U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-151/OL-86-01

Docket Nos. 50-151 and 356 Licenses No. R-115 and 117

Licensee: University of Illinois
214 Nuclear Engineering Laboratory
103 S. Goodwin Avenue
Urbana, IL 61801

Facility Name: University of Illinois

Examination Administered At: University of Illinois

Examination Conducted: January 15 and 16, 1986

Examiners: R. L. Higgins — 1/29/86 Date

T. D. Reidinger — 1/29/86 Date

Approved By: J. I. McMillen, Chief, Operating Licensing Section — 1/29/86 Date


Examination Summary

Examination administered on January 15 and 16, 1986 (Report No. 50-151/OL-86-01) to one senior reactor operator candidate.
Results: The senior reactor operator candidate passed.

## REPORT DETAILS

1. Examiners

*R. L. Higgins
T. D. Reidinger

*Chief Examiner

2. Examination Review Meeting

An examination review meeting is no longer conducted. Facility comments, followed by the NRC response, are listed below.

Question H.03. Facility Comment:

Answer should refer to the cell effect as the behavior of Zr $H_{1.7}$ provides about 55% of the negative fuel temperature coefficient. Doppler Broadening is a secondary effect and is responsible for about 20% of the negative fuel temperature coefficient. Reference NE 390 notes Section A Reactivity Coefficient Fuel Temp.

NRC Response:

Agree. The answer was changed to: "The basic reason for this reactivity decrease comes from heating the zirc hydride that is mixed with the fuel. As temperature is increased, the hydrogen atoms go into a vibrational state with an energy of 0.13 ev and may go to a second state with an energy of 0.26 ev. When a thermal neutron (0.025 ev) collides with the hydrogen atom, the energy is transferred and hence the neutron is essentially de-thermalized. (1.0)

Part of the reactivity decrease is also attributed to the Doppler broadening. The resonance peaks are broadened due to the heating of U-238, which increases the resonance absorption as the neutrons slow down." (1.0)

Question H.05. Facility Comment:

First part of answer on antimony should not be necessary to answer the question asked.

NRC Response:

Disagree. Antimony - berylium is a secondary source: the antimony is stable until it absorbs a neutron. This fact must be mentioned in order to receive full credit.

Question H.06.a. Facility Comment:

First sentence of question is ambiguous.

NRC Response:

Agree. The question should have been phrased: "Assuming a neutron source strength of 100 counts per second, . . ." The examinee had no problem interpreting the question during the examination.

Question H.06.b. Facility Comment:

Will solve with natural logs. Answer will be nearly the same.

$.001 = Keff^n$

$\ln .001 = \ln .999\ n$

$$n = \frac{\ln .001}{\ln .999} = 6904 \text{ gen.}$$

Could also have used $n = \dfrac{\ln .001}{-\ .001}$

as $\ln Keff = .999$ approximately equal to $-.001$

NRC Response:

Agree. Either of the above methods is satisfactory and will be awarded full credit.

Question H.08. Facility Comment:

Answer is correct for LOPRA but incorrect for TRIGA, it is also correct if one assumes no reactivity change associated with removal of the source. In the TRIGA removal of the source includes removal of a void from the core and hence a positive reactivity addition so power would increase.

NRC Response:

Agree. If the examinee specifies in his answer the specific reactor he is describing, either of the above answers will be awarded full credit.

Question H.10. Facility Comment:

Not very relevant.

NRC Response:

Disagree. Though no xenon oscillations occur in the TRIGA or LOPRA, xenon oscillations are described in facility literature and are thus legitimate examination topics.

Question I.05.a. Facility Comment:

There is only one damper in the exhaust system. This was corrected in some SAR Drawings and is correct in the 390R Drawings.

NRC Response:

Agree. The answer was modified to eliminate all reference to the damper in the main exhaust duct. The facility is admonished to correct the erroneous reference material. It is impossible to create an accurate answer key if the facility reference material is filled with incorrect information.

Question I.06. Facility Comment:

Not Necessary

NRC Response:

Disagree. The phrase was taken word-for-word from the TRIGA FSAR. If the delay tanks are not necessary, the facility literature should be revised to reflect this. In any event, the word "necessary" does not affect question interpretation.

Question I.08. Facility Comment:

This has changed a great deal over the years. Reactor personnel are also not involved. We call the health physics office.

NRC Response:

Partially agree. The answer for part "a" was changed to "Notify the health physics office to arrange for disposal." The facility literature should be changed to reflect current solid waste disposal procedures. Though reactor personnel do not personally package or transport solid waste they nevertheless should know which organization must be contacted in order to properly dispose of solid waste.

Question I.09. Facility Comment:

Same as I-8.

NRC Response:

Partially agree. The answer key was modified to also grant credit for the response "Notify the health physics office to arrange for disposal."

Question I.12. Facility Comment:

Answer is only in case evacuation is necessary. Otherwise he only scrams the reactor.

NRC Response:

Disagree. This question is taken from the Radiation Emergency Plan. If the procedure should be revised, the facility should revise it.

Question J.02. Facility Comments:

Two facility comments were made, and the NRC will respond to each one.

Facility Comment 1:

Not relevant.

