February 22, 2001

Mr. Ralph Butler, Chief Operating Officer
Research Reactor Facility
University of Missouri
Columbia, Missouri 65211

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-186/OL-01-01

Dear Mr. Butler:

During the week of January 29, 2001, the NRC administered initial examinations to employees of your facility who had applied for a license to operate your University of Missouri – Columbia Reactor. The examination was conducted in accordance with NUREG-1478, "Non-Power Reactor Operator Licensing Examiner Standards," Revision 1. At the conclusion of the examination, the examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report.

In accordance with 10 CFR 2.790 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 document system (ADAMS). ADAMS is accessible from the NRC Web site at (the Public Electronic Reading Room) http://www.nrc.gov/NRC/ADAMS/indesx.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 Paul Doyle at (301)415-1058 or via Internet E-mail at pvd@nrc.gov.

Sincerely,

/RA/

Ledyard B. Marsh, Chief
Events Assessment, Generic Communications
and Non-Power Reactors Branch
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Docket No. 50-186

Enclosures:
1. Initial Examination Report
   No. 50-186/OL-01-01
2. Facility comments with NRC resolution
3. Examination and answer key (RO/SRO)

cc w/encls:
Please see next page

cc:

University of Missouri
Associate Director
Research Reactor Facility
Columbia, MO 65201

A-95 Coordinator
Division of Planning
Office of Administration
P.O. Box 809, State Capitol Building
Jefferson City, MO 65101

Mr. Ron Kucera, Director
Intergovernmental Cooperation
and Special Projects
Missouri Department of Natural Resources
P.O. Box 176
Jefferson City, MO 65102

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<u>DISTRIBUTION</u> w/ encls.:

PUBLIC	REXB R/F	LMarsh
CBassett, RII	AAdams	PDoyle
Facility File (EBarnhill) O-6 D-17		

ADAMS ACCESSION #: ML010370210 **TEMPLATE #:NRR-074**

OFFICE	REXB:CE	E	IOLB	E	REXB:BC	
NAME	PDoyle		EBarnhill		LMarsh	
DATE	02/ 05 /2001		02/ 14 /2001		02/ 22 /2001	

C = COVER E = COVER & ENCLOSURE N = NO COPY

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

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

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: University of Missouri Columbia

EXAMINATION DATES: January 29-30, 2001

EXAMINER: Paul Doyle, Chief Examiner

SUBMITTED BY: ______*/RA/*______________________ __2/5/2001____
Paul V. Doyle Jr., Chief Examiner Date

SUMMARY:

During the week of January 29, 2001, the NRC administered operator licensing examinations to two reactor operator candidates and one senior reactor operator (instant) candidate. All license candidates passed all portions of their individual examinations.

REPORT DETAILS

1. Examiner: Paul V. Doyle Jr., Chief Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	2/0	1/0	3/0
Operating Tests	2/0	1/0	3/0
Overall	2/0	1/0	3/0

3. Exit Meeting: (Note: UMC = University of Missouri-Columbia)
Paul Doyle, NRC, Chief Examiner
Paul Hobbs, UMC, Reactor Manager
Ralph Butler, UMC, Chief Operating Officer, Research Reactor Facility
Kiratadas “Das” Kutikkad, UMC, Assistant Reactor Manager - Reactor Physics
John Fruits, UMC, Training Coordinator

During the exit meeting Mr. Doyle thanked the University staff for their support in the administration of examination, and informed the facility that he did not note any generic weaknesses during the administration of the operating tests. The facility staff told Mr. Doyle that they would have comments on the written exam e-mailed within the week.

E-Mail received from Les Foyto:

Mr. Doyle,

I have reviewed the Reactor Operator Licensing written examination that you administered to our three candidates at MURR on January 30th and found no major problems. I do have three minor comments though:

1. Question A.13 is no longer applicable to us because (gamma, n) and (n, 2n) reactions in the beryllium reflector as a result of activation products (i.e., structural material) from continued reactor operation have far surpassed the startup neutron population which could be introduced by a neutron source. Our source is used for subcritical multiplication measurements for spent fuel storage racks and shipping casks, and to response check, or "bug," newly installed NI detectors.

2. Question C.6 - Answer a., Source Range Monitor channel 1 inoperative, is also correct. The new Gamma-metrics NI system provides a scram input if any channel on the drawer fails. The old General Electric drawers did not have this feature. Therefore, I believe the answer to this question can be either a or c.

3. Question C.17 - As a future note, I would reword the answer to "Exhaust ducts at the top of the pool."

Other than these minor comments, I thought the exam was straightforward and fair and none of the questions should have caused the candidates any pain or confusion.

If you have any questions please feel free to call or e-mail me.

