U. S. NUCLEAR REGULATORY COMMISSION REGION I
OPERATOR LICENSING EXAMINATION REPORT

EXAMINATION REPORT NO. 86-03(OL)

FACILITY DOCKET NO. 50-223

FACILITY LICENSE NO. R-125

LICENSEE: University of Lowell
1 University Avenue
Lowell, Massachusetts 01854

FACILITY: University of Lowell

EXAMINATION DATES: September 16-17, 1986

CHIEF EXAMINER: Barry S. Norris, Reactor Engineer (Examiner) — 7 Oct 86 (Date)

REVIEWED BY: Robert M. Keller, Chief, Projects Section 1C — 10/7/86 (Date)

APPROVED BY: Harry B. Kister, Chief, Projects Branch 1 — 10/7/86 (Date)

SUMMARY: Two Reactor Operator candidates were examined during this period; one candidate received a license, the other failed the written examination.

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REPORT DETAILS

TYPE OF EXAMS: Replacement

EXAM RESULTS:

	RO Pass/Fail
Written Exam	1/1
Oral Exam	2/0
Overall	1/1

CHIEF EXAMINER AT SITE: B. S. Norris (USNRC)

OTHER EXAMINERS: R. M. Keller (USNRC)

1. Summary of generic deficiencies noted on oral exams:

    a. The candidates had not been trained in the use of the emergency breathing equipment (Scott Air-Pac).

    b. The candidates were not sure of the process for a manual start of the Emergency Generator.

2. Summary of generic deficiencies noted from grading of RO written exams:

    a. Candidates could not explain how neutron flux changes over core life.

    b. Candidates could not accurately describe the emergency electrical distribution supply to the nuclear instrumentation.

    c. Candidates could not describe the required approvals for a temporary change to a procedure.

    d. Candidates could not accurately calculate how long an individual could work in a given radiation field.

3. Personnel present at Exit Meeting:

NRC Personnel
B. S. Norris - Chief Examiner

Facility Personnel
T. Wallace - Reactor Supervisor

4. Summary of comments made at exit meeting:

a. Concern was expressed by the examiner regarding the lack of training on use of the Scott Air-Pac.

b. The examiner noted that the graph used by the Console Operator for determination of Integral rod worth was incorrectly labeled as Differential rod worth.

The facility corrected the graph.

c. Two of the four Safety Analysis Report (SAR) communications systems available to the operators are inoperative; specifically, the intercom system and the sound powered headset system. This essentially eliminates all communications into the Control Room except for face-to-face.

The facility committed to repairing or replacing the systems with a completion date no later than January 1, 1987.

This item remains unresolved pending further investigation by Region I (50-223/86-03-01).

d. The examiner noted that the Technical Specifications require all procedures be reviewed and approved by the Reactor Safety Subcommittee (RSS). Individual procedures do not show the required approval signatures; the only visible approval is on the Table of Contents by the Professor-in-Charge dated December 28, 1979; new procedures have been issued since that date with no visible evidence of approval.

The facility stated that the RSS approves the procedures by entry of such into the minutes of the RSS meetings, but that the minutes were not readily available. The facility further stated that they would develop a system which would provide a visible approval signature for the procedure and which would allow the operators to readily determine the latest revision of any procedure. The facility committed to an implementation date of November 1, 1986.

This item remains unresolved pending further investigation by Region I (50-223/86-03-02).

e. The examiner noted that a procedure exists which allows the facility to operate with only one licensed operator instead of the SAR requirement of two licensed operators. The wording in the Technical Specification (TS) has been interpreted by the facility as requiring only one licensed operator. The SAR is more definitive as to the minimum shift complement and the two documents must be made consistent.

The facility stated that they would research the differences and submit to Headquarters a change request for either the SAR or the TS. The facility committed to submit this request by April 1, 1987.

This item remains unresolved pending further investigation by Region I and Headquarters (50-223/86-03-03).

f. The facility stated that on a written examination, a Reactor Operator should not be responsible for the information contained in the Technical Specifications.

The examiner stated that material pertaining directly to the responsibilities of the Reactor Operator is considered required knowledge.

5. Changes made to written examination during exam review:

a. Questions A.01.b - answer key changed to reflect actual Am-Be reaction to produce source neutrons.

b. Question A.04.b - answer key changed to reflect correct time for Xenon to reach equilibrium.

c. Question A.05 - answer key changed to agree with a later revision of the Technical Specifications provided after the examination review.

d. Question B.05 - additional acceptable response added to answer key.

e. Question B.07.c - answer key changed to agree with a later revision of the Technical Specifications provided after the examination review.

f. Question C.01 - answer key corrected to correspond to automatic mode of operation.

g. Question D.01.a - answer key corrected to reflect actual plant conditions.

h. Question D.02.b - answer key modified to allow alternate answer.

i. Question G.06 - deleted last two parts of answer based on Technical Specification statement that no credible accident could result in these classifications.

NOTE: It should be noted that most of the changes made to the answer key were due to additional information provided to the examiner during or after the examination review. For the next set of examinations at the University of Lowell Reactor, a complete and updated set of reference materials must be provided to the examiners.

Attachments:

1) Written Examination and Answer Key (RO)

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Barry S. Norris — Date
Reactor Engineer (Examiner)

REVIEWED BY: Original Signed By: ______________________ ______________
Robert M. Keller, Chief — Date
Projects Section 1C

APPROVED BY: Original Signed By: ______________________ ______________
Harry B. Kister, Chief — Date
Projects Branch 1

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c. Question A.05 - answer key changed to agree with a later revision of the Technical Specifications provided after the examination review.

d. Question B.05 - additional acceptable response added to answer key.

e. Question B.07.c - answer key changed to agree with a later revision of the Technical Specifications provided after the examination review.

f. Question C.01 - answer key corrected to correspond to automatic mode of operation.

g. Question D.01.a - answer key corrected to reflect actual plant conditions.

h. Question D.02.b - answer key modified to allow alternate answer.

i. Question G.06 - deleted last two parts of answer based on Technical Specification statement that no credible accident could result in these classifications.

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1) Written Examination and Answer Key (RO)

Attachment 1 to Enclosure

U. S. NUCLEAR REGULATORY COMMISSION
REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: UNIVERSITY OF LOWELL

REACTOR TYPE: TEST

DATE ADMINISTERED: 86/09/17

EXAMINER: NORRIS, B. S.

CANDIDATE: Master & Key

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
14.00	14.00			A. PRINCIPLES OF REACTOR OPERATION
14.00	14.00			B. FEATURES OF FACILITY DESIGN
14.00	14.00			C. GENERAL OPERATING CHARACTERISTICS
14.10	14.10			D. INSTRUMENTS AND CONTROLS
14.40	14.40			E. SAFETY AND EMERGENCY SYSTEMS
15.50	15.50			F. STANDARD AND EMERGENCY OPERATING PROCEDURES
14.00	14.00			G. RADIATION CONTROL AND SAFETY
100.00		Final Grade		Totals

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

____

Candidate's Signature

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.

2. 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.

QUESTION A.01 (2.50)

a. Describe TWO hazards of starting up a reactor without an adequate neutron source. (1.00)

b. List the TWO neutron sources available in the ULR and describe how each reacts to produce neutrons. (1.50)

QUESTION A.02 (2.00)

A reactor startup is in progress. A systematic withdrawal of rods is in progress, and currently the count rate is level; this procedure is repeated until the reactor is critical.
Assume that K is initially 0.995 and each rod withdrawal results in an increase in K of 0.001.

a. Draw a graph of count rate vs. time until K=1.00. (1.00)

b. When the reactor is called critical, what is the indication on the startup channel? State any assumptions. (1.00)

QUESTION A.03 (1.50)

The ULR critical mass has been calculated at 2.8 kg of U-235; however, the core is loaded with 3.5 kg of U-235.

List THREE reasons why it is necessary to load excessive fuel.

QUESTION A.04 (2.00)

The two most common fission product poisons are Xenon and Samarium.

a. List the production and removal processes for Xenon and Samarium. (1.50)

b. What are the approximate times for Xenon and Samarium to reach equilibrium if power is increased from 10 kW to 1 MW? (0.50)

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

QUESTION A.05 (2.00)

a. Per the ULR Technical Specifications, define Shutdown Margin. (1.00)

b. What is the minimum Shutdown Margin per Technical Specifications? State all associated assumptions. (1.00)

QUESTION A.06 (2.25)

The reactor is critical at 2x10E1 watts; 2 minutes later power is observed to be 7x10E2 watts.

a. What is the reactor period? (0.75)

b. Given a delayed neutron fraction of 6x10E-3 and an average delayed neutron life of 12.7 seconds, how much reactivity was added for the reactor period in part a? (1.50)

QUESTION A.07 (1.75)

As the temperature of the pool water increases, will the neutron leakage increase, decrease, or not change? Explain your answer.

