February 28, 2017

Mr. Alberto Queirolo, Director of Reactor Operations
Massachusetts Institute of Technology
Nuclear Reactor Laboratory - Research Reactor
138 Albany Street
Cambridge, MA 02139

SUBJECT: EXAMINATION REPORT NO. 50-020/OL-17-02, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dear Mr. Queirolo:

During the week of February 6, 2017, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your Massachusetts Institute of Technology 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. 50-020

Enclosures:
1. Examination Report No. 50-020/OL-17-02
2. Written Examination

cc: w/o enclosure: See next page

EXAMINATION REPORT NO. 50-020/OL-17-02, MASSACHUSETTS INSTITUTE OF TECHNOLOGY DATED FEBRUARY 28, 2017.

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cc:

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Test, Research and Training
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Ms. Sarah M. Don, Reactor Superintendent
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U. S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION REPORT

REPORT NO.: 50-020/OL-17-02

FACILITY DOCKET NO.: 50-020

FACILITY LICENSE NO.: R-37

FACILITY: Massachusetts Institute of Technology Reactor

EXAMINATION DATE: February 6, 2017

SUBMITTED BY: /RA/ 02/21/17
Paulette Torres, Chief Examiner Date

SUMMARY:

During the week of February 6, 2017 the NRC administered a licensing examination to one Reactor Operator (RO) candidate. The candidate passed all applicable portions of the examinations.

REPORT DETAILS

1. Examiner: Paulette Torres, 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	0/0	1/0
Overall	1/0	0/0	1/0

3. Exit Meeting:
Paulette Torres, Chief Examiner, NRC
Frank Warmsley, Training Supervisor, MIT
Al Queirolo, Director of Reactor Operations, MIT
Sarah Don, Superintendent of Operations and Maintenance, MIT

The facility licensee agreed to email their comments on the written examination which were incorporated into the examination report (see Enclosure 2).

Enclosure 1

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

FACILITY: Massachusetts Institute of Technology

REACTOR TYPE: MITR II Research

DATE ADMINISTERED: 02/07/2017

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

ENCLOSURE 2

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 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 ___

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 *****)

<u>B. Normal/Emergency Procedures and Radiological Controls</u>

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

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

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

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

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

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

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

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

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

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

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

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

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

$$M = \frac{1 - K_{eff_1}}{1 - K_{eff_2}}$$

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

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

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

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

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

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

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

$$DR_1 d_1^2 = DR_2 d_2^2$$

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

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

$$\frac{A_T}{A_0} = \frac{1}{2^n}$$

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

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Operator Licensing Examination

Week of February 6, 2017

QUESTION A.01 [1.0 point]
__________ have the same atomic number and are therefore the same element, but differ in the number of neutrons.

a. Isobars

b. Isotones

c. Isotopes

d. Nuclides

QUESTION A.02 [1.0 point]
The energy equivalence of one electron is:

a. 511 keV

b. 931 keV

c. 1022 keV

d. 1.6 E^{-19} keV

QUESTION A.03 [1.0 point]
The neutron fluence rate ($n/cm^2/s$) describes neutron ______________.

a. Activity

b. Specific Activity

c. Intensity

d. Yield

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

a. Radiative capture

b. Elastic scattering

c. Inelastic scattering

d. Charged particle reactions

QUESTION A.05 [1.0 point]
Tritium, produced via $^{2}H(n,\gamma)^{3}H$, is a:

a. Low Energy Beta Emitter

b. Low Energy Gamma Emitter

c. High Energy Beta and Gamma Emitter

d. Low Energy Beta and High Energy Gamma Emitter

QUESTION A.06 [1.0 point]
A reactor is slightly supercritical with the following values for each of the factors in the six-factor formula:

Fast Fission factor = 1.03
Resonance escape probability = 0.96
Thermal Utilization Factor = 0.70
Fast non-leakage probability = 0.84
Thermal non-leakage probability = 0.88
Reproduction factor = 1.96

A control rod is inserted to bring the reactor back to critical. Assuming all other factors remain unchanged, the new value for the Thermal Utilization Factor is:

a. 0.698

b. 0.702

c. 0.704

d. 0.708

QUESTION A.07 [1.0 point]
During the neutron cycle from one generation to the next, several processes occur that may increase or decrease the available number of neutrons. Which ONE of the following factors describes an increase in the number of neutrons during the cycle?