Respectfully,

Les Foyto
Assistant Reactor Manager - Engineering

NRC Resolution

1. Question A.13, agree in part. Although MURR does not require an external source, it essentially has an “intrinsic” source as described above. The point of the question is not to determine the type of source, but rather why having a source is important. Therefore no grading change will be made at this time. I will make an effort to rewrite the question to show an “intrinsic” source of neutrons in the future.

2. and 3. Comments accepted as written. Examination modified accordingly.

ENCLOSURE 2

UNIVERSITY OF MISSOURI–COLUMBIA

With Answer Key

OPERATOR LICENSING

EXAMINATION

January 30, 2001

ENCLOSURE 3

QUESTION A.1 [2.0 points, 0.5 each]
Match each term in column A with the correct definition in column B.

	Column A		Column B
a.	Prompt Neutron	1.	A neutron in equilibrium with its surroundings.
b.	Fast Neutron	2.	A neutron born directly from fission.
c.	Thermal Neutron	3.	A neutron born due to decay of a fission product.
d.	Delayed Neutron	4.	A neutron at an energy level greater than its surroundings.

QUESTION A.2 [1.0 point]
You enter the control room and note that all nuclear instrumentation show a steady neutron level, and no rods are in motion. Which ONE of the following conditions CANNOT be true?

a. The reactor is critical.

b. The reactor is subcritical.

c. The reactor is supercritical.

d. The neutron source has been removed from the core.

QUESTION A.3 [1.0 point]
A reactor is subcritical with a K_{eff} of 0.955. If you add 4.5% Δk/k of positive reactivity into the core, the reactor will be …

a. subcritical

b. exactly critical

c. supercritical

d. prompt critical

QUESTION A.4 [1.0 point]
Shortly after shutting down the reactor you note that reactor period is a stable negative value. You note reactor power. Three minutes later the reactor is has the same stable negative value and reactor power has decreased by a factor of …

a. 2

b. 2.718 (e)

c. 5

d. 10

QUESTION A.5 [1.0 point]
Which ONE of the following is an example of alpha decay?

a. ${}_{35}Br^{87} \rightarrow {}_{33}As^{83}$

b. ${}_{35}Br^{87} \rightarrow {}_{35}Br^{86}$

c. ${}_{35}Br^{87} \rightarrow {}_{34}Se^{86}$

d. ${}_{35}Br^{87} \rightarrow {}_{36}Kr^{87}$

QUESTION A.6 [1.0 point]
WHICH ONE of the following is the MAJOR source of energy released during fission?

a. Kinetic energy of the fission neutrons.

b. Kinetic energy of the fission fragments.

c. Decay of the fission fragments.

d. Prompt gamma rays.

QUESTION A.7 [1.0 point]
Several processes occur that may increase or decrease the available number of neutrons. SELECT from the following the six-factor formula term that 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. Reproduction factor.

QUESTION A.8 [1.0 point]
Which ONE of the following atoms will cause a neutron to lose the most energy in an elastic collision?

a. $Uranium^{238}$

b. $Carbon^{12}$

c. $Hydrogen^{2}$

d. $Hydrogen^{1}$

QUESTION A.9 [1.0 point]
An experimenter makes an error loading a rabbit sample. Injection of the sample results in a 100 millisecond period. If the scram set point is 12.5 MW and the scram delay time is 0.1 seconds, WHICH ONE of the following is the peak power of the reactor at shutdown. (Assume Rabbit system is operational for this question.)

a. 12.5 MW

b. 25 MW

c. 34 MW

d. 125 MW

QUESTION A.10[1.0 point]
The reactor had been running for 36 hours straight at 10 megawatts when it was shutdown for maintenance. The maintenance took six hours, and you have just restarted the reactor and raised power to 10 megawatts and placed the reactor in auto control. Which ONE of the following is the expected response of the regulating rod for the next half hour?

a. Drive in

b. Drive out

c. Not move

d. Drive out then back in

QUESTION A.11[1.0 point]
You perform two startups with exactly the same conditions (temperature, xenon, samarium, rod speed, etc.). For the first startup you proceed directly to criticality. For the second startup, you stop at two inches below the ECP to change shift personnel. Following shift change the startup proceeds directly to criticality. With respect to control rod height and reactor power at criticality, for the second startup,

a. Rod height will be lower, Power will be the same.

b. Rod height will be higher, Power will be the same.

c. Rod height will be the same, Power will be lower.

d. Rod height will be the same, Power will be the higher.

QUESTION A.12[1.0 point]
The term "prompt jump" refers to:

a. the instantaneous change in power due to raising a control rod.

b. a reactor which has attained criticality on prompt neutrons alone.

c. a reactor which is critical using both prompt and delayed neutrons.

d. a negative reactivity insertion which is less than β_{eff}.

QUESTION A.13[1.0 point]
The PRIMARY reason that a neutron source is installed in the reactor is to …

a. allow for testing and irradiation of experiments when the core is shutdown.

b. supply the neutrons required to start the chain reaction for subsequent reactor startups.

c. provide a neutron level high enough to be monitored for a controlled reactor startup.

d. increase the excess reactivity of the reactor which reduces the frequency for refueling.

