U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-186/OL-88-01

Docket No. 50-186

Licensee: University of Missouri
Research Park
Columbia, MO 65201

Examination Administered At: Columbia, Missouri

Examination Conducted: September 14-15, 1988

Examiner: D. J. Damon — 9/29/88 Date

Approved By: M. J. Jordan, Chief, Operator Licensing Section 1 — 9/28/88 Date

Examination Summary

Examination administered on September 14-15, 1988 (Report No. 50-186/OL-88-011) to one Reactor Operator candidate.
Results: The candidate passed the examination.

REPORT DETAILS

1. Examiners

D. J. Damon

2. Exit Meeting

On September 16, 1988, the examiner met with Mr. W. Meyer to discuss the results of the examination. The examination was reviewed, with results as outlined below. Due to the fact that there was only one candidate, no comments of a general nature were made.

3. Examination Review

The following comments were received during the review and are accompanied by their respective NRC resolutions.

Question F.04

Facility Comment

Although this answer is correct, the way the question is worded, another obvious reason for not allowing the startup exists. SOP I.4.2.E states that "Operations affecting changes in core reactivity, other than normal steady state power control, i.e., refueling, startup, etc., will be directly supervised by a senior operator."

The question asks "Do you let him perform the startup under your supervision?" Since our candidate is seeking to be licensed as a reactor operator and not a senior operator his answer would be "no", because he is not a senior operator.

If the question had asked "Should the senior operator or shift supervisor have allowed such a startup," the original reason for answering "no" would have been sufficient.

NRC Resolution

Comment accepted. Answer Key modified to accept the additional answer.

Question F.05

Facility Comment

The answer to F.05(D) should be False as per SOP II.1.3.B.3 which states "bring the reactor to the desired power level on a period > 35 seconds, utilizing the reg blade in such a manner as to insure that it is greater than 60% withdrawn when the desired power level is reached.

NRC Resolution

Comment accepted. Answer key modified.

MASTER COPY

U. S. NUCLEAR REGULATORY COMMISSION
REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: UNIVERSITY OF MISSOURI

REACTOR TYPE: TEST

DATE ADMINSTERED: 88/09/14

EXAMINER: DAMON, D.

CANDIDATE ______________________

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheets. Points for each question are indicated in parentheses after the question. The passing grade requires at least 70% in each category. Examination papers will be picked up six (6) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	CANDIDATE'S SCORE	% OF CATEGORY VALUE	CATEGORY
15.00	14.42	________	________	A. PRINCIPLES OF REACTOR OPERATION
15.00	14.42	________	________	B. FEATURES OF FACILITY DESIGN
14.00	13.46	________	________	C. GENERAL OPERATING CHARACTERISTICS
15.00	14.42	________	________	D. INSTRUMENTS AND CONTROLS
15.00	14.42	________	________	E. SAFETY AND EMERGENCY SYSTEMS
15.00	14.42	________	________	F. STANDARD AND EMERGENCY OPERATING PROCEDURES
15.00	14.42	________	________	G. RADIATION CONTROL AND SAFETY
104.0		________ Final Grade	________%	Totals

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

____
Candidate's Signature

MASTER COPY

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. 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.

3. Use black ink or dark pencil only to facilitate legible reproductions.

4. Print your name in the blank provided on the cover sheet of the examination.

5. Fill in the date on the cover sheet of the examination (if necessary).

6. Use only the paper provided for answers.

7. Print your name in the upper right-hand corner of the first page of each section of the answer sheet.

8. Consecutively number each answer sheet, write "End of Category __" as appropriate, start each category on a new page, write only on one side of the paper, and write "Last Page" on the last answer sheet.

9. Number each answer as to category and number, for example, 1.4, 6.3.

10. Skip at least three lines between each answer.

11. Separate answer sheets from pad and place finished answer sheets face down on your desk or table.

12. Use abbreviations only if they are commonly used in facility literature.

13. The point value for each question is indicated in parentheses after the question and can be used as a guide for the depth of answer required.

14. Show all calculations, methods, or assumptions used to obtain an answer to mathematical problems whether indicated in the question or not.

15. Partial credit may be given. Therefore, ANSWER ALL PARTS OF THE QUESTION AND DO NOT LEAVE ANY ANSWER BLANK.

16. If parts of the examination are not clear as to intent, ask questions of the examiner only.

17. You must sign the statement on the cover sheet that indicates that the work is your own and you have not received or been given assistance in completing the examination. This must be done after the examination has been completed.

18. When you complete your examination, you shall:

a. Assemble your examination as follows:

(1) Exam questions on top.

(2) Exam aids - figures, tables, etc.

(3) Answer pages including figures which are part of the answer.

b. Turn in your copy of the examination and all pages used to answer the examination questions.

c. Turn in all scrap paper and the balance of the paper that you did not use for answering the questions.

d. Leave the examination area, as defined by the examiner. If after leaving, you are found in this area while the examination is still in progress, your license may be denied or revoked.

