U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No(s). 50-186/OL-85-01

Docket(s) No. 50-186

Licensee: University of Missouri - Columbia
Research Park
Columbia, Missouri 65211

Facility Name: Research Reactor

Examination Administered At: Columbia, Missouri

Examination Conducted: August 27-29, 1985

Examiner(s): E. Plettner
E Plettner

9/12/85
Date

Approved By: J. I. McMillen
J. I. McMillen, Chief
Operator LIcensing Section

9/12/85
Date

Examination Summary

Examination administered on August 27-29, 1985 (Report No(s). 50-123/OL-85-01)
The written examination was administered on August 27, 1985, and oral exams were conducted on August 28 and 29, 1985.
Results: Three candidates successfully completed the examination.

REPORT DETAILS

1. Examiners

   E. Plettner, Region III Chief Examiner

2. Examination Review Meeting

   At the conclusion of the written exam a review was conducted by E. Plettner and W. Meyer. Facility comments were for the most part editorial and have been incorporated in the examination and answer key attached.

3. Exit Meeting

   At the conclusion of the site visit E. Plettner met with W. Meyer to discuss the results of the examination. Those individuals who clearly passed the oral were identified in the meeting.

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U.S. NUCLEAR REGULATORY COMMISSION

REACTOR OPERATOR LICENSE EXAMINATION

Facility:	Univ. Missouri Columbia
Reactor Type:	Pool
Date Administered:	August 27, 1985
Examiner:	E. Pletter
Applicant:	

Instructions to Applicant:

Use separate paper for the answer; staple question sheet on top of the answer sheets. Points for each question are indicated in parenthesis after the question. The passing grade requires at least 70% in each category and a final grade of at least 70%.

Category Value	% of Total	Applicant's Score	% of Cat. Value	
16.0	16			A. Principle of Reactor Operation
15.5	15.5			B. Features of Facility Design
13.5	13.5			C. General Operating Characteristics
13.0	13.0			D. Instruments and Controls
14.0	14.0			E. Safety and Emergency Systems
14.0	14.0			F. Standard and Emergency Operating Procedures
14.0	14.0			G. Radiation Control and Safety
100				

Final Grade ______%

All work done on this exam is my own, I have neither given nor received aid.

____
Applicant's Signature

A. QUESTIONS - Principles of Reactor Operation

A.01 Define

a. Prompt critical (1.0)

b. Subcritical Multiplication (1.0)

A.02 Reactor power increases from 15 watts to 65 watts in 30 seconds. The period of the reactor is: (1.0)

a. 6.9 seconds

b. 13.6 seconds

c. 20.5 seconds

d. 130 seconds

A.03 Explain the production and removal mechanisms for Xe-135 and Sa-149. (3.0)

A.04 Why does your reactor need a neutron source? (Two required for full credit) (2.0)

A.05 What are four reasons why excess reactivity is placed in the core of your reactor? (2.0)

A.06 What is the source of decay heat in reactor? (2.0)

A.07 In each of the following cases indicate the preferred characteristics for a moderator. Briefly explain why for each answer.

a. Absorb neutrons or scatter neutrons (1.0)

b. Have a high atomic weight or low atomic weight. (1.0)

A.08 What does Beta effective refer to in an operating reactor? (1.0)

A.09 Which of the following is a true statement concerning radioactive decay? Remember the atomic number is the number of protons and the mass number is the number of neutrons plus protons. (1.0)

a. When an element decays by beta emission, the new element will have increased in atomic number by one and the mass number will remain the same as the original element.

b. When an element decays by alpha emission, the new element will have decreased in atomic number and mass number by two, from the original element.

c. When an element decays by neutron emission the new element will have increased in atomic number by one and decreased in mass number by one, from the original element.

d. When an element decays by gamma emission, the new element will have increased in atomic number by one and the mass number will remain the same as the original element.

END OF SECTION A

B. QUESTIONS - Features of Facility Design

B.01 Fill in the blanks on the drawing provided. (3.0)

B.02 In regards to the reactor convective loop:

a. How is it automatically placed in service? (1.0)

b. What other action would occur if the convective loop auto initiated? (1.0)

B.03 The reactor coolant loops consist of seven subsystems/ components connected with associated piping and valves. What are four of these subsystems/components? (2.0)

B.04 a. Pressurizer pressure is not required below 50KW if certain conditions are met. What are these conditions? (2.0)

b. What is the normal pressure in the pressurizer? (0.5)

c. What action would occur if pressure in the pressurizer reached 105% of its normal value? (1.0)

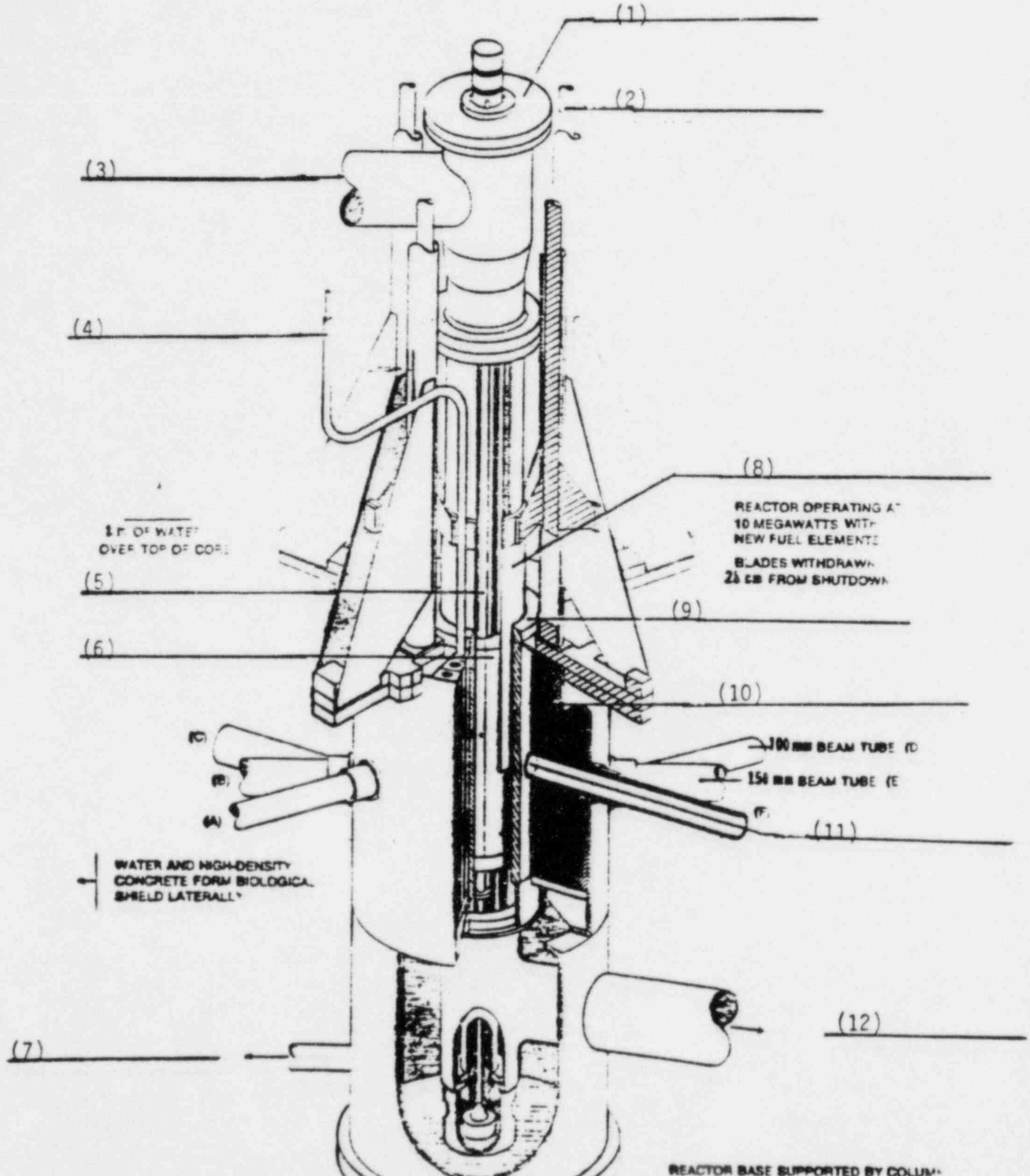
B.05 In regard to the clean up system:

