April 26, 2016

Mr. John Foster, Interim Director
of Reactor Operations
Massachusetts Institute of Technology
138 Albany Street
Cambridge, MA 02139

SUBJECT: EXAMINATION REPORT NO. 50-020/OL-16-02, MASSACHUSETTS INSTITUE OF TECHNOLOGY

Dear Mr. Foster:

During the week of March 28, 2016, the U.S. Nuclear Regulatory Commission (NRC) administered an operator licensing examination at your Massachusetts Institute of Technology 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) 415-1169 or via internet e-mail Michele.DeSouza@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-16-02
2. Written examination

cc: w/o enclosures: See next page

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ADAMS ACCESSION #:ML16116A089 **TEMPLATE #:NRR-079**

OFFICE	NRR/DPR/PROB/CE	NRR/DPR/PROB/OLA	NRR/DPR/PROB/BC
NAME	MDeSouza	CRevelle	AMendiola
DATE	04/26/2016	04/25 /2016	04/26/2016

OFFICIAL RECORD COPY

cc:

City Manager
City Hall
Cambridge, MA 02139

Department of Environmental Protection
One Winter Street
Boston, MA 02108

Mr. Jack Priest, Director
Radiation Control Program
Department of Public Health
529 Main Street
Schrafft Center, Suite 1M2A
Charlestown, MA 02129

Mr. John Giarrusso, Chief
Planning and Preparedness Division
Massachusetts Emergency Management Agency
400 Worcester Road
Framingham, MA 01702-5399

Test, Research and Training
Reactor Newsletter
P.O. Box 118300
University of Florida
Gainesville, FL 32611-8300

Ms. Sarah M. Don (Interim) Superintendent
Massachusetts Institute of Technology
Nuclear Reactor Laboratory
Research Reactor
138 Albany Street, MS NW12-116A
Cambridge, MA 02139

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

REPORT NO.: 50-020/OL-16-02

FACILITY DOCKET NO.: 50-020

FACILITY LICENSE NO.: R-37

FACILITY: Massachusetts Institute of Technology Reactor

EXAMINATION DATES: March 28, 2015

SUBMITTED BY: _____ _____
Michele DeSouza, Chief Examiner Date

SUMMARY:
During the week of March 28, 2016, the NRC administered an operator licensing examination to two Senior Reactor Operator (RO) candidates. The Senior Reactor Operator candidates passed all applicable portions of the examination.

REPORT DETAILS

1. Examiner: Michele DeSouza, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:
Michele C. DeSouza, Chief Examiner, NRC
Al Queirolo, Director of Reactor Operations Designate, MITR
John Foster, Interim Director of Reactor Operations, MITR
Sarah Don, Interim Superintendent, MITR
Frank Warmsley, Training Supervisor, MITR

Upon completion of the examination, the NRC Examiner met with facility staff representatives to discuss the results. At the conclusion of the meeting, the NRC examiner thanked the facility for their support in the administration of the examination.

ENCLOSURE 1

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

FACILITY: Massachusetts Institute of Technology

REACTOR TYPE: TANK

DATE ADMINISTERED: 03/30/2016

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 ___

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 ____ (0.25 each)

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 ___ (0.25 each)

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 ___ d ___ (0.25 each)

C10 a b c d ___

C11 a ___ b ___ c ___ d ___ (0.33 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 ___

(***** 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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]
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.02 [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.03 [1.0 point]
Which ONE of the following conditions will DECREASE the reactor core excess?

a. Fuel depletion

b. Burnable poison burnout

c. Insertion of a positive reactivity worth experiment

d. Lowering moderator temperature (assume negative temperature coefficient)

QUESTION A.04 [1.0 point]
Two common FISSION PRODUCTS that have especially large neutron cross sections and play a significant role in reactor physics are Samarium-149 and _____.

a. Nitrogen-16

b. Argon-41

c. Iodine-131

d. Xenon-135

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

QUESTION A.05 [1.0 point]
Which ONE of the following is the reason for an installed neutron source within a cold clean reactor core? A startup without an installed neutron source _____.