a. Thermal Utilization Factor

b. Resonance Escape Probability

c. Thermal Non-Leakage Probability

d. Fast Fission Factor

QUESTION A.08 [1.0 point]
Which ONE of the following nuclides has the largest microscopic cross-section for absorption for thermal neutron?

a. $_{5}B^{10}$

b. $_{54}Xe^{135}$

c. $_{62}Sm^{149}$

d. $_{92}U^{235}$

QUESTION A.09 [1.0 point]
Which ONE of the following describes the response of the reactor to equal amounts of reactivity insertion as the reactor approaches critical (K_{eff} = 1.0)? The change in neutron population per reactivity insertion is:

a. Larger, and it requires a longer time to reach a new equilibrium count rate.

b. Larger, and it takes an equal amount of time to reach a new equilibrium count rate.

c. Smaller, and it requires a shorter time to reach a new equilibrium count rate.

d. Smaller, and it requires a longer time to reach a new equilibrium count rate.

QUESTION A.10 [1.0 point]
Which ONE of the following factors has a long term effect on K_{eff} but is of no consequence during short term and transient operation?

a. Fuel burnup

b. Increase in fuel temperature

c. Increase in moderator temperature

d. Xenon and Samarium fission products

QUESTION A.11 [1.0 point]
Fuel is being loaded into the core. The operator is using a 1/M plot to monitor core loading. Which ONE of the following conditions would result in a non-conservative prediction of core critical mass, i.e., the reactor would reach criticality prior to the predicted critical mass?

a. The detector is too close to the source and the fuel.

b. The detector is too far away from the source and the fuel.

c. A fuel element is placed between the source and the detector.

d. Excessive time is allowed between fuel elements being loaded.

QUESTION A.12 [1.0 point]
Which ONE of the following statements is the predominant factor for the change in Xenon concentration following a reactor scram?

a. The concentration of ^{135}Xe will decrease by natural decay into ^{135}I.

b. The concentration of ^{135}Xe will increase due to reduced nuclear flux.

c. The concentration of ^{135}Xe will increase due to the decay of the ^{135}I inventory.

d. The concentration of ^{135}Xe will remain constant until it is removed via neutron burnout during the subsequent reactor startup.

QUESTION A.13 [1.0 point]
Following a scram, the shortest stable negative period is limited to -80 seconds as determined by the rate of decay of __________.

a. Mean Neutron Lifetime

b. Shortest Lived Delayed Neutron

c. Longest Lived Delayed Neutron

d. Fast Neutrons

QUESTION A.14 [1.0 point]
An initial count rate of 100 is doubled five times during startup. Assuming an initial K_{eff} = 0.950, what is the new K_{eff}?

a. 0.957

b. 0.979

c. 0.988

d. 0.995

QUESTION A.15 [1.0 point]
Which factors of the six factor formula are affected by an INCREASE in core temperature and how are they affected?

a. $\downarrow L_f$, $\downarrow p$, $\uparrow f$

b. $\uparrow \varepsilon$, $\uparrow L_f$, $\downarrow L_t$, $\uparrow p$

c. $\uparrow \varepsilon$, $\uparrow L_f$, $\downarrow L_t$, $\downarrow p$, $\uparrow \eta$, $\uparrow f$

d. $\uparrow \varepsilon$, $\uparrow L_f$, $\downarrow L_t$, $\uparrow p$, $\downarrow \eta$, $\downarrow f$

QUESTION A.16 [1.0 point]

What is the condition of the reactor when $k = \frac{1}{1-\beta}$?

a. critical

b. Subcritical

c. prompt critical

d. prompt supercritical

QUESTION A.17 [1.0 point]

What is β_{eff}?

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

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

c. The fraction of all delayed neutrons which reach thermal energy.

d. The fractional change in neutron population per generation.