a. What is the flow rate in GPM during normal operation? (0.5)

b. What is the flow path of the clean up system. List major components and valves which can effect operation. (1.5)

B.06 The coolant system incorporates three features designed to protect the core from a loss of coolant accident. What are these three features? (3.0)

END OF SECTION B



UNIVERSITY OF MISSOURI RESEARCH REACTOR

Question B.01

C. QUESTIONS - General Operating Characteristics

C.01 The antisiphon system is designed to provide air to break a siphon of the primary coolant system in the event of a pipe rupture.

a. What pressure must be maintained in the system for it to perform its intended function? (1.0)

b. Other than pressure is there any other requirement necessary to consider the system operable? (1.0)

c. If adequate pressure cannot be maintained, what action must be taken? (1.0)

C.02 For the following conditions, give the setpoints and the auto action (scram or run-in) for each. If the condition causes both actions, give both setpoints. (3.0)

a. Short Period

b. High Power

c. Antisiphon Line High Level

d. Building Air Plenum Hi Activity

e. Reactor Bridge

f. Reg Blade

C.03 For the following parameters, indicate the normal operating range you would expect to see. (2.0)

a. Primary Coolant Flow, 5MW operation

b. Primary Coolant Flow, 10 MW operation

c. Reactor Inlet Coolant Temperature

d. Pool Level

C.04 Under what three conditions can control blades be moved in gang control after the Reactor in Critical? (1.5)

C.05 What is the minimum number and type of nuclear instrumentation required for a reactor startup? (2.0)

C.06 What conditions must be met prior to "auto" operations? (2.0)

END OF SECTION C

D. QUESTIONS - Instruments and Controls

D.01 What automatic functions are associated with the IRM drawer? (Setpoints included for full credit) (1.5)

D.02 What are the four trips generated by the Power Range instrumentation? (2.0)

D.03 Before control rods can be pulled to start the reactor, eight interlocks must be satisfied. What are five of these conditions? (2.5)

D.04 ~~GE Model 500-551~~ Reflector differential pressure transmitter has two adjustable trip pointers. What are the modes of operation and setpoints associated with this pressure transmitter? (2.0)

D.05 The valve operator system for the Reactor System 2" outlet 527C has four control interlocks. What are three of the four interlocks? (1.5)

D.06 Reactor coolant temperature is measured at three points. List these three points either by location or name. (1.5)

D.07 Reactor coolant temperature is controlled by controlling inlet temperature. Describe in detail how this control is achieved. (1.0)

D.08 What are the two control interlocks associated with the reactor loop Isolation Valves? (1.0)

END OF SECTION D

E. QUESTIONS - Safety and Emergency Systems

E.01 What ~~two~~ three conditions must be satisfied to automatically start the generator at MURR? (2.0)

E.02 a. Explain how a trip of the Period Automatic Control circuit will affect req rod control. (1.0)

b. If the Power Automatic Control circuit were to trip, how can it be reset? (1.0)

E.03 How can a reactor isolation be initiated at MURR? (2.0)

E.04 The backup doors are operated by double acting pneumatic cylinders.

a. What happens when air to cylinders is lost? (0.5)

b. What will trip the solenoid valves? (0.5)

E.05 Concerning Nuclear Instruments:

a. What channels provide the period scram? (1.0)

b. What channels provide the high power scram? (1.0)

E.06 What is the purpose of the "~~jog in~~" when the reactor is on automatic? Auto shim circuit (2.0)

E.07 What are four of the six components that make up the reactor safety system? (2.0)

E.08 What two conditions will bypass the ~~startup interlock~~ rod withdrawal prohibit? (1.0)

END OF SECTION E

F. QUESTIONS - Standard and Emergency Operating Procedures

F.01 What are the first four actions an operator takes when a reactor scram occurs from causes other than loss of flow or pressure? (2.0)

F.02 What are the steps that will place the reactor into automatic control mode? (Assume all conditions are met) (2.5)

F.03 What four items shall be done prior to shutting down the reactor? (2.0)

F.04 What does an operator do when he detects a stuck or inoperable drive mechanism? (2.0)

F.05 What are the actions of the Console operator on a sustained electrical anomalies? (1.5)

F.06 What are the actions of the Assistant Duty Operator on a sustained electrical anomalies? (2.0)

F.07 What are four of the five ~~General~~ Facility Emergencies? (2.0)

END OF SECTION F

G. QUESTIONS - Radiation Control and Safety

G.01 Define or explain the following:

a. Dose (1.0)

b. Contamination (1.0)

c. Rad (1.0)

d. Dead Time (1.0)

e. Half Value Layer (Half Thickness) (1.0)

G.02 During any calendar quarter what --

a. Is the maximum whole body dose an individual can receive? (1.0)

b. Is the maximum whole body dose an individual under 18 year of age can receive? (1.0)

G.03 You have a tag out procedure at MURR. What are the three colors used and what does each color designate? (3.0)

G.04 Who (by job title) must give approval on the Radiation Work Permit before work can be started on the project? (1.0)

G.05 A highly radioactive component must be carried out of the containment. Discuss how the three (3) basic principles of exposure control should be used to minimize radiation doses to individual workers. Give a practical example to apply each of the principles. (3.0)

END OF SECTION G

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ANSWERS - Principles of Reactor Operation

A.01 a. The reactor is critical on prompt neutrons, alone, an uncontrollable condition for a reactor. (1.0)

b. The multiplication of source neutrons by fuel in a reactor with Keff less than 1. (1.0)

A.02 c.