NRC Response:

Disagree. The term "albedo" is mentioned in the LOPRA SAR, and the examinee should understand what it means.

Facility Comment 2:

In this case albedo refers to reflected neutrons.

NRC Response:

Agree. The answer was changed to "The fraction of neutrons reflected."

Question J.10. Facility Comment:

The Shim Rod is not used to maintain power on the squarewave. The "Slave" system does not work because the shim differential rod worth and Reg rod worths are not the same when the change over is made (i.e., Reg out to shim out, Reg in).

NRC Response:

All mention of the shim rod being automatically adjusted was removed in the answer key. Facility literature should be revised to reflect current operating practices.

Question K.01.b. Facility Comment:

Values range from .3 to .5 ¢/division.

NRC Response:

Agree. The answer key was changed to "$.003 to $.005."

Question K.01.e. Facility Comment:

60¢ - last amendment to Technical Specifications on LOPRA.

NRC Response:

Agree. The answer key was changed to "$.60."

Question K.02.a. Facility Comment:

Second tool is kept in the TRIGA Tank.

NRC Response:

Agree. The answer was changed to require the mention of a second tool in the TRIGA tank in order to receive full credit.

Question K.05.c. Facility Comment:

Correct setpoints are:

+5 high level (stop primary pump, close valves, high level scram)
-1 3 gpm flow stops

-6 8 gpm flow starts
-12 low level (stop primary pump, close valves; low level scram)

NRC Response:

Agree. The answer was changed to reflect these revised setpoints. The facility is a admonished to revise its literature to reflect actual plant setpoints.

Question K.07. Facility Comment:

1. No longer moved due to broken winch.

2. First answer is required only if LOPRA is made inoperative by Technical Specification Definition.

NRC Response:

1. Agree. Moving the assembly is one of two possible correct responses. Full credit will be awarded if the examinee states: "place a neutron-absorbing screen between the thermal column and the LOPRA."

2. Disagree. This is required by the LOPRA SAR and is therefore required for full credit. The facility is admonished to revise its literature to reflect current operating practices.

Question L.08. Facility Comment:

Hopke's Lab is the Environmental Studies Institute.

NRC Response:

Agree. Full credit will be awarded if "Hopke's Lab" is used instead of "Environment Studies Institute Annex."

Question L.14. Facility Comment:

Could have picked a more meaningful definition.

NRC Response:

Disagree. "Shutdown Reactivity" is a fundamental term with which the examinee should be familiar.

3. Exit Meeting

On January 16, 1986, at the conclusion of the oral examination, the chief examiner held an exit meeting with facility representatives Craig Pohlod, the Reactor Supervisor, and Gerry Beck, the former Reactor Supervisor. The chief examiner informed the facility representatives that the SRO candidate clearly passed the oral and plant walk-through portions of the SRO examination.

The following additional items were mentioned:

1. The literature used by the Chief examiner to prepare for the examination was incorrect and incomplete. The facility representatives agreed and assured the chief examiner that the literature would be corrected prior to the next NRC license examinations.

2. The components (pipes, valves, heat exchangers) were not labeled.

3. Some portions of the Reactor Building were quite dirty, and there was a large amount of extraneous material cluttering certain areas of the Reactor Building.

4. Two beam ports were not adequately locked shut.

5. There was no Tornado Response procedure.

6. Several radiation instruments were not properly calibrated. The portable neutron detector was almost six months overdue for calibration. The Continuous Air Monitor for the ventilation system has a missing calibration sticker.

7. The chief examiner thanked the facility representatives for their cooperation during the course of the examinations.

Master

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

FACILITY: UNIVERSITY OF ILLINOIS

REACTOR TYPE: TRIGA ADV

DATE ADMINISTERED: 86/01/15

EXAMINER: HIGGINS, R.

APPLICANT: ______________________

INSTRUCTIONS TO APPLICANT:

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 | APPLICANT'S SCORE | % OF CATEGORY VALUE | CATEGORY |
|---|---|---|---|---|
| 20.00 | 20.00 | ________ | ________ | H. REACTOR THEORY |
| 20.00 | 20.00 | ________ | ________ | I. RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS |
| 20.00 | 20.00 | ________ | ________ | J. SPECIFIC OPERATING CHARACTERISTICS |
| 20.00 | 20.00 | ________ | ________ | K. FUEL HANDLING AND CORE PARAMETERS |
| 20.00 | 20.00 | ________ | ________ | L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS |
| 100.00 | 100.00 | ________ | ________ | TOTALS |

FINAL GRADE _______________%

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

______________________________
APPLICANT'S SIGNATURE

QUESTION H.01 (1.00)

What will happen to a neutron outside the nucleus if it never gets absorbed?

QUESTION H.02 (1.50)

Why is the value of $\beta$eff different from $\beta$act?

QUESTION H.03 (2.00)

Explain why an increase in fuel temperature decreases reactivity.

QUESTION H.04 (1.00)

Why is a neutron source needed for reactor startups?

QUESTION H.05 (1.50)

Explain how the two TRIGA neutron sources produce neutrons.