QUESTION A.18 [1.0 point]

Which ONE of the following is the major source of energy released from the fission process?

a. Kinetic energy from the fission fragments

b. Kinetic energy of the fission neutrons

c. Decay of the fission fragments

d. Prompt gamma rays

QUESTION A.19 [1.0 point]
Reactor Power increases from 15 watts to 65 watts in 31 seconds. The period of the reactor is:

a. 7 seconds

b. 14 seconds

c. 21 seconds

d. 28 seconds

QUESTION A.20 [1.0 point]
As a reactor continues to operate over a period of months, for a constant power level, the average neutron flux __________. The blade height remains constant.

a. Decreases, due to the increase in fission product poisons.

b. Increases, in order to compensate for fuel depletion.

c. Decreases, because fuel is being depleted.

d. Remains the same.

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

QUESTION B.01 [1.0 point]
As a result of its interactions, the typical path of an alpha particle in air can best be described as:

a. short (< 5 cm) and straight

b. intermediate (14-16 cm) with many deflections

c. long (> 25 cm) and straight

d. long (> 25 cm) with many deflections

QUESTION B.02 [1.0 point]
After three half-lives, what fraction of radioactivity remains?

a. 1/3

b. 1/4

c. 1/6

d. 1/8

QUESTION B.03 [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.04 [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.

Type of Radiation	Quality Factor (Q)
X-, gamma, or beta radiation	1
Alpha particles, multiple-charged particles, fission fragments and heavy particles of unknown charge	20
Neutrons of unknown energy	10
High-energy protons	10

a. 10 rem

b. 13 rem

c. 40 rem

d. 39 rem/hr

QUESTION B.05 [1.0 point]
10 CFR Part 20 annual limit of 5 rem total effective dose equivalent includes:

a. The deep-dose equivalent for external exposures.

b. The committed effective dose equivalent for internal exposures.

c. The sum of items a and b.

d. The sum of items a and b and the shallow dose equivalent to the skin.

QUESTION B.06 [1.0 point]
Per MITR Emergency Plan and Procedures, which ONE of the following individual has the authority to terminate or downgrade an emergency and to initiate recovery operations?

a. The Chairman of the MIT Reactor Safeguards Committee

b. The MITR Radiation Protection Officer

c. The Director of Reactor Operations

d. The Reactor Superintendent

QUESTION B.07 [1.0 point]
The __________ of a radionuclide in air which, if inhaled continuously over the course of a year, would produce a total effective dose equivalent of 0.10 rem (100 millirem or 1.0 millisieverts) for noble gases, or 0.05 rem (50 millirem or 0.5 millisieverts) for all other nuclides.

a. Effluent Concentration

b. Airborne Radioactivity

c. Annual Limit on Intake

d. Derived Air Concentration

QUESTION B.08 [1.0 point]
Fire control, repair and damage control, attenuation of radiation by the placement of temporary shielding, cessation of a release by the closure of containment penetrations, etc. are examples of:

a. Assessment Actions

b. Corrective Actions

c. Emergency Actions

d. Protective Actions

QUESTION B.09 [1.0 point]
All of the following are the three main emergency support centers available on the MIT Campus for use in directing a response to a radiological emergency EXCEPT:

a. The Environment, Health, and Safety Office

b. The Reactor Operations Office

c. The MIT Police Headquarters

d. The MIT Medical Department

QUESTION B.10 [1.0 point]
Which ONE of the following monitor(s) has the capability to collect iodine by means of a Charcoal filter?

a. Plenum/Stack Particulate Monitors

b. Plenum/Stack Gas Monitors

c. Core Purge Monitor

d. Stack Area Monitor

QUESTION B.11 [1.0 point]
Per Technical Specifications, a dilution factor of _________ shall be applicable to the concentration of airborne effluents released from the stack except for particulates and iodines with half-lives greater than eight days in each case.

a. 500

b. 5,000

c. 50,000

d. 500,000

QUESTION B.12 [1.0 point]
Which ONE of the following conditions meets the Technical Specification definition for "Reactor Secured" at the MITR?

a. A single experiment with a reactivity of 0.2% ΔK/K is being installed in the reactor with all shim blades and regulating rod fully inserted, the console key is in the off position, and the console key is removed from the lock.

b. The minimum number of neutron absorbing control devices are fully inserted, the console key is in the off position, console key is not removed and no in-core experiments are being moved or serviced.

c. The minimum number of neutron absorbing control devices are fully inserted, the console key is in the off position, the console key is removed from the lock, no in-core experiments are being moved or serviced, and no work is in progress involving fuel in the fission converter tank.

d. Work in one shim blade drive mechanism is in progress with the drive coupled to the shim blade and at least five operable shim blades and regulating rod are fully inserted with the console key is in the off position, and the console key is removed from the lock.

