October 8, 2004

Dr. John Bernard, Director
of Reactor Operations
Nuclear Reactor Laboratory
Massachusetts Institute of Technology
138 Albany Street
Cambridge, MA 02139

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-20/OL-04-02, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dear Dr. Bernard:

During the week of September 7, 2004, the NRC administered initial examinations to employees of your facility who had applied for a license to operate your Massachusetts Institute of Technology Reactor. The examination was conducted in accordance with NUREG-1478, "Non-Power Reactor Operator Licensing Examiner Standards," Revision 1. 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 10 CFR 2.390 of the Commission's regulations, 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 (the Public Electronic Reading Room) http://www.nrc.gov/NRC/ADAMS/index.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 Mr. Kevin Witt at 301-415-4075 or internet e-mail kmw@nrc.gov.

Sincerely,

/RA/

Patrick M. Madden, Section Chief
Research and Test Reactors Section
New, Research and Test Reactors Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Docket No. 50-20

Enclosures:
1. Initial Examination Report No. 50-20/OL-04-02
2. Facility comments with NRC resolution
3. Examination and answer key

cc w/encls: Please see next page

cc:

City Manager
City Hall
Cambridge, MA 02139

Department of Environmental
Quality Engineering
100 Cambridge Street
Boston, MA 02202

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

October 8, 2004

Dr. John Bernard, Director
of Reactor Operations
Nuclear Reactor Laboratory
Massachusetts Institute of Technology
138 Albany Street
Cambridge, MA 02139

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-20/OL-04-02, MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Dear Dr. Bernard:

During the week of September 7, 2004, the NRC administered initial examinations to employees of your facility who had applied for a license to operate your Massachusetts Institute of Technology Reactor. The examination was conducted in accordance with NUREG-1478, "Non-Power Reactor Operator Licensing Examiner Standards," Revision 1. 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 10 CFR 2.390 of the Commission's regulations, 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 (the Public Electronic Reading Room) http://www.nrc.gov/NRC/ADAMS/index.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 Mr. Kevin Witt at 301-415-4075 or internet e-mail kmw@nrc.gov.

Sincerely,
/RA/

Patrick M. Madden, Section Chief
Research and Test Reactors Section
New, Research and Test Reactors Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Docket No. 50-20
Enclosures: 1. Initial Examination Report No. 50-005/OL-04-02
2. Facility comments with NRC resolution
3. Examination and answer key
cc w/encls:
Please see next page

DISTRIBUTION:
PUBLIC RNRP/R&TR r/f PMadden KWitt
Facility File (EBarnhill)

ADAMS PACKAGE ACCESSION NO.: ML041700509
ADAMS REPORT ACCESSION NO.: ML042780236 **TEMPLATE #: NRR-074**

OFFICE	RNRP:CE		RNRP:E		IROB:LA		RNRP:SC	
NAME	KWitt:vmj		PDoyle		EBarnhill		PMadden	
DATE	09/30/2004		/ /2004		10/5/2004		10/5/2004	

C = COVER **E = COVER & ENCLOSURE** **N = NO COPY**
OFFICIAL RECORD COPY

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

REPORT NO.: 50-20/OL-04-02

FACILITY DOCKET NO.: 50-20

FACILITY LICENSE NO.: R-37

FACILITY: Massachusetts Institute of Technology

EXAMINATION DATES: September 7-10, 2004

SUBMITTED BY: ______________________________ 9 /30/2004
Kevin Witt, Chief Examiner Date

SUMMARY:

During the week of September 7, 2004, the NRC administered operator licensing examinations to three Senior Reactor Operator (Instant) candidates, two Senior Reactor Operator (Upgrade) candidates, and eight Reactor Operator candidates. All Senior Operator candidates and six Reactor Operator candidates passed the examinations. Two Reactor Operator candidates failed section C of the written examination only. NOTE: Due to reactor criticality issues, the requirement to have all RO and SRO-Instant candidates perform a reactor startup (NUREG-1478, *Non-Power Reactor Operator Licensing Examiner Standards*, Section ES-301N) was waived by the chief examiner.

REPORT DETAILS

1. Examiners:
Kevin Witt, Chief Examiner
Paul Doyle, Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	6/2	3/0	9/2
Operating Tests	8/0	5/0	13/0
Overall	6/2	5/0	11/2

3. Exit Meeting:
Kevin Witt, NRC, Chief Examiner
Frank W. Warmsley, MITR, Training Supervisor
Edward S. Lau, MITR, Reactor Superintendent
John Bernard, MITR, Director of Reactor Operations

The NRC thanked the facility staff for their assistance and cooperation during the examination. The facility staff presented the Chief Examiner with comments on the written examination. Generic weaknesses noted were minor, and were discussed with the facility staff. The Chief Examiner requested that the facility include all maintenance and surveillance procedures for the next examination that will be administered at the facility.

Facility Comments with NRC Resolution

Question B.1:
What would the expected radiation levels be at the surface of the pool with the reactor operating at a power less then 100 kW and the reactor top shield lid removed?

A. 1 mR/hr

B. 100 mR/hr

C. 1 R/hr

D. 100 R/hr

Facility Comment:
We suggest this question be removed because the material is from the MITR-III SAR, which is not yet approved, and not a part of our current training. PM 5.0 of the AOPs is the normal source of dose information for various operating conditions and power histories. However, it doesn't address 100 kW operation. Also, the question does not indicate whether the 100 kW follows a period of prolonged operation for which there would be high levels of Na-24 or a long shutdown time for which there would be no Na-24.