a. Is impossible as no neutrons would be available to start up the reactor

b. Can be compensated for by adjusting the compensating voltage on the source range detector

c. Could result in a very short period due to the reactor going critical before the neutron population is built up high enough to be read on nuclear instrumentation

d. Would be very slow due to the long time to build up the neutron population from such a low level

QUESTION A.06 [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.07 [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.08 [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

QUESTION A.09 [1.0 point]
Which factors of the six factor formula are affected by an INCREASE in core temperature and how are they affected? L_f - Fast non-leakage probability L_t – Thermal non-leakage probability ε - Fast fission factor p – Resonance escape probability η – Thermal fission factor f – Thermal utilization factor

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

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

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

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

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

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

QUESTION A.11 [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.12 [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 (kinetic energy)

QUESTION A.13 [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.14 [1.0 point]
Reactor is critical. What would be the corresponding k_{eff} when removing 0.06 Δk/k from its criticality?

a. 0.9244

b. 0.9433

c. 0.9753

d. 1.0526

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

QUESTION A.15 [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.16 [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.17 [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.18 [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%

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

QUESTION A.19 [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.20 [1.0 point]

What is the condition of the reactor when $k = \frac{1}{1-\beta}$? (Note: β not β_{eff})

a. Subcritical

b. Critical

c. Super critical

d. Prompt critical

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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.01 [1.0 point]
Which ONE of the following reactor primary coolant conditions is a violation of MITR Technical Specifications?

a. Primary coolant conductivity is 5 μS/cm

b. Primary coolant flow rate is 35 gpm

c. Primary coolant outlet temperature is 60°C

d. Primary coolant pH is 6.0

QUESTION B.02 [1.0 point]
In accordance with MITR emergency plan exposure guidelines, the emergency task "protection of major equipment not vital for the nuclear safety of the reactor" is priority _____ with maximum exposure guideline _____.

a. Low, 5 Rem

b. Low, 10 Rem

c. High, 25 Rem

d. High, >25 Rem

QUESTION B.03 [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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.04 [1.0 point]
In accordance with MITR emergency plan, which individual is "authorized to terminate or downgrade the emergency and to initiate recovery operation"?

a. SRO with the most years of experience licensed at MITR

b. MITR Radiation Protection Officer

c. Director of Reactor Operations

d. Off-site Emergency Coordinator

QUESTION B.05 [1.0 point]
Per MITR 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. 0.03 Δk/k

c. 0.1% Δk/k

d. 0.3% Δk/k

QUESTION B.06 [1.0 point]
MITR emergency plan states "the operations boundary will be the limits of the ____1.____ while the site boundary will be the ____2.____".

a. 1. Restricted area, reactor parking lot, and all of NW12, 2. containment building

b. 1. Containment building 2. restricted area, reactor parking lot, and all of NW12

c. 1. Protective action guide, 2. containment building

d. 1. Containment building 2. restricted area, reactor parking lot, and all of NW12

QUESTION B.07 [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

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.08 [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

QUESTION B.09 [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.10 [1.0 point]
10 CFR 20 limits the annual occupational exposure to the SKIN of an individual to:

a. 5 rem

b. 15 rem

c. 50 rem

d. 100 rem

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.11 [1.0 point]
Which ONE of the following meets the MINIMUM staffing requirement when the reactor is NOT shutdown?

a. 1 RO in the control room, 1 SRO on site, and 1 health physics technician on call

b. 1 SRO in the control room and 1 health physics technician on call

c. 1 RO in the control room and the Radiation Protection Officer onsite

d. 1 RO in the control room and 1 SRO and the Radiation Protection Officer onsite

QUESTION B.12 [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.13 [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

QUESTION B.14 [1.0 point]
What is the reason a normal reactor startup requires reactor power to be maintained at 1MW for 5 minutes?

a. Allows for cooling tower flow to be switched to spray

b. Prevents buckling of the voltage potentiometers

c. Excess reactivity must be measured prior to achieving full power

d. Thermal equilibrium between the core and coolant reduces stress on fuel cladding

Category B: Normal/Emergency Operating Procedures and Radiological Controls

QUESTION B.15 [1.0 point]
What emergency classification is identified if an individual is contaminated and injured when attempting to maintain the core tank level for an abnormal primary coolant loss?