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

QUESTION B.01 (3.00)

The reactor is operating at 1 MW; using Figure B.1, answer the following:

a. Identify all of the NUMBERED items. (2.00)

b. Indicate the flow paths. (0.30)

c. For each of the LETTERED instruments, indicate what kind of parameter is being measured (i.e. pressure, temperature, flow). (0.70)

QUESTION B.02 (1.50)

There are TWO major short-lived isotopes produced during reactor operations. What are these TWO isotopes and what TWO design features are provided at the ULR to minimize the effects of the radiation from the two isotopes?

QUESTION B.03 (2.00)

Using the attached Figure B.2, show where the following components are located:

a. Proportional counter(s)
b. Compensated ionization chamber(s)
c. Startup source(s)
d. Graphite reflector element(s)
e. Fuel element(s)
f. Servo control element(s)
g. Control element(s)
h. Radiation basket(s)

QUESTION B.04 (2.00)

a. Spent fuel is stored in the reactor pool. Describe the geometric array utilized and why that particular array was selected. (1.25)

b. Describe the fuel handling tool. (0.75)

QUESTION B.05 (1.50)

What are THREE functions of the water in the reactor pool?

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

QUESTION B.06 (1.00)

TRUE or FALSE:
During power operations, the bridge cannot be moved.
Justify your answer.

QUESTION B.07 (3.00)

In accordance with the ULR Technical Specifications:

a. What is the objective of Safety Limits? (0.50)

b. What is the relationship between Safety Limits and Limiting Safety System Setpoints? (0.50)

c. What are the FOUR variables measured in the forced convection mode of operation to assure Safety Limits are not violated, and what is the associated Limiting Safety System Setpoint (minimum or maximum) for each variable? (2.00)

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

QUESTION C.01 (2.50)

Assume the ULR is operating at 1MW with all controls in the normal mode of operation and no operator action.

Describe the sequence of events which would cause the reactor to scram if the SECONDARY pump were secured.

QUESTION C.02 (2.00)

What THREE reactivity effects are compensated for by the burnable poison filler in the control blades?

QUESTION C.03 (2.00)

Indicate what effect (increase, decrease, or no change) each of the following has upon the Keff of the ULR. Consider each case separately.

a. Placing a large air-filled steel canister next to the core.
b. Irradiating an Argon gas sample via the rabbit system.
c. Removing a graphite reflector element from the core periphery.
d. Flooding a beamport with water.

QUESTION C.04 (2.00)

The reactor is operating at full power, over a period of time the temperature of the coolant increases from 22 C to 31 C. Assuming a temperature cooefficient of -0.815E(-4) Delta K/K/C and a rod worth of 0.3% Delta K/K/inch and a rod speed of 78 inch/minute for the regulating rod, how far and in what direction will the control rod move?

QUESTION C.05 (2.50)

Figure C.1 is a graph of INTEGRAL rod worth for a single control blade.

a. Label the axis and show approximate values for the points shown. (1.50)

b. Why is the slope of the curve steeper at Point 1 than Point 2? (1.00)

QUESTION C.06 (2.00)

If the reactor is operated at a constant power level, explain how and why neutron flux changes over core life. Include in your discussion both fast and thermal neutron flux. Assume no fuel changes are made.

QUESTION C.07 (1.00)

Fill in the missing information, show your work and state any assumptions:

Tube side		Shell side
114 F	T in	82 F
103 F	T out	__________
1600 gpm	Flow	1500 gpm

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

QUESTION D.01 (2.10)

For the below listed conditions, state whether there is an alarm only, an alarm and scram, a scram only, or none of the above:

a. Pool temperature (natural convection mode) - 104 F
b. High flux (2 detectors) - 1.10 ratio
c. High temperature of primary coolant entering core - 106 F
d. Low flow rate of primary coolant - 0.7 ratio
e. High conductivity of primary coolant
f. Coolant gates half open
g. Regulating rod at uper limit of travel

QUESTION D.02 (2.50)

a. Describe the operation of the Compensated Ion Chamber (CIC). (2.00)

b. Which CIC detectors feed the Safety Channels? (0.50)

QUESTION D.03 (2.50)

a. What is the purpose of the servo-controlled regulating element drive system? (0.50)

b. What are the THREE components of the system? (1.50)

c. Under what conditions of critical operations is the use of the automatic mode prevented.

QUESTION D.04 (1.50)

How is the temperature of the primary coolant automatically controlled?

QUESTION D.05 (2.50)

a. Briefly describe HOW a conductivity cell works. (1.00)

b. List the location of THREE conductivity cells at the ULR. (1.50)

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

QUESTION D.06 (2.00)

a. List FIVE conditions which will achieve a General Reaction of the Ventilation System (GRVS). (1.25)

b. Two of the valves that close on a GRVS will automatically open when the GRVS signal is cleared. What are those TWO valves? (0.50)

c. Which valve is not affected by a GRVS? (0.25)

QUESTION D.07 (1.00)

The process of determining an instrument's accuracy by visually comparing that indication to other independent instrument channels measuring the same parameter is defined in Technical Specifications as a:
(Choose the BEST answer)

A. Channel Calibration
B. Channel Check
C. Channel Measurement
D. Channel Test

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

QUESTION E.01 (1.00)

In accordance with the ULR Technical Specifications, a Control Rod is considered safety equipment but a Regulating Rod is NOT safety equipment. Why?

QUESTION E.02 (2.00)

a. How is containment integrity maintained during access. (1.20)

b. In the event of failure of all power, how can a containment entry be made? (0.80)

QUESTION E.03 (2.40)

Draw the electrical distribution to the Nuclear Instrumentation during a loss of the normal power supply. Include in your drawing the power source, the distribution panels, and all necessary breakers.

QUESTION E.04 (2.50)

Answer the following questions about the Scram Circuits:

a. Briefly describe the difference between an electronic scram and a relay scram. (1.50)

b. List TWO conditions which will cause an electronic scram. Include setpoints. (1.00)

QUESTION E.05 (2.50)

a. What will cause automatic initiation of the Emergency Exhaust System? (0.50)

b. After an automatic start of the Emergency Exhaust system, what TWO conditions will cause the system to auto-stop? (1.00)

c. Describe, or sketch, the flowpath for Emergency Exhaust. (1.00)

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

QUESTION E.06 (2.00)

a. The control room, the reactor basement and the Reactor Supervisor's office can all communicate simultaneously using the Intercom system. TRUE or FALSE. Justify your answer. (1.00)

b. The best system for communications during refueling operations would be the ________________________ system.
Fill in the blank. Justify your answer. (1.00)

QUESTION E.07 (2.00)

Reactor power is 100kW in the natural circulation mode of operation. One of the flanges on one of the inlet bypass valves to the Hold-up Tank begins to leak. Describe, in detail, the sequence of events which will or will not cause the core to become uncovered.

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

QUESTION F.01 (2.00)

In accordance with the ULR Technical Specifications and the Authority Section of your procedures manual: If a temporary change is required for an existing procedure, what approvals are required prior to implementation of the change? Discuss changes that alter intent and changes that do not alter intent.

QUESTION F.02 (1.00)

In accordance with R.O.1 "Critical Experiments": how is minimum shutdown capability ensured?

QUESTION F.03 (2.00)

Fill in the blanks in accordance with E.O.1, "Radiation Emergency":

If the cause of a radiation level in excess of ______ or an airborne level in excess of _________ in a personnel accessible area cannot bethe cause of determined within ________, the reactor must be shut down.
If the reactor shutdown is not effective in reducing the levels, then _____________.

QUESTION F.04 (1.00)

In accordance with E.O.7, "Stuck Rod or Safety Blade": what is the immediate action of the Console Operator if a rod or blade becomes stuck or appears to be stuck?

QUESTION F.05 (2.00)

The ULR Technical Specifications require that surveillances be performed on the pool water. What are the TWO surveillances and why is each performed?

QUESTION F.06 (2.10)

In accordance with S.P.12, "Calibration of Temperature Monitoring Devices":

Describe the procedure for the Pool Temperature Channel Calibration.