QUESTION B.13 [1.0 point]
Which ONE of the following at MITR does not require the presence or action from of a Senior Reactor Operator (SRO)?

a. Implementation of a new procedure or a change to an existing procedure.

b. Performance of previously approved experiments.

c. Maintenance, repair, and modification of the medical therapy facilities.

d. Manipulation of reactor console controls by a student in training.

QUESTION B.14 [1.0 point]
The following statement, "The minimum shutdown reactivity is 1% ΔK/K and the most restrictive operating condition is cold (10 °C), xenon-free, with all movable and non-secured experiments in their most reactive state." provided in the MITR Technical Specifications is an example of a (an)….

a. Safety Limit

b. Limiting Safety System Setting (LSS)

c. Limiting Condition For Operation (LCO)

d. Administrative Control

QUESTION B.15 [1.0 point]
Which ONE of the following is a TRUE statement regarding the MITR Technical Specifications requirement to maintain coolant height 4" below overflow or 10 feet above top of fuel plates (min)?

a. The loss of primary coolant will cause fuel temperature to exceed the limit for melting.

b. Incipient boiling will cause a significant positive reactivity addition and could cause overpower conditions.

c. Due to the loss of coolant height, the primary cleanup system will be unable to remove fission products from the reactor water.

d. This coolant height corresponds to a saturation temperature of 107 °C.

QUESTION B.16 [1.0 point]
The Low Flow Primary Coolant alarm occurs at __________.

a. 1000 gpm

b. 1800 gpm

c. 1900 gpm

d. 2000 gpm

QUESTION B.17 [1.0 point]
Which ONE of the following alarms indicates/means that there is a malfunction in the auxiliary flow loop?

a. No Overflow H_2O Medical Shutter

b. Low Level Primary Storage Tank

c. Trouble Primary / Secondary Pump VFD

d. Abnormal Recombiner Temperature

QUESTION B.18 [1.0 point]
Which ONE of the following requires a One Pump Operation?

a. 2.45 MW

b. 5.90 MW

c. 6.00 MW

d. 7.40 MW

QUESTION B.19 [1.0 point]
All of the following are some of the preconditions required for the performance of a refueling EXCEPT:

a. Primary flow is secured.

b. The D_2O reflector is normally dumped.

c. The reactor is in a Non-Operating but Attended Condition.

d. The building ventilation and the radiation monitoring system be in normal operation.

QUESTION B.20 [1.0 point]
Readings of the designated control room instruments and other experiments, as required, shall normally be made _________ during reactor operation.

a. Once half hour

b. Once every hour

c. Once two hours

d. Once per licensed operator-in-charge shift

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

QUESTION C.01 [1.0 point]
Liquid waste is discharged to the municipal sanitary sewer systems from two waste storage tanks and from the cooling tower basin. Which ONE of the following is NOT an NRC criterion for disposal of liquid waste into the sanitary sewer system?

a. Less than 5 Ci of H-3 can be disposed of per year.

b. Disposal can only be done at a central point under the control of the Radiation Safety Officer.

c. The average monthly concentration must be less than concentrations specified in the Appendix to 10 CFR 20.

d. The material must be soluble (biological material must be dispersible).

QUESTION C.02 [1.0 point]
The power history of the MITR is more than sufficient to maintain a strong __________ neutron source.

a. Alpha

b. Photo

c. Spontaneous fission

d. Accelerator

QUESTION C.03 [1.0 point]
The automatic control channel uses a _________ as its indicator of reactor power.

a. Fission chamber

b. Ion chamber

c. Uncompensated ion chamber

d. Scintillation detector

QUESTION C.04 [1.0 point]
One specific characteristic of a TLD is that:

a. It is large and bulky.

b. It reads in dose rate instead of dose.

c. It cannot be used for longer than two weeks.

d. It needs to be sent to the vendor for processing.

