 3.2, pg. 56
The probability of fission is $\sigma_f / (\sigma_\gamma + \sigma_f) = 582 / (99 + 582) = 0.855$

A.14
Answer: b
REF: Burns, Section 7.2 and 7.3, pg. 7-1 to 7-10

A.15
Answer: c
REF: Burns, Section 1.3.3, pg. 1-6 and 1-7

A.16

Answer: c

REF: Lamarsh, 3rd edition, Section 7.2, pg. 340
1st generation = 1×10^8
2nd generation = $(1.001)\ 1 \times 10^8 = 1.001 \times 10^8$
Increase = 2nd generation - 1st generation = 1×10^5
Of the increase, $(1-\beta) = 0.993$ is the fraction of the neutrons that are prompt = $(0.993)\ 1 \times 10^5 = 99{,}300$

A.17

Answer: c

REF: Burns, Section 2.4.5, pg. 2-28

A.18

Answer: b

REF: $P = P_0\ e^{t/\tau}$
$\ln(P/P_0) = t/\tau$
$\tau = t/(\ln(P/P_0)$
$\tau = 100/\ln(20) = 33.381$

A.19

Answer: c

REF: Burns, Example 3.3.7(e), pg. 3-31

A.20

Answer: c

REF: Burns, Example 3.2(a), pg. 3-2

B.01
Answer: c
REF: 10 CFR 55.53(e)

B.02
Answer: a
REF: TS 5.3, pg. A-58

B.03
Answer: d
REF: TS 1.34, pg. A-5

B.04
Answer: c
REF: AP-RO-110, Section 6.3.1, pg. 10

B.05
Answer: a
REF: 10 CFR 20.202

B.06
Answer: d
REF: TS 6.7, pg. A-74

B.07
Answer: c
REF: Emergency Plan, Section 9.8, pg. 22

B.08
Answer: b
REF: TS 1.27, pg. A-5

B.09
Answer: a
REF: 10 CFR 20.1208 (a)

B.10
Answer: c
REF: 10 CFR 20.1004

Radiation	Absorbed dose (D)	Exposure time	Quality factor (Q)	Effective Dose equivalent (exposure time x D x Q)
Gamma	30 R/hr	20 min	1	30 R/hr x 1hr/60 min x 20 min x 1 = 10 rem
Neutrons of unknown energy	9 R/hr	20 min	10	9 R/hr x 1hr/60 min x 20 min x 10 = 30 rem
			Total absorbed exposure:	10 rem + 30 rem = 40 rem

B.11
Answer: b
REF: $DR_1d_1^2 = DR_2d_2^2$
$100 \text{ mR/hr} \times (12 \text{ m})^2 = DR_2 \times (4 \text{ m})^2$
$DR_2 = 900 \text{ mR/hr}$

B.12
Answer: b
REF: TS 3.8, pg. A-32

B.13
Answer: a
REF: Emergency Plan, Section 2.1, pg. 4

B.14
Answer: d
REF: Emergency Plan, Section 5.1.5, 5.2.5, 5.3.5, pg. 13-15

B.15
Answer: b and d (Per Facility Suggestion)
REF: Emergency Plan, Section 2.3, pg. 6 and Figure II, pg. 7

B.16
Answer: a
REF: Emergency Plan, Table I, pg. 26

B.17
Answer: a
REF: REP-RO-100, Rev. 20, REP-5, pg. 9

B.18
Answer: a
REF: AP-RO-135, Introduction, pg. 3 & Attachment 9.2, pg. 1 of 2

B.19
Answer: a
REF: FM-11, pg. 1 and 2

B.20
Answer: c
REF: FM-57 NOTE, pg. 1 of 6 & FM-58 NOTE, pg. 1 of 1

C.01
Answer: c
REF: MURR Operations Training Manual, pg. 4-5B

C.02
Answer: c
REF: MURR Operations Training Manual, pg. 2-4A

C.03
Answer: d
REF: MURR Operations Training Manual, pg. 2-9B, 3-9B

C.04
Answer: b
REF: MURR Operations Training Manual, pg. 1-8C

C.05
Answer: b
REF: MURR Operations Training Manual, pg. 1-9E

C.06
Answer: a,3 b,1 c,4 d,2
REF: TS 3.3h, pg. A-22
FM-20, pg. 1 of 1
SAR 16.1.4, pg. 16-5
MURR Operations Training Manual, pg. 2-6C

C.07
Answer: c
REF: OP-RO-210, Section 5.1 NOTE, pg. 5

C.08
Answer: c
REF: MURR Operations Training Manual, pg. 2-2A

C.09
Answer: a
REF: MURR Operations Training Manual, pg. 2-2B

C.10
Answer: d
REF: MURR Operations Training Manual, pg. 2-3A

C.11
Answer: c
REF: MURR Operations Training Manual, pg. 2-3B

C.12
Answer: b
REF: TS 4.3 b, pg. A-45

C.13
Answer: b
REF MURR Operations Training Manual, pg. 1-4A & 2-4A

C.14
Answer: c
REF: MURR Operations Training Manual, pg. 1-4E, 2-4E & 1-4F

C.15
Answer: a
REF: MURR Operations Training Manual, pg. 1-5A

C.16
Answer: d
REF: MURR Operations Training Manual, pg. 2-5D

C.17
Answer: A,2 B,7 C,6 D,3
REF: MURR Operations Training Manual, pg. 1-8A

C.18
Answer: b
REF: MURR Operations Training Manual, pg. 2-8B

C.19
Answer: d
REF: MURR Operations Training Manual, pg. 2-8C

C.20
Answer: c
REF: MURR Operations Training Manual, pg. 1-9A, 2-9A, 3-9A, 10-9A, 12-9A