U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-150/OL-88-01

Docket No. 50-150 License No. R-75

Licensee: Ohio State University
Nuclear Reactor Laboratory
1298 Kinnear Road
Columbus, OH 43212

Facility Name: Nuclear Reactor Laboratory

Examination Administered At: Ohio State University, Columbus, Ohio

Examination Conducted: May 3-4, 1988

Examiner: D. J. Damon 6/8/88
Date

Approved By: for John C. Bjorgen
Michael J. Jordan, Chief
Operator Licensing Section 1
6/8/88
Date

Examination Summary

Examination administered on May 3-4, 1988 (Report No. 50-150/OL-88-01))
Examinations administered to two Senior Reactor Operator candidates.
Results: Both candidates passed the examinations.

REPORT DETAILS

1. Examiner

   D. J. Damon

2. Exit Meeting

   On May 5, 1988, the examiner met with R. D. Myser to discuss findings made during the examination. Due to the limited number of candidates, no findings of a general nature were made concerning candidate strengths and weaknesses.

   The examiner did note that not all preventive maintenance items had an associated written procedure. Mr. Myser agreed to review the need for written procedures for maintenance items that currently do not have a procedure.

3. Examination Review

   The facility comments on the written exam and their associated NRC resolutions are attached.

Facility Comments

Comment H.03:

I can work through the problem in one of three way none of which is particularly easy to ascertain correct answer. They are listed below:

1. Similar to how you worked the problem.

$$\frac{C_2}{C^1} = \frac{1-K_1}{1-K_2}$$

$$1-K_2 = \frac{1-K_1}{\frac{C_2}{C_1}}$$

$$1-K_2 = (1-K_1)\,\frac{1}{3}$$

$$1-K_2 = \frac{1}{3} - \frac{1}{3}K_1$$

$$K_2 = \frac{2}{3} + \frac{1}{3}K_1$$

The value $\frac{2}{3}$ shows up but I'm not sure how to interpret this.

2. Similar to above except using real values for K_1 and C_1 and C_2 is a littler easier to understand.

$CR_1 = 10 \quad K_1 = .94$

$CR_2 = 30 \quad K_2 = \ ?$

$$\frac{30}{10} = \frac{1 - .94}{1-K_2}$$

$$1-K^2 = \frac{1 - .94}{3}$$

$1-K_2 = .02 \qquad K_2 - K_1 = \frac{.04}{.06} = \frac{2}{3}$

$K_2 = .98 \qquad Crit.-K_1 =$

3. Using an equation from another training manual.

$M = \frac{1}{1-X}$ Where X is the fraction toward critical and M is the count rate multiplier, in this case 3.

$3 = \frac{1}{1-X} \qquad 3-3X = 1 \quad 3X = 2 \quad x = \frac{2}{3}$

Again this works but why seems rather ambiguous.

I don't really have a recommendation for how to grade or improve this question. In my judgment it is too ambiguous.

Resolution H.03:

Comment Accepted. Credit will be given for alternate answers that are supported by applicable formulas.

Comment H.05:

An additional correct answer is to utilize the gamma ray spectroscopy system (analyzer) to identify the radioactive materials present.

Resolution H.05:

Comment Accepted. Answer key expanded to include additional correct answer.

Comment H.07:

From another training manual it indicates the correct answer to be "critical". I have attached a copy of the page (Question 203) for your review. I believe that if you keep the "units" as K then the answer is critical. If one converts K to reactivity then the answer appears to supercritical.

Due to the conflict in training materials, I would suggest credit for either critical or supercritical. Also I don't think Section 5.14 of Glasstone & Sesonske is the proper reference for this question.

Resolution H.07:

Comment partially accepted. Keeping the "units" as K is acceptable when K is sufficiently close to 1 so that K is linear with reactivity. Generally, reactivity is a log function with K.

Answer key modified to include critical as a correct answer if the assumption is stated that K is close to 1.

Comment H.09:

Please refer to Appendix H of RS-06 on the calibration of the PNR-4. The correct answer should include at least an awareness on the part of the examinees that the source actually increases with time up to a point. I have included a copy of the discussion about source increase for your information.