QUESTION C.05 [1.0 point]
The _________ prevents mechanical overloading or jamming in the Shim Blade Drive Mechanism.

a. Shear Pin

b. Timing Belt

c. Electromagnet

d. Pinion Gear Shaft

QUESTION C.06 [1.0 point]
There are four modes of Emergency Core Cooling. The assumption that all process systems are normal except for the loss of power corresponds to:

a. Mode 1

b. Mode 2

c. Mode 3

d. Mode 4

QUESTION C.07 [1.0 point]
Which ONE of the following is considered an Engineered Safety Feature at the MITR?

a. The reactor overpower trip.

b. Heat Exchangers HE-D1 and HE-D2.

c. Protection against containment building vacuum and overpressure.

d. The emergency fill connection from the city water supply.

QUESTION C.08 [1.0 point]
With a nominal battery load of 72 amps, the battery bank of the emergency electrical power distribution system has sufficient capacity to provide selected instrument and pump power for approximately:

a. 2 hours

b. 3 hours

c. 8 hours

d. 16 hours

QUESTION C.09 [1.0 point]
Which ONE of the following will NOT result in a heavy-water reflector dump?

a. Loss of Electricity

b. Loss of Primary Coolant Flow

c. Loss of Compressed Air System

d. Manual Action

QUESTION C.10 [1.0 point]
The CO_2 system, that supplies many of the experimental facilities, displaces air and thus greatly reduces the formation of:

a. Ar-41, nitrous oxide, and condensed moisture.

b. Ar-41, N-16 and Helium.

c. N-16 and fission product gases such as xenon, krypton, and iodine.

d. N-16, Na-24 and Al-28

QUESTION C.11 [1.0 point]
Which ONE of the following Non-Nuclear Safety System scram conditions have a scram set point of ≥400 gpm?

a. Low Flow D_2O, DF-1

b. Low Flow Shield Coolant, PF-1

c. Low Flow Primary Coolant, MF-1

d. Low Flow Secondary, HF-1

QUESTION C.12 [1.0 point]
It is April 1, 2016. You have actively performed the functions of a Reactor Operator for the following hours during the last quarter:

January 11, 2016	0.5 hours
February 24, 2016	1.5 hours
March 16, 2016	1.0 hours

What requirements must you meet in order to maintain your Reactor Operator license today?

a. None. You've met the minimum requirements of 10 CFR 55.53.

b. You must perform 4 hours of shift functions under the direction of a licensed operator or licensed senior operator as appropriate.

c. You must perform 6 hours of shift functions under the direction of a licensed operator or licensed senior operator as appropriate.

d. You must submit a new application form to the NRC requesting a waiver to reactivate your license.

QUESTION C.13 [1.0 point]
Per Technical Specifications, the ___________ radiation monitor has an engineered safety feature in the form of an interlock that will cause the main ventilation isolation dampers to close.

a. Core Purge (off-gas)

b. Stack effluent

c. Plenum effluent

d. Building Airborne Radioactivity

QUESTION C.14 [1.0 point]
If the shift supervisor and/or the console operator determines that an evacuation of the containment building is warranted, all of the following occur EXCEPT:

a. An amber light appears on the console monitor after isolation of the containment building ventilation system.

b. The evacuation siren sounds for five seconds and then is off for six seconds.

c. The back-lighted signs are energized at each personnel lock door.

d. The intercom is used to broadcast evacuation directions.

QUESTION C.15 [1.0 point]
Forced convection cooling via the primary cooling system is normally maintained for _________ following a reactor shutdown after extended full-power operation.