NRC Resolution:
Comment accepted. The question will be deleted and will not factor into the candidates grades. In the future the question will be modified accordingly.

Question B.2:
What is the primary concern if there are fission products circulating in the primary coolant?

A. Radiation levels, especially in the equipment room, may be excessively high.

B. Corrosiveness of fission products will lead to a leak in the primary coolant system.

C. Cooling of the fuel elements will be decreased due to lower thermal conductivity.

D. Release of fission products to the environment can expose the public to radiation.

Facility Comment:
We suggest answers (a) and (d) both be acceptable because both are legitimate concerns if fission products are circulating in the primary coolant. (Note: For answer (d), see PM (AOP) 5.2.3 - Immediate Action - Step 3).

NRC Resolution:

Comment not accepted. The question asks the candidate to identify the main hazard if the coolant contains suspended radioactive materials in the form of fission products. According to PM 4.5.1.a, *Review of Accident Potentials: Loss of Coolant*, “there is no credible accident that could cause any one, let alone all three, of the [coolant] barriers to fail.” Since it is not deemed to be credible that the coolant can escape from the tanks, there is a very low likelihood that there would be a release of fission products in the coolant to the environment, therefore answer (d) cannot be considered to be correct.

Question B.14:

Which ONE of the following emergency scenarios is considered to be the MOST credible at the MITR-II?

A. Loss of coolant below the level of the anti-siphon valves..

B. Improper handling or storage of spent fuel.

C. Containment building fire resulting in failure of a safety system.

D. Blockage of fuel element cooling channels.

Facility Comment:

We suggest this question be removed because the official answer of “blockage of fuel element cooling channels” is taken from PM 4.5.2 which categorizes accidents as (1) credible accidents possibly leading to an offsite radiological emergency, (2) credible accidents not leading to an off-site radiological emergency, or (3) very-low probability accidents. It does not refer to which is the “most” credible. All of the answers given in this section are listed as per PM 4.5.2 and all would be equally valid answers. PM 4.5.2 does not address the issue of “most”.

NRC Resolution:

Comment accepted. The question will be deleted and will not factor into the candidates grades. In the future the question will be modified accordingly.

Question C.8:

Which ONE of the following activates the secondary city-water makeup system?

A. Manual switch in control room.

B. Valve in physics lab.

C. Low level detection in the basins of both of the cooling towers.

D. Low flow detection in suction line of main secondary pumps.

Facility Comment:

We suggest answers (a), (b), and (c) all be acceptable. Answer (a) is for manual initiation; answer (b) is the shut-off valve; answer (c) is for automatic initiation. (See RSM diagram of Secondary Coolant System).

NRC Resolution:
Comment accepted. As specified in NUREG-1478, *Non-Power Reactor Operator Licensing Examiner Standards*, Section ES-403N, if three or more answers could be considered correct, the question shall be deleted. The question will be deleted and will not factor into the candidates grades.

Question C.10:
During a NORMAL reactor startup, which ONE of the following contributes to defeating the subcritical interlock?

A. Waiting for the power level to reach a stable level.

B. Pulling and holding the “subcritical-bypass” joystick.

C. Having all shim blades at the subcritical position.

D. Withdrawing the regulating rod to reach a critical power level.

Facility Comment:
We suggest answers (b) and (c) both be acceptable because both are normal means of satisfying the subcritical interlock. Answer (c) contributes to meeting the interlocks requirements, while answer (b) is a means of defeating (i.e. bypassing) it. (See RSM Pg. 4-3). The question hinges on the words ‘normal’ and ‘defeating’. We describe startups as ‘routine’ and ‘non-routine’ (PM 2.3.2) but not as ‘normal’ or ‘abnormal’. So, the word ‘defeating’ does have special meaning in that one bypasses the interlock during blade calibrations, which are otherwise done using the routine (normal) startup procedure (RSM 4-3). Hence, the question’s language points to both (b) or (c) as valid answers.

NRC Resolution:
Comment accepted. The answer key will be modified to accept both “b” and “c” as correct answers.

Question C.11:
Which ONE of the following neutron flux detectors provides a signal indicating the Log N period of the reactor?

A. Fission chamber

B. Compensated ion chamber

C. Gamma ion chamber

D. Boron-trifluoride detector

Facility Comment:
We suggest answers (a), (b), and (c) be acceptable because the Log N period signal is fed by the fission chambers and gamma ion chambers of Nuclear Safety System Channels 1 and 2, as well as by the compensated ion chamber of Channel 3. (See RSM Section 5.3.1 as well as 5.3.2. Also see Figure 5.3 of RSM Pg. 5-14 which shows that Channel 1,2 and 3 feed to the Log N recorder).

NRC Resolution:
Comment accepted. As specified in NUREG-1478, *Non-Power Reactor Operator Licensing Examiner Standards*, Section ES-403N specifies if three or more answers could be considered correct, the question shall be deleted. The question will be deleted and will not factor into the candidates grades.

Question C.18:
Which ONE of the following materials are the in-core sample assemblies constructed of?

A. Titanium

B. Stainless steel

C. Cadmium

D. Aluminum

Facility Comment:
We suggest answers (a), (b), and (d) all be acceptable because in-core sample assemblies have been constructed using all three materials. (Note: The outer material is normally aluminum, but it could be stainless steel (see TS 5.2.2(b) and TS 5.3 Specification). The interiors have been aluminum, steel and titanium.)