Resolution H.09:

Comment accepted. A discussion of the source counts increasing will be accepted for credit.

Comment I.01:

"Supplementary" surveys are done as deemed necessary by the SRO on duty. The phrase "whichever is most frequent" is weighted too heavily in relation to the other parts of the question. Perhaps make all parts worth (.33).

Resolution I.01:

Comment accepted. Point values redistributed.

Comment I.02:

The Eberline RO4A air ionization chamber will detect both (f) gamma and beta radiation.

Resolution I.02:

Comment not accepted. No additional materials sent to support the facility comment. The reference cited supports the original answer. Answer key remains unchanged.

Comment K.03:

Reg Rod	Shim-Safety Rod
Smooth	Grooved
Hollow	Solid

Ref. Fig. 4 OSU Reactor Control Rod Poison Sections.

Resoultion K.03:

Comment accepted. Answer key expanded to include additional answers.

Comment K.06:

Only answer 1 to this question is correct. Answer 2 is a correct statement but does not strictly apply to the question. Perhaps delete part two.

Resoultion K.06:

Comment accepted. Part 2 of answer is deleted and point value adjusted accordingly.

Comment L.01:

The correct answers for d. and e. are reversed. Correct answers are as indicated below:

d. (80% full scale on any range; this is the same as 120%).

e. (150% full power; this is the same as 15KW).

Resolution L.01:

Comment accepted. Answer key modified as requested.

Comment L.05:

The correct answer should be that one person is required to be in the control room any time magnet keys are unlocked and in the control room. This one person can be an R.O. or an S.R.O. It must be a licensed individual.

Resolution L.05:

Comment accepted. Answer key modified as requested.

Comment L.09:

The important part of this question is that the examinee realize that a licensee from the University of Wisconsin is not valid at the OSURR. Therefore, the individual from Wisconsin could not perform a startup by himself. However, it has been the practice at the OSURR to interpret 10 CFR 55.13(a)(1) rather broadly. As a part of the individual's training as a "student" we would allow a visiting professor to startup the reactor if we deemed it appropriate. It is standard practice to allow legitimate directly supervised operation of the OSURR by as many "students" as possible. We define a student similarly to Webster's New Collegiate Dictionary as:

1. Scholar, learner.

2. One who studies: an attentive and systematic observer.

I would recommend the following point distribution for this question.

(1.5) for recognition that the Professor could not operate by himself.

(1.0) for familiarity with 10 CFR 55.13.

Resolution L.09:

Comment not accepted. Per 10 CFR 55.13(a)(1), a "student" is defined as follows: a person who is in training for a license on the reactor, or a person who is enrolled in a course that includes manipulating the controls of the reactor as part of the course. No other definition of "student" is in keeping with 10 CFR 55. Thus, the visiting professor is not considered a student unless enrolled in a course to manipulate the reactor.

Credit will be given for a "yes" answer if the statement is made that the professor is at OSU as part of course work and performs a startup under supervision as part of that course.

The answer key remains unchanged.

MASTER COPY

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

FACILITY: OHIO STATE UNIVERSITY

REACTOR TYPE: TEST

DATE ADMINISTERED: 88/05/03

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
20.00	20.20	________	________	H.	REACTOR THEORY
20.00	20.20	________	________	I.	RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS
20.00	20.20	________	________	J.	SPECIFIC OPERATING CHARACTERISTICS
19.00	19.19	________	________	K.	FUEL HANDLING AND CORE PARAMETERS
20.00	20.20	________	________	L.	ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS
99.00		________ Final Grade	________ %		Totals

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

____
Candidate's Signature

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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 eproductions.

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.