Reference: Standard Nuclear Principles (1.0)

A.03 a. Xe is a daughter of I which is a daughter of Te (a fission prod). Xe also is a direct fission prod. It can be removed by decay to cesium or "burnup" by absorbing a thermal neutron. (1.5)

b. Sm is a daughter is promethium (formed by fission and also a daughter of neudymium). It can be removed by "burnup," but Sm is stable. (1.5)

Reference: Standard Nuclear Principles

A.04 a. To have a minimum count level above background to insure instrumentation is working correctly. (1.0)

b. Can monitor subcritical multiplication and reactivity change in the core. (1.0)

Reference: NRC Exam Bank

A.05 Poisons, burnup, coefficient, experiments. (ea @ 0.5)

Reference: NRC Exam Bank

A.06 Attenuation of the beta and gamma from fission products in reactor materials. (2.0)

Reference: Standard Nuclear Principles

A.07 a. Scatter, so neutrons are lowered in energy rather than lost. (1.0)

b. Low atomic weight so that fewer scattering collisions are required. (1.0)

Reference: Standard Nuclear Principles

A.08 Refers to fraction of delayed neutrons under equilibrium conditions. (1.0)

Reference: Standard Nuclear Principles

A.09 a. (1.0)

Reference: Standard Nuclear Principles

END OF SECTION A

ANSWERS - Feature of Facility Design

B.01 See attached figure (ea. 0.25)

Reference: MURR Training Manual, page 3

B.02 a. Opening of valves 546A and B as sensed by DPS 929/DPS 928A/B and,

b. Reactor scram from core differential pressure.

a. opening of valves 507 A/B.

Reference: MURR TM, page I26 + page I-63

B.03 a. An invert loop within the pool

b. A pressurizer system

c. A bypass loop

d. Main circulating pumps

e. Heat exchangers

f. An antisiphon system

g. Remote-manual shut-off valves

H. Demin System I VENT TANK System

Any four each 0.5

Reference: MURR TM, page I-21

B.04 a. If natural convection flange and pressure vessel cover removed <u>or</u> in operation with the reactor subcritical by a margin of at least 0.015ΔK. (2.0)

b. 70# (0.5)

c. Pressure controller (940) would open the 545 valve and blowdown to off-gas system, ~~if not in test or in Auto~~. (1.0)

Reference: MURR TM, page I-47

B.05 a. 50 gpm (0.5)

b. Tc leg of primary coolant through an air operated isolation valve (0.25), a hold-up tank (0.25), ~~PT~~ DI pump (0.25), filter and demineralize (0.5), through an air operated isolation valve on TH leg (0.25).

Reference: MURR TM, page I-51, 52

B.06 a. Reactor vessel is located in water filled pool (1.0)

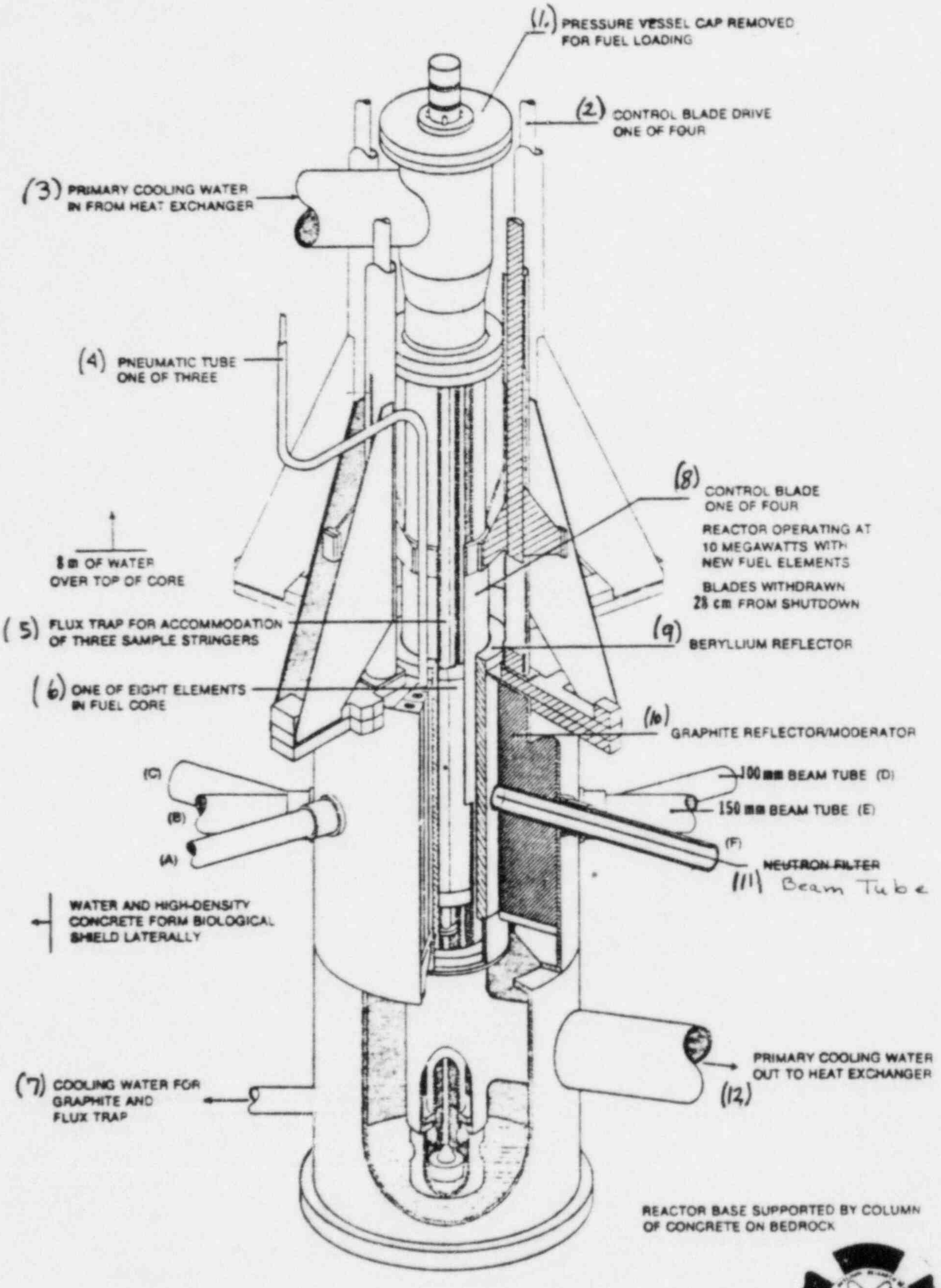
System breaks (valve 550 C/D) open.

b. Antisiphon system (1.0)

c. Automatically actuated isolation valves (1.0)

Reference: MURR TM, page I-9

END OF SECTION B



UNIVERSITY OF MISSOURI RESEARCH REACTOR

Answer B.01
Each 00.25

ANSWERS - General Operating Characteristics

C.01 a. To perform its intended function the antisiphon system must be able to maintain 27 psig. (1.0)

b. Water level must be [less than] 6" above the antisiphon valves. (1.0)

c. If adequate pressure (27#) cannot be maintained, the reactor must be shutdown. (1.0)

Reference: MURR SOP IV3.1

C.02 a. 9 [8] scram 11 [10] run-in (0.5)

b. 120 scram 115 run-in (0.5)

c. >6 above valves [run-in] (0.5)

d. 1.0 [mr/hr] scram (0.5)

e. 50 mR/hr [Scram] (0.5)

f. Reg Blade <10% or bottomed [RUN-IN] (0.5)

Reference: MURR SOP, Table IV

C.03 a. 1900 ±50 gpm (0.5)

b. 3800 ±100 gpm (0.5)

c. 120°F (0.5)

d. 29'-7" ±3" (0.5)