NRC Resolution:
Comment accepted. As specified in NUREG-1478, *Non-Power Reactor Operator Licensing Examiner Standards*, Section ES-403N, if three or more answers could be considered correct, the question shall be deleted. The question will be deleted and will not factor into the candidates grades.

Question C.19:
Which ONE of the following is correct regarding the loss of normal electrical power?

A. Wall receptacles are supplied by emergency power in the control room and the medical therapy room.

B. Power must be manually transferred from normal electrical distribution to emergency power distribution.

C. The reactor will continue to operate due to instantaneous transfer to emergency power.

D. Only equipment powered through panel 1A (i.e. primary coolant auxiliary pump MM-2) will operate through emergency power.

Facility Comment:

We suggest answers (a) and (d) both be acceptable because Panel 1A and Panel 1 (Circuits 13-20) are the items supplied by emergency power. Certain control room wall receptacles are picked up. (See RSM Table 8-8-3 on Pg. 8-34 and RSM Section 8.8.2 on Pg. 8-30, especially the third paragraph). (Note: Strictly speaking, none of the answers is correct because:

a) Not all wall receptacles are supplied by emergency power. Only those supplied from Panel #1 Circuit #14 are covered.
b) Not true.
c) Not true.
d) Equipment from Panel #1 (circuits 13-20) and panel #1A are operated on emergency power.

Another point of possible confusion is that the medical room wall receptacles were recently removed from the emergency power system.)

NRC Resolution:

Comment partially accepted. Answer choice (d) says that <u>only</u> equipment powered through panel 1A will operate through emergency power. Since there is equipment that is supplied by emergency power through another circuit panel (Panel 1), this choice cannot be correct. However, since the facility has changed, and the medical room wall receptacles are no longer powered through emergency power, choice (a) cannot be considered correct either. Since no one of the choices is correct, the question will be deleted and will not factor into the candidates grades. As specified in NUREG-1478, *Non-Power Reactor Operator Licensing Examiner Standards*, Section ES-201N, Attachment 1, Enclosure 1, the facility shall provide approved final issues of system descriptions, including the emergency power system.

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

FACILITY:	Massachusetts Institute of Technology
REACTOR TYPE:	MITR-II
DATE ADMINISTERED:	09/07/04
CANDIDATE:	______________________________

INSTRUCTIONS TO CANDIDATE:
Answers are to be written on the answer sheet provided. Attach the answer sheets to the examination. Points for each question are indicated in brackets for each question. A 70% in each section is required to pass the examination. Examinations will be picked up three (3) hours after the examination starts.

Category Value	% of Total	Candidates 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 3

QUESTION A.1 [1.0 point]
Which ONE of the following is the definition of the multiplication factor (K)?

A. The number of neutrons absorbed divided by the number of neutrons leaked.

B. The number of neutrons available to fission with the fuel material divided by the total number of neutrons.

C. The number of neutrons born at high energies divided by the number of neutrons born at low energies.

D. The number of neutrons produced in one generation divided by the number of neutrons produced in the previous generation.

QUESTION A.2 [1.0 point]
Delayed neutrons are born at ________ energies then prompt neutrons which leads to the **effective** delayed neutron fraction being _______ then the delayed neutron fraction.

A. higher; higher

B. higher; lower

C. lower; higher

D. lower; lower

QUESTION A.3 [1.0 point]
What is the reactivity for a reactor that is exactly critical?

A. 0 β

B. 0.0768 β

C. 1 β

D. 1000 β

(*** Category A continued on next page *****)**

QUESTION A.4 [1.0 point]
Which ONE of the following will be seen when the reactor is at power between control rod 1 - a normal control rod; and control rod 2 - a control rod with twice as much poison content? (Assume that both rods are exposed to the same conditions - same core position and flux profile)

Control rod 2 will...

A. have twice the reactivity worth of control rod 1.

B. have half the reactivity worth of control rod 1.

C. last half as long as control rod 1.

D. last twice as long as control rod 1.

QUESTION A.5 [1.0 point]
What effect does Doppler Broadening for U-238 have on neutrons in a critical core?

A. More absorption

B. More fissioning

C. More scattering

D. More leakage

QUESTION A.6 [1.0 point]
Xe-135, which is one of the largest poisons in an operating reactor, is created mostly through the decay of Te-135. Where does Te-135 come from?

A. Structural materials in the core.

B. Fission of U-235.

C. Burnable poison in the fuel.

D. Delayed neutron precursor.

(*** Category A continued on next page *****)**

QUESTION A.7 [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.8 [1.0 point]
Which ONE of the following parameter changes will require control rod INSERTION to maintain constant power level following the change?

A. Removal of an experiment containing cadmium.

B. Insertion of a void into the core.

C. Pool water temperature increase.

D. Buildup of samarium in the core.

QUESTION A.9 [1.0 point]
Which ONE of the following atoms will cause a neutron to lose the most energy in an elastic collision?

A. U-238

B. Pb-208

C. C-12

D. H-1

(*** Category A continued on next page *****)**

QUESTION A.10 [1.0 point]
A 1/M curve is being generated as fuel is loaded into a core. After some fuel elements have been loaded, the count rate existing at that time is taken to be the new initial count rate, CR_0. Additional elements are then loaded and the inverse count rate ratio continues to decrease. As a result of changing the initial count rate:

A. criticality will occur with the same number of elements loaded.

B. criticality will occur earlier (i.e. with fewer elements loaded.)

C. criticality will occur later (i.e. with more elements loaded.)

D. criticality will be completely unpredictable.

QUESTION A.11 [1.0 point]
Which ONE of the reactions below is an example of a photoneutron source?