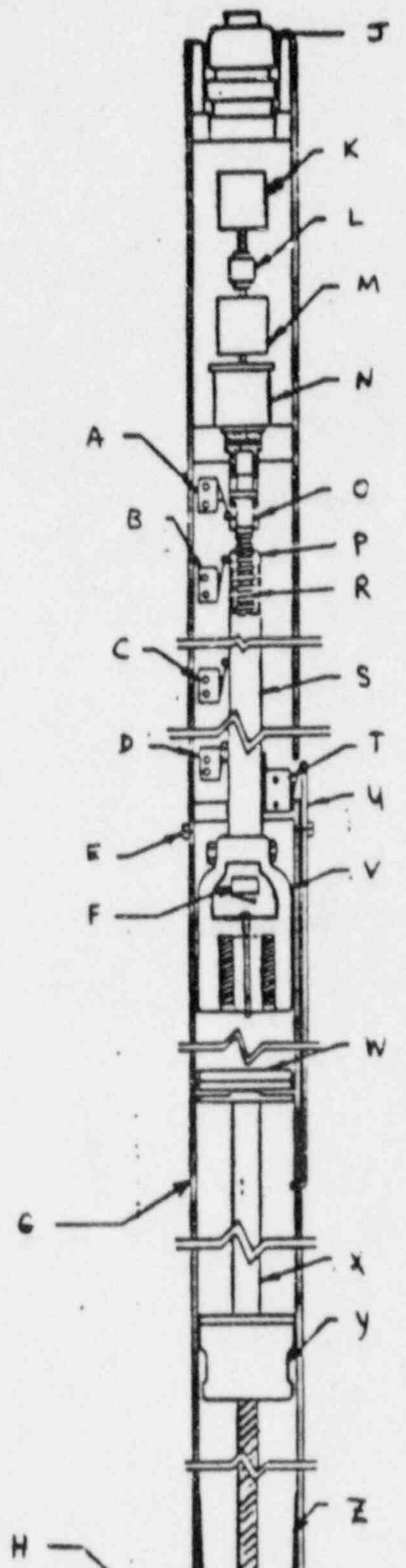

Figure J.07

DATA SHEET

REACTOR THEORY FORMULAS:

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

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

$$P = \frac{\Sigma \, \bar{\phi}_{th} \, V}{3.12 \times 10^{10} \text{ fissions/sec}}$$

$$SUR = 26.06/\tau$$

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

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

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

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

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

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

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

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

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

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

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

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

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

DATA_SHEET

THERMODYNAMICS_AND_FLUID_MECHANICS_FORMULAS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

$$G = \frac{\Sigma_f \bar{\phi}_{th}}{8.8 \times 10^9}$$

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

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

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

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 x 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 x 10^{-24} grams
π = 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 x 10^{-16} Btu	°K = °C + 273
h = 4.13 x 10^{-21} M-sec	
1 W = 3.12 x 10^{10} fissions/sec	
g_c = 32.2 lbm-ft/lbf-sec^2	c^2 = 931 MEV/AMU
1 inch = 2.54 cm	C = 3 x 10^8 m/sec
σ = 0.1714 x 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):

				10 CFR 20 Appendix B			
				Table I		Table II	
Material	Half-Life	Gamma Energy MEV per Disintegration		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	9×10^{-7}	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 (neutrons / $cm^2 \times sec$)
thermal	970×10^{6}	670
0.02	400×10^{6}	280
0.5	43×10^{6}	30
10	24×10^{6}	17

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 H.01 (1.00)

Briefly explain the difference between K effective and K infinity.

QUESTION H.02 (3.00)

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

a. Prompt Neutrons

b. Delayed Neutrons

c. Fast Neutrons

d. Thermal Neutrons

QUESTION H.03 (1.50)

If the count rate in a subcritical reactor were to triple, calculate how much the margin to criticality would change. Show all calculations used to support your answer.

QUESTION H.04 (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 H.05 (.75)

Assume that samples of four different materials were placed in the reactor for irradiation experiments and that the samples were mixed up after they were removed from the reactor. You no longer knew which sample is which. Explain how, using only radiation survey instruments available at OSURR, you can identify the samples. State any assumptions you make.

QUESTION H.06 (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?

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

QUESTION H.07 (.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.

QUESTION H.08 (.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 H.09 (1.50)

Assume that the Pu-Be neutron source used in the 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 count rate before replacement is 1000 counts per second.

QUESTION H.10 (1.50)

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

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

QUESTION H.11 (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)

QUESTION H.12 (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 H.13 (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 H *****)

QUESTION 1.01 (1.00)

According to RS-9, "Area Radiation Surveys", how often shall routine beta-gamma area radiation surveys be performed in the Reactor Building area?