DATA SHEET

REACTOR THEORY FORMULAS:

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

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

$$P = \frac{\Sigma \phi_{th} V}{3.12 \times 10^{10} \text{ fissions/sec}}$$

$$SUR = 26.06/\tau$$

$$P_{th} = \frac{1}{1 + (B^2 L_{th}^2)} = e^{-(B^2 L_{th}^2)}$$

$$\rho = \frac{l^*}{\tau} + \frac{\bar{\beta}_{eff}}{1 + \lambda\tau}$$

$$P_f = e^{-(B^2 L_f^2)}$$

$$\rho = \frac{K - 1}{K}$$

$$p = e^{-[N][I_{eff}]/\xi\Sigma_s}$$

$$\Delta\rho = \ln \frac{K_{final}}{K_{initial}}$$

$$C_1 (1-K_{eff1}) = C_2 (1-K_{eff2})$$

$$\tau = \frac{\bar{\beta}_{eff} - \rho}{\lambda\rho}$$

$$m = \frac{1}{1-K} = \frac{C_{final}}{C_{initial}}$$

$$\tau = \frac{l^*}{\rho}$$

$$\alpha_T = \frac{1}{f}\frac{\Delta f}{\Delta t} + \frac{1}{p}\frac{\Delta p}{\Delta t} - B^2 \left(\frac{\Delta L_f^2}{\Delta t} + \frac{\Delta L_{th}^2}{\Delta t}\right)$$

$$K_{eff} = \epsilon P_f \, p \, P_{th} \, f \, \eta$$

$$P_1 = P_0 \frac{\bar{\beta}_{eff} - \rho_0}{\bar{\beta}_{eff} - \rho_1}$$

DATA SHEET

THERMODYNAMICS AND FLUID MECHANICS FORMULAS:

$$\dot{Q} = \dot{m} \Delta h$$

$$\dot{Q} = U A (\Delta T_m)$$

$$\dot{Q} = \dot{m} c_p (\Delta T)$$

$$\eta = \frac{\dot{Q}_{in} - \dot{Q}_{out}}{\dot{Q}_{in}}$$

$$\eta_p = \frac{W_{actual}}{W_{supplied}}$$

$$\dot{m} = \rho A V$$

$$\dot{m} = KA \sqrt{\Delta P_x \rho}$$

$$\Delta T_m = \frac{\Delta T (in) - \Delta T (out)}{\ln \left(\frac{\Delta T (in)}{\Delta T (out)} \right)}$$

$$T_{cl} - T_{ps} = \frac{Gr^2}{4k}$$

$$\dot{Q} = \frac{A \, \Delta T_{total}}{\frac{\Delta x_a}{K_a} + \frac{\Delta x_b}{K_b} + \ldots + \frac{\Delta x_n}{K_n}}$$

$$\dot{Q} = \frac{2 \pi L \Delta T}{\frac{1}{K} + \frac{\ln R_2/R_1}{K_2} + \frac{\ln R_3/R_2}{K_3}}$$

$$\dot{Q} = \alpha \delta A R^4$$

$$\eta = \frac{(h_{in} - h_{out})real}{(h_{in} - h_{out})ideal}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\dot{m}_{nc} = KA_Q \sqrt[3]{Q} = KA \Delta T \sqrt{\Delta T} = KA \Delta p \sqrt{\Delta P}$$

$$G = \frac{\Sigma_f \phi_{th}}{3.8 \times 10^9}$$

$$\dot{Q} = \frac{kA\Delta T}{\Delta x}$$

DATA SHEET

CENTRIFUGAL PUMP LAWS:

$$\frac{N_1}{N_2} = \frac{\dot{m}_1}{\dot{m}_2} \qquad \frac{(N_1)^2}{(N_2)^2} = \frac{H_1}{H_2} \qquad \frac{(N_1)^3}{(N_2)^3} = \frac{P_1}{P_2}$$

RADIATION AND CHEMISTRY FORMULAS:

$R/hr = 6CE/d^2$ $\qquad I_x = I_0 e^{-mx}$ $\qquad C_1V_1 = C_2V_2$

$G = \frac{\text{Dilution Rate}}{\text{Volume}}$ $\qquad I = I_0 \left(\frac{1}{10}\right)^n$ $\qquad C = C_0 e^{-Gt}$

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

CONVERSIONS:

$1\ gm/cm^3 = 62.4\ lbm/ft^3$	Density of water (20 C) = $62.4\ lbm/ft^3$
1 gal = 8.345 lbm	
$1\ ft^3 = 7.48$ gal	Avogadro's Number = 6.023×10^{23}
1 gal = 3.78 liters	Heat of Vapor (H_2O) = 970 Btu/lbm
1 lbm = 454 grams	Heat of Fusion (ICE) = 144 Btu/lbm
e = 2.72	1 AMU = 1.66×10^{-24} grams
$\pi = 3.14159$	Mass of Neutron = 1.008665 AMU
1 KW = 738 ft-lbf/sec	Mass of Proton = 1.007277 AMU
1 KW = 3413 Btu/hr	Mass of Electron = 0.000549 AMU
1 HP = 550 ft-lbf/sec	One atmosphere = 14.7 psia = 29.92 in. Hg
1 HP = .746 KW	°F = 9/5 °C + 32
1 HP = 2545 Btu/hr	°C = 5/9 (°F - 32)
1 Btu = 778 ft-lbf	°R = °F + 460
1 MEV = 1.54×10^{-16} Btu	°K = °C + 273
$h = 4.13 \times 10^{-21}$ M-sec	
1 W = 3.12×10^{10} fissions/sec	
$g_c = 32.2\ lbm\text{-}ft/lbf\text{-}sec^2$	$c^2 = 931$ MEV/AMU
1 inch = 2.54 cm	$C = 3 \times 10^8$ m/sec
$\sigma = 0.1714 \times 10^{-8}\ Btu/hr\ ft^2\ R^4$	

DATA_SHEET

AVERAGE_THERMAL_CONDUCTIVITY_(K)