QUESTION H.06 (2.00)

a. Assuming a neutron source strength of 100 ~~neutrons~~ counts per second, what will be the equilibrium count rate if the source is placed in the presence of a reactor assembly which has an effective multiplication constant (Keff) of .99? Show your work. (1.0)

b. If Keff is raised to .999, how many neutron generations must elapse before the count rate attains 99.9% of its equilibrium value (within 0.1% of its equilibrium value)? Show your work. (1.0)

QUESTION H.07 (1.50)

If the TRIGA has a Keff of .96, how much reactivity, in dollars, must be added to make the reactor critical? Show your work.

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

QUESTION H.08 (1.00)

What would happen if the neutron source is removed from a reactor which is just critical?

QUESTION H.09 (2.00)

With a reactor period of 50 seconds, how long will it take for reactor power to increase from 50 watts to 1 kilowatt? Show your work.

QUESTION H.10 (2.00)

Explain how rod motion can cause xenon oscillations.

QUESTION H.11 (1.50)

What will reactor power be immediately after a reactor trip from 1 MW, assuming $8.00 of negative reactivity is added by the control rods? Show your work.

QUESTION H.12 (1.00)

Why don't delayed neutrons cause fission in U-238?

QUESTION H.13 (1.00)

Choose the correct response. Samarium as a poison in the core reaches an equilibrium reactivity value in approximately:

a. 40 hours

b. 400 hours

c. 4000 hours

d. the time depends upon the neutron flux level.

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

QUESTION H.14 (1.00)

Which one of the following will NOT affect the peak power of a $3 pulse:

a. delayed neutron fraction.

b. average neutron lifetime.

c. number of fuel elements in the core.

d. heat capacity of the fuel.

(***** END OF CATEGORY H *****)

QUESTION I.01 (1.00)

What are the three NRC limits for external radiation exposure?

QUESTION I.02 (1.00)

What three criteria must be satisfied/observed to allow a radiation worker to exceed the NRC external whole body radiation exposure limits?

QUESTION I.03 ( .50)

What external whole body radiation exposure limit must be observed for individuals under 18 years of age?

QUESTION I.04 (1.00)

Name two fission products, other than iodine, which are gases at room temperature.

QUESTION I.05 (2.00)

a. What automatic action takes place to limit iodine release through the ventilation system? (1.5)

b. What detector is used to cause this automatic action? (0.5)

QUESTION I.06 (2.50)

According to the FSAR, it is necessary that the radioactive coolant water emerging from the core be delayed about 90 seconds before being introduced into areas that may be occupied.

a. Write the equation for the formation of the radioactive isotope which makes this delay necessary. (1.0)

b. What is the half-life of this radioactive isotope? (0.5)

c. What design feature(s) is/are installed to provide this 90 second delay? (1.0)

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

QUESTION I.07 (2.00)

What is the function of the Beam Catchers?

QUESTION I.08 (3.00)

a. Describe how the University of Illinois disposes of high-level solid radioactive wastes. (2.0)

b. Where are high-level solid radioactive wastes stored at the University of Illinois? (1.0)

QUESTION I.09 (1.00)

How does the University of Illinois dispose of liquid radioactive wastes from the retention tank if the activity in the tank is too high to allow release to the sanitary sewer system?

QUESTION I.10 (1.00)

How is radioactive Argon 41 produced?

QUESTION I.11 (1.00)

a. What sound does the audible alarm for the Tracerlab 5-Channel Ion Chamber System make? (0.5)

b. What sound does the audible alarm for the Air Particulate Monitor make? (0.5)

QUESTION I.12 (3.00)

What six immediate actions must the licensed operator take if high off-gas activity occurs while the reactor is in operation?

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

QUESTION I.13 (1.00)

a. True or False. Rubidium-88 is a Radon daughter. (0.5)

b. True or False. Materials composed of elements with high atomic weights make the best neutron shields. (0.5)

(***** END OF CATEGORY I *****)

QUESTION J.01 (1.00)

Explain how and why the reactivity of the LOPRA will change if the LOPRA is moved from its normal position next to the bulk shielding thermal column.

QUESTION J.02 (1.00)

The LOPRA SAR states that 'the portion of the thermal column containing two feet of graphite is lined with polyethylene to provide a greater albedo.' What is 'albedo'?

QUESTION J.03 (3.00)

Explain how the natural convective cooling loop is designed to allow natural convection to automatically commence upon loss of forced convection while avoiding interference with the coolant flow during forced convection.

QUESTION J.04 (3.00)

a. What are the two functions of the emergency core spray cooling system? (2.0)

b. What design feature is installed in the emergency core spray cooling system to prevent a leak in the emergency core spray cooling system piping from draining the Reactor Tank? (1.0)

QUESTION J.05 (2.00)

Explain why a reduction in the level of the bulk shielding facility could cause a LOPRA scram.

QUESTION J.06 (2.00)

Why would a leak in the primary coolant lines between the TRIGA core and the isolation valves not result in the complete draining of the Reactor Tank?

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

QUESTION J.07 (2.00)

Explain why all the TRIGA rods scram when electrical power is lost.

QUESTION J.08 (2.00)

During forced convection, the temperature rise through the core will double if reactor power doubles. During free convection, the temperature rise through the core will increase, though by less than a factor of two, if reactor power doubles. Explain why the increase in the temperature rise across the core is less for the free convection case than it is for the forced convection case.