QUESTION 1.02 (3.00)

Complete the following table concerning radiation detection instruments used at OSURR: (.3 ea)

Instrument	Detector Type	Radiation
Eberline E-530	(a)	(b)
Johnson GSM-5	(c)	(d)
Eberline RO-4A	(e)	(f)
ARM's	(g)	(h)
Eberline PNR-4	(i)	(j)

QUESTION 1.03 (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 1.04 (3.00)

a. 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 3 mrem/hr area and not exceed any 10 CFR 20 limits, if he works an 8 hour day? Show your work. (1.5)

b. 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)

(***** CATEGORY 1 CONTINUED ON NEXT PAGE *****)

QUESTION 1.05 (3.00)

How long would a person have to spend in each of the following fields to receive his/her quarterly whole body dose? (.75 ea)

a. 400 mr/hr gamma

b. 100 mRAD/hr neutron

c. 300 mREM/hr beta

d. A field containing all of the above

QUESTION 1.06 (3.50)

A. Define the following per 10 CFR 20:

1. RADIATION AREA (1.0)

2. HIGH RADIATION AREA. (1.0)

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

QUESTION 1.07 (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? Justify your answer.

QUESTION 1.08 (1.50)

For each of the following documents, state whether or not the document is required to be posted per 10 CFR 19.11. Limit your answer to YES or NO. (.25 ea)

a. the license for the facility

b. the operator's licenses

c. the operating procedures

d. 10 CFR 19

e. 10 CFR 20

f. form NRC-3 (Notice to Employees)

QUESTION 1.09 (1.50)

What prevents leakage and leaching of radioactive pool water through the concrete of the pool wall?

(***** END OF CATEGORY 1 *****)

QUESTION J.01 (1.50)

What two interlocks must be met before magnet power can be applied?

QUESTION J.02 (1.00)

Why is a bypass feature provided for the Low Source Level Scram?

QUESTION J.03 (.50)

True or False:

Life of the fuel elements at DSURR is determined by corrosion considerations and not by fuel burnup.

QUESTION J.04 (1.50)

Describe the makeup of the DSURR fuel material, including materials used, the percent contribution of each material, and enrichment.

QUESTION J.05 (2.00)

Describe the difference between a "slow scram" and a "fast scram".

QUESTION J.06 (4.00)

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 10 KW, the effect on the CIC output of changing compensating voltage is almost negligible. Explain this phenomenon.

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

QUESTION J.07 (4.00)

Refer to the attached figure.

Match the letters on the figure to the following components in the shim-safety control rod assembly:

1. Magnet
2. Magnet armature
3. Connecting rod
4. Poison section
5. Fuel element
6. Up switch
7. Down switch
8. Bottom switch
8. Drive motor
10. Position indicator transmitter (fine or course)

QUESTION J.08 (2.50)

Per Technical Specifications, complete the following concerning specifications and characteristics of the OSURR: (.5 ea)

1. Maximum allowable power level is _____.

2. Maximum legal excess reactivity is _____.

3. Maximum scram insertion time shall not exceed _____.

4. Maximum number of fuel elements that may be loaded into the core is _____.

5. The control system shall have a shutdown margin of at least _____.

QUESTION J.09 (3.00)

Per Technical Specifications section 5.4, there shall be 5 channels of nuclear instrumentation operating at all times. List these channels and the minimum operating ranges per Technical Specifications.

(***** END OF CATEGORY J *****)

QUESTION K.01 (1.50)

If a pool leak develops which necessitates draining the pool for repair, explain how protection from fuel element radiation is provided.

QUESTION K.02 (2.00)

Describe how a control-rod fuel element differs from a standard fuel element.

QUESTION K.03 (3.00)

Describe three differences between a shim-safety rod and the regulating rod. (1.0 ea)

QUESTION K.04 (2.00)

Per procedure OM-7, "Fuel Element Inspections", what precaution must be taken in regards to the core prior to removal of a control element if an inspection is to be performed on the control element?

QUESTION K.05 (.50)

True or False:

The "housing" of the Central Irradiation Facility (CIF) can only be located in matrix position (3,3).