Material	K
Cork	0.025
Fiber Insulating Board	0.028
Maple or Oak Wood	0.096
Building Brick	0.4
Window Glass	0.45
Concrete	0.79
1% Carbon Steel	25.00
1% Chrome Steel	35.00
Aluminum	118.00
Copper	223.00
Silver	235.00
Water (20 psia, 200 degrees F)	0.392
Steam (1000 psia, 550 degrees F)	0.046
Uranium Dioxide	1.15
Helium	0.135
Zircaloy	10.0

MISCELLANEOUS_INFORMATION:

$E = mc^2$

$KE = 1/2\ mv^2$

$PE = mgh$

$V_f = V_0 + at$

Geometric Object	Area	Volume
Triangle	$A = 1/2\ bh$	//////////////////
Square	$A = S^2$	//////////////////
Rectangle	$A = L \times W$	//////////////////
Circle	$A = \pi r^2$	//////////////////
Rectangular Solid	$A = 2(L \times W + L \times H + W \times H)$	$V = L \times W \times H$
Right Circular Cylinder	$A = (2\pi r^2)h + 2(\pi r^2)$	$V = \pi r^2 h$
Sphere	$A = 4\pi r^2$	$V = 4/3\ (\pi r^2)$
Cube	//////////////////////////////	$V = S^3$

DATA SHEET

MISCELLANEOUS INFORMATION (continued):

Material	Half-Life	Gamma Energy MEV per Disintegration	10 CFR 20 Appendix B				
				Table I		Table II	
				Col I Air uc/ml	Col II Water uc/ml	Col I Air uc/ml	Col II Water uc/ml
Ar-41	1.84 h	1.3	Sub	2×10^{-6}	-----	4×10^{-8}	------
Co-60	5.27 y	2.5	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
I-131	8.04 d	0.36	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
Kr-85	10.72 y	0.04	Sub	1×10^{-5}	-----	3×10^{-7}	------
Ni-65	2.52 h	0.59	S	$9\times10^{-}$[illegible]	4×10^{-3}	3×10^{-8}	1×10^{-4}
Pu-239	2.41×10^{4} y	0.008	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
Sr-90	29 y	-----	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
Xe-135	9.09 h	0.25	Sub	4×10^{-6}	-----	1×10^{-7}	------
Any single radionuclide with $T_{1/2}$ > 2 hr which does not decay by alpha or spontaneous fission				3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}

Neutron Energy (MEV)	Neutrons per cm^2 equivalent to 1 rem	Average flux to deliver 100 mrem in 40 hours
thermal	970×10^{6}	670
0.02	400×10^{6}	280
0.5	43×10^{6}	30
10	24×10^{6}	17

Units of average flux: $\frac{\text{neutrons}}{cm^2 \times sec}$

Linear Absorption Coefficients μ (cm^{-1})				
Energy (MEV)	Water	Concrete	Iron	Lead
0.5	0.090	0.21	0.63	1.7
1.0	0.067	0.15	0.44	0.77
1.5	0.057	0.13	0.40	0.57
2.0	0.048	0.11	0.33	0.51
2.5	0.042	0.097	0.31	0.49
3.0	0.038	0.088	0.30	0.47

QUESTION A.01 (1.00)

Briefly explain the difference between K effective and K infinity.

QUESTION A.02 (2.25)

Describe what is meant by each of the following terms: (.75 ea)

a. Prompt Neutrons

b. Delayed Neutrons

c. Thermal Neutrons

QUESTION A.03 (1.50)

You are required to increase power from 1 watt to 10 KW in 10 minutes on a smooth ramp. Calculate the reactor period required to accomplish this. Show all work.

QUESTION A.04 (1.50)

How much reactivity has been added to a subcritical reactor if the count rate has increased from 75 cps to 150 cps and if the initial value of Keff was .95?

QUESTION A.05 (0.50)

You are performing a reactor startup and add enough reactivity to double the count rate. If the same amount of reactivity were again added to the subcritical reactor, what condition would the reactor be in? Limit your answer to SUBCRITICAL, CRITICAL, OR SUPERCRITICAL.

(***** CATEGORY A CONTINUED ON NEXT PAGE *****)

QUESTION A.06 (0.75)

The -80 second period (-1/3 DPM SUR) following a reactor trip is caused by which of the following?

a. The decay constant of the longest lived group of delayed neutrons precursors.

b. The ability of U-235 to fission with source neutrons.

c. The amount of negative reactivity added on a trip being greater than the Shutdown Margin.

d. The amount of negative reactivity added on a trip being greater than beta.

QUESTION A.07 (1.50)

Assume that a Plutonium-Beryllium neutron source used in a reactor was a 5 curie source when it was manufactured 30 years ago. If that source were replaced by a new 5 curie source, what would be the change in counts per second seen on the startup channel? Show all calculations and state all assumptions. Assume that today's c nt rate before replacement is 1000 counts per second.

QUESTION A.08 (1.50)

Describe the nuclear reactions that take place to produce neutrons from a Plutonium-Beryllium (Pu-Be) source.

QUESTION A.09 (3.00)

For each of the following terms from the four-factor formula, give a word definition: (1.0 ea)

a. fast fission factor (epsilon)

b. reproduction factor (eta)

c. thermal utilization factor (f)

(***** CATEGORY A CONTINUED ON NEXT PAGE *****)

QUESTION A.10 (1.50)

An irradiated sample, just removed from the reactor, reads 21 mrem/hr on an Eberline beta-gamma instrument. A survey 30 minutes later shows 1.2 mrem per hour. Calculate the half-life of the irradiated sample.

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

QUESTION B.01 (1.50)

Describe the makeup of the fuel material, including materials used and enrichment.

QUESTION B.02 (1.00)

What two conditions must be satisfied before the control rod startup interlock may be bypassed?