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

QUESTION F.07 (2.00)

Answer the following questions TRUE or FALSE per R.O.16, "Movement of Co-60 Source in the Reactor Pool":

a. The Co-60 source may be moved to the reactor end of the pool while the reactor is in operation.

b. It is not recommended to put the Co-60 in a frame while moving them.

c. In no circumstance should the Co-60 sources be moved or handled while the reactor primary coolant system is in forced circulation operation.

d. The sources may be handled above the 8 foot level when a dedicated radiation monitor is present.

e. The reactor pool gate should be open when handling individual strips.

QUESTION F.08 (1.50)

A Fire Alarm sounds concurrently with a report of a fire in the area of the Beam Tubes while experiments are under way. In accordance with E.O.2, "Fire" list FIVE actions you, as the Console Operator, should take.

QUESTION F.09 (1.90)

Power is 1 kW, you are the Console Operator, and the following ALARMS are received simultaneously:

water temperature - high
stack monitor activity - high
primary coolant conductivity - high

Which alarm should be investigated first? Justify your answer.

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

QUESTION G.01 (2.50)

A maintenance man is working inside the containment while the reactor is at power. He is working in a radiation field of 850 mrem/hr gamma and 30 mrad/hr thermal and fast neutron.
The maintenance man is 28 years old and has a lifetime exposure through last quarter of 48 Rem on his NRC Form 4; additionally, he has accumulated 1.0 Rem so far this quarter.

a. How long can the man work in the area before he exceeds his 10CFR20 limits? Show all work and state all assumptions. (1.50)

b. During a declared emergency, this individual volunteers to enter a high radiation area and perform work necessary to prevent further effluent release. In accordance with the Emergency Plan, what is his maximum allowed whole body exposure? (0.50)

c. Whose authorization is needed in part b. (0.50)

QUESTION G.02 (2.00)

A small piece of metal on the floor near the pool is reading 1800 mrem/hr of gamma at a distance of 2 meters. What is the minimum distance from the source you can stand and not exceed a dose rate of 80 mrem/hr? Show all work and state all assumptions.

QUESTION G.03 (1.50)

In accordance with the ULR Emergency Plan, list THREE responsibilities of the Reactor Operator during a declared emergency?

QUESTION G.04 (2.50)

The following is a quotation from the ULR SAR:
"The simultaneous tripping ... of different detectors, each from a different category (I, II, III) is intended to be indicative of a potentially hazardous situation which would warrant initiation of the General Radiation Emergency Alarm."

Category I: Airborne Radioactivity
List ONE of the two monitors

Category II: Gross Radiation
List THREE of the four monitors

Category III: Fission Product Release
List ONE of the two monitors

QUESTION G.05 (2.00)

Explain the operation of a Tracerlab "Snoopy" NP-2 portable radiation detector. Include in your discussion the type of detector used and the type of radiation detected.

QUESTION G.06 (1.50)

In accordance with the ULR Emergency Plan, what are the ~~FIVE~~ Three emergency classifications in order of least severe to most severe.

QUESTION G.07 (2.00)

a. The major Source Term for GASEOUS Radioactive Waste is due to what nuclear reaction to form what radionuclide? (1.00)

b. What are the TWO major Source Terms for LIQUID Radioactive Waste? (1.00)

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

EQUATION SHEET

$f = ma$

$v = s/t$

Cycle efficiency = (Net work out)/(Energy in)

$w = mg$

$s = V_o t + 1/2\ at^2$

$E = mc^2$

$KE = 1/2\ mv^2$

$a = (V_f - V_o)/t$

$A = \lambda N$

$A = A_o e^{-\lambda t}$

$PE = mgh$

$V_f = V_o + at$

$w = \theta/t$

$\lambda = \ln 2/t_{1/2} = 0.693/t_{1/2}$

$W = v\ \Delta P$

$A = \dfrac{\pi D^2}{4}$

$t_{1/2}eff = \dfrac{[(t_{1/2})(t_b)]}{[(t_{1/2}) + (t_b)]}$

$\Delta E = 931\ \Delta m$

$\dot{m} = V_{av} A \rho$

$I = I_o e^{-\Sigma x}$

$\dot{Q} = \dot{m} C_p \Delta t$

$\dot{Q} = UA \Delta T$

$I = I_o e^{-ux}$

$Pwr = W_f \Delta h$

$I = I_o\ 10^{-x/TVL}$

$TVL = 1.3/u$

$P = P_o 10^{sur(t)}$

$HVL = -0.693/u$

$P = P_o e^{t/T}$

$SUR = 26.06/T$

$SCR = S/(1 - K_{eff})$

$CR_x = S/(1 - K_{effx})$

$SUR = 26\rho/\ell^* + (\beta - \rho)T$

$CR_1(1 - K_{eff1}) = CR_2(1 - K_{eff2})$

$T = (\ell^*/\rho) + [(\beta - \rho)/\bar{\lambda}\rho]$

$M = 1/(1 - K_{eff}) = CR_1/CR_o$

$T = \ell/(\rho - \beta)$

$M = (1 - K_{effo})/(1 - K_{eff1})$

$T = (\beta - \rho)/(\bar{\lambda}\rho)$

$SDM = (1 - K_{eff})/K_{eff}$

$\rho = (K_{eff} - 1)/K_{eff} = \Delta K_{eff}/K_{eff}$

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

$\bar{\lambda} = 0.1\ \text{seconds}^{-1}$

$\rho = [(\ell^*/(T K_{eff})] + [\bar{\beta}_{eff}/(1 + \bar{\lambda}T)]$

$I_1 d_1 = I_2 d_2$

$I_1 d_1{}^2 = I_2 d_2{}^2$

$P = (\Sigma\phi V)/(3 \times 10^{10})$

$R/hr = (0.5\ CE)/d^2(\text{meters})$

$\Sigma = \sigma N$

$R/hr = 6\ CE/d^2$ (feet)

Water Parameters

1 gal. = 8.345 lbm.
1 gal. = 3.78 liters
1 ft^3 = 7.48 gal.
Density = 62.4 lbm/ft^3
Density = 1 gm/cm^3
Heat of vaporization = 970 Btu/lbm
Heat of fusion = 144 Btu/lbm
1 Atm = 14.7 psi = 29.9 in. Hg.
1 ft. H_2O = 0.4335 lbf/in.

Miscellaneous Conversions

1 curie = 3.7×10^{10} dps
1 kg = 2.21 lbm
1 hp = 2.54×10^3 Btu/hr
1 mw = 3.41×10^6 Btu/hr
1 in = 2.54 cm
°F = 9/5°C + 32
°C = 5/9 (°F-32)
1 BTU = 778 ft-lbf