QUESTION K.06 (1.00)

Describe the interlock feature associated with the shim-safety rod system that prevents exceeding maximum reactivity addition rates.

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

QUESTION K.07 (3.00)

There are several lights provided on the control panel for each shim-safety rod. For each of the following lights, describe what the light indicates when illuminated, and what color the light is:

a. Jam

b. Up

c. Down

d. Bottom

e. Engage

QUESTION K.08 (1.50)

Per Technical Specifications, define an "experiment".

QUESTION K.09 (2.50)

Answer each of the following questions TRUE or FALSE regarding Technical Specifications: (.5 ea)

a. The neutron source shall be positioned vertically between the grid plate and the top of the fuel elements during startup.

b. A minimum of four channels of nuclear instrumentation shall be on scale, providing meaningful information through all power ranges.

c. During a critical experiment, subcritical multiplication plots shall be obtained from at least four instrumentation channels.

d. The maximum reactivity worth of any single independent experiment shall not exceed 0.5% in reactivity.

e. The reactor shall be operated only when all lattice positions internal to the active fuel boundary are occupied by either a standard or control fuel element.

QUESTION K.10 (2.00)

Concerning fuel handling, per Technical Specifications:

a. How many individuals are required to be present when handling fuel? (.5)

b. How many licensed individuals are required to be present? (.5)

c. What type of licenses are required as a minimum? (1.0)

(***** END OF CATEGORY K *****)

QUESTION L.01 (2.50)

Per Technical Specifications Table 1, for the following conditions or signals, provide the applicable scram setpoint. Assume that none of the scrams are bypassed. (.5 ea)

a. Neutron count rate
b. Reactor period slow scram
c. Reactor period fast scram
d. Reactor power slow scram
e. Reactor power fast scram

QUESTION L.02 (3.75)

Assume that you are the Senior Operator on Duty and that the Laboratory Director and Associate Director are not available when a nuclear emergency occurs. Per Emergency Procedure EP-01, what 5 actions are you responsible for performing?

QUESTION L.03 (2.50)

Per Technical Specifications section 3, what are the limits on pool water depth, water temperature, pH, and conductivity?

QUESTION L.04 (1.50)

Who must approve new procedures before they may be entered into the NRL Procedures Manual?

QUESTION L.05 (1.50)

Per OM-1, "Reactor Power Changes", how many persons with what kind of licenses must be present in the control room any time the magnet control power key is unlocked?

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

QUESTION L.06 (1.50)

Answer the following questions per OM-7, "Fuel Element Inspections":

a. How often should ALL fuel and control rod elements be visually inspected for evidence of pitting and corrosion?

b. In between complete inspections, how many fuel elements must be inspected at least annually?

QUESTION L.07 (2.25)

The Technical Specifications describe an "exclusion area" for OSURR.

a. Define "exclusion area". (1.5)

b. What is the boundary for the exclusion area for OSURR? (.75)

QUESTION L.08 (2.00)

Per Technical Specifications, list four areas that must be monitored by area radiation monitors.

QUESTION L.09 (2.50)

Assume that you are the licensed senior reactor operator on duty at OSURR. 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 Triga reactor. All personnel requirements of the Technical Specifications are met. Do you let him perform the startup under your supervision? Why or why not?

(***** END OF CATEGORY L *****)
(************* END OF EXAMINATION ***************)

ANSWER H.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

ANSWER H.02 (3.00)

a. prompt neutrons are born directly from the fission process

b. delayed neutrons are born from unstable fission daughters

c. fast neutrons have energy levels on the order of 1 Mev (or greater)

d. 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

ANSWER H.03 (1.50)

M = 1/(1-K) where M = count rate multiplier and K = fraction toward critical

M = 3 so K = 2/3 (.75)

Margin to criticality is cut by 2/3 or reactivity in the core is 1/3 of the original (.75)

Credit given for alternate answers that are supported by applicable formulas.