Reference: MURR SOP, Table III

C.04 a. Reduce Power (0.5)

b. Shutdown the reactor (0.5)

c. Automatic shimming operation (0.5)

Reference: MURR SOP, I.4.3D

C.05 a. One source range (0.5)

b. Two intermediate range each with [period] trip (0.5)

c. Two power channels (0.5)

d. One wide range (0.5)

Reference: MURR SOP, I.4.3H

C.06 a. The period as indicated by both IRM-2 and IRM-3 must indicate not less than 35 seconds. (0.5)

b. The WRM selector switch must be in the 5KW red scale position or above. (0.5)

c. The power trace pointer (black) on the WRM recorder must be reading greater than the auto control prohibits set points (red). (0.5)

d. The reg blade position must be greater than 60% withdrawn, such that 60% annunicator alarm is energized. (0.5)

Reference: MURR SOP, II.1.3A

END OF SECTION C

ANSWERS - Instruments and Controls

D.01 a. Rod run-in and alarm at ~~10.5 seconds~~ 10 plus (0.5)

b. Scram and alarm at 8 seconds plus (0.5)

c. A 25 second prohibit trip to transfer to automatic control. (0.5)

Reference: MURR TM, II-33

D.02 a. Loss of high voltage trip (0.5)

b. Power level scram trip circuit (0.5)

c. Power level run-in trip circuit (0.5)

d. Module removed or switch out of operation (NI Anamoly) (0.5)

Reference MURR TM II-40

D.03 a. Master switch in the "On" position

b. "Rod Run-In" switch reset

c. No nuclear instruments anomalies

d. Shim rods bottomed and in contact with magnets

e. Startup channel more than 1 count per second

f. Thermal column door closed

g. ~~154~~ 1S4 switch must be operated (control blade operate)

h. 153 control blade selector in positions of blade or gang (1S3)

Any 5 @ (0.5) each

Reference: MURR, II 77-78

D.04 a.	Mode I (10MW)	2.52 and 8.00 psig	(0.5)
b.	Mode II (5MW) setpoints	.63 and 2:00 psig	(0.5)
c.	Mode III (50KW) setpoints	.63 and 2.00 psig	(0.5)
d.	Mode III natural convection - setpoints bypassed		(0.5)

Reference: MURR TM, page II-71

D.05 a. Low pressurizer level from 935 to close valve (at scram level). (0.5)

b. Panel manual open - close when master control switch is in "Test" only. (0.5)

c. Valve to close whenever 507A or 507B is closed (off-open). (0.5)

d. Interlock with valve 527D so that valve 527C can't be manually opened when 527D is open. (0.5)

Reference: MURR TM, page I-61

D.06 a. Reactor Outlet Temperature (0.5)

b. Reactor Inlet Temperature (0.5)

c. Valve to close whenever 507A or 507B is closed (off-open). (0.5)

d. Interlock with valve 527D so that valve 527C can't be manually opened when 527D is open. (0.5)

Reference: MURR TM, page I-61

D.06 a. Reactor Outline Temperature (0.5)

b. Reactor Inlet Temperature (0.5)

c. Outlet of heat exchangers 503A and B (0.5)

Reference: MURR TM, page I-35

D.07 Control is achieved by varying secondary flow through the heat exchanger by an electro-hydraulic valve operator mounted on 8" butterfly valve S1. (1.0)

Reference: MURR TM, page I-36

D.08 a. (Low pressure from 944A and 944B) - close valve and shut off pump 501A and B and scram. (0.5)

b. (Panel manual open) - close when master control switch is in "test" only and the valve mode switch is in manual position. (0.5)

Reference: MURR TM, page I-59

END OF SECTION D

ANSWERS - Safety and Emergency Systems

E.01 a. Loss of site electrical power at substation "B" (1.0)

b. A time delay waits <10 seconds then the engine starts. (1.0)

c. Local Switch must be in remote

Reference: MURR TM, page III-8

E.02 a. A trip of the period automatic control circuit will prevent the regulating control rod from being operated in the automatic mode. (1.0)

b. The system will automatically reset when the period becomes greater than the trip point of 35 seconds. (1.0)

Reference: MURR TM, page II-32

E.03 a. Any of three radiation monitors (1.0)

b. From a switch on the reactor console (1.0)

Reference: MURR TM, page II-54

E.04 a. Doors will close by gravity (0.5)

b. 3.5 mR/hr signal from associated radiation monitor. (0.5)

Reference: MURR TM, page II-58

E.05 a. Channels 2 and 3 (1.0)

b. Channels 4, 5, and 6 (1.0)

Reference: MURR TM, II-61

E.06 To drive the shim rods in when the regulating rod is at some preset point until the regulating rod is pulled out to the 60% position. (2.0)

Reference: MURR Hazards Report 9-3 or TM II-81

E.07 Scram logic circuits, and trip actuator amplifiers, rod run-in logic, and trip actuator amplifies alarm and annunciator circuits.

(any 4 @ 0.5 each)

Reference: MURR Hazards Report 9-17 or TM II-60

E.08 a. Masterswitch in "test" position (0.5)

b. Rod magnets are de-energized (0.5)

Reference: MURR Hazards Report 9-21
or TM II-77

END OF SECTION E

F.01 a. Monitor nuclear instrumentation to assure reactor is in shutdown mode. (0.5)

b. Acknowledge cause of scram and take corrective action as required. (0.5)

c. Notify Shift Supervisor of scram. (0.5)

d. Verify control rod drives at full-in position. (0.5)

Reference: MURR SOP, EPP-II-2

F.02 a. Set low level trip in wide range recorder at 75% of desired operating power. (0.5)

b. Using power schedual switch (159) bring setpoint indicator to approximately 3% below desired power level. (0.5)

c. Raise reactor power on a period greater than 35 seconds so reg rod will be greater than 60% withdrawn. (0.5)

d. Depress the blue "auto" control switch. (0.5)

e. Observe both reg blade positions ~~s~~ and wide range monitor channel 4 raise the power level set until desired power is obtained by wide range monitor instrumentation. (0.5)

Reference: MURR SOP, II.1.3

F.03 a. Turn on the source range recorder and time and date the chart. (0.5)

b. Insert the fission chamber until a count of approximately 10^5 cps is obtained on the SRM recorder. (0.5)

c. Place the IRM recorder in fast speed and time and date the chart. (0.5)

d. Take a set of nuclear and process data. (0.5)

Reference: MURR SOP, II.1.6

F.04 a. Scram the reactor, noting the approximate stuck position. (0.5)

b. Verify the reactor is scrammed as indicated by the nuclear instrumentation. (0.5)

c. Make no effort to move the stuck mechanism. ~~and note if rod drives move down as required~~. (0.5)

d. Notify the Shift Supervisor (0.5)

Reference: MURR, EP-II.8

F.05 a. Check reactor shutdown (0.5)

b. Turn all pump and cooling tower switches off in the most expeditious manner. (0.5)

c. Place all valve controls in their normal shutdown position and manual mode. (0.5)

Reference: MURR, EP II.9.2

F.06 a. If a rabbit is in the reactor at the time electrical power is lost, transfer the p-tube blower to emergency power and return the rabbit. (0.5)

b. Trip the master supply breaker on substation "B". (0.5)

c. Check emergency generator and its load for proper operation. (0.5)

d. Trip the supply breakers for MCC-1 and 2 in the cooling tower. (0.5)