a. Unusual event

b. Alert

c. Site Area emergency

d. General emergency

QUESTION B.16 [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.17 [1.0 point]
Which ONE of the following is the MAIN purpose for limiting the H_2 concentration in the air space above the core?

a. Prevent liquid concentration on safety systems

b. Prevent flammable concentrations

c. Prevent violation of Federal Regulation limits

d. Prevent implosion due to positive pressure buildup

QUESTION B.18 [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.19 [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. 20 [1.0 point]
Which ONE of the following surveillance checks shall be tested at least quarterly?

a. Power measuring channels

b. Scram times

c. Rod withdrawal and insertion speeds

d. Reactivity worth of control devices

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

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

QUESTION C.01 [1.0 point]
What instrumentation region is associated with "the voltage is such that every primary ion produces an avalanche of secondary ions"? This region also cannot differentiate between types of radiation.

a. Region I, Recombination

b. Region II, Ionization

c. Region III, Proportional

d. Region IV, Geiger-Mueller

QUESTION C.02 [1.0 point]
What is the main reason that, beyond the subcritical position, operating procedures require all six shim blade heights within two inches of each other?

a. Creates more fast neutrons

b. Prevents an unbalanced power distribution

c. Maintains fuel integrity

d. Dissipates residual gammas

QUESTION C.03 [1.0 point]
Which ONE of the following is used to limit the production of Argon-41 in the graphite region?

a. H_2O

b. B^{10}

c. N^{16}

d. CO_2

QUESTION C.04 [1.0 point]
Which ONE of the following, observed on the LED display of the radiation area monitor control unit, is indicated by the display of all "9's"?

a. Detector saturation

b. Control unit test is in progress

c. Over-range of count rate

d. Source check is remotely activated

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

QUESTION C.05 [1.0 point]
MITR Technical Specifications requires fuel elements stored outside of the reactor core in a safe array where the MAXIMUM k_{eff} shall be no more than _____.

a. 0.6

b. 0.7

c. 0.8

d. 0.9

QUESTION C.06 [1.0 point]
Prior to a change in core configuration requires a review and approval by a MINIMUM of the _____ and _____?

a. Reactor Operator and Senior Reactor Operator

b. Two Senior Reactor Operators

c. Reactor Operator and Reactor Engineer

d. Reactor Engineer and Senior Reactor Operator

QUESTION C.07 [1.0 point]
Which ONE of the following will initiate a reactor SCRAM? (Assume reactor is critical)

a. Core purge flow is 2 cfm

b. Reactor outlet temperature is 50^{o}C

c. Shield coolant flow is 55 gpm

d. Primary cleanup temperature is 52^{o}C

QUESTION C.08 [1.0 point]
Which ONE of the following regions of the pulse size versus applied voltage characteristic curve does MIT's emergency channel (8) operate?

a. Proportional

b. Limited proportional

c. Ion chamber

d. Geiger-Mueller

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

QUESTION C.09 [1.0 point, 0.25 each]
Match the input signals listed in Column A with the AUTOMATIC responses listed in Column B. (Answers may be used more than once or not at all; Assume reactor is at full power)

Column A	Column B
a. Dump valve open	1. Normal
b. 9 second period	2. Rod run down
c. D_2O flow rate is 100 gpm	3. Interlock
d. Main intake damper oil pressure is 650 psig	4. Scram

QUESTION C.10 [1.0 point]
MIT Technical Specification requires the worth of all single movable experiments not to exceed _____ and the worth of non-secured single experiments not to exceed _____.

a. 0.2% Δk/k and 0.5% Δk/k

b. 0.3% Δk/k and 0.5% Δk/k

c. 0.4% Δk/k and 0.6% Δk/k

d. 0.5% Δk/k and 0.8% Δk/k

QUESTION C.11 [1.0 point, 0.33 each]
Match the following limitations in Column A with its specification in Column B (Assume natural convection; Answers may be used more than once or not at all)

Column A	Column B
a. Safety Limit	1. Shutdown Margin 1% Δk/k
b. Limiting Safety System Setting	2. Core outlet temperature maximum 60°C
c. Limiting Condition for Operation	3. Maximum 250 kW