REFERENCE
OSURR student notes, page 5a

ANSWER H.04 (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
OSURR student notes, page 13

ANSWER H.05 (.75)

Take initial readings of each sample and record. Wait some period of time, take another set of readings, and record along with the time difference between readings. This would allow you to calculate a halflife, and thus identify which sample was which. (Alternate wordings acceptable. Alternate explanations acceptable as long as they are supported by viable assumptions.)
Will accept use of the gamma spectroscopy system for credit.

REFERENCE
Glasstone and Sesonske, sec. 2.2 to 2.9

ANSWER H.06 (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=+.027
OR
delta rho = ln (Keff2/Keff1) = ln (.975/.95) = +.026 (.75)

REFERENCE
Glasstone and Sesonske, Sec. 5.14

ANSWER H.07 (.50)

supercritical

Will accept critical if assumption is stated that K is close to 1.

REFERENCE
Glasstone and Sesonske, sec 5.14

ANSWER H.08 (.75)

a

REFERENCE
Glasstone and Sesonske, Sec. 2.156 to 2.172, 5.28 to 5.32, 5.46 to 5.47

ANSWER H.09 (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

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

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.)

Will accept explaination of source term increasing for first 30 years with a plutonium source.

REFERENCE
Glasstone and Sesonske, Sec. 2.4

ANSWER H.10 (1.50)

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

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

REFERENCE
Glasstone and Sesonske, Sec. 2.71 to 2.72

ANSWER H.11 (3.00)

a. $\dfrac{\text{number of fast neutrons slowing down past fission threshold for U-238}}{\text{number of neutrons produced by thermal neutron fissions}}$

b. $\dfrac{\text{average number of neutrons produced directly from fission}}{\text{number of neutrons absorbed in fuel}}$

c. $\dfrac{\text{number of thermal neutrons absorbed in fuel}}{\text{total number of thermal neutrons absorbed}}$

(1.0 ea)

REFERENCE
Glasstone and Sesonske, Sec. 4.1 to 4.14

ANSWER H.12 (2.00)

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

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

ANSWER H.13 (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
RS-06, Appendices A and C

ANSWER I.01 (1.00)

Weekly (.33) or on the day of reactor operations (.33), whichever is most frequent (.34)

REFERENCE
RS-9, sec V.A.1

ANSWER I.02 (2.00)

(a)	G-M	(b)	beta-gamma
(c)	G-M	(d)	beta-gamma
(e)	air ionization	(f)	gamma
(g)	scintillation	(h)	gamma
(i)	BF3 proportional	(j)	neutrons

REFERENCE
RS-06 Appendix C

ANSWER I.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

ANSWER 1.04 (3.00)

a. 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)

b. Provided that (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) rems where N = the person's age at his last birthday (.5)

REFERENCE
10 CFR 20.101

ANSWER 1.05 (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

ANSWER 1.06 (2.50)

A.1 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).

A.2 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).

B. R1 D1**2 = R2 D2**2 (0.50)
Radiation Area= 5 mrem/hr OR 100 mrem/week (2.5 mrem/hr)

```
D2**2    = 10 (100)/5 = 200  OR   = 10 (100)/2.5
D2       = 14.14 ft               = 20 ft            (1.0)
```

REFERENCE
10 CFR 20.202

ANSWER 1.07 (1.00)

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

REFERENCE
10 CFR 20

ANSWER 1.08 (1.50)

b. no, all others yes (.25 ea)

REFERENCE
10 CFR 19.11

ANSWER 1.09 (1.50)

The pool is completely lined with an epoxy-based paint, reinforced with fiberglass.

REFERENCE
OSURR Hazard Summary Report, sec 1.6.1

ANSWER J.01 (1.50)

1. Control and Instrument power must be supplied.
2. Key switch must be inserted and turned on. (.75 ea)

REFERENCE
OSURR Hazard Summary Report, sec 1.7.6

ANSWER J.02 (1.00)

This scram must be bypassed during fuel changing operations, since the shim-safety rods may be partially withdrawn when changing fuel positions.