QUESTION B.03 (2.00)

What are four kinds of experimental facilities at MURR?

QUESTION B.04 (3.00)

List or describe 6 signals or conditions that will result in a rod run-in.

QUESTION B.05 (2.00)

Per Technical Specifications, what are the four major loads that the emergency generator must be able to supply?

QUESTION B.06 (2.50)

Concerning the pressurizer system:

a. Briefly describe automatic pressure and level control of the pressurizer. (1.0)
b. What scram functions are initiated from the pressurizer system? Setpoints not required. (1.5)

QUESTION B.07 (2.50)

Describe the automatic operation of the emergency generator system, from the time of a loss of site power until the generator system secures.

(***** CATEGORY B CONTINUED ON NEXT PAGE *****)

QUESTION B.08 (0.50)

..ue or False:
The control blades cannot be operated in gang control except during hot startup approach to critical following a scram.

(***** END OF CATEGORY B *****)

QUESTION C.01 (3.00)

For each of the following parameters, state the upper limit during steady state operations, and explain the reasons for the limit. (1.5 ea)

a. primary coolant pressure
b. pool temperature

QUESTION C.02 (3.00)

What are the four major hazards involved with beamport experiments?

QUESTION C.03 (2.00)

Technical Specifications list two major negative reactivity coefficients which can halt the rapid power escalation following a positive step reactivity insertion. Identify the coefficients and state their values as listed in Technical Specifications

QUESTION C.04 (3.00)

The reactor shall be considered secure whenever it contains insufficient fuel in the reactor core to establish criticality with all control rods removed. Describe three other conditions that will also meet the reactor secured criteria.

QUESTION C.05 (1.50)

Per Technical Specifications, what is the minimum shutdown margin requirement at the MURR?

(***** CATEGORY C CONTINUED ON NEXT PAGE *****)

QUESTION C.06 (1.50)

Per Technical Specifications, complete the following: (.5 ea)

a. the maximum rate of reactivity insertion for the four shim blades operating simultaneously shall not exceed ________ delta k/sec.
b. the reactivity worth of each secured removable experiment shall be limited to ________ delta k.
c. the regulating blade maximum rate of reactivity insertions shall be ________ delta k/sec.

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

QUESTION D.01 (2.00)

Describe how an uncompensated ionization chamber detects incident thermal neutrons, including in your answer any nuclear reactions that take place in the detector.

QUESTION D.02 (3.00)

At low power, adjusting the compensating voltage on a compensated ion chamber (CIC) will have a very noticeable effect on the output of the detector. However, as power level approaches full power, the effect on the CIC output of changing compensating voltage is almost negligible. Explain this phenomenon.

QUESTION D.03 (1.00)

Why is the bridge ARMS placed in the upscale position prior to removing a control blade offset mechanism?

QUESTION D.04 (3.00)

What are the setpoints for the following scrams? (.5 ea)

a. period.

b. primary coolant low pressure.

c. high power.

d. pool level.

e. pressurizer low level.

f. pressurizer high pressure.

QUESTION D.05 (2.00)

The reactor is not allowed to be started up unless there is adequate neutron flux level monitoring. Name the two ways which are mentioned in Technical Specifications by which this requirement can be satisfied.

(***** CATEGORY D CONTINUED ON NEXT PAGE *****)

QUESTION D.06 (2.00)

What is the minimum nuclear instrumentation for a reactor startup? Include number of channels required.

QUESTION D.07 (1.00)

Explain why, during normal operating conditions, the reactor will scram if the Reactor Convective Loop Valves 546A and 546B are opened. (1.0)

QUESTION D.08 (1.00)

Concerning the nuclear instrument intermediate range channels:
a. What does the Period Automatic Control Interlock Trip prevent? (.5)
b. How is the Period Scram Trip reset? (.5)

(***** END OF CATEGORY D *****)

QUESTION E.01 (3.00)

The reactor is operating at 5 Megawatts with a core inlet pressure of 65 ~~psia~~ psig. For some unexplained reason pressure slowly begins to increase to 115 psig. Describe all actions (including alarms) that will be taken by the pressurizer and safety systems to control or mitigate this pressure increase. (Include setpoints.)

QUESTION E.02 (2.00)

a. Describe how a Reactor Loop Low Pressure Scram initiated by signals from pressure transmitters PT944A or PT944B must be reset. (0.75)

b. Explain why this type of lockout was installed. (0.75)

c. When can this type of scram be bypassed? (0.5)

QUESTION E.03 (1.00)

Which of the following component(s) can be supplied with air from the Emergency Backup Air Compressor? (Note: more than one answer may be correct.)

(1) Pool Loop Isolation Valve 509
(2) Reactor Loop Isolation Valve 507A
(3) Containment Building Exhaust Isolation Valve 16A
(4) Emergency Generator
(5) Freight Door 101 Gasket

QUESTION E.04 (3.00)

a. From what two locations can the Facility Evacuation Alarm be manually initiated. (1.0)

b. Describe four automatic actions which will result from a Facility Evacuation alarm. (2.0)

(***** CATEGORY E CONTINUED ON NEXT PAGE *****)

QUESTION E.05 (2.00)

Which of the following conditions will result in a reactor scram?

(1) Source Range Monitor Channel 1 Inoperative
(2) Low Pool Level
(3) Thermal Column Door Open
(4) High Off-gas Activity
(5) Low Reflector Differential Pressure
(6) Low Pressurizer Level
(7) Low Pool Flow

QUESTION E.06 (2.00)

What is the reason for having a scram associated with differential pressure across the reflector region? Consider both high and low delta P. Include the possible cause of the high and low delta P.