A. $_{92}U^{238} \rightarrow {}_{35}Br^{87} + {}_{57}La^{148} + 3n + \gamma$

B. $_{1}H^{2} + \gamma \rightarrow {}_{1}H^{1} + n$

C. $_{51}Sb^{123} + n \rightarrow {}_{51}Sb^{124} + \gamma$

D. $_{4}Be^{9} + \alpha \rightarrow {}_{6}C^{12} + n$

QUESTION A.12 [1.0 point]
The reactor is at a power of 1 watt, with a 26 second stable period. How long will it take for power to reach 1000 watts?

a. ~180 seconds

b. ~153 seconds

c. ~121 seconds

d. ~78 seconds

(*** Category A continued on next page *****)**

QUESTION A.13 [1.0 point]
Suppose that the reactor is shutdown with a K_{eff} of 0.84, and β_{eff} is 0.00786. Calculate the amount of reactivity required to achieve criticality.

A. 12.8 β

B. 16 β

C. 24 β

D. 30 β

QUESTION A.14 [1.0 point]
Which ONE of the following is the reason that Xenon peaks after a shutdown?

A. Xenon decays faster than Iodine decays

B. Xenon decays faster than Tellurium

C. Iodine decays faster than Xenon decays

D. Tellurium decays faster than Xenon decays

QUESTION A.15 [1.0 point]
Excess reactivity is the amount of reactivity:

A. associated with samples.

B. needed to achieve prompt criticality.

C. available above that which is required to make the reactor subcritical.

D. available above that which is required to keep the reactor critical.

(*** Category A continued on next page *****)**

QUESTION A.16 [1.0 point]
Why is the stable negative period following a scram always the same value, regardless of initial power level?

The rate of power change is dependent on the:
A. constant decay rate of prompt neutrons.

B. mean lifetime of the longest lived delayed precursor.

C. mean lifetime of the shortest lived delayed neutron precursor.

D. constant decay rate of prompt gamma emitters.

QUESTION A.17 [1.0 point]
Based on the time versus exposure rate table below, which ONE of the following is the half life of an experimental sample irradiated in the core?

Time	Exposure Rate
0	20 mR/hr
5 min	15.7 mR/hr
10 min	12.3 mR/hr
15 min	9.6 mR/hr
20 min	7.6 mR/hr

A. 11 min

B. 14 min

C. 17 min

D. 20 min

(*** Category A continued on next page *****)**

QUESTION A.18 [1.0 point]
An Integral Rod Worth (IRW) curve is ________________, while a Differential Rod Worth (DRW) curve is __________.

A. the slope of the DRW curve at the point of withdrawal; the area under the IRW curve up to the point of withdrawal.

B. the total reactivity worth of the rod up to the point of withdrawal; the reactivity change per unit movement of the rod.

C. at its maximum value when the rod is approximately half-way out of the core; at its maximum value when the rod is fully withdrawn from the core.

D. the reactivity change per unit movement of the rod; the total reactivity worth of the rod up to the point of withdrawal.

QUESTION A.19 [1.0 point]
What type of reactivity effect will occur if heavy water leaks from the reflector into the light water reflector at the top of the core and eventually into the core proper?

A. Negative

B. Positive

C. Negative then strongly positive

D. Positive then strongly negative

QUESTION A.20 [1.0 point]
What type of reaction forms the Ar^{41} that we worry about from reactor operations?

A. ${}_{16}S^{38}$ (α, n) ${}_{18}Ar^{41}$

B. ${}_{18}Ar^{40}$ (n, γ) ${}_{18}Ar^{41}$

C. ${}_{19}K^{42}$ (γ, p) ${}_{18}Ar^{41}$

D. ${}_{19}K^{41}$ (n, p) ${}_{18}Ar^{41}$

(*** End of Category A *****)**

QUESTION B.1 [1.0 point] Question deleted due to facility comments
What would the expected radiation levels be at the surface of the pool with the reactor operating at a power less then 100 kW and the reactor top shield lid removed?

A. 1 mR/hr

B. 100 mR/hr

C. 1 R/hr

D. 100 R/hr

QUESTION B.2 [1.0 point]
What is the primary concern if there are fission products circulating in the primary coolant?

A. Radiation levels, especially in the equipment room, may be excessively high.

B. Corrosiveness of fission products will lead to a leak in the primary coolant system.

C. Cooling of the fuel elements will be decreased due to lower thermal conductivity.

D. Release of fission products to the environment can expose the public to radiation.

QUESTION B.3 [1.0 point]
The procedure *“Startup for Less than 100 kW Operation”* (PM 3.1.3) requires the person completing the checklist to bypass the MP-6 and MP-6A scrams. Which ONE of the following is the lowest level of authority that can complete this step?

A. Director of Reactor Operations

B. Superintendent of Reactor Operations

C. Shift Supervisor

D. Reactor Operator

(*** Category B continued on next page *****)**

QUESTION B.4 [1.0 point]
When doing a normal reactor startup, the procedures requires reactor power to be maintained at 1 MW for 5 minutes. What is the reason for this?

A. Excess reactivity must be measured before full power is reached.

B. The method of cooling tower flow must be switched to spray.

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

D. Compensating voltage on some power channels must be adjusted due to increased temperatures.

QUESTION B.5 [1.0 point]
What step should be taken if reactor power does not immediately decrease after a minor scram for an emergency shutdown?