REFERENCE
OSURR Hazard Summary Report, sec 1.7.7

ANSWER J.03 (.50)

True

REFERENCE
OSURR Hazard Summary Report, sec 1.3.1

ANSWER J.04 (1.50)

14.1 weight-% (.5) U-Al alloy (.5), 93% U-235 enrichment (.5)

REFERENCE
OSURR Hazard Summary Report, sec 1.1

ANSWER J.05 (2.00)

slow scram - power is removed from the slow scram coil, opening a contact in the magnet circuit, allowing the control rod to drop (1.0)

fast scram - biasing is removed from a transistor in the magnet circuit, acting as an electronic switch, allowing the control rod to drop (1.0)

ANSWERS -- OHIO STATE UNIVERSITY -88/05/03-DAMON, D.

REFERENCE
OSURR student notes

ANSWER J.06 (4.00)

At low power, gamma current is relatively large compared to the neutron current in the detector. 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. (2.0)

At high power, gamma current is relatively small compared to the neutron current. 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. (2.0)

REFERENCE
OSU memo from B. K. Hajek dated 7/29/77

ANSWER J.07 (4.00)

1. V
2. W
3. X
4. B
5. H
6. B
7. D
8. T
9. N
10. K or M

REFERENCE
OM-11 attachment C

ANSWER J.08 (2.50)

1. 10 KW

2. 1.5% dk/K

3. 600 msec

4. 2°

5. 6% (.5 ea)

REFERENCE
OSURR Hazard Summary Report, sec 1.1
Technical Specifications 4.1.3, 4.2.3, 4.2.4

ANSWER J.09 (3.00)

startup channel	2 cps to 150 x 10E-4% full power
Log N-period channel	150 x 10E-6% to 150% full power
Linear level channel #1	150 x 10E-6% to 150% full power
Level safety channel #1	150 x 10E-3% to 150% full power
Level safety channel #2	150 x 10E-3% to 150% full power

(.3 for each channel, .3 for each range = 3.0 total)

REFERENCE
Technical Specifications section 5.4

ANSWER K.01 (1.50)

The fuel would be moved into the storage pit and a lead cover is put over the pit, reducing the radiation levels.

REFERENCE
OSURR Hazard Summary Report, sec 1.6.2

ANSWER K.02 (2.00)

The central 4 fuel plates are removed (1.0) and the plates adjacent to the channel are pure aluminum. (1.0)

REFERENCE
OSURR Hazard Summary Report, sec 1.3.2

ANSWER K.03 (3.00)

Any 3 of the following: (1.0 ea)

1. poison section of regulating rod attached directly to drive screw
2. no magnet or magnet engage light on regulating rod
3. 10-turn potentiometer in the drive train of the regulating rod
4. poison section of regulating rod is an aluminum clad stainless steel can instead of borated stainless steel
5. Reg rod is smooth, shim-safety is grooved.
6. Reg rod is hollow, shim-safety is solid.

REFERENCE
OSURR Hazard Summary Report, sec. 1.8.2

ANSWER K.04 (2.00)

All standard fuel elements shall be unloaded (1.0) and stored in the fuel element storage pit (1.0)

REFERENCE
OM-7 section IV.E

ANSWER K.05 (.50)

False

REFERENCE
OSURR Hazard Summary Report, sec. 1.5.6

ANSWER K.06 (1.00)

pushbuttons are mechanically interlocked to prevent withdrawing more than one shim-safety at a time (1.0)

REFERENCE
OSURR Hazard Summary Report, sec. 1.8

ANSWER K.07 (3.00)

(.5 for each purpose, .1 for each color)

a. indicates control rod malfunction. color - red
b. indicates control rod lead screw at upper limit of travel. color - orange
c. indicates control rod lead screw at lower limit of travel. color - green
d. indicates control rod at bottom of core. color - green
e. indicates control rod engaged to the magnet. color - white

REFERENCE
OSURR Hazard Summary Report, sec. 1.8.1

ANSWER K.08 (1.50)

Any apparatus, device, or material installed in or near the core which could conceivably have a reactivity effect on the core (.75) and which itself is not a core component or experimental facility. (.75)