QUESTION E.07 (2.00)

The annunciator system is equipped to back-light windows in two colors other than white. State the other two colors, and what each of the THREE colors mean.

(***** END OF CATEGORY E *****)

QUESTION F.01 (3.00)

Per Technical Specification 2.2, "Limiting Safety System Settings", complete the following: (.5 ea)

a. Safety System Settings during Mode 1 operations:
   Reactor Power 125% Full Power (_____ MW) (max)
   Primary Coolant Flow _____ gpm either loop (min)
   Reactor Inlet Water Temperature _____ degrees F (max)
   Primary Coolant Pressurizer Pressure _____ psia (min)

b. Safety System Settings during Mode 2 operations:

   Reactor Power 125% Full Power (_____ MW) (max)

c. Safety System Settings during Mode 3 operations:
   Reactor Power 125% Full Power (_____ KW) (max)

QUESTION F.02 (1.50)

Technical Specification 3.2, "Control Blade Operation", specifies how the shim blades shall be operated when power level is above 100 KW in order to prevent flux tilting. Explain the method of operation as described in this Technical Specification.

QUESTION F.03 (2.00)

Per Technical Specifications, define an "experiment".

QUESTION F.04 (2.50)

Assume that you are the licensed reactor operator on duty at MURR. A visiting professor from the University of Wisconsin asks if he may perform a startup. He currently holds a senior operator license on the UW Madison Triga reactor. All personnel requirements of the Technical Specifications are met. Do you let him perform the startup under your supervision? Explain why or why not.

(***** CATEGORY F CONTINUED ON NEXT PAGE *****)

QUESTION F.05 (2.00)

True or False:

a. When increasing reactor power, the reactor power level shall be increasing on no greater than a 100 second period.
b. When performing a reactor startup, the stable period shall be no less than 30 seconds.
c. Prior to assuming automatic control for reactor operation, the period as indicated by both IRM-2 and IRM-3 must indicate not less than 35 seconds.
d. When in automatic control for reactor operation, the reg blade must be utilized in such a manner to insure that it is less than 60% withdrawn when the desired power level is reached.

QUESTION F.06 (1.00)

Who can authorize a reactor startup following a scram where the cause has not been determined but all systems are found to be normal?

QUESTION F.07 (3.00)

Describe the three conditions that must be satisfied before the Reactor Short-form Pre-critical Checksheet can be used.

(***** END OF CATEGORY F *****)

QUESTION G.01 (1.00)

Which of the following radiation exposures would inflict the greatest biological damage to man: 1 Rem of GAMMA, 1 Rem of ALPHA, or 1 Rem of NEUTRON? Explain.

QUESTION G.02 (2.00)

One of the immediate actions steps of SEP-4, "Site Area Emergency Procedure", is to send an operator to the west tower with a radiation monitor. List or describe 4 actions that this individual must perform.

QUESTION G.03 (2.50)

A gamma source emits 8 R/hr at one foot. How long could a person work at a distance of 4 feet from the source without exceeding the quarterly whole body limit in 10 CFR 20? Show your work.

QUESTION G.04 (1.50)

A 23 year old individual has accumulated a lifetime occupational dose of 24 rem of whole body exposure documented in accordance with 10 CFR 20 and has received no exposure during the present calendar quarter. How long may he work in a 7 mrem/hr area and not exceed any 10 CFR 20 limits, if he works an 8 hour day? Show your work.

QUESTION G.05 (1.50)

Per 10 CFR 20, an individual in a restricted area may be allowed to receive a whole body dose in excess of the quarterly limit under certain conditions. Describe these three conditions. (1.5)

QUESTION G.06 (3.00)

Calculate the length of time it would take a person to reach their quarterly whole body dose in each of the following fields. Treat each case separately and assume that there is no previous dose received for this quarter. (.75 ea)

a. 400 mr/hr gamma

b. 100 mRAD/hr fast neutron

c. 300 mREM/hr beta

d. A field containing all of the above

QUESTION G.07 (2.00)

Define the following per 10 CFR 20:

a. RADIATION AREA (1.0)

b. HIGH RADIATION AREA. (1.0)

QUESTION G.08 (1.50)

A fuel element is removed from the reactor and the radiation dose rate at 10 feet is 10 mr/hr beta-gamma. At what distance from the fuel element would you post a "Radiation Area" sign?

(***** END OF CATEGORY G *****)
(********** END OF EXAMINATION **********)

ANSWER A.01 (1.00)

K effective takes into account the non-leakage factors that K infinity ignores. (K infinity assumes no leakage.)

REFERENCE

Glasstone and Sesonske, sec 4.4
Training module 3, 1.3-2

ANSWER A.02 (2.25)

a. prompt neutrons are born directly from the fission process

b. delayed neutrons are born from unstable fission daughters

c. thermal neutrons have energy levels in equilibrium with their environment (usually less than 1 ev)

REFERENCE

Glasstone and Sesonske, sec. 1.32, 2.164 to 2.169
Training module 3, 1.5-1 to 1.5-2, 5.1-2 to 5.1-4

ANSWER A.03 (1.50)

P = Po exp (t/T) or T = t/(ln P/Po) (.75)

P= 10E3 watts Po=1 watt t=600 seconds (.25)

T= 600 sec/(ln 10E3) = 600 / 9.2 = 65 seconds (+/- 1 sec) (.5)

REFERENCE

Training module 3, 6.4-2 to 6.4-3

(***** CATEGORY A CONTINUED ON NEXT PAGE *****)