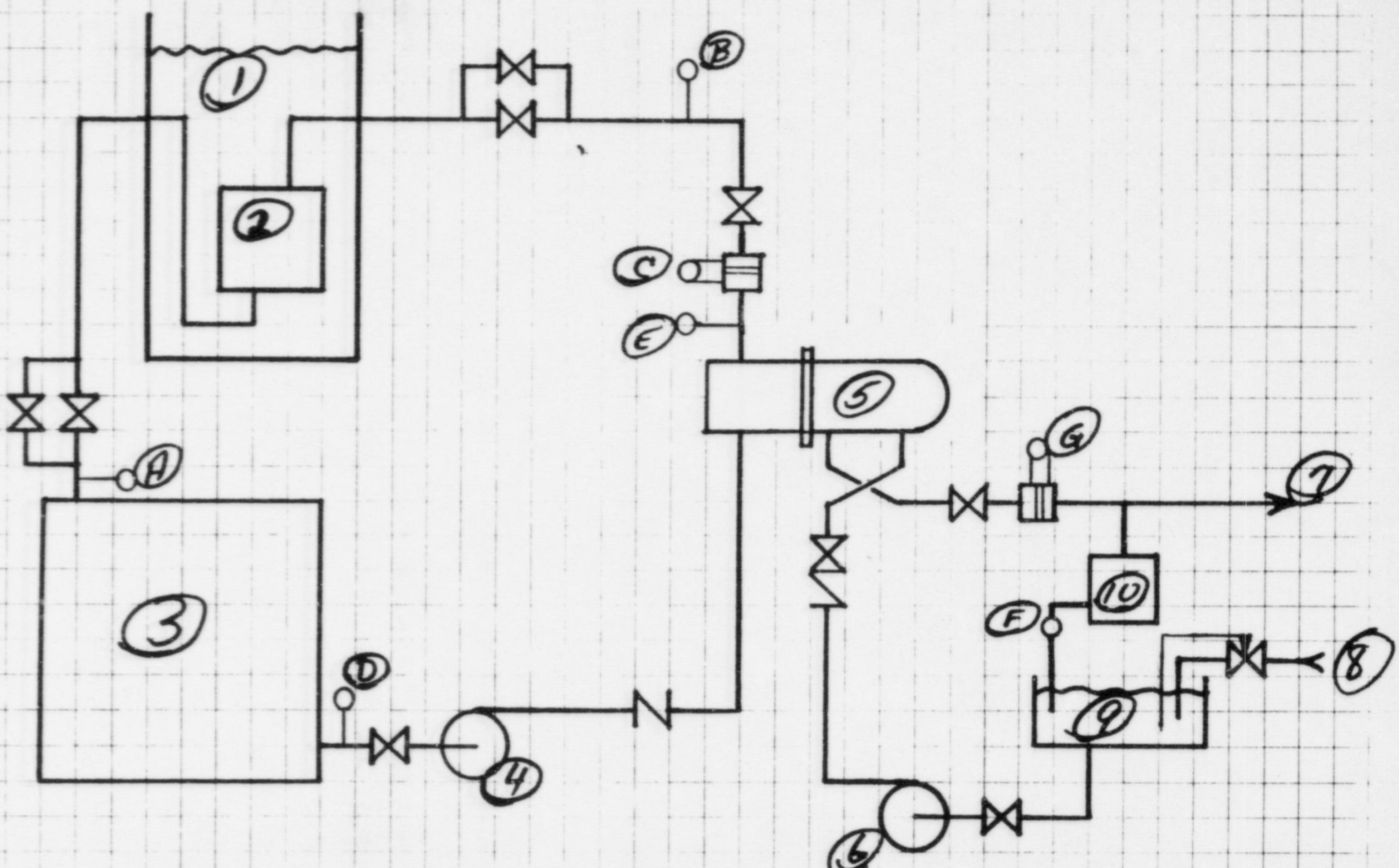
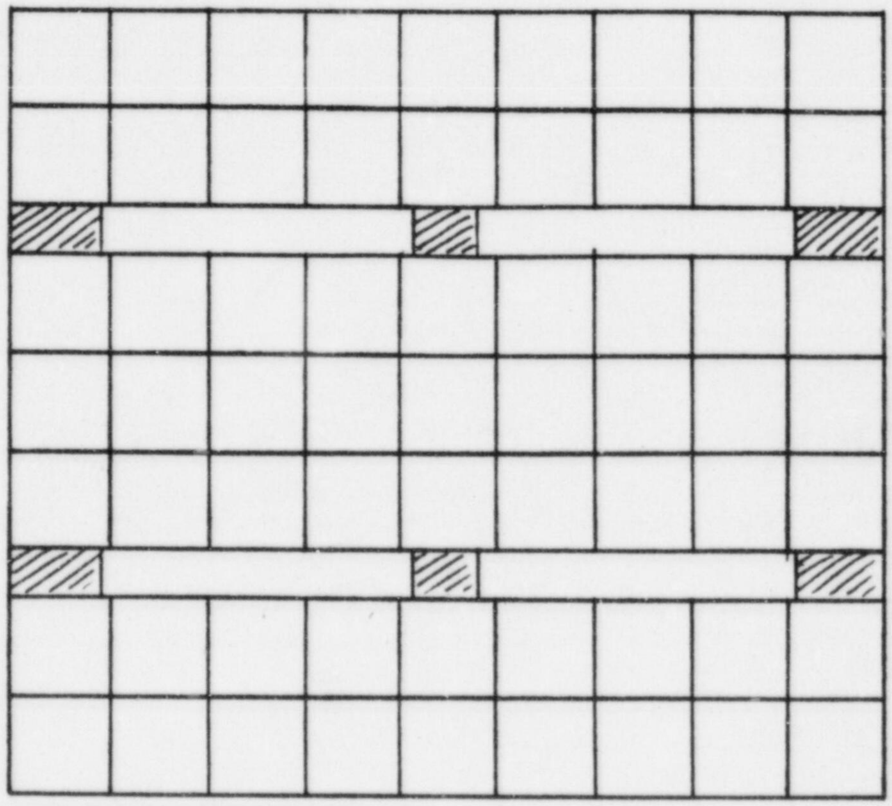


Figure B.1

G-23-8112



LEGEND

A = Proportional Counter

B = Compensated Ionization Chamber

C = Control Element

D = Startup Source

E = Graphite Reflector Element

F = Fuel Element

G = Servo Control Element

H = Radiation Basket

Figure B.2

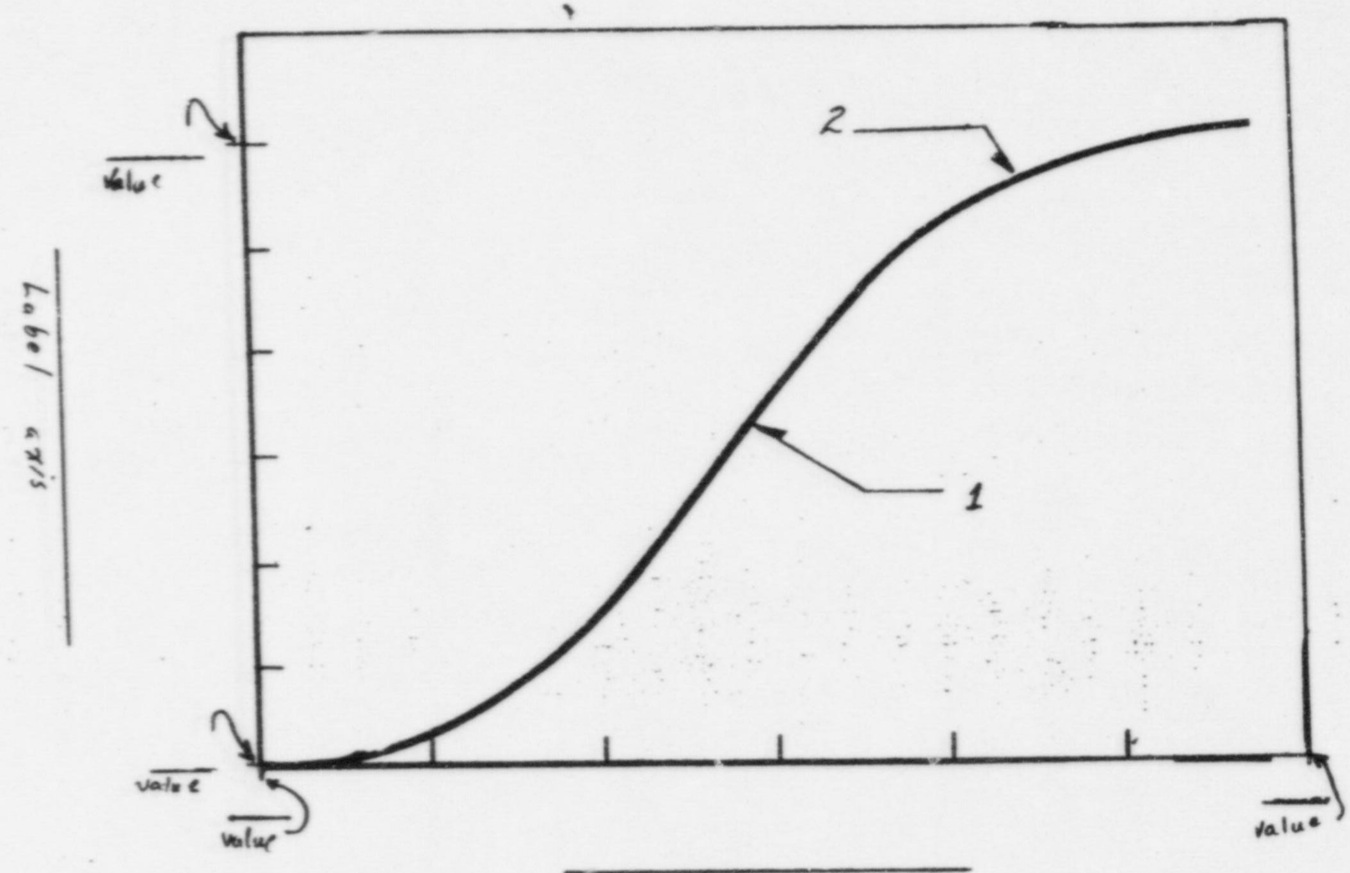


Figure C.1

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

ANSWER A.01 (2.50)

a. By the time power is indicated on the NI's the reactor would be supercritical (0.50)
resulting in a large power excursion before the protective system could react. (0.50)

b. Americium-Beryllium (Am-Be) (0.25)
~~Am-241 ---> Cm-241 + Gamma~~
~~Be-9 + Gamma ---> 2He-4 + neutron~~ (0.50)
Am-241 -> Np-237 + Alpha
Be-9 + Alpha -> C-12 + Neutron