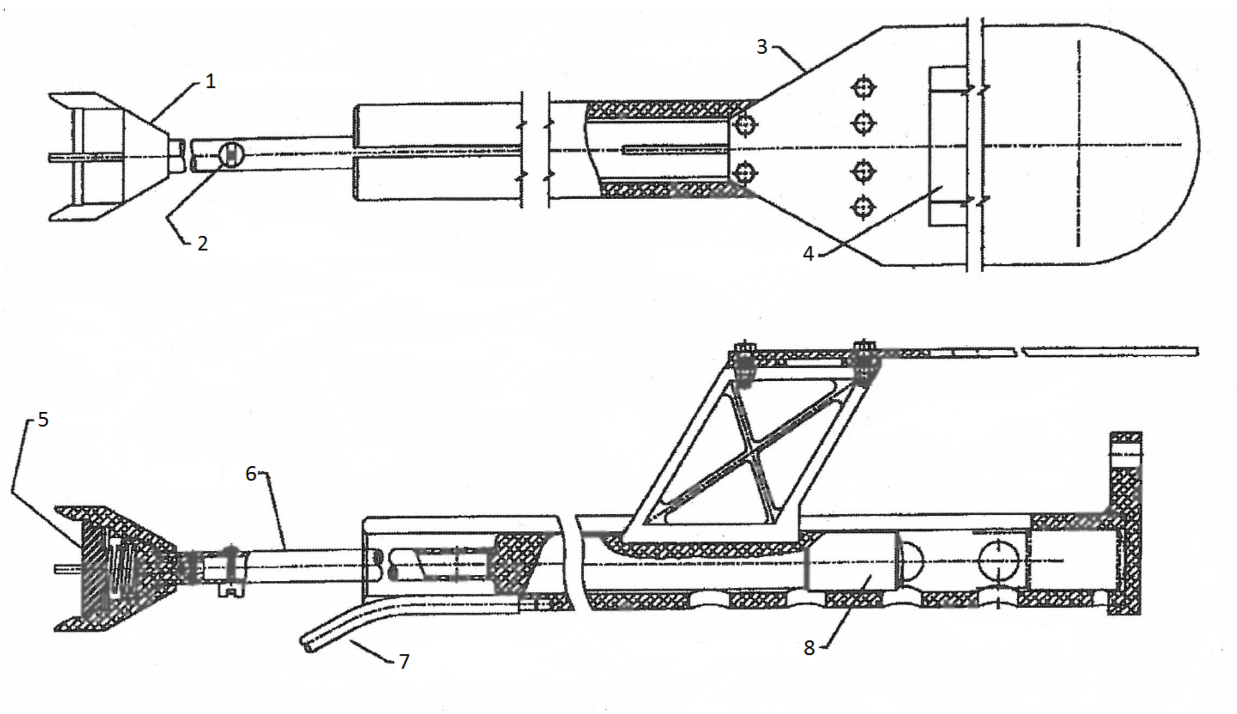
a. ½ hour

b. 2 ½ hours

c. 3 hours

d. 4 hours

QUESTION C.16 [1 point, 0.25 each]
Identify the best answer from the components labeled 1 through 8 on the figure of the Control Blade Assembly provided. (Note: Only one answer per number.)



CONTROL BLADE ASSEMBLY

a. Limit Switch Guide Tube _____

b. Grid Latch Slot _____

c. Magnet Coupling _____

d. Armature _____

QUESTION C.17 [1.0 point]
Which ONE of the following is a correct flow path of the Reflector Coolant System?

a. Top of Reactor Core, Reflector Tank, Main Circulating Pump DM-1, Heat Exchanger HE-D1

b. D_2O Shutter Tank, Main Circulating Pump DM-1, Heat Exchanger HE-D2, Dump Line

c. Dump Line, Main Circulating Pump DM-1, Heat Exchanger HE-D1, Reflector Tank

d. Dump Valve, Main Circulating Pump DM-2, Heat Exchanger HE-D2, D_2O Shutter Tank

QUESTION C.18 [1.0 point]
Which ONE of the following instruments is generally best for detecting low levels of beta-gamma contamination on a person's hands?

a. Ionization Chamber

b. NaI detector

c. End Window GM

d. Pancake GM

QUESTION C.19 [1.0 point]
The _________ is (are) the console operator's principal indication of reactor power.

a. Linear Flux Channel

b. Period Channels

c. Level Channels

d. Channel 8

QUESTION C.20 [1.0 point]
Which ONE of the following is NOT a permanently installed experimental facility?

a. One 12-inch diameter port, radial, with shutter.

b. 2PH1 - high flux pneumatic tube.

c. In-reflector (graphite) irradiation facilities.

d. In-core sample assemblies.

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

A.01
Answer: c
REF: DOE-HDBK, Vol. 1, NP-01, pg. 6

A.02
Answer: a
REF: Burns, Example 2. 2.1 (a), pg. 2-2 & Section 2.4.1, pg. 2-20

A.03
Answer: c
REF: DOE-HDBK, Vol. 1, NP-02, pg. 15

A.04
Answer: b
REF: Lamarsh 3rd ed., Section 3.6, pg. 68-71
Basic Nuclear Engineering 4th ed., Slowing Down of Neutrons, pg. 226-227

A.05
Answer: a
REF: Chart of the nuclides. Tritium is the lowest energy beta emitter known with a total transition, or endpoint, energy of 18.6 keV.