ANSWER A.04 (1.50)

cr1 /cr2 = (1-Keff2)/(1-Keff1) --> 75/150 = (1-Keff2) / (1-0.95)
therefore Keff2=.975 (.75)

rho=(Keff-1)/Keff ==> rho1=-.0526 and rho2=-.0256
and delta rho=+.02699
OR
delta rho = ln (Keff2/Keff1) = ln (.975/.95) = +.026
OR
delta rho = (Keff2-Keff1)/Keff2*Keff1 = .02699 (0.75)
(all answers allowed a tolerance of +/- 0.001)

REFERENCE

Glasstone and Sesonske, Sec. 5.14
Training module 3, 6.1-3

ANSWER A.05 (0.50)

supercritical

REFERENCE

Glasstone and Sesonske, sec 5.14
Training module 3, 6.1-3

ANSWER A.06 (0.75)

a

REFERENCE

Glasstone and Sesonske, Sec. 2.196 to 2.172, 5.28 to 5.32, 5.46 to 5.47
Training module 3, 5.2-2 to 5.2-4, 6.2-1 to 6.2-4

ANSWER A.07 (1.50)

Plutonium has a half life of 2.411 x 10E4 years. Using the formula N = No exp (-.693t/halflife), after 30 years the production of alphas by the plutonium would be

$$e^{-(30 \text{ yrs} \times .693/2.411 \times 10E4 \text{ yrs})} = .9991$$

times its initial value, or the new source would be producing 1/.9991 =1.0009 times more than the old source. Therefore the change in count rate is about 0.1%. This is about 1 count per second. (Will accept a statement that the change is not noticeable as long as the proper calculations are performed.)

REFERENCE

Glasstone and Sesonske, Sec. 2.4
Training module 2, 10.3-1 to 10.3-2
Training module 2, 11.3-1 to 11.3-2

ANSWER A.08 (1.50)

$${}^{239}_{94}Pu \rightarrow {}^{235}_{92}U + {}^{4}_{2}He \quad (0.75)$$

$${}^{9}_{4}Be + {}^{4}_{2}He \rightarrow {}^{12}_{6}C + {}^{1}_{0}n \quad (0.75)$$

REFERENCE

Glasstone and Sesonske, Sec. 2.71 to 2.72
Training module 2, 11.3-1 to 11.3-2

ANSWER A.09 (3.00)

a. number of neutrons from all fissions
----
number of neutrons produced by thermal neutron fissions

b. average number of neutrons produced directly from fission
----
number of neutrons absorbed in fuel

c. number of thermal neutrons absorbed in fuel
----
total number of thermal neutrons absorbed

(1.0 ea)

REFERENCE

Glasstone and Sesonske, Sec. 4.1 to 4.14
Training module 3, 2.1-4 to 2.1-5

ANSWER A.10 (1.50)

A = Ao exp (-.693 t/halflife) (.5)

halflife = (.693 t) / (ln A/Ao) (.25)

halflife = (.693 * 30) / (ln 21/1.2) = 7.26 minutes (.75)

REFERENCE

Training module 2, 10-4.1 to 10.4-3

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

ANSWER B.01 (1.50)

U-Al alloy (.75), 93.5% U-235 enrichment (.75)

REFERENCE

Hazard Summary Report, sec 4.2

ANSWER B.02 (1.00)

master switch in the "test" position
rod magnets are de-energized (.5 ea)

REFERENCE

Hazard Summary Report, 9.5

ANSWER B.03 (2.00)

any four @ .5 ea:
- flux trap
- beamports
- irradiation baskets
- pneumatic tubes
- thermal column

REFERENCE

Hazard Summary Report, 8.2, 8.3, 8.4, 8.5, 8.6

ANSWER B.04 (3.00)

any 6 @ 0.5 ea:
- short period
- high power
- low pool level
- vent tank low level
- antisiphon line high level
- rod not in contact with magnet
- regulating rod bottomed
- regulating rod <= 10% withdrawn
- truck entry open

REFERENCE

Training Manual, II-65 to II-66
Hazard Summary Report, Fig 9-34

ANSWER B.05 (2.00)

emergency lighting system
reactor exhaust system
reactor instrumentation
air lock doors (.5 ea)

REFERENCE

Technical Specification 4.5

ANSWER B.06 (2.50)

a. Constant pressure is maintained by automatically feeding in or bleeding out nitrogen gas. (.5) Water level is automatically maintained by pumping in or draining out water. (.5)
b. hi pressurizer pressure (.5)
lo pressurizer pressure (.5)
lo pressurizer level (.5)

REFERENCE

Training Manual, I-46 to I-48

ANSWER B.07 (2.50)

after a time delay, the engine starts (.5)
alternator supplies the loads continuously for 5 minutes after site power is restored (1.0)
generator system then secures and reverts to ready standby mode (1.0)

REFERENCE

Training Manual, III-8 to III-9

ANSWER B.08 (0.50)

False

(***** CATEGORY B CONTINUED ON NEXT PAGE *****)

REFERENCE

SOP I.4.3.D and E

(***** END OF CATEGORY B *****)

ANSWER C.01 (3.00)

a. 110 psig (.5) Assures that the system design pressure of 125 psig is not exceeded (1.0)
b. 120 degrees F (.5) Assures the adequate cooling of pool components during all modes of operation (1.0)

REFERENCE

Technical Specification 3.4

ANSWER C.02 (3.00)

1. changes in reactor reactivity due to beamport activities (such as draining or flooding a beamport)
2. exposure of personnel to radiation (as a result of movements of shielding or inadequate shielding)
3. release of radioactive gases (such as Ar-41) which are produced in the beamport
4. production of explosive or toxic materials in the beamport.
(.75 ea)

REFERENCE

SOP VIII.4.1.A

ANSWER C.03 (2.00)

Void coefficient (.5) -2.0 x 10E-3 delta k/percent void (.5)
temperature coefficient (.5) -6.0 x 10E-5 delta k/degree F (.5)

REFERENCE

Technical Specification 3.1

(***** CATEGORY C CONTINUED ON NEXT PAGE *****)

ANSWER C.04 (3.00)

any 3 @ 1.0 ea:

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.