QUESTION J.09 (2.00)

a. The poison section of the TRIGA control rod consists of _____. (0.5)

b. The _____ rods are 'fuel follower' rods. (0.5)

c. Why is the adjustable transient rod constructed with an air follower? (1.0)

QUESTION J.10 (2.00)

How are rods controlled during square-wave operation?

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

QUESTION K.01 (2.50)

a. Burn-up of U-235 for a TRIGA reactor is estimated to be _____ per MW day of operation. (0.5)

b. A single rod division is worth approximately _____ in reactivity. (0.5)

c. The equilibrium reactivity value of Xenon for the TRIGA at 1.5 MW is approximately _____. (0.5)

d. The equilibrium reactivity value of Samarium for the TRIGA is approximately _____. (0.5)

e. The excess reactivity in the LOPRA is limited to _____. (0.5)

QUESTION K.02 (1.50)

a. Where ~~is~~ are the fuel handling tools kept? (1.0)

b. What precaution is taken to prevent unauthorized movement of the fuel-moderator elements? (0.5)

QUESTION K.03 (1.00)

Which two individuals control the keys to the room where the cold fuel elements are stored?

QUESTION K.04 (2.00)

Explain how irradiated fuel elements can be placed inside the fuel transfer cask without exposing fuel handling personnel to high radiation fields.

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

QUESTION K.05 (6.50)

a. The normal Reactor Tank water level (reference point) is _____ above the top grid plate of the core assembly. (0.5)

b. The two intermediate level trips are _____ below the reference point and _____ ~~above~~ below the reference point. (1.0)

c. What automatic action occurs if the Reactor Tank water level drops to the lower intermediate water level trip setpoint? (0.5)

d. What automatic action occurs if the Reactor Tank water level rises to the upper intermediate water level trip setpoint? (0.5)

e. The emergency level trips are set at _____ below and _____ above the reference point. (1.0)

f. What is the basis for the higher emergency water level trip? ~~(0.5)~~ (1.0)

g. What ~~four~~ three automatic actions will take place if water level drops to the lower emergency water level trip setpoint? ~~(1.0)~~ (2.0)

QUESTION K.06 (1.50)

a. How many scram-capable rods does the LOPRA have? (0.5)

b. What neutron-absorbing material is used in the LOPRA control rods? (0.5)

c. Movements of LOPRA fuel shall not be made except under the direct supervision of _____. (0.5)

QUESTION K.07 (2.00)

List two modifications which must be done to the LOPRA if the TRIGA is to be operated above one kilowatt and no experimental work with the LOPRA is in progress.

QUESTION K.08 (3.00)

a. The reactivity worth of a single experiment must be less than _____. (0.5)

b. The TRIGA may be operated for a maximum time of _____ when the ventilation system is not in operation, provided that reactor power is not raised above _____. (1.0)

c. The total of the absolute values of all experiments in the TRIGA must be less than _____. (0.5)

d. A fuel temperature scram will occur if the maximum fuel temperature of a B-ring instrumented element exceeds _____. (0.5)

e. A water temperature scram will occur if the bulk water temperature of the core exit coolant exceeds _____. (0.5)

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

QUESTION L.01 (1.00)

What is the Shutdown Margin requirement for the TRIGA?

QUESTION L.02 (1.00)

Escorted visitors may be taken into the reactor area only with the approval of the _____ or the _____.

QUESTION L.03 (2.00)

a. What is the whole body dose limit for saving a life? (0.5)

b. Whose permission must be obtained prior to exceeding normal occupational radiation exposure limits? (0.5)

c. Whose permission must be obtained prior to re-entering the reactor building after a radiation emergency? (0.5)

d. True or False. Any member of Group B can take any action which he deems necessary if he considers a delay to be deterimental to the safety of personnel in the immediate area. (0.5)

QUESTION L.04 (1.00)

a. A radiological emergency which requires evacuation of the reactor building would be classified as a(n) _____. (0.5)

b. A radiological emergency which requires evacuation of adjacent buildings would be classified as a(n) _____. (0.5)

QUESTION L.05 (1.00)

Name the two basic checks which are used to determine whether all personnel who had been in the reactor building prior to an evacuation have left the building.

QUESTION L.06 (1.00)

Where are personnel who have evacuated the reactor building required to reassemble?

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

QUESTION L.07 (1.00)

What is the primary means of communication used to notify the onsite emergency organization during an emergency?

QUESTION L.08 (1.00)

In which buildings are the alternate emergency support centers located?

QUESTION L.09 (1.00)

What environmental factor is used to decide which emergency support center to use?

QUESTION L.10 (1.00)

What is meant by the term 'Reactor Shutdown'?

QUESTION L.11 (2.00)

What is meant by the term 'Reactor Secured'?

QUESTION L.12 (1.00)

What are the two TRIGA Safety Limits?

QUESTION L.13 (1.00)

State two actions which must be taken immediately after a TRIGA safety limit is exceeded.

QUESTION L.14 (2.00)

What is meant by the term 'Shutdown Reactivity'?

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

QUESTION L.15 (1.00)

Who can make temporary changes to a TRIGA operating procedure, assuming the changes do not modify the procedure's original intent?