Reference: MURR, EP II.9.2

F.07 a. Facility evacuation

b. Reactor isolation

c. Fire

d. Medical

e. Security

Any four @ (0.5) each

Reference: MURR, EP-I.0

END OF SECTION F

ANSWERS - Radiation Control and Safety

G.01 a. Dose - The quantity of radiation absorbed per unit mass by the body or by any portion of the body. (1.0)

b. Contamination - The deposition of radioactivity material in any place where it is not desired, particularly if its presence is harmful to personnel. (1.0)

c. Rad - A measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of tissue. 100 ergs/g tissue. (1.0)

d. Dead Time - The time when a detector operating in the Geiger-Mueller region of the curve is insensitive to incoming radiation due to the process causing the anode to be engulfed by position ive ions. (1.0)

e. Half Value Layer - A term used to represent shielding. A half value layer of material, HVL, reduces the intensity of incident radiation by a factor of 2. Also called half thickness. (1.0)

Reference: Standard Radiological Principles

G.02 a. 1.25 rem (1.0)

b. .125 rem (1.0)

Reference: 10 CFR 20.201 and 20.104

G.03 Red - Danger to personnel (1.0)

Yellow - Danger to equipment (1.0)

White - Supplemental information concerning an operating procedure (1.0)

Reference: MURR SOP, I.4.10.2

G.04 a. Job Supervisor (0.5) (0.34)

b. Health Physics (0.5) (0.33)

c. Shift Supervisor. (0.33)

Reference: MURR SOP, I.4.7

G.05 Time: Preplanning, procedures, rehearsing, rotating people (1.0)

Distance: Remote handling tools (1.0)

Shielding: Materials like lead, steel or concrete (1.0)

Reference: 10 CFR 20

END OF SECTION G

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U.S. NUCLEAR REGULATORY COMMISSION
SENIOR REACTOR OPERATOR LICENSE EXAMINATION

Facility Univ of Missouri Columbia

Reactor Type Pool

Date Administered August 27, 1985

Examiner E. Plettner

Applicant ____________________

Instructions to Applicant:

Use separate paper for the answers; staple question sheet on top of the answer sheets. Points for each question are indicated in parenthesis after the question. The passing grade requires at least 70% in each category and a final grade of at least 70%.

Category Value	% of Total	Applicant's Score	% of Cat. Value	
20	20	____	____	H. Reactor Theory
20	20	____	____	I. Radioactive Material Handling, Disposal and Hazards
20	20	____	____	J. Specific Operating Characteristics
20	20	____	____	K. Fuel Handling and Core Parameters
20	20	____	____	L. Administrative Procedures, Conditions and Limitations
100		____		TOTALS

Final Grade _____%

All work done on this exam is my own, I have neither given nor received aid.

____
Applicant's Signature

H. REACTOR THEORY

H.01 a. If during startup, the count rate is 40 cps and $K_{eff} = 0.95$, what will the count rate be when $K_{eff} = 0.98$? (2.0)

b. If the control rods were moved an increment of 2 inches to achieve this increase in count rate, about how many more inches would you have to withdraw the rods to achieve criticality? Assume rod worth is linear over distance to be traveled. (2.0)

H.02 At time=0, the power level signal of a reactor is 10^{-10} amps. Three minutes later the power level indicated $5x10^{-8}$ amps. What is the resulting stable period if the reactor was initially critical? State any assumptions. (3.0)

H.03 Explain the production and removal mechanisms for Xe-135 and Sm-149. (3.0)

H.04 What is the source of decay heat in a reactor? (1.0)

H.05 In each of the following cases indicate the preferred characteristics for a moderator. Briefly explain why for each answer.

a. Absorb neutrons or scatter neutrons. (1.0)

b. Have a high atomic weight or low atomic weight. (1.0)

H.06 What does Beta effective refer to in an operating reactor? (1.0)

H.07 Briefly explain the difference between

a. Fast and prompt neutrons (1.0)

b. Slow and Delayed neutrons (1.0)

c. Activity and Reactivity (1.0)

H.08 What effect does a moderator temperature increase have on:

a. Core reactivity (1.0)

b. Control rod worth (1.0)

Explain your answer.

H.09 While withdrawing control rods to take the reactor critical, does the startup instrumentation require the same time to level out at each subcritical level? Explain your answer. (1.0)

END OF SECTION H

I. RADIOACTIVE MATERIALS, HANDLING, DISPOSAL, AND HAZARDS

I.01 Does the biological effect of a 100 REM depend on whether it is a neutron or a gamma dose? Explain. (2.0)

I.02 According to 10 CFR 20, an individual in a restricted area may be allowed to receive a whole body dose of radiation greater than the 1.25 REMS per quarter when three conditions are met. What are these conditions? Assume non-emergency conditions. (3.0)

I.03 10 CFR 20 sets more stringent limits on radiation exposure of minors than for adults. What are these limits? (1.0)

I.04 A health physics smear is taken on a surface area believed to be contaminated. Using the following data, determine if the area should be considered contaminated. State any assumptions. Defend your answer. (2.0)

Data

smeared area = 4 inches by 4 inches
5 min count = 450
background = 25 cpm
counter efficiency = 18%

I.05 Define or explain the following

a. Dose (1.0)

b. Contamination (1.0)

c. Rad (1.0)

d. Dead Time (1.0)

e. Half Value Layer (Half thickness) (1.0)

I.06 a. Explain the difference in characteristics between portable monitoring instruments, one of which was a GM tube and the other an ion chamber. (2.0)

b. Under what circumstances would it be better to use the GM instrument than the ion chamber instrument? (1.0)

I.07 What are the four (4) major hazards involved with beamport experiments according to your SOP? (3.0)

I.08 Explain why iodine-131 is the limiting isotope in many accident analysis. (1.0)

END OF SECTION I

J. SPECIFIC OPERATING CHARACTERISTICS

J.01 a. List the two major negative reactivity coefficients which can halt the rapid power escalation following a positive step reactivity insertion. (1.0)

b. What are their values as listed in Tech. Spec. (1.0)

J.02 What are the limits for the following parameters during steady state operation? Explain the reasons for the limit.

a. Primary coolant pressure (1.5)

b. Anti-siphon system pressure (1.5)

c. Pool temperature (1.5)

J.03 What three items or systems shall be operable when the reactor is operating in Mode I or II? (1.5)

J.04 What are the four major loads that the emergency generator supply? (2.0)

J.05 What are the two surveillance requirements for the reactor control blade system? (2.0)

J.06 What are the weight/time limits that apply to samples irradiated in the p-tube? Include any exceptions in the answer. (4.0)

J.07 The pressurizer system in the reactor coolant loop provides the required reactor inlet pressure.

a. Describe the operation of the system. (2.0)

b. What instrumentation and control system are provided for the operation of the system? (1.0)

J.08 What two conditions when satisfied will bypass the ~~startup interlock~~ rod withdrawal prohibit? (1.0)

END OF SECTION J

K. FUEL HANDLING AND CORE PARAMETERS

K.01 Define

a. special nuclear material (1.0)

b. source material (1.0)

c. byproduct material (1.0)

K.02 Assume the following data were obtained during a core loading: (not necessarily for MURR)