REFERENCE

Technical Specification 1.20

ANSWER C.05 (1.50)

The reactor shall be subcritical by a margin of at least .02 k (.75), with any one shim blade fully withdrawn (.75).

REFERENCE

Technical Specification 3.1.e

ANSWER C.06 (1.50)

a. 3.0 x 10E-4 (.5 ea)
b. .006
c. 2.5 x 10E-4

REFERENCE

Technical Specifications 3.1.a, d, g, b, c, e

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

ANSWER D.01 (2.00)

Neutrons interact with the boron in the detector according to the following formula:

$${}^{10}_{5}B + {}^{1}_{0}n \rightarrow ({}^{11}_{5}B)^{*} \rightarrow {}^{7}_{3}Li + {}^{4}_{2}He + \text{electrons} \qquad (1.0)$$

The ions are accelerated in the electric field of the detector, causing additional ionizations in the gas. When the ions reach the electrodes, a pulse is generated. (1.0)

REFERENCE

Glasstone and Sesonske, Sec. 2.84
Training Manual, II-4 to II-7

ANSWER D.02 (3.00)

At low power, gamma current is relatively large compared to the neutron current in the detector. (.5) Thus, changing compensating voltage will have a large effect on the total current output of the detector since this effects only the gamma portion of the detector current. (1.0)

At high power, gamma current is relatively small compared to the neutron current. (.5) Changing the compensating voltage again changes only the gamma portion of the detector current, but since the percentage is so small, the effect is almost not noticeable. (1.0)

REFERENCE

Training Manual, II-7 to II-9

ANSWER D.03 (1.00)

Prevent a building isolation alarm while the blade is being handled out of water.

REFERENCE

SOP II.3.2.A

ANSWER D.04 (3.00)

a. 8 seconds
b. 63 psig
c. 120%
d. 23 feet
e. 13-14 inches below centerline
j. 78 psig

REFERENCE

SOP I, Table IV

ANSWER D.05 (2.00)

1. Source range indicates at least 1 cps and wide range indicates a power level greater than 1 watt. (1.0)
2. Source range indicates at least 2 cps and is verified to be responding to neutrons just prior to startup. (1.0)

REFERENCE

Tech Spec 3.4.e

ANSWER D.06 (2.00)

1 (.25) Source Range (.25)
2 (.25) Intermediate Range (.25)
2 (.25) Power Range (.25)
1 (.25) Wide Range (.25)

REFERENCE

SOP I.4.3.H

ANSWER D.07 (1.00)

Will cause water to bypass the core resulting in low differential pressure. (0.5) Differential pressure switch 929 signal will cause trip unit to reach flow scram setpoint. (0.5)

REFERENCE

Training Manual, p. I-26

ANSWER D.08 (1.00)

a. Prevents the regulating control rod from being operated in the automati mode (0.5)
b. reset using the reset switch (0.5)

REFERENCE

Training Manual, p. II-30, II-31, II-32.

(***** END OF CATEGORY D *****)

ANSWER E.01 (3.00)

When pressurizer pressure exceeds 105% of 70 psi valve 545 will open to bleed off nitrogen gas to the offgas system. (0.75) If pressure exceeds 110% of 70 psi pressurizer high pressure alarm will sound in the control room. (0.75) A reactor scram occurs at 115% of 70 psi. (0.75) At 100 psig the excess pressure will be vented through safety relief valve 537 to the offgas system. (0.75)

REFERENCE

Training Manual, I-46 to I-47

ANSWER E.02 (2.00)

a. Master Control Switch (1S1) has been turned to "test" and then back to "on". (0.75)
b. With the present antisiphon system the core stays pressurized and the 944s can remake, causing cycling of the pumps and valves if not for the circuit lockout. (0.75)
c. Can be bypassed in 50 kilowatt mode. (0.5)

REFERENCE

Training Manual, I-34, II-75

ANSWER E.03 (1.00)

(3) and (5)

REFERENCE

Training Manual, IV-5

(***** CATEGORY E CONTINUED ON NEXT PAGE *****)

ANSWER E.04 (3.00)

a. Reactor Control Room (0.5)
Lobby Control Center (0.5)

b. any 4 of the following @ .5 ea:
Reactor scrams
Containment ventilation system isolation doors close
Containment exhaust isolation valves close
Facility horn sounds
Flashing red light exterior to the containment personnel airlock door is energized

REFERENCE

FEP-1, p. 1.