A. Isolate the ventilation system.

B. Dump the heavy water reflector.

C. Secure makeup to and blowdown from the cooling towers.

D. Investigate the cause for the abnormal conditions.

QUESTION B.6 [1.0 point]
The English units for absorbed dose and dose equivalent, respectively, are:

A. Rad; Rem

B. Rem; Becquerel

C. Curie; Sievert

D. Sievert; Gray

(*** Category B continued on next page *****)**

QUESTION B.7 [1.0 point]
Removing a “warning tag” requires approval from a __________ and removing a lockout requires direction from a _________.

A. Senior operator; senior operator

B. Senior operator; console operator

C. Console operator; console operator

D. Console operator; senior operator

QUESTION B.8 [1.0 point]
When is the regulating rod withdrawn during a reactor startup?

A. After the B-10 counter is secured and the power range instrumentation is on scale.

B. When reactor power reaches 10 watts.

C. After all control blades are withdrawn to the subcritical position.

D. After the third control blade is withdrawn to subcritical position.

QUESTION B.9 [½ point each] Question modified during examination administration.
Match the following activities with the placement of the SRO:

A. Recovery from an unplanned shutdown.

B. Routine Insertion/Removal of a graphite thimble sample. (Reactor is S/D)

C. Operation at a steady power level.

D. Normal reactor startup to full power.

1. Must be in control room
2. Must be within allowable distance
3. Does not have to be in facility or on call

(*** Category B continued on next page *****)**

QUESTION B.10 [1.0 point]
Which ONE of the following conditions requires immediate actions during normal reactor operations (Secondary is operating) as specified in the technical specifications?

A. D_2 concentration of 4% in the Helium blanket.

B. The banked position of five shim blades are within 3 inches of each other, with the inoperable blade full out. Assume that the difference between the lowest and the highest blades in the banked position is 3 in. (Comment added during examination administration).

C. The time from initiation of a scram signal to 80% of full insertion is 0.5 seconds for a shim blade.

D. One secondary water radiation monitor is inoperable.

QUESTION B.11 [1.0 point] Question modified during examination administration.
Which ONE of the following will indicate that a shim blade has become stuck/inoperable during normal operations?

A. Reactor stability will be difficult to control when increasing power.

B. Automatic control will detect a problem and give a “Control on Manual” alarm.

C. Reactor period will not change when blade insertion ~~button~~ switch is pressed.

D. Blade drive will start binding and “Shim Servo Error” alarm will appear.

QUESTION B.12 [1.0 point]
Per the Emergency Plan, three (3) emergency classifications are considered credible at the MIT reactor: Alert (A), Notification of Unusual Event (N), and Site Area Emergency (S). Which ONE of the following choices correctly lists the classifications in order from least to most severe?

A. A S N

B. N A S

C. S N A

D. N S A

(*** Category B continued on next page *****)**

QUESTION B.13 [1.0 point]
Which ONE of the following interlocks is NOT required for medical therapy facility operations?

Beam delivery control shutters:
A. must be able to be closed manually as well if they are pneumatically operated.

B. cannot be opened unless the shield door is closed.

C. must be able to be closed from within the medical therapy facility.

D. cannot be opened unless the console operator maintains control over the shutters.

QUESTION B.14 [1.0 point] Question deleted due to facility comments
Which ONE of the following emergency scenarios is considered to be the MOST credible at the MITR-II?

A. Loss of coolant below the level of the anti-siphon valves..

B. Improper handling or storage of spent fuel.

C. Containment building fire resulting in failure of a safety system.

D. Blockage of fuel element cooling channels.

QUESTION B.15 [1.0 point]
Which ONE of the following lists the correct values for the limiting safety system settings with 2 primary pumps operating?

A. W_T = 1800 gpm; P_T = 6.0 MW; L = 4" below overflow pipe; T_{OUT} = 60°C

B. W_T = 900 gpm; P_T = 3.0 MW; L = 4" below overflow pipe; T_{OUT} = 50°C

C. W_T = 900 gpm; P_T = 3.0 MW; L = 4" below overflow pipe; T_{OUT} = 60°C

D. W_T = 1800 gpm; P_T = 6.0 MW; L = 4" below overflow pipe; T_{OUT} = 50°C

(*** Category B continued on next page *****)**

QUESTION B.16 [1.0 point]
Suppose you remove a sample from the core, which contains 5 Ci of Au-190. This source has a half life of 43 minutes and emits 295 keV gamma rays 100% of the time. What will be the approximate dose rate at 5 feet from the source if the sample decays for 10 minutes after being removed from the core? Do NOT take any of the intermediate or subsequent radionuclides into consideration.

A. 100 mrem/hr

B. 200 mrem/hr

C. 300 mrem/hr

D. 400 mrem/hr

QUESTION B.17 [1.0 point]
Which ONE of the following items will ALLOW a reactor operator to continue to operate the reactor? (Assume today is the two year anniversary of receiving your RO license)

A. Last physical examination was 3 years ago.

B. Written exam administered by Senior Review Board was 10 months ago.

C. 2 hours on the console last quarter performing the functions of a licensed operator.

D. Performing 9 manipulations over the past 2 years.

QUESTION B.18 [1.0 point]
Which ONE of the following federal regulations establish procedures and criteria for the issuance of licenses to operators and senior operators?