QUESTION A.14[1.0 point]
Which ONE of the following describes the response of a SUBCRITICAL reactor to EQUAL insertions of positive reactivity as the reactor approaches criticality? Each reactivity insertion causes …

a. a SMALLER increase in the neutron flux, resulting in a LONGER time to reach equilibrium.

b. a LARGER increase in the neutron flux, resulting in a LONGER time to reach equilibrium.

c. a SMALLER increase in the neutron flux, resulting in a SHORTER time to reach equilibrium.

d. a LARGER increase in the neutron flux, resulting in a SHORTER time to reach equilibrium.

QUESTION A.15[1.0 point]
In a reactor at full power, the thermal neutron flux (β) is 2.5 x 10^{12} neutrons/cm^2/sec. and the macroscopic fission cross-section Σ_f is 0.1 cm^{-1}. The fission reaction rate is:

a. 2.5 x 10^{11} fissions/sec.

b. 2.5 x 10^{13} fissions/sec.

c. 2.5 x 10^{11} fissions/cm^3/sec.

d. 2.5 x 10^{13} fissions/cm^3/sec.

QUESTION A.16[1.0 point]
By definition, an exactly critical reactor can be made prompt critical by adding positive reactivity equal to …

a. the shutdown margin

b. the K_{excess} margin

c. the β_{eff} value

d. 1.0 %ΔK/K.

QUESTION A.17[1.0 point, ¼ each]
Identify each isotope as being produced by the irradiation of air, irradiation of water, or is a fission product.

a. N^{16}

b. Ar^{41}

c. H^{3}

d. Xe^{135}

QUESTION A.18[1.0 point]
The number of neutrons passing through a one square centimeter of target material per second is the definition of which one of the following?

a. Neutron Population (np)

b. Neutron Impact Potential (nip)

c. Neutron Flux (nv)

d. Neutron Density (nd)

QUESTION A.19[1.0 point]
Given a source strength of 100 N/sec and a multiplication factor of 0.8, the expected stable neutron count rate is:

a. 125 N/sec

b. 250 N/sec

c. 400 N/sec

d. 500 N/sec

QUESTION (B.1) [2.0 points, – point each]
Title 10 of the Code of Regulations Parts 1 to 199 contain most NRC Regulations. Identify each of the listed groups of requirements to the applicable part of 10CFR, (20, 50 or 55).

a. Domestic Licensing of Production and Utilization Facilities

b. Standards for Protection against Radiation

c. Operator's Licenses

QUESTION (B.2) [2.0 points, ½ point each]
Match the NRC operator license requirement from column A with the appropriate time period from column B. (Note choices from column B may be used more than once or not at all.)

Column A (Requirement)	Column B (years)
a. Renew license	6
b. Facility administered Requalification Written Examination	4
c. Facility administered Requalification Operating Test	2
d. Medical Examination	1

QUESTION B.3 [2.0 points, ½ point each]
Match the type of radiation in column A with its associated Quality Factor from column B.

Column A	Column B
a. alpha	1
b. beta	2
c. gamma	5
d. neutron (unknown energy)	10
	20

QUESTION (B.4) [1.0 point]
The procedure for starting up the secondary system for 10 Mw operation requires a 5 to 10 minute delay in starting the second pump. Which ONE of the following is the correct reason for this delay?

a. To prevent an electrical overload on the system.

b. To prevent damage to the pump discharge check valves.

c. To prevent a low sump level trip.

d. To prevent water hammer damage to the heat exchangers.

QUESTION (B.5) [1.0 point]
Two inches of shielding reduce the gamma exposure in a beam of radiation from 400 mR/hr to 200 mR/hr. If you add an **additional four inches** of shielding what will be the new radiation level? (Assume all reading are the same distance from the source.)

a. 25 mR/hr

b. 50 mR/hr

c. 75 mR/hr

d. 100 mR/hr

QUESTION (B.6) [1.0 point]
According to Technical Specification 3.1 “Each movable experiments or the movable parts of any individual experiment shall not exceed ____ Δk/k.”

a. 0.001

b. 0.0025

c. 0.006

d. 0.00738

QUESTION (B.7) [1.0 point]
In the case of a partial site area evacuation, according to SOP-5, all personnel who have evacuated the reactor building will proceed to

a. USDA Research Laboratory parking lot

b. Dalton parking lot

c. Science Instrument Shop

d. Research Park Development Building

QUESTION (B.8) [1.0.]
Technical Specification 3.8(d) specifies “All fuel elements or fueled devices outside the reactor core shall be stored in a geometry such that the calculated K_{eff} is less than _____ under all conditions of moderation.”