ANSWER E.05 (2.00)

(2), (5), (6), (7)
(4 required - 0.5 pts each - Will subtract 0.5 pts. for each incorrect answer given up to total value of question)

REFERENCE

SOP I-15 to I-18

ANSWER E.06 (2.00)

hi delta P - possible core blockage (.75)
lo delta P - indicates reduced flow (.75)
both serve as a backup to pool coolant low flow scram (.5)

REFERENCE

Training Manual, II-63, II-70
Technical Specification 3.3

ANSWER E.07 (2.00)

Red (.25) - scram condition (.5)
Blue (.25) - rod run-in condition (.5)
White - simple alarm condition (.5)

(***** CATEGORY E CONTINUED ON NEXT PAGE *****)

REFERENCE

Training Manual, II-67

(***** END OF CATEGORY E *****)

ANSWER F.01 (3.00)

a. 10 MW (0.5 ea)
1625 gpm
155 degrees F
75 psia
b. 5 MW
c. 50 KW

REFERENCE

Technical Specifications 2.2.a, 2.2.b, 2.2.c

ANSWER F.02 (1.50)

The maximum distance between the highest and lowest shim blade (.75) shall not exceed one inch. (.75)

REFERENCE

Technical Specification 3.2.b

ANSWER F.03 (2.00)

Any device or material which is exposed to significant radiation from the reactor and is not part of the reactor. (1.0)
Any operation designed to measure or monitor reactor characteristics or parameters. (1.0)

REFERENCE

Technical Specification 1.5

(***** CATEGORY F CONTINUED ON NEXT PAGE *****)

ANSWER F.04 (2.50)

Would not allow him to perform the startup. (.75)

10 CFR 55 allows non-licensed persons to manipulate the controls of a reactor under supervision only if it is part of the non-licensed individuals training program. The professor is not in training. (1.75)

(Will allow full credit for allowing startup if candidate states the assumption that the professor meets the requirements of being in training as defined at MURR. Credit deducted if allowance is made for the Triga license.)

(Will also accept explaination that the RO cannot supervise reactivity manipulations)

REFERENCE

10 CFR 55.13

ANSWER F.05 (2.00)

a. false
b. true
c. true
d. false (.5 ea)

REFERENCE

SOP II.1.4.C.1, II.1.1.1, II.1.3.A.1, II.1.3.B.3

ANSWER F.06 (1.00)

The Reactor Manager (.5) or his authorized delegate. (.5)

REFERENCE

SOP 1.4.3.A

ANSWER F.07 (3.00)

1. The systems and instrumentation other than those referred to in the short form pre-startup checksheet have been in continuous operation since the completion of the last comprehensive startup checksheet (.5) and the routine systems check has revealed no abnormalities. (.5)
2. A full power or low power pre-startup checksheet has been completed within eight hours prior to the time a short form checksheet is to be used (.5) or the reactor has been operating at some time within the previous eight hours, and a shutdown checksheet has not been completed within this period. (.5)
3. No anomaly with regard to any systems not covered by the short form checksheet has occurred since completion of the last comprehensive startup checksheet (1.0)

REFERENCE

SOP I.4.F.1

(***** END OF CATEGORY F *****)

ANSWER G.01 (1.00)

All the same. (.25) Rem is a unit of biological damage regardless of the source of radiation. (.75)

REFERENCE

10 CFR 20
Training module 5, 2.1-2

ANSWER G.02 (2.00)

1. Verify radiation background at stack monitor
2. verify control room readings
3. mark initial needle position on analog display with the time
4. verify flow rate through monitor to 7 +/- 1 SCFM

REFERENCE

SEP-4, immediate action step 5

ANSWER G.03 (2.50)

$D1 \times (R1)^2 = D2 \times (R2)^2$ [0.6]
8 R/hr x 1 sqft = D2 x 16 sqft [0.4]
D2 = .5 R/hr [0.1]

stay time = total allowed dose / dose rate [0.6]
= 1.25 R / .5 R/hr [0.4] [0.3 for limit]
= 2.5 hr [0.1]

REFERENCE

10 CFR 20.101
Training module 5, 3.2-2 to 3.2-3

(***** CATEGORY G CONTINUED ON NEXT PAGE *****)

ANSWER G.04 (1.50)

may receive 1.25 REM this quarter since he has no quarterly exposure (.5)

Max. Dose = Dose Rate X Time
1.25 Rem = 0.003 Rem/hr X 8 hr/day X No. of Days
No. of Days= 52.1 days (1.0)

REFERENCE

10 CFR 20.101

ANSWER G.05 (1.50)

(1) He does not exceed 3 rem per quarter ((.5)

(2) His radiation history is known and recorded on the proper form (NRC Form 4) (.5)

(3) The dose received when added to his radiation history does not exceed 5(N-18) rem where N = the person's age at his last birthday (.5)

REFERENCE

10 CFR 20.101

ANSWER G.06 (3.00)

a. 1250 mREM/400 mREM = 3.125 hr (QF=1)

b. 1250 mREM/(100mRAD x QF of 10) = 1.25 hr

c. 1250 mREM/300 mREM = 4.17 hr

d. 1250 mREM/(400 mREM + 1000 mREM + 300 mREM) = .74 hr

REFERENCE

10 CFR 20.101
Training module 5, 2.1-2, 3.1-2 to 3.1-3

(***** CATEGORY G CONTINUED ON NEXT PAGE *****)

ANSWER G.07 (2.00)

a. Radiation Area: Any accessible area in which a major portion of the body could receive in one hour a dose in excess of 5 millirems, or in any 5 consecutive days a dose in excess of 100 millirems (1.0).

b. High Radiation Area: Any accessible area in which a major portion of the body could receive in one hour a dose in excess of 100 millirems (1.0).

REFERENCE

10 CFR 20.202

ANSWER G.08 (1.50)

R1 D1**2 = R2 D2**2 (0.25)
Radiation Area- 5 mrem/hr OR 100 mrem/5 days
assuming 8 hr days => 2.5 mrem/hr most limiting (0.5)
D2**2 = 10 (100)/2.5
D2 = 20 ft (0.75)

REFERENCE

10 CFR 20.202
Training module 5, 3.2-2 to 3.2-3

(***** END OF CATEGORY G *****)
(********** END OF EXAMINATION **********)