A.06
Answer: a
REF: $1.03 \cdot 0.96 \cdot X \cdot 0.84 \cdot 0.88 \cdot 1.96 = 1.00$
$X = 1 / (1.03 \cdot 0.96 \cdot 0.84 \cdot 0.88 \cdot 1.96)$
$X = 0.698$

A.07
Answer: d
REF: DOE-HDBK, Vol. 2, NP-03, pg. 3

A.08
Answer: b
REF: Burns, Introduction to Nuclear Reactor Operations, Table 2.5, pg. 2-59

A.09
Answer: a
REF: Burns, Section 5.3, pg. 5-7

A.10
Answer: a
REF: Burns, Session 3.3.2, pg. 3-18

A.11
Answer: b
REF: Burns, Section 5.5, pg. 5-18

A.12
Answer: c
REF: DOE-HDBK, Vol 2, NP-03, pg. 38

A.13
Answer: c
REF: ~~Burns, Section 4.5, pg. 4-12 to 4-16~~
Per MIT discussion with Frank Warmsley

A.14
Answer: d
REF: $CR_1/CR_2 = (1 - K_{eff2})/(1 - K_{eff1})$; CR_1=100, CR_2= 100 x 2 x 5 = 1000, K_{eff1} = 0.950
100/1000 = (1 - K_{eff2})/(1 - 0.95), 0.1 = (1 - K_{eff2}) / 0.05, 0.005 = (1 - K_{eff2}), K_{eff2} = 0.995

A.15
Answer: a
REF: DOE-HDBK, Vol 2, NP-03, pg. 10
As reactor core temperature increases, the moderator to fuel ratio will decrease due to the decrease in density of the water. Therefore, due to this fact:

↓L_f (Fast Non-Leakage Factor): is the probability that neutrons will not leak out while still fast. Therefore, with less moderator in the core, the probability that they will not leak out decreases.

↓p (Resonance Escape Probability): is the probability that a neutron will be reduced to thermal energy levels without being absorbed by U-238. Due to the increase in temperature and Doppler Broadening effects, the probability of escape decreases.

↑f (Thermal Utilization Factor): is the ratio of absorption in fuel to the amount absorbed in the core (e.g., fuel, moderator, control rods, etc.). When the temperature rises, the water moderator expands, and a significant amount of it will be forced out of the reactor core. This means that Nm, the number of moderator atoms per cm3, will be reduced, making it less likely for a neutron to be absorbed by a moderator atom. This reduction in Nm results in an increase in thermal utilization as moderator temperature increases because a neutron now has a better chance of hitting a fuel atom.

A.16

Answer: c

REF: Lamarsh 3rd ed., Section 7.2, pg.340-341

The multiplication factor (k) is proportional to the total number of neutrons, prompt and delayed, emitted per fission. However, since only the fraction (1-β) of the fission neutrons are prompt, the fraction of prompt neutrons from with regards to the multiplication factor is (1-β)k. Therefore, when (1-β)k=1, the reactor is critical on prompt neutrons alone, and the reactor is said to be prompt critical. If you rearrange (1-β)k=1 it will read $k = \frac{1}{1-\beta}$.

A.17

Answer: c

REF: DOE-HDBK, Vol 2, NP-04, pg. 12

Effective delayed neutron fraction is the fraction of neutrons at thermal energies which were born delayed.

A.18

Answer: a

REF: Burns, Table 3.2, pg. 3-5

A.19

Answer: c

REF: $P = P_0 e^{t/T}$, ln(65/15) = 31 sec/T

T = (31 sec)/(ln 4.3333) = 21.14

A.20

Answer: b

REF: Burns, Problem 3.4.8, pg. 3-35

B.01
Answer: a
REF: DOE-HDBK, Vol 1, NP-01, pg. 64

B.02
Answer: d
REF: Cember & Johnson, 2009, Equation 4.17, pg. 99
From the definition of the half-life, it follows that the fraction of a radionuclide remaining after *n* half-lives is given by the relationship $\frac{A_T}{A_0} = \frac{1}{2^n}$ (provided in the exam Equation Sheet) where A_0 is the original quantity of activity and A is the activity left after *n* half-lives. Therefore, $\frac{A_T}{A_0} = \frac{1}{2^n} = \frac{1}{2^3} = \frac{1}{8}$.