a. 0.8

b. 0.85

c. 0.9

d. 0.95

QUESTION (B.9) [1.0 point]
Which ONE of the following types of experiments may NOT be irradiated within the confines of the pool?

a. explosive materials

b. fueled experiments

c. materials corrosive to reactor components

d. cryogenic liquids

QUESTION (B.10) [1.0 point]
Per the Emergency plan, “The Emergency Director may authorize personnel voluntary whole body exposures up to ____ rem dose equivalent per individual for lifesaving actions.”

a. 25

b. 50

c. 75

d. 100

QUESTION (B.11) [1.0 point]
The control element drop times were last measured on July 31, 2001. Which one of the following dates is the latest the maintenance may be performed again without exceeding a Technical Specifications requirement?

a. October 31, 2001

b. November 30, 2001

c. December 31, 2001

d. February 28, 2001

QUESTION (B.12) [1.0 point]
The NRC has four standard emergency classifications. Which ONE of the four listed below is NOT applicable at MURR?

a. Notification of Unusual Event

b. General Emergency

c. Site Area Emergency

d. Alert

QUESTION (B.13) [1.0 point]
Which ONE of the following statements correctly describes the relationship between a Safety Limit (SL) and a Limiting Safety System Setting (LSSS)?

a. The SL is a maximum operationally limiting value that prevents exceeding the LSSS during normal operations.

b. The SL is a parameter that assures the integrity of the fuel cladding. The LSSS initiates protective action to preclude reaching the SL.

c. The LSSS is a parameter that assures the integrity of the fuel cladding. The SL initiates protective action to preclude reaching the LSSS.

d. The SL is a maximum setpoint for instrumentation response. The LSSS is the minimum number of channels required to be operable.

QUESTION (B.14) [1.0 point]
You are operating the reactor when it scrams (unscheduled). After looking for hours neither you nor the SRO, nor the shift supervisor can find the reason for the scram. Which one of the following conditions must be met to restart the reactor?

a. You may NOT startup the reactor under any conditions until the cause of the scram is found and corrected.

b. You may startup the reactor if authorized by any Senior Reactor Operator.

c. You may startup the reactor if authorized by the designated Shift Supervisor.

d. You may startup the reactor if authorized by the Reactor Manager.

QUESTION (B.15) [1.0 point]
Which ONE of the following conditions is correct to satisfy containment integrity?

a. Truck door capable of being closed and sealed.

b. Utility seal trench filled with water to maintain a water seal of 2.5 feet.

c. Reactor mechanical equipment room exhaust system including particulate and halogen filters, is operable.

d. Containment building ventilation system automatically closing doors and automatically closing valves are operable or placed in the open position.

QUESTION (B.16) [1.0 point]
You receive 100 mRem of beta (β), 25 mRem of (β) and 5 mRem of neutron radiation dose. What is your total dose?

a. 130 mRem

b. 150 mRem

c. 175 mRem

d. 205 mRem

QUESTION (B.17) [1.0 point]
According to REP-08, which one of the following immediate actions should be taken by the operator if he detects a stuck drive mechanism during reactor power operation?

a. Attempt to drive the effected rod in until power level decreases by 2%

b. Drive all shim rods in verifying the stuck rod fails to move

c. Scram the reactor, noting the position of the stuck rod

d. Stop all rod movement and notify the Shift Supervisor

QUESTION C.1 [1.0 point]
Which ONE of the following is ***NOT*** a feature of the pneumatic tube system designed to limit radiation hazards?

a. Speed at which the sample container is transported through the system.

b. Both blowers energizing simultaneously.

c. Facility exhaust fans operation prevent stagnant air in the vicinity of the rabbit system.

d. Double encapsulation of samples

QUESTION C.2 [1.0 point]
Which ONE of the choices correctly identifies two of the radiation detectors which if either trips will generate a Reactor Isolation?

a. Air Plenum 2 and Nucleopore

b. North wall and Room 114

c. Bridge Alara and Fuel Vault

d. Air Plenum 1 and Bridge

QUESTION C.3 [1.0 point]
Given the following, choose the correct reason that the regulating blade will not go into automatic mode.

Wide Range	10 Kilowatt range with black pen reading higher than red.
Annunciator Panel Status	All lights deenergized except “Reg Blade out of Auto”
IRM 2&3 Period	45 Seconds

a. Wide range meter range selected is too low.

b. Power is too low on selected range.

c. Regulating blade position is too low.

d. Intermediate range period is too short.