Antimony-Beryllium (Sb-Be) (0.25)
Sb-124 ---> Te-124 + Gamma
Be-9 + Gamma ---> 2He-4 + neutron (0.50)

REFERENCE
SAR, paragraph 4.1.6, pg 4-6
TVA Introduction to Nuclear Power, pgs 156-157

ANSWER A.02 (2.00)

a. Graph must show 5 distinct increases in count rate with a leveling off at each new count rate (0.20)
Each increase in count rate must be logrithmically larger (0.40)
Each increase must take a progressively longer period of time (0.40)

b. Count rate increasing on a steady slope (0.50)
with no rod motion (0.50)

REFERENCE
TVA Introduction to Nuclear Power, pgs 170-173

ANSWER A.03 (1.50)

1. buildup of Xe and Sm (fission product poisons)
2. increase in temperature
3. fuel burnup (0.50 each)

REFERENCE
SAR, paragraph 4.5.3, pgs 4-84 to 4-89

ANSWER A.04 (2.00)

a. Xenon-production
1. directly from fission
2. decay of I-135

removal
1. decay to Cs-135
2. neutron absorption

Samarium-production
1. decay of Pm-149

removal
1. neutron absorption (0.25 each)

b. Xenon ~~10-12 hours~~ 40-50 hours
Samarium 2-3 days (0.25 each)

REFERENCE
Lamarsh, Introduction to Nuclear Engineering, pgs 284-291

ANSWER A.05 (2.00)

a. ~~The amount of negative reactivity by which the reactor is subcritical.~~ (1.00)

b. Minimum SDM is ~~3%~~ 2.7% delta k/k (0.55)
Cold (0.15), xenon-free (0.15), and most reactive safety rod stuck out (0.15) (0.45)

REFERENCE
ULR TS, pgs IV-4 & IV-12

a. The minimum shutdown reactivity necessary to provide confidence the reactor can be made subcritical.

ANSWER A.06 (2.25)

a. $P = Po(e)^{t/T}$ (0.25)

$7\times 10E2 = (2\times 10E1)(e)^{120/T}$ (0.25)

$35 = e^{120/T}$

3.555 = 120/T

T = 120/3.555 = 33.75 sec (0.25)

b. Beta-eff = 0.006 (0.40)

Lambda-eff = 1/12.7 = 0.08 (0.40)

T = (Beta - rho)/rho(lambda) (0.30)

33.75 = (0.006 - rho)/rho(0.08)

rho = 0.006/3.70 = 0.00162 (0.40)

REFERENCE

Lamarsh, Introduction to Nuclear Engineering, pgs 241-256

ANSWER A.07 (1.75)

Increase (0.75)

Increased pool temperature causes moderator density to decrease (0.50)
which increases the average neutron diffusion length and slowing
down length, thus increasing leakage. (0.50)

REFERENCE

Lamarsh, Introduction to Nuclear Engineering, pg 279

ANSWER B.01 (3.00)

a.
1. pool
2. core
3. hold-up tank
4. primary pump
5. heat exchanger
6. secondary pump
7. blowdown path
8. raw water supply
9. sump tank
10. cooling tower (0.20 each)

b. Primary flowpath & Secondary flowpath (0.10 each)
Blowdown flowpath & raw water flowpath (0.05 each)

c.
A. temperature
B. temperature
C. flow
D. pressure
E. temperature
F. temperature
G. flow (0.10 each)

REFERENCE
SAR, figure 4-11

ANSWER B.02 (1.50)

1. N-16 & O-19 (0.40 each)

2. Hold-up tank allows for decay of the isotopes (0.40)
and it is vented under water to the reactor pool (0.30)

REFERENCE
SAR, pgs 4-26 to 4-27

ANSWER B.03 (2.00)

a. Proportional counter (0.25)
b. Three compensated ion chambers (0.25)
c. Proper positioning of startup source (0.25)
d. Proper positioning of Reflector elements (0.25)
e. Proper positioning of fuel elements (0.25)
f. Proper positioning of servo control element (0.25)
g Proper positioning of control elements (0.25)
h. Proper positioning of radiation baskets (0.25)

See attached drawing

REFERENCE
SAR, figure 4.1

ANSWER B.04 (2.00)

a. Spent fuel is stored in the pool in a planar array (0.50)
to prevent the possibility of inadvertent criticality. (0.75)

b. The fuel handling tool is a bayonet-type fitting (0.75)

REFERENCE
ULR SAR, pgs 6-1 to 6-4

ANSWER B.05 (1.50)

1. Moderate (any 3 at 0.50 each)
2. Cool
3. Reflect
4. Shield

REFERENCE
SAR, pg 1-5

ANSWER B.06 (1.00)

True (0.25)
The bridge is interlocked to prevent any movement while the reactor control blades are withdrawn. (0.75)

REFERENCE
SAR, pg 4-16

ANSWER B.07 (3.00)

a. Safety Limits assure that the integrity of the fuel cladding is maintained. (0.50)

b. LSSS's assure that protective action is initiated in order to prevent a Safety Limit from being exceeded. (0.50)

c. Reactor thermal power (P) = 1.25 MWt (max)
Coolant flow rate (W) = ~~1170 gpm (min)~~ 1250 gpm (min)
Reactor coolant inlet temperature (Ti) = 108F (max)
Height of water above the center line of the core (L) = 24.25 ft (min)
(0.25 for each variable & 0.25 for each limit)

REFERENCE
ULR TS, pgs IV-~~5~~ 7 & IV-~~8~~ 10 ~~to IV-9~~

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

ANSWER C.01 (2.50)

Pool temperature will increase adding negative reactivity (0.80) ~~(0.75)~~
~~Reactor power will decrease~~ ~~(0.50)~~
Primary coolant high temperature alarm (either entering or leaving) (0.80) ~~(0.50)~~
Scram on primary coolant high temperature (0.90) ~~(0.75)~~

REFERENCE
ULR SAR, pg 4-73

ANSWER C.02 (2.00)

Minimizing the negative reactivity effects resulting from the buildup of fission products (0.67)
Negative reactivity due to burnup of the fuel (0.67)
Allows for more excess fuel to be added (0.66)

REFERENCE
ULR, SAR pgs 4-6 to 4-7, and 4-84

ANSWER C.03 (2.00)

a. Decrease
b. No change
c. Decrease
d. Increase (0.50 each)

REFERENCE
ULR SAR, pgs 4-89 & 4-91

ANSWER C.04 (2.00)

Rod will move out (0.50)
Reactivity added by temperature increase:
[-0.815E(-4) Delta K/K/C] x [9 C] = -7.335E(-4) Delta K/K (0.75)
To compensate, rods must move out by:
[7.335(-4) Delta K/K]/[0.003 Delta K/K/inch] = 0.24 inches (0.75)

REFERENCE
ULR SAR, pg 4-89

ANSWER C.05 (2.50)

See ULR SAR Figure 9.8, pg 9-45 for graph:
- ~~basic shape of curve~~ ~~(0.50)~~
- labeling of the axis (1.00) ~~(0.50)~~
- approximate values (0.50)

Slope of the curve is steeper in the center of the core due to larger neutron flux. (1.00)

REFERENCE
ULR SAR, pg 9-45

ANSWER C.06 (2.00)

Since fast neutron flux is proportioal to power (0.50)
the fast neutron flux will reamin constant. (0.50)

Since the concentration of fuel decreases over core life (0.50)
the number of thermal neutron available for fission must increase to cause to same power. (0.50)

REFERENCE
CAF

ANSWER C.07 (1.00)

[flow 1][delta T 1] = [flow 2][delta T 2] (0.25)
[1600 gpm][114 F - 103 F] = [1500 gpm][delta T 2] (0.25)
[1600/1500][11 F] = 11.73 F (0.25)
Therefore, T out on the shell side = 82 F + 11.73 F = 93.73 F (0.25)