A. 10 CFR 20

B. 10 CFR 50

C. 10 CFR 55

D. 10 CFR 73

(*** Category B continued on next page *****)**

QUESTION B.19 [1.0 point]
Nitrogen-16 is produced by neutron absorption of Oxygen-16. A majority of the Nitrogen-16 decays by:

A. a 6.1 MeV gamma with a half-life of 7 seconds.

B. a 1.3 MeV beta with a half-life of 7 seconds.

C. neutron emission with a half-life of 1.8 hours.

D. a 1.3 MeV gamma with a half-life of 1.8 hours.

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

QUESTION C.1 [1.0 point]
How is the regulating control rod attached to its rod drive during normal operations?

A. Shaft and pin

B. Solenoid gripper

C. Electro-magnet

D. Welded

QUESTION C.2 [1.0 point]
In the event of an extended reactor shutdown, which ONE of the following neutron sources would be used for a reactor startup?

A. AmBe

B. PoBe

C. PuBe

D. SbBe

QUESTION C.3 [1.0 point] Question modified during examination administration.
Which ONE of the following best describes the design of the fuel elements used in the MITR-II? Neglect the notch on the element.

A. The top and bottom are the same, and the element's sides can fit two ways into the grid plate.

B. The top and bottom are different, and the element's sides can fit two ways into the grid plate.

C. The top and bottom are the same, and the element's sides can only fit one way into the grid plate.

D. The top and bottom are different, and the element's sides can only fit one way into the grid plate.

(*** Category C continued on next page *****)**

QUESTION C.4 [1.0 point] Question modified during examination administration.
Which ONE of the following is TRUE at full power regarding the vertical thimbles in the graphite reflector?

A. A Nitrogen gas purge is used to reduce the production of Ar-41.

B. The cooling water in the thimbles is provided by the shield coolant system.

C. The thimbles are designed to accommodate sample removal during reactor operations.

D. There are a total of 8 vertical thimbles in the graphite reflector.

QUESTION C.5 [1.0 point]
Which ONE of the following is NOT a function of the primary cleanup system?

A. Provide emergency core cooling spray.

B. Maintain level within the core tank.

C. Remove decay heat during reactor shutdown.

D. Supply cooling for the lead thermal shields.

QUESTION C.6 [½ point each]
Match the following reactor components with their respective cover gases:

A.	Core tank	1.	Helium
B.	Heavy Water Reflector	2.	Carbon Dioxide
C.	Graphite Reflector	3.	Air
D.	Thermal Shield Coolant Storage Tank	4.	Nitrogen

(*** Category C continued on next page *****)**

QUESTION C.7 [1.0 point]
Where does overflow from the D_2O reflector tank go?

A. Heat exchanger HE-D1.

B. Reflector cleanup loop.

C. Reflector storage tank.

D. Reflector dump tank.

QUESTION C.8 [1.0 point] Question deleted due to facility comments
Which ONE of the following activates the secondary city-water makeup system?

A. Manual switch in control room.

B. Valve in physics lab.

C. Low level detection in the basins of both of the cooling towers.

D. Low flow detection in suction line of main secondary pumps.

QUESTION C.9 [1.0 point]
What type of detectors are used in the reactor floor Argon-41 monitor?

A. Geiger-Mueller

B. Proportional counter

C. Ionization chamber

D. β^- Scintillation

(*** Category C continued on next page *****)**

QUESTION C.10 [1.0 point]
During a NORMAL reactor startup, which ONE of the following contributes to defeating the subcritical interlock?

A. Waiting for the power level to reach a stable level.

B. Pulling and holding the "subcritical-bypass" joystick.

C. Having all shim blades at the subcritical position.

D. Withdrawing the regulating rod to reach a critical power level.

QUESTION C.11 [1.0 point] Question modified during examination administration
Question deleted due to facility comments
Which ONE of the following neutron flux detectors provides a signal indicating the Log N period of the reactor at full power?

A. Fission chamber

B. Compensated ion chamber

C. Gamma ion chamber

D. Boron-trifluoride detector

QUESTION C.12 [1.0 point]
Which ONE of the following temperature measuring devices utilizes the presence of a temperature difference that can be seen by the voltage generated between two dissimilar metals?

A. Resistance temperature detector

B. Bimetallic thermometer

C. Capillary tube type thermoswitch unit

D. Thermocouple

(*** Category C continued on next page *****)**

QUESTION C.13 [1.0 point]
Which ONE of the following conditions in the thermal shield cooling system will cause a SCRAM of the reactor?

A. High pressure

B. Low pressure

C. High temperature

D. Low temperature

QUESTION C.14 [1.0 point]
Where in the ventilation system is the filtering unit (coarse and absolute filters) located?

A. Entrance of the plenum.

B. Before the fast-closing exhaust butterfly damper.

C. Before the two inlet bleeder ducts for the stack exhaust fan.

D. After the stack exhaust fans.

(*** Category C continued on next page *****)**

QUESTION C.15 [1.0 point]
Which ONE of the following correctly describes the method for determining the location of a leak in the primary system using the leak detection system? [Question will be modified in the future due to a system change]

A. The neon lamp that is illuminated on the leak alarm console is compared to the leak tape location list.

B. Buttons are pressed individually until the illuminated neon lamp on the leak alarm console is extinguished.

C. A knowledgeable staff member must physically check each tape location in the set to verify where the leak is.

D. All push buttons in the leaking set must be pressed simultaneously until the annunciator panel alarm clears.

QUESTION C.16 [1.0 point]
Which ONE of the following instruments does NOT provide indication in the ESC (Operations Office)?

A. Reactor power

B. Reactor floor radiation level

C. Wind direction and speed

D. Core tank level

(*** Category C continued on next page *****)**

QUESTION C.17 [1.0 point]
If during an accident the Containment Building begins to approach its design pressure, what design feature provides for containment protection?