QUESTION L.16 (2.00)

List two of the six general categories of Abnormal Occurrences.

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

# EQUATIONS

## REACTOR THEORY

$$P = P_o e^{t/\tau} = P_o 10^{SUR \cdot t}$$

$$\tau = \frac{\bar{l}^*}{\rho} + \frac{\beta - \rho}{\lambda\rho} \quad \text{or} \quad \tau = \frac{\beta - \rho}{\lambda\rho}$$

$$\rho = \frac{k - 1}{k} \qquad \frac{k_2 - k_1}{k_2 k_1} = \Delta\rho$$

$$\frac{cps_2}{cps_1} = \frac{1 - k_1}{1 - k_2} \qquad k < 1$$

$$\frac{1}{M} = 1 - k$$

$$\frac{1}{M} = \frac{cps_o}{cps_n}$$

$$\rho_{net} = \Delta(\rho_{doppler} + \rho_{mod} + \rho_{void} + \rho_{Xe} + \rho_{Sm} + \rho_{Pu} + \rho_{Boron} + \rho_{rod} + \rho_{fuel} + \rho_{Poisons})$$

$$k_2 = k_1 + \delta k$$

$$\delta k = k - 1$$

$$SUR = \frac{26.06}{\tau}$$

$$P = \frac{\Sigma\phi V}{3.1 \times 10^{10}}$$

$$\Sigma = N\sigma$$

$$\phi = nv$$

Defect = Coeff x $\Delta$ Parameter

## RADIATION

$$N = N_o e^{-\lambda t}$$

$$A = \lambda N$$

$$I = I_o e^{-\mu x} = I_o 10^{-x/TVT}$$

$$\lambda T_{1/2} = 0.693$$

$$\text{R/hr @ d feet} = \frac{6CE}{d^2}$$

$I_1 d_1^2 = I_2 d_2^2$ point source

$I_1 d_1 = I_2 d_2$ - line source

R/hr x time = R

Rad x QF = Rem

$$T_{1/2\,eff} = \frac{T_{1/2\,Bio} \times T_{1/2\,Rad}}{T_{1/2\,Bio} + T_{1/2\,Rad}}$$

## MATH

$$y^a = b$$

$$\log_y b = a$$

$$\log x^c = c \log x$$

$$\log \frac{x}{y} = \log x - \log y$$

$$\log xy = \log x + \log y$$

## FLUIDS/THERMO/HEAT TRANSFER

$$\dot{m} = A_1\rho_1V_1 = A_2\rho_2V_2$$

$$Q = A_1V_1 = A_2V_2$$

$$E_{in} = E_{out} + \Delta E_{stored}$$

$$E = KE + PE + U + pV + Q + W$$

$$PE = \frac{mg}{g_c} z$$

$$KE = \frac{1}{2} m \frac{V^2}{g_c}$$

reduced for - turbine, SG pump, nozzle, orifice, condenser, pipe, Rx

$$\text{flow} \propto \sqrt{dp}$$

$$\text{head loss} = f\frac{L}{D}\frac{V^2}{2g_c} \quad \text{or head loss} \propto V^2$$

$$\text{head loss} \propto \Delta p = k\frac{V^2}{2g_c}$$

$$p = h + p_{ambient}$$

$$F = pA$$

$$\Delta P_{2\,phase} = \Delta P_{1\,phase} \times K$$

k = f(quality & Pressure)

Pump laws speed $\propto$ flow

(speed)$^2$ $\propto$ pressure

(speed)$^3$ $\propto$ power

$$Q = kA\Delta T = hA\Delta T = UA\Delta T$$

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

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

$$Q = \epsilon\sigma T$$

$$\Delta H = mc_p\Delta T$$

$$\Delta U = mc_v\Delta T$$

$$H = U + pV$$

$$\Delta S = \frac{\Delta Q}{T}$$

$$pV = nRT$$

$$\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$$

$$C_1V_1 + C_2V_2 = C_3(V_1 + V_2)$$

Master



ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER H.01 (1.00)

Beta decays to a proton (hydrogen).

REFERENCE
NE 390R Notes, p 3

ANSWER H.02 (1.50)

Prompt neutrons are born at a higher average energy than delayed neutrons (.75), so a smaller percentage of delayed neutrons is lost while slowing down (.75).

REFERENCE
NE 390R Notes, p 2

ANSWER H.03 (2.00) Zirc-hydride resonance, which tends to dethermalize the neutrons (1.0)

Doppler Broadening. When U-238 temperature increases, the relative motion between the neutrons and U-238 atoms increases, broadening the resonant absorption peaks (~~1.0~~ .5). The probability of parasitic neutron absorption by U-238 increases, decreasing the probability that neutrons will reach thermal energies (~~1.0~~ .5).

REFERENCE
NE 390R Notes, p 5

ANSWER H.04 (1.00)

Provide a neutron level which is high enough to be detected by nuclear instrumentation (0.5), allowing reactivity changes taking place in the reactor to be observed (0.5).