REFERENCE
ULR SAR, pg 4-26

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

ANSWER D.01 (2.10)

a. Scram ~~only~~ & alarm (setpoint 104F) (0.30 each)
b. Alarm only (setpoint for alarm 1.1, for scram 1.20)
c. Scram & alarm (setpoint for alarm 100 F, for scram 104 F)
d. Scram & alarm (setpoint for alarm 0.9, for scram 0.8)
e. Alarm only (no setpoint)
f. Scram & alarm (off closed seat)
g. Alarm only (no setpoint)

REFERENCE
ULR SAR, pgs 4-72 to 4-73

ANSWER D.02 (2.50)

a. Two concentric cans, the outer can is lined with boron to detect neutrons (0.50)
and filled with gas to detect gammas (0.50)
the inner can is only filled with the gas and detects only gammas (0.50)
The voltages to the two cans is adjusted such that the current is proportional only to the neutron flux. (0.50)

b. (Detectors 1223 and 1224) A1 & A9 (0.25 each)

REFERENCE
ULR SAR, pg 4-67

ANSWER D.03 (2.50)

a. Provides automatic control of reactor power level (0.50)

b. CIC/picoammeter (0.50 each)
Servo amplifier
Power schedule device (reference power level)

c. Cannot shift to automatic control if the reactor period is less than 30 seconds. (0.50)

REFERENCE
ULR SAR, pgs 4-61 to 4-62

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

ANSWER D.04 (1.50)

The heat exchanger motor operated outlet valve (0.50)
receives a signal from the temperature controller (0.50)
when the temperature of the primary coolant out of the heat exchanger
exceeds the preset setpoint. (0.50)

REFERENCE
ULR SAR, pg 4-79

ANSWER D.05 (2.50)

a. Conductivity = 1/resistivity (0.50)
Resistivity is determined by applying a voltage across electrode
immersed in water and measuring the current (0.50)

b. 1. Holdup tank (0.50 each)
2. Pool cleanup
3. Makeup system

REFERENCE
ULR SAR, pg 4-81

ANSWER D.06 (2.00)

a. 1. Activation of the LREA/GREA in the Control Room
2. Activation of the GREA in the Reactor Supervisor's office
3. Manual operation of the switches in the Control Room
4. Loss of power
5. Activation of the ventilation freeze alarm (0.25 each)

b. Valve G (Sanitary system vent - CR) (0.25)
Valve H (Acid vent - basement) (0.25)

c. Valve D (Emergency exhaust) (0.25)

REFERENCE
SAR, pgs 3-10, & 3-23 to 3-24

ANSWER D.07 (1.00)

B. Channel Check (1.00)

REFERENCE
ULR TS, pgs IV-1 & IV-2

ANSWER E.01 (1.00)

A Control Rod has SCRAM capability while a Regulating Rod does not. (1.00)

REFERENCE
ULR TS, pgs IV-2 & IV-4

ANSWER E.02 (2.00)

a. By means of a double door system, (0.60)
only one of which can be opened at a time. (0.60)

b. By manual operation of the doors. (0.80)

REFERENCE
ULR SAR, pgs 3-2 to 3-8

ANSWER E.03 (2.40)

Drawing must include the following:
- Emergency generator (0.30)
- Automatic line transfer switch (0.30)
- Emergency Distribution Switchboard (0.30)
- Breaker to ELPL-R1 (0.20)
- ELPL-R1 distribution panel (0.30)
- Breaker to Console and Nuclear Instrumentation Cabinet (0.20)
- Console and NI Cabinet (0.30)
- Breaker to Nuclear Instrumentation (0.20)
- Nuclear Instrumentation (0.30)
(See attached figure E.1)

REFERENCE
ULR SAR, Figures 5.2 - 5.4

ANSWER E.04 (2.50)

a. The electronic scram deenergizes the scram magnets via the logic unit and trip actuator amplifier. (0.75)
The relay trips are series connected in the safety chain which leads to two master scram relays which deenergize the logic and trip amplifier. (0.75)

b. High flux (125%)
Short period (~~3~~7 seconds)
(0.30 each for name of scram, 0,20 each for correct setpoint)

REFERENCE
ULR SAR, pg 4-69

ANSWER E.05 (2.50)

a. Pcontainment - Pambient >or= 0.25 inch water (0.50)

b. Pcontainment - Pambient <-0.25 inch water (0.50)
Pcontainment - Pambient >or= 0.50 inch water (0.50)

c. Roughing & Charcoal & Absolute filters (0.10 each)
Emergency Exhaust fan (EF-14) (0.25)
Valve D (0.25)
Taps into main exhaust header DOWNSTREAM of all other valves (0.20)

REFERENCE
ULR SAR, pgs 3-10, 3-21, & 3-24 to 3-25

ANSWER E.06 (2.00)

a. False (0.40)
The system only allows two stations to communicate at a time. (0.60)

b. Sound powered headset system. (0.40)
The system allows all stations to communicate simultaneously (0.30)
and is a continuous bidirectional system. (0.30)

REFERENCE
ULR SAR, pgs 6-5 & 6-6

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

ANSWER E.07 (2.00)

Antisiphon lines are connected to the primary piping.	(0.75)
Loss of the backpressure on the check valves causes them to open	(0.30)
when pool level decreases to the piping penetration	(0.40)
the vacuum is broken thus stopping the siphon effect	(0.30)
thereby, keeping the core covered.	(0.25)

REFERENCE
ULR SAR, pgs 4-24 to 4-25

ANSWER F.01 (2.00)

If the change does not alter the intent of the original procedure, the change may by approved by the Reactor Supervisor (0.50)
and implemented at once. (0.50)

If the change is substantive in nature, the change shall be approved by the Reactor Safety Subcommittee (0.25)
and the Professor in Charge of Reactor (PICR) (0.25)
and the change shall not be implemented prior to such approvals. (0.50)

REFERENCE
ULR TS, pg IV-42
ULR Authority Section of the Procedure Manual, pg 3

ANSWER F.02 (1.00)

At least two safety blades shall be withdrawn (0.50)
to at least 12 inches. (0.50)

REFERENCE
R.O.1, pg 4

ANSWER F.03 (2.00)

1 rem/hr (0.50 each)
100 times MPC
15 minutes
all but essential personnel must be evacuated

REFERENCE
E.O.1, pg 1

ANSWER F.04 (1.00)

Shut down the reactor by running in the unstuck blades and the regulating rod. (1.00)

ANSWERS -- UNIVERSITY OF LOWELL -86/09/17-NORRIS, B. S.

REFERENCE
E.O.7, pg 1

ANSWER F.05 (2.00)

1. Conductivity (0.50)
   Minimize chances of corrosion (0.50)

2. Radioactivity (0.50)
   Allow early determination of significant buildup of radioactivity due to reactor operation or the Co-60 source. (0.50)

REFERENCE
ULR TS, pgs IV- 33 & IV-34

ANSWER F.06 (2.10)

1. Immerse RTD and thermometer into ice bath (0.30)
   As necessary adjust the zero setting of the recorder (0.30)

2. Immerse RTD and thermometer into hot bath (0.30)
   As necessary adjust the span control of the recorder (0.30)

3. Repeat steps 1 & 2 until no further adjustments are necessary (0.30)

4. Check linearity by allowing both to come to room temperature (0.30)
   Repeat above process until no further adjustments are required (0.30)

REFERENCE
S.P.12, pgs 1-2

ANSWER F.07 (2.00)

a. False (0.40 each)
b. False
c. True
d. True
e. False

REFERENCE
R.O.16, pg 1

ANSWER F.08 (1.50)

1. Scram and secure the reactor. (0.30 each)
2. Notify Health Physics.
3. Close the containment system.
4. Evacuate the building.
5. Account for all personnel that were in the containment building.