A. A pressure relief blower automatically initiates at 2.0 psig.

B. A containment relief valve will automatically open at 1.75 psig.

C. A manually operated relief valve may be opened to protect containment.

D. The main damper will cycle open and closed to maintain containment pressure less than 1.75 psig.

QUESTION C.18 [1.0 point] Question deleted due to facility comments
Which ONE of the following materials are the in-core sample assemblies constructed of?

A. Titanium

B. Stainless steel

C. Cadmium

D. Aluminum

(*** Category C continued on next page *****)**

QUESTION C.19 [1.0 point] Question deleted due to facility comments
Which ONE of the following is correct regarding the loss of normal electrical power?

A. Wall receptacles are supplied by emergency power in the control room and the medical therapy room.

B. Power must be manually transferred from normal electrical distribution to emergency power distribution.

C. The reactor will continue to operate due to instantaneous transfer to emergency power.

D. Only equipment powered through panel 1A (i.e. primary coolant auxiliary pump MM-2) will operate through emergency power.

(*** End of Category C *****)**

Section A: R$_x$ Theory, Thermodynamics & Facility Operating Characteristics ANSWERS

A.1 D
REF: MITR II Reactor Physics Notes - Reactor Startup and Reactor Subcritical Multiplication

A.2 C
REF: MITR II Reactor Physics Notes - Reactor Kinetics Section (c)

A.3 A
REF: MITR II Reactor Physics Notes - Reactor Kinetics Section (a)

A.4 D
REF: MITR II Reactor Physics Notes - Reactor Feedback Section (1)

A.5 A
REF: MITR II Reactor Physics Notes - Reactor Feedback Section (5)(b)

A.6 B
REF: MITR II Reactor Physics Notes - Reactor Feedback Section(e)

A.7 C
REF: MITR II Reactor Physics Notes - Reactor Kinetics

A.8 A
REF: Standard NRC Question...

A.9 D
REF: Glasstone and Sesonske, *Nuclear Reactor Engineering*, Chapter 3, Section 3.77

A.10 A
REF: MITR II Reactor Physics Notes - Reactor Startup and Reactor Subcritical Multiplication

A.11 B
REF: Glasstone and Sesonske, *Nuclear Reactor Engineering*, Chapter 2, Section 2.73

A.12 A
REF: MITR II Reactor Physics Notes - Reactor Kinetics Section (g) - Reactor Period

$$= P_0 \, e^{\frac{t}{-}}$$

A.13 C
REF: Standard NRC Question...

$$\rho = \frac{K_{eff} - 1}{K_{eff}} = \frac{0.84 - 1}{0.84} = -\frac{0.16}{0.84} = -0.19\,\delta k/k = \frac{-0.19\,\delta k/k}{0.00786\,\frac{\delta k/k}{\beta}} = 23.809\beta \approx 24\beta$$

A.14 C

REF: MITR II Reactor Physics Notes - Reactor Feedback Section(e)

A.15 D

REF: Glasstone and Sesonske, *Nuclear Reactor Engineering*, Chapter 5, Section 5.114

A.16 B

REF: MITR II Reactor Physics Notes - Reactor Kinetics Section(e)

A.17 B

REF: Standard NRC Question

$$DR = DR_0 e^{-\lambda t} \rightarrow 12.3 = 20e^{-\lambda * 10} \rightarrow \lambda = -1 * \frac{\ln\left(12.3/20\right)}{10} = 0.0486\,\text{min}^{-1}$$

$$t_{1/2} = \frac{\ln 2}{\lambda} = \frac{\ln 2}{0.0486\,\text{min}^{-1}} = 14.258\,\text{min}$$

A.18 B

REF: MITR II Reactor Physics Notes - Reactor Feedback - Control Rod Calibration Experiment

A.19 D

REF: MITR-II RSM Pg. 10-11

A.20 B

REF: Standard NRC Question

$${}_{8}Ar^{40} + {}_{0}n^{1} \rightarrow {}_{8}Ar^{41} + \gamma$$

Section B: Normal / Emergency Procedures & Radiological Controls ANSWERS

B.1 C Question deleted
REF: Safety Analysis Report for the MIT Research Reactor (MITR-III) Rev. 1 Pg. 4-25

B.2 A
REF: PM 5.2.3 - Follow-Up Action - Step 1

B.3 D
REF: PM 1.9.2

B.4 C
REF: PM 2.3.1 - Step 21

B.5 B
REF: PM 2.5.2 - Step 2

B.6 A
REF: Glasstone and Sesonske, *Nuclear Reactor Engineering; Third Edition*, Pg. 778

B.7 D
REF: PM 1.14.3 - Step 4 and Step 6

B.8 C
REF: PM 2.3.1 - Step 6

B.9 A 1; B 2; C 2; D 1
REF: PM 2.3.3
PM 1.14.2.3 - Step 5&6
PM 1.14.1 - Step 2
PM 2.3.1 - Precondition # 3

B.10 B
REF: TS 3.11 (#2.c)

B.11 C
REF: PM 5.8.9

B.12 B
REF: PM 4.4

B.13 D
REF: TS 6.5 (#5.a-f); Pg. 6-22

B.14 D Question deleted
REF: PM 4.5.2

B.15 A
REF: TS 2.2

B.16 C
REF: Standard NRC Question

$$\lambda = \frac{\ln 2}{t_{1/2}} = \frac{\ln 2}{43\min * 60 \sec/\min} = 2.69E-4\,s^{-1}$$

$$A = A_0 e^{-\lambda t} = 5Ci * e^{-\left(2.69E-4\sec^{-1} * 600\sec\right)} = 4.26Ci$$

$$DR = \frac{6CiE(n)}{d^2} = \frac{6 * 4.26Ci * .295\,MeV}{5\,ft^2} = .302\,rem/hr$$