REFERENCE
NE 390R Notes, p 6

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER H.05 (1.50)

1. Radium emits an alpha (.25). The alpha enters a Be-9 nucleus which then splits, emitting a neutron(0.5).
2. Antimony 123 absorbs a neutron, becoming antimony 124 (.25). Antimony 124 emits a gamma which strikes a Be-9 nucleus, causing it to emit a neutron (0.5).

REFERENCE
NE 390R Notes, p 6

ANSWER H.06 (2.00)

a. Count rate = S/(1-Keff) = 100/(1-.99) = 100/.01 = 10,000 counts per second (1.0).

b. Count rate = S x $(1+Keff+Keff^2+...+Keff^n+...)$ (.2)
Keff = 0.1% = .001 (.2)
.999 = .001 (.2)
n log(.999) = log(.001) = -3 (.2)
n = -3/log(.999) = -3/.0004345 = 6905 generations (.2)

REFERENCE
NE 390R Notes, p 8 and 9

ANSWER H.07 (1.50)

$\Delta\rho = (K_2-K_1)/(K_2 \times K_1) = (1-.96)/(1 \times .96) = .04/.96 = .041667$ (.75)
$\Delta\rho = .041667 \times (\$1/.0073) = \$5.71$ (.75)

REFERENCE
NE 390R Notes, p 9

ANSWER H.08 (1.00)

The power level would decrease for a short time (0.5) before leveling off at a constant value (0.5).

REFERENCE
NE 390R Notes, p 10

ANSWER    H.09        (2.00)

$P = P_0 \times e\ exp(t/\tau)$     (0.5)
$P/P_0 = e\ exp(t/\tau)$     (0.5)
$\ln(P/P_0) = t/\tau$     (0.5)
$t = \tau \ln(P/P_0) = (50\ \text{seconds}) \times \ln(1000w/50w) = 50 \ln(20) = 50 \times 3$
$t = 150$ seconds     (0.5)

REFERENCE
NE 390R Notes, p 11

ANSWER    H.10        (2.00)

If a control rod is removed, flux in the vacated region increases, increasing xenon burnout (0.5). Xenon concentration temporarily decreases, further increasing the localized flux (0.5).
If a control rod is inserted, flux in the vicinity decreases, decreasing the xenon burnout (0.5). Xenon concentration temporarily increases, futher decreasing the localized flux (0.5).

REFERENCE
NE 390R Notes, p 15

ANSWER    H.11        (1.50)

$P = P_0\ [\beta/(\beta-\rho)]$     (.75)
$P = 1\ MW\ [\$1/(\$1 - \$8)] = 1\ MW\ [1/9] = 111\ KW$     (.75)

REFERENCE
NE 390R Notes, p 11

ANSWER    H.12        (1.00)

Delayed neutrons are born at lower energies than the threshold energy for U-238 fission.

REFERENCE
NE 390R Notes, p 2

ANSWER H.13 (1.00)

d

REFERENCE
NE 390R Notes, p 15

ANSWER H.14 (1.00)

a.

REFERENCE
NE 451 Final Exam, 76/07/30, #7

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER I.01 (1.00)

Whole Body - 1.25 rems per quarter. (0.5)
Extremities - 18.75 rems per quarter. (.25)
Skin - 7.5 rems per quarter. (.25)

REFERENCE
10CFR20.101

ANSWER I.02 (1.00)

1. Quarterly dose does not exceed 3 rems (.3)
2. Lifetime exposure does not exceed 5(N-18) (.4)
3. NRC Form 4 is completed (.3)

REFERENCE
10CFR20.101

ANSWER I.03 ( .50)

.125 rems per quarter

REFERENCE
10CFR20.104

ANSWER I.04 (1.00)

Krypton (0.5) and Xenon (0.5).

REFERENCE
FSAR V-14

ANSWER I.05 (2.00)

a. ~~The damper in the main exhaust duct will be closed automatically (.75) and~~ The damper in the duct containing the charcoal filter will be opened ~~(.75)~~ (1.5)
b. Air Particulate Monitor (0.5).

REFERENCE
FSAR V-15b

ANSWER I.06 (2.50)

a. Oxygen-16 plus a neutron gives Nitrogen-16 plus a proton. (1.0)

b. 7 seconds. (0.5)

c. Two delay tanks are installed in the primary coolant system on the outlet loop from the reactor. (1.0)

REFERENCE
FSAR IV-2,5

ANSWER I.07 (2.00)

Reduce the background radiation during usage of a beam port.

REFERENCE
FSAR IX-13

ANSWER I.08 (3.00)

Notify health physics office to arrange for disposal.

a. ~~Placed in shielded storage until activity is low enough to treat as low-level radioactive waste (1.0), then packaged in 55 gallon steel drums and shipped to a disposal facility (1.0)~~.

b. Four storage pits located in the floor of the truck bay. (1.0)

REFERENCE
FSAR XI-1

ANSWER I.09 (1.00)

Tank contents can be discharged through the hose bleed valve into a tank truck.

REFERENCE
FSAR XI-5

ANSWER I.10 (1.00)

Neutron capture by the naturally-occurring Argon-40 in the atmosphere.