QUESTION C.4 [2.0 points, ½ point each]
Identify the components labeled a through d on the figure of the primary system provided. (Note: Only one answer per letter.

a. A	1. Flow Control Valve
	2. Primary Heat Exchanger
b. B	3. Primary Coolant Pump
	4. Pressurizer
c. C	5. Isolation Valve
	6. Flow Orifice
d. D	7. In-Pool Heat Exchanger
	8. Anti-siphon Valves
	9. Pressure Vessel

QUESTION C.5 [1.0 point]
On a loss of normal power, the emergency generator starts …

a. five seconds after the loss, but must be manually transferred back to normal power operation after normal power restoration.

b. one second after the loss, and automatically transfers back to normal power operation immediately after normal power restoration.

c. five seconds after the loss, and automatically shuts down ten minutes after normal power restoration.

d. one second after the loss, and automatically transfers back to normal power operation ten minutes after normal power restoration.

QUESTION C.6 [1.0 point]
Which ONE of the following conditions will result in a reactor scram?

a. Source Range Monitor channel 1 inoperative.

b. High Off-gas Activity.

c. Low Reflector Differential Pressure

d. Thermal Column Door Open

QUESTION C.7 [1.0 point]
Which ONE of the following conditions will ***NOT*** cause a rod run-in?

a. High Power

b. Low Pressurizer Pressure

c. Rod Not in Contact with Magnet

d. Vent Tank Low Level

QUESTION C.8 [1.0 point, – each]
Match the appropriate response condition (1 through 3) with the correct back light color (a through d).

a. Scram	1. Red
b. Rod run-in	2. Yellow
c. Alarm	3. White
	4. Blue

QUESTION C.9 [1.0 point]
Which of the following conditions will **NOT** result in a reactor scram?

a. Low Pool Level

b. Thermal Column Door Open

c. Low Reflector Differential Pressure

d. Low Pool Flow

QUESTION C.10 [1.0 point]
You've been asked to retrieve a rabbit sample. There is some concern that the experimenter made a math error and the sample may have a stronger radiation field than anticipated. Which ONE of the following detectors would you use as you approach the sample?

a. Geiger-Müller

b. GeLi

c. Scintillation

d. Ion Chamber

QUESTION C.11 [1.0 point]
Which ONE of the following signals does NOT feed into the digital power meter?

a. Pool ΔT

b. Pool Flow

c. Primary Demin Flow

d. Channel 4 Power Level

QUESTION C.12 [1.0 point]
Which ONE of the following describes the response of the regulating blade to a reactor scram signal?

a. It's electromagnetic clutch deenergizes and the rod falls into the core via the force of gravity.

b. The rod will be driven into the core.

c. The rod will withdraw in an attempt to compensate for the shim blades insertion.

d. The rod will remain in its position.

QUESTION C.13 [1.0 point]
Which one of the following describes the operation of the containment building ventilation exhaust valves on a loss of electrical power?

a. Air is applied to the close side of the east valve (16A) causing the valve to close

b. Air is applied to the close side of the west valve (16B) causing the valve to close

c. Air is vented from the open side of the west valve (16B allowing spring pressure to close the valve

d. Air is vented from the open side of the east valve (16A) allowing air pressure on the close side to close the valve

QUESTION C.14 [2.0 points, ¼ point each]
Identify the components labeled a through h on the figure of a Control Blade Drive Mechanism provided. (Note: Items are used only once. Only one answer per letter.)

a. ___	1. Drive Tube Bearing
b. ___	2. Gear Motor
c. ___	3. Lead Screw
d. ___	4. Limit Switch Actuator
e. ___	5. Lower Limit Switch and Stop
f. ___	6. Position Transmitter
g. ___	7. Scram Magnet Assembly
h. ___	8. Upper Limit Switch and Stop

QUESTION C.15 [2.0 points, ½ each]
For each status description "a" through "d" of the Alarm and Annunciate System indicate which of the conditions (1) through (4) would result in that status.

a. Illumination On Dim	1. Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.
b. Illumination Flashing	2. Alarm was received but the operator has not yet pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.
c. Illumination On Bright	3. Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition subsequently cleared but the operator has not yet pressed the Reset button.
d. Illumination Off	4. Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition subsequently cleared and the operator pressed the Reset button.

QUESTION C.16 [1.0 point]
Which ONE of the following correctly describes the actions of the automatic shim control circuit?
Shim rods will automatically insert when the regulating rod reaches the ____ withdrawn position. The insertion will be enough to drive the regulating rod to ____ withdrawn.

a. 20% 60%

b. 20% 70%

c. 30% 70%

d. 30% 70%

QUESTION C.17 [1.0 point]
Which one of the following design features minimizes the effects of H^3 (Tritium) at MURR?

a. Vents at the top of the pool

b. Hold up tanks in the primary coolant system

c. Primary demineralize system

d. Controlled release of the gases held in the beam ports

A.1 a, 2; b, 4; c, 1; d, 3
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 2, *Reactor Theory (Neutron Characteristics),* Enabling Objectives 2.12 and 3.1.