B.17 B
REF: PM 1.16.1.3

B.18 C
REF: 10 CFR 55.1(a)

B.19 A
REF: Chart of The Nuclides: http://www2.bnl.gov/ton

Section C: Facility and Radiation Monitoring Systems ANSWERS

C.1 D
REF: MITR-II RSM Pg. 1-11

C.2 C
REF: Safety Analysis Report for the MIT Research Reactor (MITR-III) Rev. 1 Pg. 4-19

C.3 A
REF: MITR-II RSM Pg. 1-5

C.4 B
REF: MITR-II RSM Pg. 2-8

C.5 D
REF: Safety Analysis Report for the MIT Research Reactor (MITR-III) Rev. 1 Pg. 5-2

C.6 A–3; B–1; C–2; D–3
REF: MITR-II RSM Pg. 3-4
MITR-II RSM Pg. 1-6
MITR-II RSM Pg. 1-11
MITR-II RSM Pg. 3-16

C.7 D
REF: Safety Analysis Report for the MIT Research Reactor (MITR-III) Rev. 1 Pg. 5-33

C.8 C Question deleted
REF: MITR-II RSM Pg. 3-14

C.9 A
REF: MITR-II RSM Pg. 7-7

C.10 C and B [2nd answer added per facility comments]
REF: MITR-II RSM Pg. 4-3

C.11 B Question deleted
REF: MITR-II RSM Pg. 5-7

C.12 D
REF: MITR-II RSM Pg. 6-3

C.13 B
REF: MITR-II RSM Pg. 6-35

C.14 C
REF: MITR-II RSM Pg. 8-15

C.15 B
REF: MITR-II RSM Pg. 3-11

C.16 A
REF: MITR-II RSM Pg. 9-21

C.17 C
REF: MITR-II RSM Pg. 8-22

C.18 D Question deleted
REF: MITR-II RSM Pg. 2-12

C.19 A Question deleted
REF: MITR-II RSM Pg. 2-31

Section A Ŗ Theory, Thermo, and Facility Characteristics

MULTIPLE CHOICE (Circle your choice)
If you change your answer, write your selection in the blank.

A.1 a b c d ___

A.2 a b c d ___

A.3 a b c d ___

A.4 a b c d ___

A.5 a b c d ___

A.6 a b c d ___

A.7 a b c d ___

A.8 a b c d ___

A.9 a b c d ___

A.10 a b c d ___

A.11 a b c d ___

A.12 a b c d ___

A.13 a b c d ___

A.14 a b c d ___

A.15 a b c d ___

A.16 a b c d ___

A.17 a b c d ___

A.18 a b c d ___

A.19 a b c d ___

A.20 a b c d ___

Section B Normal/Emerg. Procedures & Rad Con

MULTIPLE CHOICE (Circle your choice or write your selection for the matching)
If you change your answer, write your selection in the blank.

B.1 a b c d ___

B.2 a b c d ___

B.3 a b c d ___

B.4 a b c d ___

B.5 a b c d ___

B.6 a b c d ___

B.7 a b c d ___

B.8 a b c d ___

B.9 a__ b__ c__ d__

B.10 a b c d ___

B.11 a b c d ___

B.12 a b c d ___

B.13 a b c d ___

B.14 a b c d ___

B.15 a b c d ___

B.16 a b c d ___

B.17 a b c d ___

B.18 a b c d ___

B.19 a b c d ___

Section C Facility and Radiation Monitoring Systems

MULTIPLE CHOICE (Circle your choice or write your selection for the matching)
If you change your answer, write your selection in the blank.

C.1 a b c d ___

C.2 a b c d ___

C.3 a b c d ___

C.4 a b c d ___

C.5 a b c d ___

C.6 a__ b__ c__ d__

C.7 a b c d ___

C.8 a b c d ___

C.9 a b c d ___

C.10 a b c d ___

C.11 a b c d ___

C.12 a b c d ___

C.13 a b c d ___

C.14 a b c d ___

C.15 a b c d ___

C.16 a b c d ___

C.17 a b c d ___

C.18 a b c d ___

C.19 a b c d ___

EQUATION SHEET

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

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

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

$$\lambda_{eff} = 0.1 \text{ seconds}^{-1}$$

$$CountRate = \frac{S}{-\rho} \approx \frac{S}{1 - K_{eff}}$$

$$R_1(1 - K_{eff_1}) = CR_2(1 - K_{eff_2})$$
$$CR_1(-\rho_1) = CR_2(-\rho_2)$$

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

$$M = \frac{1 - K_{eff_0}}{1 - K_{eff_1}}$$

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

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

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

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

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

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

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

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

$$T_{1/2} = \frac{\ln 2}{\lambda}$$

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

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

$$DR = \frac{6CiE(n)}{R^2}$$

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

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

$$A = A_0 \, e^{-\lambda t}$$

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

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 **$^\circ F = 9/5\ ^\circ C + 32$**

1 gal (H_2O) $\approx$ 8 lbm **$^\circ C = 5/9\ (^\circ F - 32)$**

c_P = 1.0 BTU/hr/lbm/$^\circ$F **c_p = 1 cal/sec/gm/$^\circ$C**