REFERENCE
FSAR XI-6

ANSWER I.11 (1.00)

a. Loud horn. (.5)

b. Continuous pulsing of the alarm bell. (0.5)

REFERENCE
FSAR XI-25

ANSWER I.12 (3.00)

1. Initiate building evacuation. (0.5)
2. Scram the reactor. (0.5)
3. Turn off both water circulation systems. (0.5)
4. Close the isolation valves. (0.5)
5. Turn off the circulation fan for the air conditioner. (0.5)
6. Close the diverting valve on the exhaust system. (0.5)

REFERENCE
Radiation Emergency Plan, p 10

ANSWER I.13 (1.00)

a. False (0.5)

b. False (0.5)

REFERENCE
FSAR XI-24,25

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER J.01 (1.00)

Reactivity will decrease, since graphite in the thermal column serves as a reflector.

REFERENCE
LOPRA FSAR III.C.3.c

ANSWER J.02 (1.00)

The fraction of ~~electromagnetic radiation (gamma rays)~~ neutrons reflected.

REFERENCE
Webster's New Collegiate Dictionary

ANSWER J.03 (3.00)

Piping connects the plenum below the reactor to the outer housing above the reactor (.75). Located in this piping is an automatic control valve with a counterbalanced lever system (.75). When forced circulation is taking place the valve is held shut by the force of the flow (.75). If forced circulation is lost, the counterbalance weight will cause the valve to open, allowing natural circulation flow to begin (.75).

REFERENCE
FSAR VI-2

ANSWER J.04 (3.00)

a. 1. Supply demineralized water so the chamber above the core remains full of water (1.0).
   2. Supply water to the core for cooling should all water drain from the core (1.0).

b. Anti-syphon check valve (1.0).

REFERENCE
FSAR VI-9, 10 and 11

ANSWER J.05 (2.00)

As the level drops, shielding is reduced, raising the radiation level above the bulk shielding tank where the gamma monitor is located (1.0). If the radiation level rises high enough, the gamma monitor will generate a LOPRA scram (1.0).

REFERENCE
LOPRA SAR p 10 and 13

ANSWER J.06 (2.00)

The primary coolant lines pass through a tunnel which has a sealed barrier located in it to limit the tunnel's volume to less than the volume of the Reactor Tank.

REFERENCE
FSAR VI-13

ANSWER J.07 (2.00)

1. The motor driven rods are held in position by an electrical magnet which will deenergize upon loss of electrical power, allowing the rods to drop by gravity (1.0).
2. The transient rods depend on electrically operated solenoid valves to retain the necessary pressure to hold them in the UP position. If electrical power is lost, the solenoid deenergizes, allowing air pressure to diminish, causing the rods to drop by gravity (1.0).

REFERENCE
FSAR VII-24

ANSWER J.08 (2.00)

In the free convection case, as power increases, the temperature rise through the core increases, increasing the density difference between the inlet and outlet coolant, thus increasing free convection flow. Some of the power increase is absorbed by the increased core flow (1.0).
In the forced convection case, the increased power is only removed by increasing the enthalpy of the coolant as it passes through the core, since the core flow remains constant (1.0).

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

REFERENCE
FSAR IV-34

ANSWER J.09 (2.00)

a. Graphite impregnated with boron carbide (0.5).

b. Manually driven (0.5).

c. To diminish the flux peaking if water filled the rod channel after the rod was withdrawn (1.0).

REFERENCE
FSAR III-16

ANSWER J.10 (2.00)

The fast transient rod and the motor driven rods are used to obtain an initial steady-state power level (.7). The adjustable transient rod is then fired to obtain a rapid increase in power (.7). To compensate for the negative reactivity that occurs as the fuel temperature increases, the regulating ~~and shim~~ rod~~s~~ ~~are~~ automatically withdrawn to stabilize power at the preset level (.6).

REFERENCE
FSAR VII-11

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER K.01 (2.50)

a. \$.02 (0.5)

b. \$.003 to \$.005 (0.5)

c. \$3.53 (0.5)

d. \$1.40 (0.5)

e. ~~\$.30~~ \$.60 (0.5)

REFERENCE
NE 390R Notes, p 10, 15 and 17
LOPRA SAR, p 1

ANSWER K.02 (1.50)

a. In a rack suspended on the outside of the concrete shield (~~1.0~~ .5).
a second tool is suspended in the tank. (.5)

b. The fuel handling tool is locked in place (0.5).

REFERENCE
FSAR IX-6

ANSWER K.03 (1.00)

Reactor Supervisor (0.5) and Reactor Health Physicist (0.5).

REFERENCE
FSAR IX-7

ANSWER K.04 (2.00)

The lead plug is removed from the bottom of the cask (0.5). The cask is brought over the irradiated element, the fuel handling tool is extended down through the cask onto the fuel element (1.0). The fuel element is raised into the cask, at which time the lead plug is closed and the fuel element is released from the fuel handling tool (0.5).