Number of Fuel Elements	Count Rate (CPS) Rods In	Count Rate (CPS) Rods Out
0	20	20
4	25	27
6	29	32
8	35	40
10	43	53
12	55	79

a. Estimate the number of fuel elements required for criticality. Briefly describe how you obtained that answer. (2.0)

b. Calculate the approximate reactivity worth (%Δk/k) of the rods. Show all work. (2.0)

K.03 Describe how a leaking or ruptured fuel element can be identified. (2.0)

K.04 Once the leaking or ruptured fuel element is identified, describe how it is handled. (1.5)

K.05 List the two requirements in your technical specifications which apply to fuel storage at the MURR. (2.0)

K.06 Why do we limit the fuel burnup? (2.0)

K.07 What people by job title are required to be present during fuel handling? (1.0)

K.08 Describe the latching and unlatching sequence when using the manually operated fuel handling tool. Include any cautions that may exist. (3.0)

K.09 Why must you always allow the air operated fuel handling tool to float up off the element? (1.5)

END OF SECTION K

L. ADMINISTRATIVE PROCEDURE CONDITIONS AND LIMITATIONS

L.01 The reactor shall be considered secured whenever it contains insufficient fuel in the reactor core to establish criticality with all control rods removed. What three out of five conditions will also meet the reactor secured criteria? (3.0)

L.02 What are three out of six conditions that are considered as abnormal occurrences in your technical specifications? (3.0)

L.03 a. List the three tags and explain their meanings. (1.5)

b. Who by title must fill out and attach the tags and the tag log? (0.5)

c. Who by title must approve tags before they are removed? (0.5)

d. When the tags are removed what information is recorded in the log? (1.0)

L.04 Describe your Reactor Advisory Committee and indicate at least 3 circumstances that require their review. (3.0)

L.05 Who by title must sign and date the radiation work permit? (1.0)

L.06 During normal operation

a. A complete set of nuclear data will be taken every _____ hour(s) during steady state operation. (0.5)

b. A complete set of process data will be taken every _____ hour(s) during steady state operation. (0.5)

c. During routine operation, a routine patrol of the facility will be made every _____ hour(s) according to an approved routine patrol checksheet. (0.5)

L.07 What are the experiment limits on total inventory of

a. iodine 131-135 (0.5)

b. strontium 90 (0.5)

L.08 List four of six conditions that must be satisfied for reactor containment integrity to exist. (4.0)

END OF SECTION L

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ANSWERS - H. REACTOR THEORY

H.01 a. $\frac{C_1}{C_2} = \frac{1-k_2}{1-k_1}$

$C_1 = 40,\ k_1 = 0.95,\ k_2 = 0.98$

$C_2 = \frac{C_1(1-k_1)}{1-k_2} = \frac{40(1-0.95)}{(1-0.98)}$

$C_2 = 100$

b. $p = \frac{\Delta k}{k} = \frac{0.03}{0.95} = 0.0315\ \Delta k/k$

For 2 in. of travel, this gives a value of $\frac{0.0315\Delta k/k}{2\text{ in.}} = \frac{0.0157\Delta k/k}{\text{in.}}$

Assuming that the control rod worth remains approximately constant over the region of interest, the required reactivity addition to reach criticality is

$p = \frac{1.0-0.98}{0.98} = 0.0204\Delta k/k$ (2.0)

Travel = 0.0204/0.0157 = 1.29 in.

Reference: Standard Nuclear Principles

H.02 $N/No = e^{t/T}$; $\frac{500 \times 10\text{-}10\text{ amps}}{10\text{-}10\text{ amps}} = 500 = e^{180\text{ sec}/T}$ (3.0)

$\ln 500 = \frac{180}{T}$ or $T = 180/\ln 500 = 180/6.214$

$T = 28.96$

Reference: Standard Nuclear Principles

H.03 a. Xe is a daughter of I which is a daughter of Te (a fission prod). Xe also is a direct fission prod. It can be removed by decay to cesium or "burnup" by absorbing a thermal neutron. (1.5)

b. Sm is a daughter of promethium (formed by fission and also a daughter of neudymium). It can be removed by "burnup," but Sm is stable. (1.5)

Reference: Standard Nuclear Principles

H.04 Attenuation of the beta and gamma from fission products in reactor materials. (1.0)

Reference: Standard Nuclear Principles

H.05 a. Scatter, so neutrons are lowered in energy rather than lost. (1.0)

b. Low atomic weight so that fewer scattering collisions are required. (1.0)

Reference: Standard Nuclear Principles

H.06 Refers to fraction of delayed neutrons under equilibrium conditions. (1.0)

Reference: Standard Nuclear Principles

H.07 a. Fast neutrons refer to those at high energy levels (0.5)

Prompt neutrons refer to those released at the time of fission. (0.5)

b. Slow neutrons are neutrons at low energy levels. (0.5)

Delayed neutrons are those which appear at some time after the fission event due to fission product decay. (0.5)

c. Activity refers to the rate of radioactive decay. (0.5)

Reactivity expresses the deviation of a reactor from the critical condition. (0.5)

Reference: Standard Nuclear Principles

H.08 a. Core reactivity is decreased. The temperature increase causes a density decrease of the moderator. There is less moderation and more neutron leakage, which is a negative effect. (1.0)

b. Control rod worth increases. As moderation is decreased and the probability of leakage into a control rod increases, the effectiveness of the control rods increase. (1.0)

Reference: Standard Nuclear Principles

H.09 No, as K_{eff} gets closer to 1.0 the fractional change in neutron population per generation is smaller for equal reactivity additions. Therefore, it takes more generation to steady out at the new subcritical count rate. (1.0)

Reference: Standard Nuclear Principles

END OF SECTION H

ANSWERS - I. RADIOACTIVE MATERIALS, HANDLING, DISPOSAL AND HAZARDS

I.01 No. The unit REM already considers the different effects (1.0). REM is a biological unit thus different radiations causing the same dose in REM should have the same effect (1.0).

Reference: Standard Nuclear Principles

I.02 a. He does not exceed 3 REM per quarter. (1.0)

b. His radiation history is known and recorded on NRC Form 4. (1.0)

c. The dose rate received when added to his radiation history does not exceed 5(N-18). (1.0)

Reference: 10 CFR 20

I.03 10% of the adult limit or .125 REM (1.0)

Reference: 10 CFR 20

I.04 16 sq. in. $\cong$ 100 cm^2
450 cts/5 min = 90 cpm
corrected cpm 90 - 25 = 65 cpm
dis. per min. = corr. cpm/efficiency
= 65/0.18 = 361 dis. per min/100 cm^2 (1.0)

Since the limit for a contaminated area is > dis. per min/100 cm^2, this area is a contaminated area. (1.0)

Reference: Standard Nuclear Principles

I.05 a. Dose - The quantity of radiation absorbed per unit mass by the body or by any portion of the body. (1.0)

b. Contamination - The deposition of radioactive material in any place where it is not desired, particularly if its presence is harmful to personnel. (1.0)

c. Rad - A measure of the dose of any ionizing radiation to body tissues in terms of the energy absorbed per unit mass of the tissue. 100 ergs/g tissue. (1.0)

d. Dead Time - The time when a detector operating in the Geiger-Mueller region of the curve is insensitive to incoming radiation due to the process causing the anode to be engulfed by positive ions. (1.0)

e. Half Value Layer - A term used to represent shielding. A half value layer of a material, HVL, reduces the intensity of incident radiation by a factor of 2. Also called half thickness. (1.0)