QUESTION C.12 [1.0 point]
The reactor is operating at 5.9 MW with an experiment in the pneumatic system. What will the temperature be about 6 minutes after receiving a 'vacuum off pneumatic system' alarm?

a. 50°C

b. 100°C

c. 250 °C

d. 500°C

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

QUESTION C.13 [1.0 point]
Sampling of the secondary system occurs once every 24 hours during normal operation to detect which ONE of the following isotopes?

a. H-3

b. B-10

c. Ar-41

d. I-131

QUESTION C.14 [1.0 point]
Thermal power output is based on a heat balance derived from _____ and _____.

a. Power and coolant level

b. Flow rates and temperature rises

c. Period rise and shutdown margin

d. Count rate and k-effective

QUESTION C.15 [1.0 point]
What is the MAXIMUM number of hours a licensed operator can work in a week?

a. 24 hours

b. 48 hours

c. 60 hours

d. 72 hours

QUESTION C.16 [1.0 point]
In the event of a loss of building power, where will the emergency battery DIRECTLY provide a 120 volt to DC power to?

a. No systems directly receive power from the emergency battery

b. Entire building can be powered by the emergency battery

c. Radiation area, continuous air, and stack gas monitors

d. Emergency lighting panel

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

QUESTION C.17 [1.0 point]
Which ONE of the following conditions will NOT activate the "waste tanks" alarm on the control room scam panel?

a. A leak in the waste tank system

b. Ambient temperature below 32°C

c. Waste tank filled with more than 900 gallons

d. Auxiliary building door is entered during reactor operations

QUESTION C.18 [1.0 point]
Which ONE of the following containment surveillances shall be performed annually?

a. Building overpressure

b. Basement personnel lock gaskets deflated

c. Main personnel lock gaskets deflated

d. Function test of the independent vacuum relief breakers

QUESTION C.19 [2.0 points, 0.5 each]
Match the location or feature in Column A with the respective gases listed in Column B. (Answers may be used more than once or not at all.)

Column A	Column B
a. D_2O Reflector	1. Air
b. Primary Pool Water Void	2. Argon
c. Medical Shutter Blister Tank Cover	3. Helium
d. Pneumatic Tube Operating Gas	4. Nitrogen

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

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

A.01
Answer: b
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 4

A.02
Answer: d
Reference: CR=S/(1-k)→250/(1-0.5) = 500 N/sec

A.03
Answer: a
Reference: NRC previous exam, October, 2014; decreasing core reactivity worth will decrease the core excess

A.04
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 8.1, Page 8-1

A.05
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 5.2.2, Pages 5-2 - 5-4

A.06
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 1, Module 2

A.07
Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 7.2

A.08
Answer: d
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 3.3.2, Page 3-7

A.09
Answer: a
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory*, Volume 2, Module 1

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

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

A.11
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 2.5.1, Pages 2-38-43

A.12
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.13
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 3.3.4, Page 3-20&21
$\Delta\rho=(k_{eff2}-k_{eff1})/(k_{eff1}*k_{eff2}) = (0.966-0.917)/(0.966*0.917) = 0.0553\Delta k/k=5.53\%\Delta k/k$

A.14
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.15
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.16
Answer: b
Reference: Burn, *Introduction to Nuclear Reactor Operations*, Section 6.2.3

A.17
Answer: c
Reference: Burn, *Introduction to Nuclear Reactor Operations,* Section 5.4

A.18
Answer: c
Reference: $P/P_o = 120\%$, T = 20 seconds, t = 0.5, $P/P_o = 120\ e^{\wedge 0.5/20} = 123\%$

A.19
Answer: b
Reference: Chart of the Nuclides

A.20
Answer: d
Reference: LaMarsh, *Introduction to Nuclear Engineering*, Page 340-341
$(1-\beta)k=1$ manipulated reads $k=1/(1-\beta)$

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.1
Answer: b or c
Reference: MITR TS 6.6.1.2, Specification 1.