A.2 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objectives 1.1, and 3.3,

A.3 a
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 1.3

$SDM = \frac{1-k_{eff}}{k_{eff}} = \frac{1-0.955}{0.955} = \frac{0.045}{0.955} = 0.04712$ *If you add* 0.045, *the result will still be* 0.212% *shutdown*

A.4 d
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 2.6

$P = P_0\ e^{t/\beta}$, where t = 180 seconds and β = -80 seconds, $P/P_0 = e^{-180/80} = 0.1054$

A.5 a
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 1, *Atomic and Nuclear Physics,* Enabling Objective 2.1

A.6 b
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 1, *Atomic and Nuclear Physics,* Enabling Objectives 4.9 and 4.10

A.7 d
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 3, *Reactor Theory (Nuclear Parameters),* Enabling Objective 1.2

A.8 d
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 1, *Atomic and Nuclear Physics,* Enabling Objective 3.1

A.9 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 2.6

P = P0 et/β, P = 12.5 Mw att × $e^{0.1/0.1}$ = 12.5 × e = 33.979.

A.10 a
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 3, *Reactor Theory (Nuclear Par*ameters), Enabling Objective 4.5

A.11 d
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 1.1

A.12 a
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 2.7

A.13 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 1, *Reactor Theory (Reactor Operations),* Enabling Objective 3.1

A.14 b
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 1, *Atomic and Nuclear Physics,* Enabling Objective 1.1

A.15 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 2, *Reactor Theory (Neutron Characteristics),* Enabling Objective 2.10
$R = \beta\ \Sigma_f = (2.5 \times 10^{12}) \times 0.1 = 2.5 \times 10^{11}$

A.16 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective 2.8

A.17 a Water; b, Air; c, Water; d, Fission Product.
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective

A.18 c
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 1, Module 2, *Reactor Theory (Nuclear Characteristics),* Enabling Objective 2.1.b

A.19 d
REF: DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Volume 2, Module 4, *Reactor Theory (Reactor Operations),* Enabling Objective
$CR = S/(1-K_{eff}) = 100 \div (1 - 0.8) = 100 \div 0.2 = 500$

B.1 a, 50; b, 20; c, 55
REF: 10CFR20, 50 & 55.

B.2 a, 6; b, 2; c, 1d, 2
REF: 10CFR55 §§ 53(I), 55, and 59.a(2).

B.3 a, 20; b, 1; c, 1; d, 10
REF: 10CFR20.1004, Table 1004(B)

B.4 c
REF: EBB question 9045, also SOP/VI

B.5 b
REF: 2 inches equal a half-thickness. Adding 4 inches results in a total of three half-thicknesses for (400) × $(½)^3$ = 400/8 = 50 mR/hr

B.6 a
REF: Technical Specification 3.1(I)

B.7 b
REF: SEP-5, § Bc, pg. 1.

B.8 c
REF: Technical Specification 3.8(d).

B.9 d
REF: Technical Specification 3.6(m)

B.10 c
REF: Emergency Plan § 5.01, 4th ¶, pg. 12.

B.11 b
REF: Technical Specification 5.3(a).

B.12 b
REF: MURR Emergency Plan, § 3.0 Classification of Emergency Conditions

B.13 b
REF: T.S. § A Definitions

B.14 d
REF: SOP I.4.3.A

B.15 c
REF: Technical Specifications § 1.15

B.16 a
REF: 10 CFR 20 (A rem is a rem is a rem)

B.17 c
REF: MURR REP-8

C.1 b
REF: HER 8-20–8-25. Also NRC question Bank.

C.2 d
REF: RO Training Manual § II.9. p, II.9.2, 4th ¶.

C.3 c
REF: RO Training Manual § II.14, *Rod Control System*, also SOP II Reactor Operating Procedures § II.1,3 *Assuming Automatic Reactor Control.*

C.4 a, 8; b, 4; c, 5; d, 2
REF: MURR Schematic Diagram of the Primary Coolant System, Figure B.1.

C.5 d
REF: MURR Hazards Summary Report § 7, p. 7-4.

C.6 c
REF: SOP/I-15, I-16–I-18.

C.7 b
REF: MURR SOP/I-15–I-18.

C.8 a. 1 b. 4 c. 3
REF: MURR Training Manual II-67

C.9 b
REF: SOP/I-15, I-16, I-17, I-18

C.10 d
REF: Standard NRC question, also NRC Examination Question Bank (MURR exam administered April, 1994.)

C.11 d
REF: Facility Requalification Examination (11/17/93).

C.12 d
REF: Training Manual for Ros, § II.14 Rod Control System

C.13 b
REF: MURR Training Manual for Reactor Operators Section I.11 pp I

C.14 a, 2; b, 6; c, 8; d, 3; e, 4; f, 5; g, 1; h, 7
REF: MURR Schematic Diagram of a Control Blade Mechanism

C.15 a. 3; b. 2; c. 1; d. 4
REF: MURR Training Manual, p. II-68 MURR Hazards Summary Report, p. 9-19

C.16 a
REF: MURR Training Manual, p. II, also rewrite of NRC question administered July, 1986.