REFERENCE
E.O.2, pg 1

ANSWER F.09 (1.90)

Stack monitor activity high should be investigated first (0.90)
as this could result in an immediate release to the public (1.00)

REFERENCE
CAF

ANSWER G.01 (2.50)

a. 5(N-18) = 50 REM (0.30)
Total lifetime to date = 48 + 1 = 49 REM
Total lifetime available = 50 - 49 = 1 REM (0.30)
Total this quarter available = 3 - 1 = 2 REM (0.30)
Lifetime is more restrictive than quarterly limit

0.85 REM/HR gamma + (.03 RAD/HR)(10 QF) neutron =1.15 REM/HR dose rate (0.30)
1.0 REM/1.15 REM/HR = 0.87 HRS = 52 MIN (0.30)
[0.2 for using the conservative quality factor]

b. 25 REM whole body one time exposure (0.50)

c. Emergency Director & Radiation Safety Officer (0.25 each)

REFERENCE
10 CFR 20
E Plan, pg 8

ANSWER G.02 (2.00)

Assume a point source (0.50)

$$\frac{D1}{(R2)(R2)} = \frac{D2}{(R1)(R1)}$$ (0.60)

$$\frac{1800\ \text{mrem/hr}}{(R2)(R2)} = \frac{80\ \text{mrem/hr}}{(2m)(2m)}$$ (0.60)

R2 = 9.49 meters (0.30)

REFERENCE
Glasstone & Sesonske, Nuclear Reactor Engineering, pg 569

ANSWER G.03 (1.50)

1. Safe shutdown and securing of the reactor (any 3 at 0.50 each)
2. Inform the on-duty SRO of observed action levels
3. Take immediate actions as necessary to minimize reactor damage
4. Take immediate actions as necessary to minimize radioactive release

REFERENCE
E Plan, pg 5

ANSWER G.04 (2.50)

Category I (any one) (0.50 each)
Stack Monitor
Reactor Constant Air Monitor (CAM)

Category II (any three)
Building Exhaust Plenum
Bridge
Opposite Thermal Column
Control Room

Category III (any one)
F. P. Monitor
Core Exit Line

REFERENCE
ULR SAR, pgs 10-18 & 10-19

ANSWER G.05 (2.00)

CAF
Type of detector Proportional Counter (0.50)
Operation of detector paraffin surrounding detector (0.25) ~~(1.00)~~
to slow neutrons and read out directly in Rem/hr (0.25)
Boron in detector reacts with the neutrons to
create a Pulse of current (0.50)
Neutron radiation (0.50)

REFERENCE
ULR SAR, pg 8-8

ANSWER G.06 (1.50)

1. Non-Reactor Safety Related Events
2. Notification of Unusual Events
3. Alert
4. ~~Site Area Emergency~~
5. ~~General Emergency~~ (~~0.25~~ 0.40 each, ~~0.25~~ 0.30 for correct order)

REFERENCE
ULR E-Plan, pgs 8-11

ANSWER G.07 (2.00)

a. Ar-40 + n (0.50)
--> Ar-41 (0.50)

b. Radioactive corrosion products (0.50 each)
Fission products

REFERENCE
ULR SAR, pgs 7-1 & 7-2

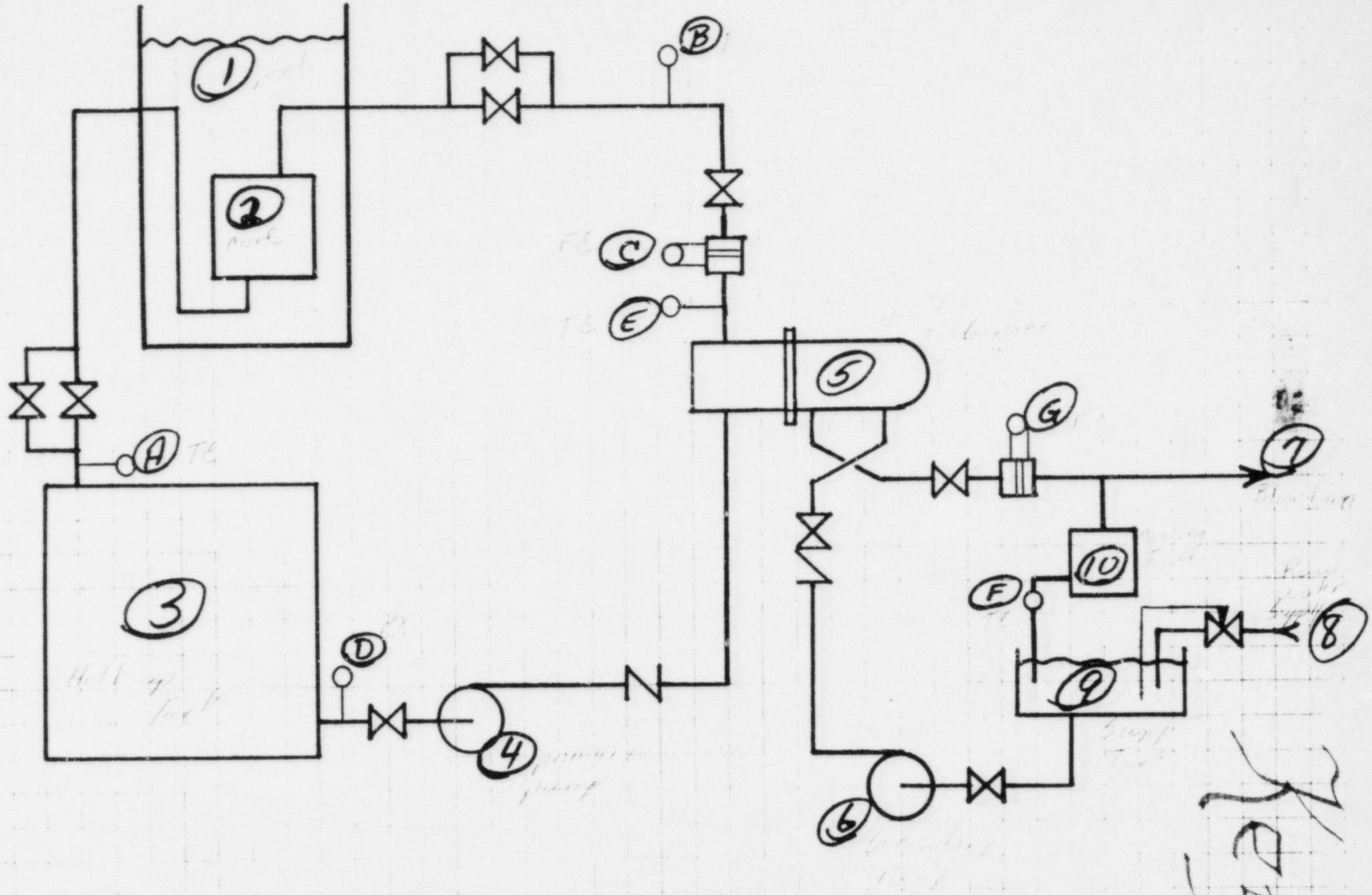
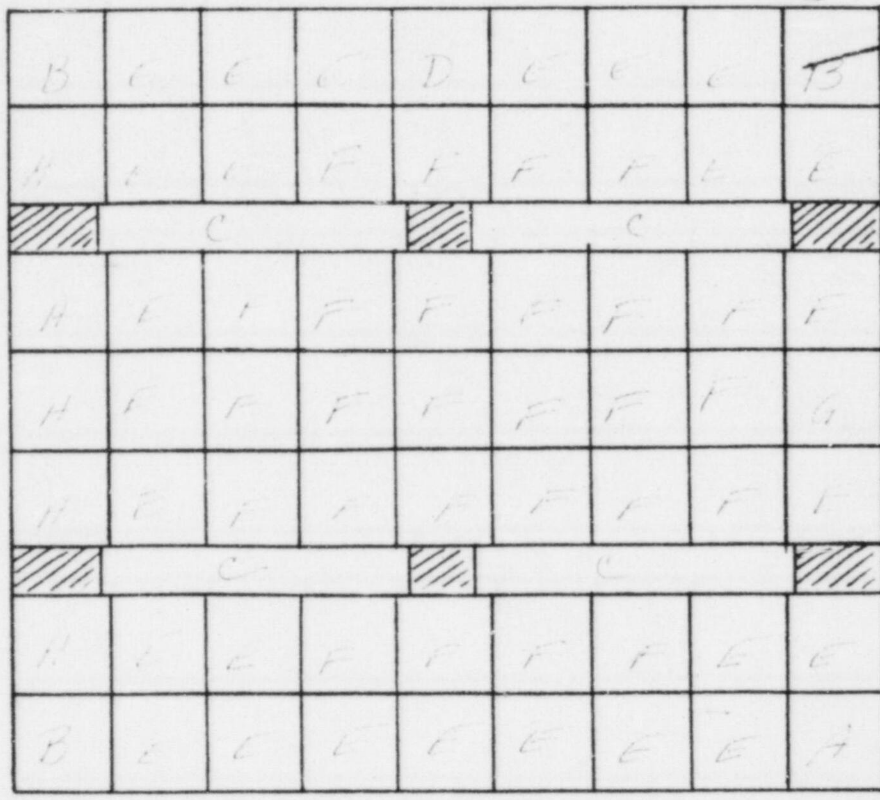