REFERENCE
FSAR IX-8

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER K.05 (6.50)

a. 16 feet (0.5)

b. 6 inches (0.5); 1 inch (0.5)

c. Turns on the 8 gpm emergency core spray cooling make-up system (0.5)

d. Stops the addition of make-up water via the 3 gpm emergency core spray cooling system (0.5)

e. 12 inches (0.5); 5 inches (0.5)

f. Prevent water from overflowing the Reactor Tank (0.5)

g. 1. Reactor scram (0.5)
   2. Cooling system isolation valves close (0.5)
   3. Primary pump stops (0.5)
   4. AV2 opens to increase emergency core spray cooling make-up flow to 5 to 8 gpm (0.5)

REFERENCE
FSAR VI-10, VII-20

ANSWER K.06 (1.50)

a. 2 (0.5)

b. Cadmium (0.5)

c. Licensed operator of the LOPRA. (0.5)

REFERENCE
LOPRA SAR, p 26 and 36

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

ANSWER K.07 (2.00)

1. Remove enough fuel elements and plug the fuel holes so that Keff is less than .99 with the safety control and poison rods removed (remove two or more central fuel elements) (1.0).
2. One of the following (1.0):
   a. Move the platform containing the grid plates and remaining fuel elements several feet from the thermal column and lock it into position. OR
   b. Place a neutron absorbing screen between the thermal column and the LOPRA core.

REFERENCE
LOPRA SAR, p 36

ANSWER K.08 (3.00)

a. $3.00 (0.5)

b. 2 days (0.5); 1 MW (0.5)

c. $5.00 (0.5)

d. 800 C (0.5) 755

e. 120 F (0.5)

REFERENCE
FSAR VII-30
Tech Specs 3.1.c, 3.1.i and 3.7

ANSWER L.01 (1.00)

Greater than $.50 in the cold, xenon-free condition (0.5) with the highest worth control rod withdrawn (0.5).

REFERENCE
Tech Spec 3.1.h

ANSWER L.02 (1.00)

Reactor Supervisor (0.5); Reactor Health Physicist (0.5)

REFERENCE
FSAR XI-26

ANSWER L.03 (2.00)

a. 25 rems (0.5)

b. Group A (0.5)

c. Unanimous consent of Group A (0.5)

d. True (0.5)

REFERENCE
Radiation Emergency Plan, p 6, 7 and 13

ANSWER L.04 (1.00)

a. Alert (0.5)

b. Site Area Emergency (0.5)

REFERENCE
Radiation Emergency Plan, p 9

ANSWER L.05 (1.00)

The film badge rack (0.5) and the dosimeter list (0.5).

REFERENCE
Radiation Emergency Plan, p 11

ANSWER L.06 (1.00)

In the building at the main south entrance of the Coordinated Science Building to the northwest of the Reactor Building.

REFERENCE
Radiation Emergency Plan, p 11

ANSWER L.07 (1.00)

Phone

REFERENCE
Radiation Emergency Plan, p 13

ANSWER L.08 (1.00)

Nuclear Engineering Laboratory (0.5) and Environmental Studies Institute Annex (0.5).

REFERENCE
Radiation Emergency Plan, p 4

ANSWER L.09 (1.00)

Wind Direction

REFERENCE
Radiation Emergency Plan, p 14

ANSWER L.10 (1.00)

Sufficient control rods are inserted so as to assure that the reactor is subcritical by at least $1.00 (0.5) and an SRO is in charge of any work in progress (0.5).

ANSWERS -- UNIVERSITY OF ILLINOIS -86/01/15-HIGGINS, R.

REFERENCE
Tech Spec 1.1

ANSWER L.11 (2.00)

1. Sufficient control rods are inserted to assure subcriticality by \$1.00. (0.5)
2. Power to the control rod magnets and actuating solenoids is off, and the key is removed. (1.0)
3. No work is in progress involving fuel, in-core experiments or maintenance of the core structure, control rods, or control rod drive mechanisms. (0.5)

REFERENCE
Tech Spec 1.2

ANSWER L.12 (1.00)

1. The temperature in a stainless-steel clad, high hydride fuel element shall not exceed 1000 C under any conditions of operation (0.5).
2. The temperature in a low hydride fuel element shall not exceed 550 C under any conditions of operation (0.5).

REFERENCE
Tech Spec 2.1

ANSWER L.13 (1.00)

Any two of the following (0.5 each):

1. The reactor shall be shutdown.
2. An immediate report of the occurence shall be made to the Chairman of the Nuclear Reactor Committee.
3. An immediate repo t shall be made to the Nuclear Regulatory Commission in Washington, D. C.

REFERENCE
Tech Specs 6.4 and 6.7

ANSWER L.14 (2.00)

The minimum reactivity worth required in the control and safety rod system at all times, starting from any permissible operating condition, such that the reactor can be made subcritical by no less than the shutdown margin (1.0) assuming that the reactor is in the cold, xenon-free condition (.4) with the highest worth rod fully withdrawn (.3) and with the highest worth non-secured experiment in its most reactive state (.3).

REFERENCE
Tech Spec 1.26

ANSWER L.15 (1.00)

Reactor Supervisor

REFERENCE
Tech Spec 6.3

ANSWER L.16 (2.00)

Any two of the following (1.0 each):

1. Operating with any actual safety system setting less conservative than specified in Tech Specs.
2. Violation of a limiting condition for operation.
3. Malfunction of a required reactor or experiment safety system component which could render or threaten to render the system incapable of performing its intended safety function.
4. Release of fission products from a fuel element.
5. An uncontrolled or unanticipated change in reactivity.
6. 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.

REFERENCE
Tech Spec 1.14