REFERENCE
Technical Specification 6.2.1

ANSWER K.09 (2.50)

a. True
b. False
c. False
d. False
e. False

REFERENCE
Technical Specifications 4.4.1, 5.4, 10.1, 6.2.3, 7.4

ANSWER K.10 (2.00)

a. 3
b. 2
c. RO, SRO

REFERENCE
Technical Specification 8.4

ANSWER L.01 (2.50)

a. 2 cps (.5 ea)
b. +5 sec
c. +1 sec
d. 80% full power (120% scale)
e. 150% full power (15 KW)

REFERENCE
Technical Specifications, Table 1

ANSWER L.02 (3.75)

a. Account for all NRL and experimental personnel by physically examining every office and laboratory area in the Reactor Building.

b. Inform appropriate supervisory personnel

c. Survey all personnel who have evacuated the NRL

d. Proceed with discretion, and with a survey instrument, toward the NRL.

e. Take charge of establishment of exclusion areas, personnel recovery, etc.

REFERENCE
EP-01, step B.2

ANSWER L.03 (2.50)

depth - 15 feet above the top of the active core
max temperature - 145 degrees F
min temperature - 40 degrees F
pH - less than or equal to 8.0
conductivity - less than or equal to 2 umho/cm (.5 ea)

REFERENCE
Technical Specifications section 3

ANSWER L.04 (1.50)

The Associate Director (.75) or Senior Reactor Operator (.75)

REFERENCE
AP-06, step B.2

ANSWER L.05 (1.50)

1 reactor operator OR
1 senior reactor operator

Either answer for 1.5

REFERENCE
OM-1, sec IV.A

ANSWER L.06 (1.50)

a. every three years (.75)
b. five elements (.75)

REFERENCE
OM-7, sec II

ANSWER L.07 (2.25)

a. that area surrounding the reactor, in which the reactor licensee has the authority to determine all activities including exclusion or removal of personnel and property from the area. (1.5)

b. the fence surrounding the Research Center. (.75)

REFERENCE
10 CFR 100..3.a
Technical Specification 1.2

ANSWER L.08 (2.00)

thermal column, beam ports, pool surface above core, demineralizers (.5 ea)

REFERENCE
Technical Specification 5.7

ANSWER L.09 (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)

REFERENCE
10 CFR 55.13

QUESTION	VALUE	REFERENCE
H.01	1.00	DMN0000349
H.02	3.00	DMN0000350
H.03	1.50	DMN0000351
H.04	1.50	DMN0000352
H.05	.75	DMN0000353
H.06	1.50	DMN0000354
H.07	.50	DMN0000355
H.08	.75	DMN0000356
H.09	1.50	DMN0000357
H.10	1.50	DMN0000358
H.11	3.00	DMN0000359
H.12	2.00	DMN0000360
H.13	1.50	DMN0000361
	20.00	
I.01	1.00	DMN0000362
I.02	3.00	DMN0000363
I.03	2.50	DMN0000364
I.04	3.00	DMN0000365
I.05	3.00	DMN0000366
I.06	3.50	DMN0000367
I.07	1.00	DMN0000368
I.08	1.50	DMN0000369
I.09	1.50	DMN0000370
	20.00	
J.01	1.50	DMN0000371
J.02	1.00	DMN0000372
J.03	.50	DMN0000373
J.04	1.50	DMN0000374
J.05	2.00	DMN0000375
J.06	4.00	DMN0000376
J.07	4.00	DMN0000377
J.08	2.50	DMN0000378
J.09	3.00	DMN0000379
	20.00	
K.01	1.50	DMN0000380
K.02	2.00	DMN0000381
K.03	3.00	DMN0000382
K.04	2.00	DMN0000383
K.05	.50	DMN0000384
K.06	1.00	DMN0000385
K.07	3.00	DMN0000386
K.08	1.50	DMN0000387
K.09	2.50	DMN0000388
K.10	2.00	DMN0000389

QUESTION	VALUE	REFERENCE

	19.00	
L.01	2.50	DMN0000390
L.02	3.75	DMN0000391
L.03	2.50	DMN0000392
L.04	1.50	DMN0000393
L.05	1.50	DMN0000394
L.06	1.50	DMN0000395
L.07	2.25	DMN0000396
L.08	2.00	DMN0000397
L.09	2.50	DMN0000398

	20.00	

	99.00	

DOCKET NO 150