Figure B.1

Key



LEGEND

A = Proportional Counter
B = Compensated Ionization Chamber
C = Control Element
D = Startup Source
E = Graphite Reflector Element
F = Fuel Element
G = Servo Control Element
H = Radiation Basket

Figure B.2

Key

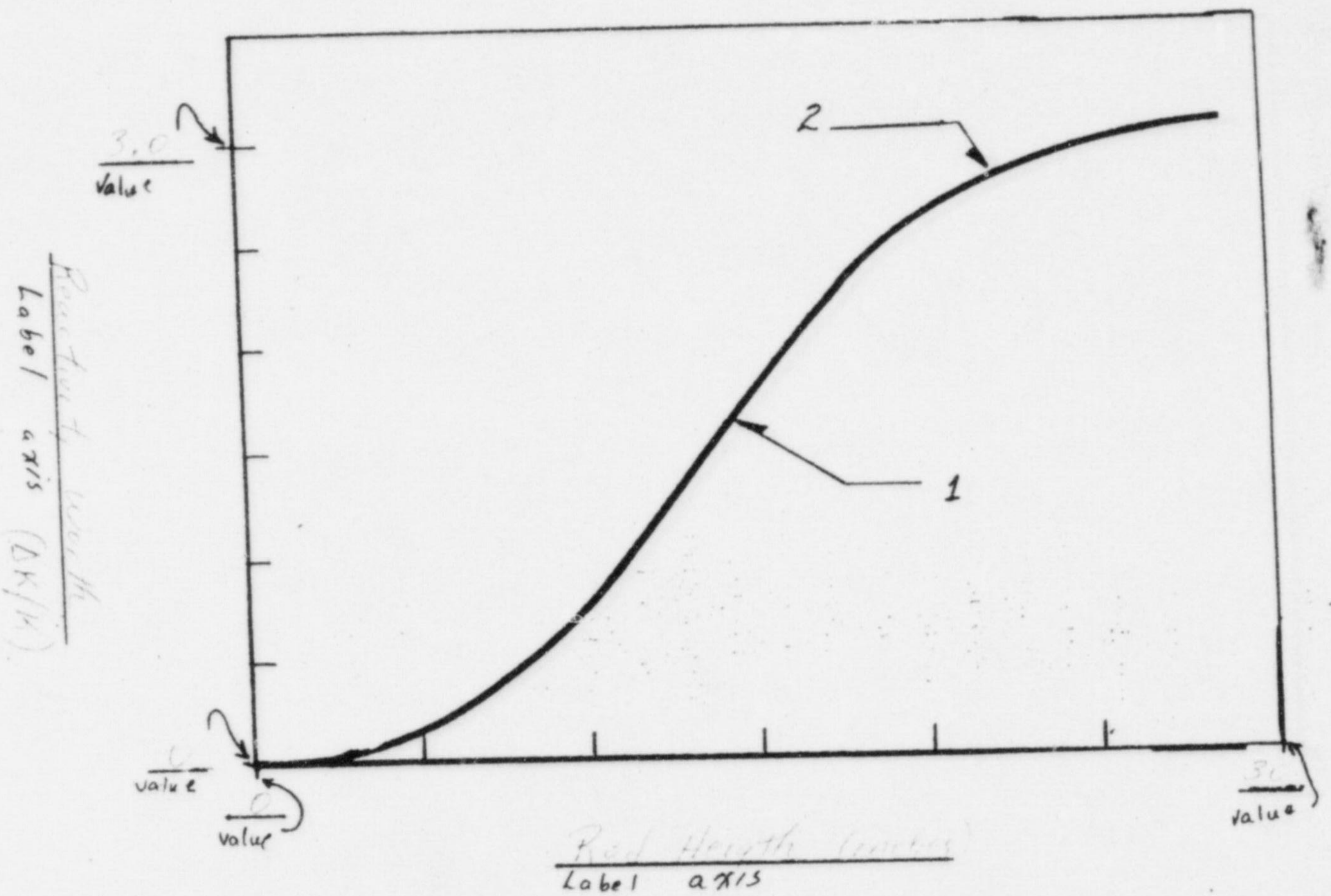


Figure C.1

Key

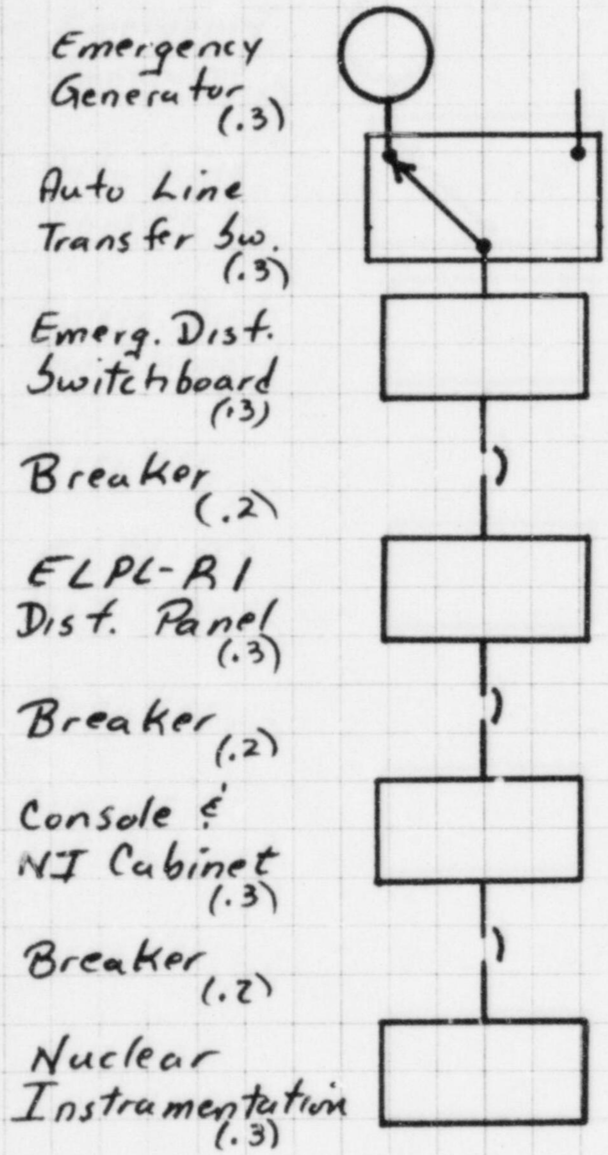


Figure E.1

Answer Key to Question E.03

QUESTION	VALUE	REFERENCE
A.01	2.50	BSN0000312
A.02	2.00	BSN0000313
A.03	1.50	BSN0000314
A.04	2.00	BSN0000315
A.05	2.00	BSN0000316
A.06	2.25	BSN0000317
A.07	1.75	BSN0000318
	14.00	
B.01	3.00	BSN0000321
B.02	1.50	BSN0000322
B.03	2.00	BSN0000323
B.04	2.00	BSN0000344
B.05	1.50	BSN0000325
B.06	1.00	BSN0000326
B.07	3.00	BSN0000327
	14.00	
C.01	2.50	BSN0000329
C.02	2.00	BSN0000330
C.03	2.00	BSN0000331
C.04	2.00	BSN0000332
C.05	2.50	BSN0000333
C.06	2.00	BSN0000335
C.07	1.00	BSN0000341
	14.00	
D.01	2.10	BSN0000336
D.02	2.50	BSN0000337
D.03	2.50	BSN0000338
D.04	1.50	BSN0000340
D.05	2.50	BSN0000342
D.06	2.00	BSN0000324
D.07	1.00	BSN0000345
	14.10	
E.01	1.00	BSN0000346
E.02	2.00	BSN0000347
E.03	2.40	BSN0000348
E.04	2.50	BSN0000349
E.05	2.50	BSN0000350
E.06	2.00	BSN0000351
E.07	2.00	BSN0000352
	14.40	
F.01	2.00	BSN0000353

QUESTION	VALUE	REFERENCE
F.02	1.00	BSN0000354
F.03	2.00	BSN0000356
F.04	1.00	BSN0000357
F.05	2.00	BSN0000358
F.06	2.10	BSN0000359
F.07	2.00	BSN0000360
F.08	1.50	BSN0000361
F.09	1.90	BSN0000362
	15.50	
G.01	2.50	BSN0000363
G.02	2.00	BSN0000364
G.03	1.50	BSN0000365
G.04	2.50	BSN0000366
G.05	2.00	BSN0000367
G.06	1.50	BSN0000368
G.07	2.00	BSN0000369
	14.00	
	100.00	