B.2
Answer: b
Reference: MITR, EP Table 4.7.5.1-1

B.3
Answer: c
Reference: 10CFR20.1003

B.4
Answer: c
Reference: MITR EP 4.3.3.1

B.5
Answer: a
Reference: MITR TS 1.3.43

B.6
Answer: b or d
Reference: MITR EP 4.2.1 i), r), and y)

B.7
Answer: c
Reference: $T\ A = A_{\circ} * e^{-\lambda t}$
$2Ci = 100Ci * e^{-\lambda(t)}$ Note: $\lambda = -\ln 2/t^{1/2} = -0.1315$
$\ln(2/100) = -\ln 2/5.27\ yr * (t)$ --> -3.912/-0.1315 →
solve for t: 29.75 years

B.8
Answer: c
Reference: 10CFR55.53(e)

B.9
Answer: a (check), b (test), c (cal) , d (test)
Reference: MITR TS definitions 1.3.2, 1.3.3, and 1.3.4

B.10
Answer: c
Reference: 10 CFR 20.1201

B.11
Answer: a or d
Reference: MITR TS 7.1.3

B.12
Answer: d
Reference: 20mrad Alpha x 20 = 400mrem, 10mrad Gamma x 1 = 10mrem, 5mrad neutron x 10 = 50mrem → 400mrem + 10mrem + 50mrem = 460mrem

Category B: Normal/Emergency Operating Procedures and Radiological Controls

B.13
Answer: d
Reference: $I_1D_1^2=I_2D_2^2 \rightarrow$ 330mR/hr@$(4ft)^2=I_2$@$(2ft)^2 \rightarrow$1320mR/hr

B.14
Answer: d
Reference: MITR PM 2.3.1 (21)

B.15
Answer: a
Reference: MITR EP, Table 4.5.3-1

B.16
Answer: a (3), b(2), c(1), d(4)
Reference: 10CFR19.11, 10CFR20.1501(2)(i), 10CFR50.34(1)(ii)(A), 10CFR55.21

B.17
Answer: b
Reference: MITR TS 3.3.2

B.18
Answer: d
Reference: 10CFR20.1301(a)(2)

B.19
Answer: d
Reference: I=6CEn=R/hr@ft.$\rightarrow$2Ci x 2Mev x 100% = 24 R/hr@ $(1ft)^2$ =
24 R/hr = 0.1 R/hr@ D^2 = $\sqrt{}$240 R/hr = 15.5 ft.

B.20
Answer: a
Reference: MITR TS 4.2

Category C: Facility and Radiation Monitoring Systems

C.01
Answer: d
Reference: MITR RSM Figure 5.9, NRC standard question

C.02
Answer: b
Reference: MIT RSM 4.2

C.03
Answer: d
Reference: MIT RSM 1.1 and 1.8.3

C.04
Answer: c
Reference: MIT RSM 7.2.1

C.05
Answer: d
Reference: MITR TS 5.4.4 and PM 1.15.1

C.06
Answer: d
Reference: MIT PM 1.15

C.07
Answer: c
Reference: MIT TS Table 3.2.3-1 and RSM 6.5.7

C.08
Answer: c
Reference: MIT RSM 5.6.2

C.09
Answer: a (2), b (4), c (1), d (2)
Reference: MIT TS Table 3.2.3-1, RSM 9.3.1, 9.4.1 and 9.4.3

C.10
Answer: a
Reference: MIT TS 6.1.1

C.11
Answer: a(3), b(2), c(1)
Reference: MIT TS 2.1.2 Table, Table 2.2-1, and 3.1.2

C.12
Answer: b
Reference: MIT PM 5.5.1

C.13
Answer: a
Reference: MIT RSM 7.4.1

Category C: Facility and Radiation Monitoring Systems

C.14
Answer: b
Reference: MIT PM 2.4.2

C.15
Answer: d
Reference: MIT PM 1.14

C.16
Answer: d
Reference: MIT RSM Figure 8.11

C.17
Answer: d
Reference: MIT RSM 8.5

C.18
Answer: d
Reference: MIT TS 4.4.4 and 4.4 basis

C.19
Answer: a(3), b(1), c(3), d(1)
Reference: MIT RSM 2.5, 3.2.5, 3.3.1, 3.3.4