B.03
Answer: b
REF: $DR_1 d_1^2 = DR_2 d_2^2$
$100 \text{ mR/hr} \times (12 \text{ m})^2 = DR_2 \times (4 \text{ m})^2$
$DR_2 = 900 \text{ mR/hr}$

B.04
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
Neutron	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.05
Answer: c
REF: 10 CFR 20.1003 Definitions, 10 CFR 20.1201

B.06
Answer: c
REF: Emergency Plan & Procedures, Section 4.3.3.1, pg. 18 of 76

B.07
Answer: a
REF: Emergency Plan & Procedures, Section 4.2.1 (f), pg. 4 of 76
10 CFR 20, App. B, Table 2

B.08
Answer: b
REF: Emergency Plan & Procedures, Section 4.2.1 (c), pg. 4 of 76

B.09
Answer: d
REF: Emergency Plan & Procedures, Section 4.8.1, pg. 64 of 76

B.10
Answer: a
REF: Emergency Plan & Procedures, Table 4.1.2.1.1, pg. 41 of 76

B.11
Answer: c
REF: TS 3.7.2, pg. 3-56

B.12
Answer: c
REF: TS 1.3.28, pg. 1-7, PM 2.2.1.1 (5)

B.13
Answer: d
REF: TS 6.5 (15), TS 7.4.2, TS 7.5.2 (3), SAR 12.1.3, pg. 12-7, 10 CFR Part 55.13

B.14
Answer: c
REF: TS 3.1.2, pg. 3-3

B.15
Answer: d
REF: TS 2.2 Basis, pg. 2-7

B.16
Answer: c
REF: PM 5.2.4

B.17
Answer: a
REF: PM 5.2.4

B.18
Answer: a
REF: PM 2.2.1.1 (2)

B.19
Answer: c
REF: PM 2.7, pg. 4 of 8, TS 3.2.3 Basis, pg. 3-21, PM 2.2.1.1

B.20
Answer: b
REF: PM 1.14.1 (7), pg. 2 of 7

C.01
Answer: b
REF: 10 CFR 20.2003

C.02
Answer: b
REF: SAR 4.2.4, pg. 4-19

C.03
Answer: b
REF: SAR 7.3.2.5, pg. 7-19

C.04
Answer: d
REF: SAR 11.1.5.1, pg. 11-14

C.05
Answer: a
REF: SAR 4.2.2.2, pg. 4-12 & 4-13

C.06
Answer: a
REF: SAR 5.2.5, Table 5-3, pg. 5-19

C.07
Answer: c
REF: SAR 6.1, pg. 6-1 to 6-2

C.08
Answer: c
REF: SAR 8.2.2, pg. 8-6

C.09
Answer: b
REF: SAR 1.2.3 i), pg. 1-5, SAR 3.1.3.2, pg. 3-8

C.10
Answer: a
REF: SAR 9.9, pg. 9-21 & 9-22

C.11
Answer: d
REF: SAR 7.4.2, Table 7-2, pg. 7-25

C.12
Answer: c
REF: SAR 12.10.10, pg. 12-35, 10 CFR 55.53 (e) & (f)

C.13
Answer: c
REF: TS 3.7.1 2a), pg. 3.-50, 3.7.1 Basis, pg. 3-52 and Table 3.7.1-1, pg. 3-54

C.14
Answer: a
REF: PM 4.7.4.1.2, pg. 56 of 76

C.15
Answer: d
REF: SAR 5.2.4, pg. 5-17

C.16
Answer: a = 7; b = 4; c = 1; d = 5
REF: SAR Figure 4-4

C.17
Answer: c
REF: SAR 5.3.1.2, pg. 5-24 and SAR Figure 5-2

C.18
Answer: d
REF: SAR 11.1.4.2, pg. 11-11

C.19
Answer: a
REF: SAR 7.6.1, pg. 7-26

C.20
Answer: d
REF: SAR 10.1, pg. 10-1 and SAR Table 10-1, pg. 10-2