C.17 a
REF: MURR SEA pp 7-2

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

FACILITY: University of Missouri-Columbia

REACTOR TYPE: TANK

DATE ADMINISTERED: 2001/01/30

REGION: III

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	% of Candidates Score	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

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.

13. When you have completed and turned in you examination, leave the examination area. If you are observed in this area while the examination is still in progress, your license may be denied or revoked.

EQUATION SHEET

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

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

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

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

$$SCR = \frac{S}{-\beta} \approx \frac{S}{1 - K_{eff}}$$

$$CR_1(1 - K_{eff_1}) = CR_2(1 - K_{eff_2})$$
$$CR_1(-\beta_1) = CR_2(-\beta_2)$$

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

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

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

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

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

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

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

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

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

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

$$T_{1/2} = \frac{0.693}{\beta}$$

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

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

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

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

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

$$\frac{(\beta_2 - \beta)^2}{Peak_2} = \frac{(\beta_1 - \beta)^2}{Peak_1}$$

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

1 kg = 2.21 lam.

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 lam.

°C = 5/9 (°F - 32)

c_p = 1.0 BTU/hr/lam./°F

c_p = 1 cal/sec/gm/°C

A.1a 1 2 3 4 ___

A.1b 1 2 3 4 ___

A.1c 1 2 3 4 ___

A.1d 1 2 3 4 ___

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.9 a b c d ___

A.10 1 2 3 4 ___

A.11 1 2 3 4 ___

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.17a Air Water FP ___

A.17b Air Water FP ___

A.17c Air Water FP ___

A.17d Air Water FP ___

A.18 a b c d ___

A.19 a b c d ___

B.1a 20 50 55 ___

B.1b 20 50 55 ___

B.1c 20 50 55 ___

B.2a 6 4 2 1 ___

B.2b 6 4 2 1 ___

B.2c 6 4 2 1 ___

B.2d 6 4 2 1 ___

B.3a 1 2 5 10 20 ___

B.3b 1 2 5 10 20 ___

B.3c 1 2 5 10 20 ___

B.3d 1 2 5 10 20 ___

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 ___

C.1 a b c d ___

C.2 a b c d ___

C.3 a b c d ___

C.4a 1 2 3 4 5 6 7 8 ___

C.4b 1 2 3 4 5 6 7 8 ___

C.4c 1 2 3 4 5 6 7 8 ___

C.4d 1 2 3 4 5 6 7 8 ___

C.5 a b c d ___

C.6 a b c d ___

C.7 a b c d ___

C.8a 1 2 3 ___

C.8b 1 2 3 ___

C.8c 1 2 3 ___

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.14a 1 2 3 4 5 6 7 8 ___

C.14b 1 2 3 4 5 6 7 8 ___

C.14c 1 2 3 4 5 6 7 8 ___

C.14d 1 2 3 4 5 6 7 8 ___

C.14e 1 2 3 4 5 6 7 8 ___

C.14f 1 2 3 4 5 6 7 8 ___

C.14g 1 2 3 4 5 6 7 8 ___

C.14h 1 2 3 4 5 6 7 8 ___

C.15a 1 2 3 4 ___

C.15b 1 2 3 4 ___

C.15c 1 2 3 4 ___

C.15d 1 2 3 4 ___

C.16 a b c d ___

C.17 a b c d ___

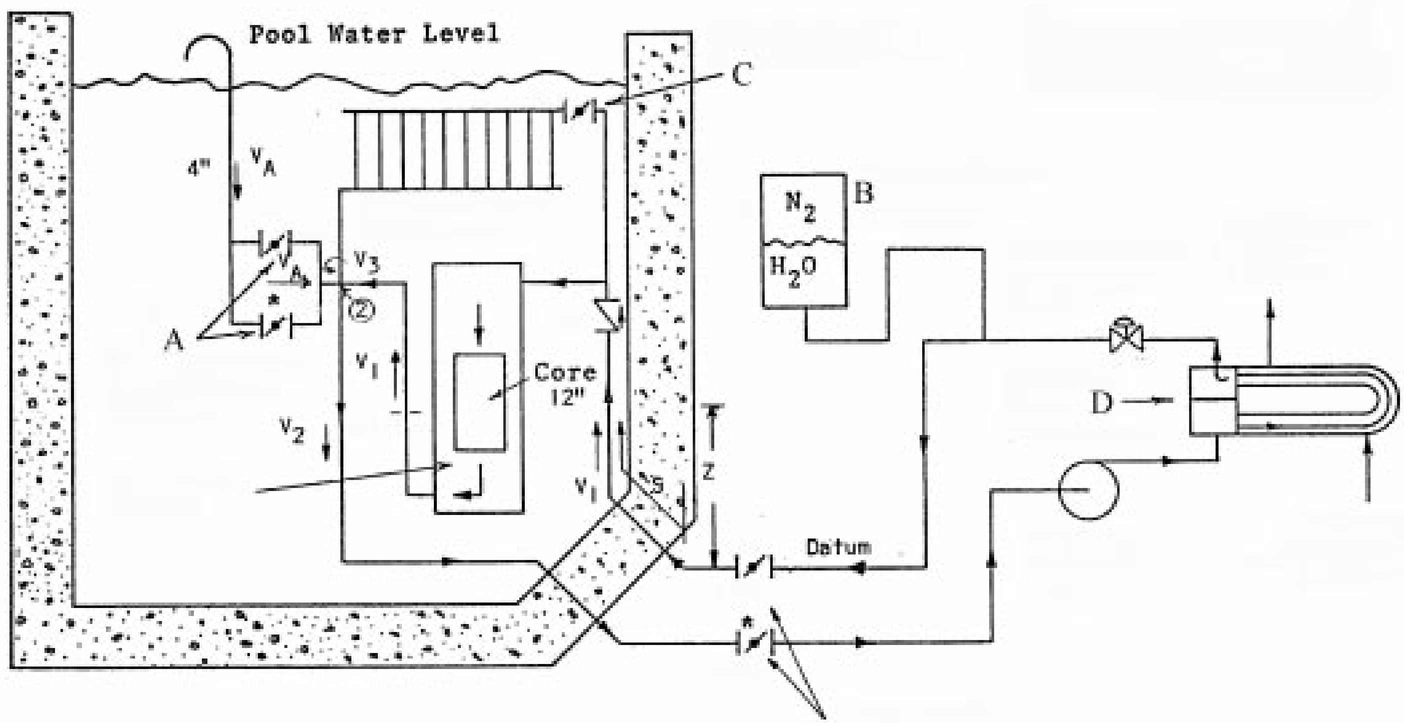
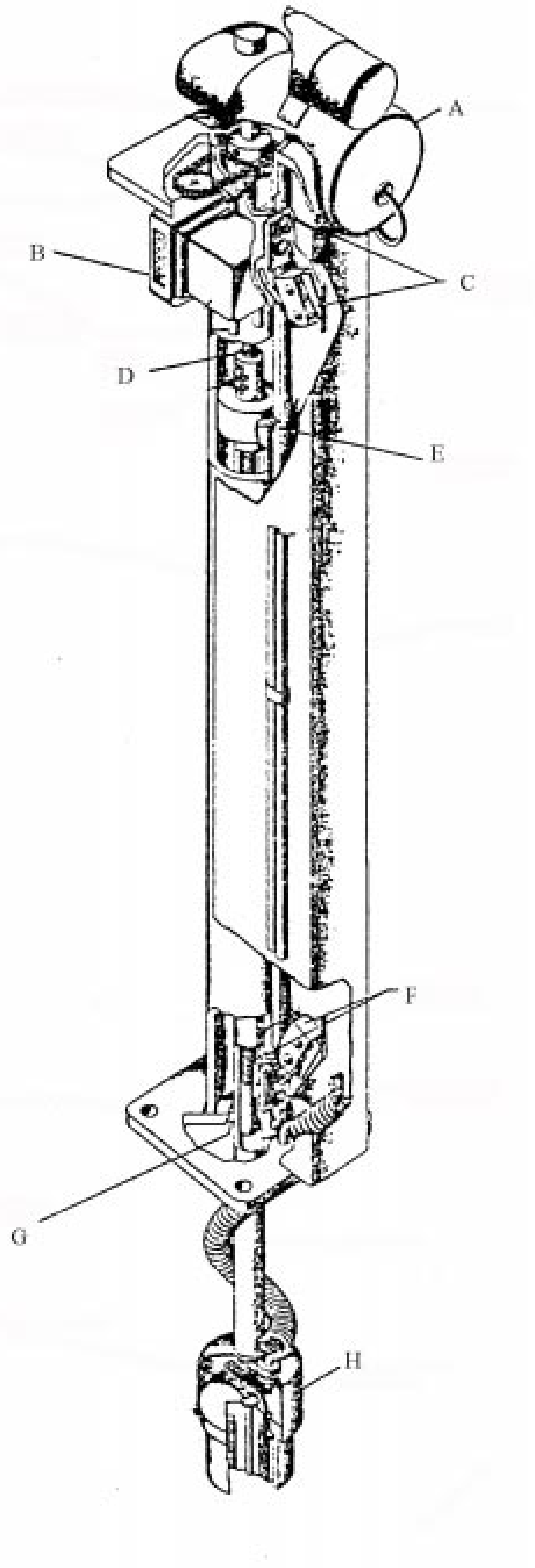


FIGURE B.1
SCHEMATIC DIAGRAM OF THE MURR PRIMARY COOLANT SYSTEM



Control Blade Drive Mechanism