Reference: Standard Nuclear Principles

I.06 a. There are two basic differences:

1. The GM instrument is more sensitive due to the amplification of the ionization by the GM probe. (1.0)

2. The ion chamber gives an indication of the energy of the incident radiation because the higher the energy the more ionization there will be in the chamber. The GM probe produces a large pulse which is independent of the energy of the incident radiation. (1.0)

b. As a survey instrument looking for and measuring low level radiation. (1.0)

Reference: Standard Nuclear Principles

I.07 1. Changes in reactor reactivity due to beamport activities such as draining or flooding a beamport. (.75)

2. Exposure of personnel to radiation as a result of movements of shielding or inadequate shielding. (.75)

3. Release of radioactive gases such as Ar-41 which are produced in the beamport. (.75)

4. A production of explosive or toxic materials in the beamport. (.75)

Reference: MURR SOP VIII.4.1

I.08 Iodine-131 concentrates in the thyroid and can produce severe damage. It is the most hazardous fission product excluding Pu; therefore, it is the most limiting factor. (1.0)

Reference: Standard Nuclear Principles

END OF SECTION I

ANSWERS - J. SPECIFIC OPERATING CHARACTERISTICS

J.01 a. Void coefficient and temperature coefficient (1.0)

b. -2.0×10^{-3} Δk/% void (0.5)
-6.0×10^{-5} Δk/°F (0.5)

Reference: MURR Tech. Spec. 3.1

J.02 a. 110 psig (max) (0.5)

To assure that the system design pressure of 125 psig is not exceeded. (1.0)

b. 27 psig (min) (0.5)

To insure that the system will adequately perform its function. (1.0)

c. 120°F (max) (0.5)

To assure the adequate cooling of pool components during all modes of operation. (1.0)

Reference: MURR Tech. Spec. 3.4

J.03 a. siphon break system (0.5)

b. primary coolant isolation valves (0.5)

c. reactor convective cooling loop (0.5)

Reference: MURR Tech. Spec. 3.9

J.04 a. emergency lighting system (0.5)

b. reactor exhaust system (0.5)

c. reactor instrumentation (0.5)

d. air lock doors (0.5)

Reference: MURR Tech. Spec. 4.5

J.05 a. drop time of each rod shall be measured quarterly (1.0)

b. one of four blades inspected each six months so that every blade is inspected every two years (1.0)

Reference: MURR Tech. Spec. 5.3

J.06 a. For irradiation times up to 30 minutes, the maximum weight of irradiated materials in one rabbit will be 2 grams with two exceptions: (1.0)

1. A maximum of 10 grams of water or dried feces; (0.5)

2. Only 1 mg of chemical compounds in solution. (0.5)

b. For irradiation times of 30 minutes to 1 hour, the maximum weight of irradiated materials in one rabbit will be 1 gram with two exceptions: (1.0)

1. A maximum of 10 grams of water or dried feces; (0.5)

2. Only 500 µg of chemical compounds in solution. (0.5)

Reference: MURR SOP VIII.3.2 F

J.07 a. 1. The reactor pressurizer pressure is maintained at 75 psia for both 1800 gpm and 3600 gpm operation. (1.0)

2. Pressurizer water level is maintained by a positive displacement pump which is valved into the pressurizer tank on demand for more water. (1.0)

b. Pressure is maintained in the pressurizer by nitrogen gas which is automatically admitted or released in response to system instrumentation signal. (1.0)

Reference: MURR HSR 2.1

J.08 a. Master switch in "test" position (0.5)

b. Rod magnets are de-energized (0.5)

Reference: MURR HSR 9.5

END OF SECTION J

ANSWERS - K. FUEL HANDLING AND CORE PARAMETERS

K.01 a. Special nuclear material = Pu, U-233, U enriched with 233 or 235 or any other material decided to be so by the NRC. (1.0)

b. Source material = U or Th or any combination thereof, ores with 0.05% or more U or Th. Doesn't include SNM (1.0)

c. Byproduct material = any r/a material (except SNM) yielded in or made r/a by exposure to radiation incident to process of producing or using SNM. (1.0)

Reference: 10 CFR 20

K.02 Evaluate 1/M (=Co/C) after each loading get:

No. of Elements	Rods CPS	Out 1/M	Rods CPS	In 1/M
0	20	1.00	20	1.00
4	27	0.74	25	0.80
6	32	0.625	29	0.69
8	40	0.50	35	0.57
10	53	0.377	43	0.465
12	79	0.253	55	0.364

a. Graphic method (see attached figure):

plot 1/m vs elements loaded (rods out data), extrapolate to 1/m = 0.0, get 16 elements for critical. (2.0)

Analytic method

Use rods out data choose any two points (say @ 0 & 8 elements loaded): N/8 = 1.0/.5 => N=16

b. At critical (1/m 0, rods out data), 1/m $\simeq$ 0.15 with rods in (see attached figure).

$1/m = 1-k \Rightarrow k = 0.85$

$\rho\ (rods) = |(k-1)/k| = +\ .176$ or ~17.6%Δk/k (2.0)

Reference: Standard Nuclear Principles

K.03 a. Have the HP personnel move the portable gaseous and particulate monitors to the reactor bridge for continuous monitoring. HP personnel will be present. (0.5)

b. Move four elements from the core to the "X" basket and the "Y" basket separately. (0.5)

c. Draw a grab sample from above each element and give to lab group for analysis. (0.5)

d. Visual inspection. (0.5)

K.04 a. Commence recirculating water through the element. (0.5)

b. The leaking element will be placed in the special single element storage cask and placed in the "Z" basket area. (0.5)

c. The element will remain sealed in the cask until ready for shipment. (0.5)

Reference: MURR EP-II.20.F

K.05 a. It shall be stored in geometry such that the calculated K_{eff} is less than 0.8 under all conditions of moderation. (1.0)

b. Irradiated fuel elements shall be stored in an array which will permit sufficient natural convection cooling such that the fuel element temperature will not exceed design values. (1.0)

Reference: MURR Tech. Spec. 3.8

K.06 The fuel burnup limits restrict the peak atom percent burnup of values correlated to result in less than a 10% swelling of the fuel plates. It has been found that fuel plate swelling of less than 10% has no detrimental effect on fuel plate performance. (2.0)

Reference: MURR Tech. Spec. 3.8

K.07 a. Senior Reactor Operator (0.5)

b. Reactor Operator or trainee (0.5)

Reference: MURR SOP II.2.1.H

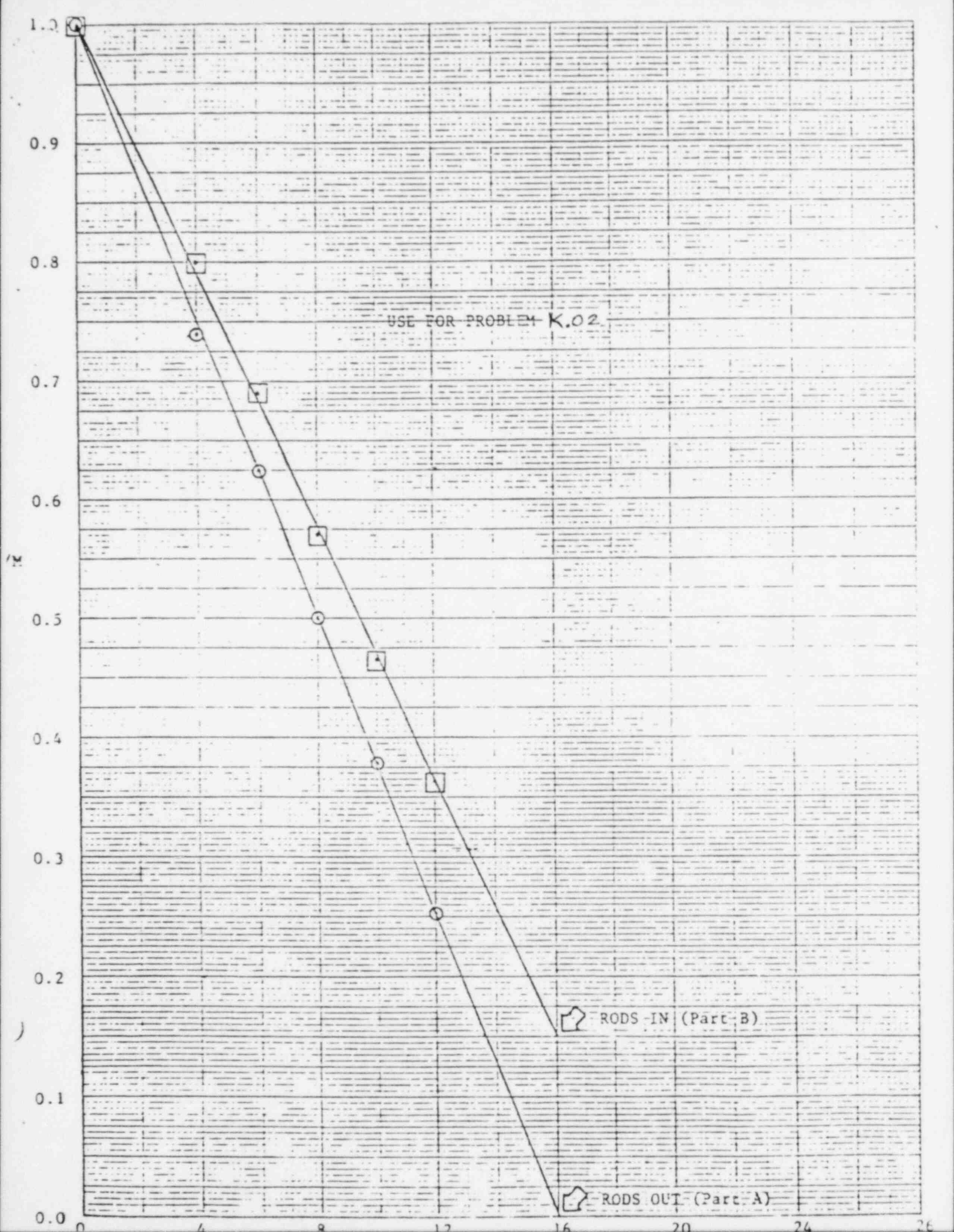
K.08 When latching a fuel element, the red indicator will come up when the tool has engaged properly (0.5). A locking key is then inserted in a groove which prevents the unlatching handle from moving (0.5). However, DO NOT lift this handle when moving the element (0.5). To unlatch the element, remove the locking key (0.5) and hold down on the top of the tool with one hand (0.5) and lift the unlatching handle with the other (0.5).

Reference: MURR SOP II.2.1.K

K.09 Failing to release the element in this matter may result in accidentally lifting and leaving the element a few inches off of its seated position without realizing it. (1.5)

Reference: MURR SOP II.2.1.L

END OF SECTION K



1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
/M
0
4
8
12
16
20
24
USE FOR PROBLEM K.02
RODS IN (Part B)
RODS OUT (Part A)

ANSWERS - L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS

L.01 a. All shim rods are fully inserted.

b. One of the following conditions exists:

1. The "Master Control" switch is in the "off" position with the key locked in the key box or in the custody of a licensed operator.

2. A licensed operator is present in the Control Room and the dummy load control rod test connectors are installed.

c. No work is in progress involving transferring fuel in or out of the core.

d. No work is in progress involving the control rods or control rod drives with the exception of installing or removing dummy load control rod test connectors.

e. The reactor pressure vessel cover is secured in position and no work is in progress on the pressure vessel or its supports.

Any three @ 1.0 each

Reference: MURR Tech. Spec. 1.20

L.02 a. Any actual safety system setting less conservative than specified in the Limiting Safety System Setting's section of the Technical Specifications.

b. Operation in violation of a Technical Specification.

c. Safety system component malfunction or other component or system malfunction which could, or threaten to, render the system incapable of performing its intended safety function.

d. Release of fission products from a fuel element.

e. An uncontrolled or unanticipated significant change in reactivity.

f. An observed inadequacy in the implementation of either administrative or procedural controls, such that the inadequacy could have caused the existence or development of an unsafe condition in connection with the operation of the reactor.

Any three @ 1.0 each

Reference: MURR Tech. Spec. 1.1

L.03 a. Red - Danger to personnel (0.5)
Yellow - Danger to equipment (0.5)
White - Supplemental information concerning operating procedure (0.5)

b. a licensed operator (0.5)

c. Shift Supervisor (0.5)

d. The date of removal (0.5) and the initials of the individual clearing the tags (0.5).

Reference: MURR SOP I.4.10.2 & 3

L.04 a. Proposed changes to the MURR equipment or procedures when such changes have safety significance, or involve an amendment to the reactor license, a change in the Technical Specifications incorporated in the license, or an unreviewed safety question pursuant to 10 CFR 50.59. (1.0)

b. Proposed experiments significantly difference from any previously reviewed or which involve an unreviewed safety question pursuant to 10 CFR 50.59. (1.0)

c. The circumstances of all abnormal occurrences and violations of Technical Specifications and the measures taken to prevent a recurrence. (1.0)

Reference: MURR Tech. Spec. 6.1

L.05 a. job supervisor ~~(0.5)~~ 0.34

b. Health Physics ~~(0.5)~~ 0.33

c. Shift supervisor (0.33)

Reference: MURR SOP I.4.7

L.06 a. one (0.5)

b. two (0.5)

c. four (0.5)

Reference: MURR SOP I.44

L.07 a. 150 curies (0.5)

b. 300 millicuries (0.5)

Reference: MURR Tech. Spec. 3.6

L.08 a. The truck entry door closed and sealed.

b. The utility seal trench filled with water to the depth required to maintain a minimum water seal of 4.25 feet.

c. All containment building ventilation system automatically-closing doors and automatically-closing valves are operable or placed in the closed position.

d. The reactor mechanical equipment room exhaust system, including the particulate and halogen filters, is operable.

e. The personnel airlock door operable.

f. The most recent building leak test was satisfactory.

Any four @ 1.0 each

Reference: MURR Tech. Spec. 1.15

END OF SECTION L