U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-151/OL-85-01

Docket No. 50-151

Licensee: University of Illinois
214 NEL 103 S. Goodwin
Urbana, IL 61801

Facility Name: University of Illinois

Examination Administered At: TRIGA Facility

Examination Conducted: 1 SRO

Examiner: R. R. Ferrell — July 30, 1985
Date

Approved By: J. I. McMillen
Operating License Section — July 30, 1985
Date

Examination Summary

Examination Administered on July 24-25, 1985 (Report No. 50-151/OL-85-01)
Results: 1 SRO passed the written and operational exam.

REPORT DETAILS

1. Examiner

   R. R. Ferrell, Chief Examiner

2. Examination Review Meeting

   At the conclusion of the written examination, the examiner met with Gerald Beck and Craig Pohlod of the Reactor Staff to review the written examination. A list of comments was generated and, along with the examiners responses, is included as a separate attachment.

3. Exit Meeting

   At the conclusion of the site visit, the examiner met with members of the reactor staff to discuss results of the examination. They were informed that the one (1) SRO candidate clearly passed the operational portion of the examination.

UNIVERSITY OF ILLINOIS

EXAM COMMENTS

General

The time allotted for a thorough review was inadequate and hence some of the comments may not have the clarity that is desired. The following comes from notes that were taken during the review. Only those questions where some concern was noted are included.

Examiner Response

The two hour time limit for the review was in accordance with the Operator Licensing Standard. This policy has been changed and as of August 1, 1985, the facility will be given a copy of the exam to keep following it's administration. A list of comments will be generated and given to the examiner by the end of the site visit.

Comment H.1(b)

It was not clear what the question wants. After looking at the expected answer, I was even more confused. Any concepts from same had never previously been seen. Apparently the only source for the question a was previous exam as the relationships do not appear in any textbook.

Examiner Response H.1(b)

Agreed. This question was deleted from the exam as it required the applicant to provide an answer derived from information not provided in the question.

Comment H.1(d)

The answer was basically correct, although some delayed neutrons can have sufficient energy to cause a fast fission with U-238.

Examiner Response H.1(d)

Agreed. The above comment was added to the answer key.

Comment H.2

Buckling is not covered in our operational lectures. To me, it is only of interest to reactor design rather than operation.

Examiner Response H.2

Disagree. Buckling is a concept the operator should be aware of for a good understanding of overall reactor operation. As buckling affects many plant parameters, as well as other parameters affecting it, the operator should have a brief knowledge of it. The candidate did well on the question.

Comment H.5

If a system is just "prompt critical" some of the short half-life delayed neutrons will be involved in determining the period. The expected answer occurs when a system is above "prompt critical."

Examiner Response H.5

Agreed. The above comment was added to the answer key and question graded accordingly.

Comment H.7

NE 390 notes will include the fact that the control rods will absorb more neutrons. The cell effect considers only the fuel and moderator although both of these cause thermal utilization to decrease.

Examiner Response H.7

Agreed. The above comment was added to the answer key.

Comment H.8(b)

Because of 20% enrichment, the thermal lifetime is shorter since there are more U235 atoms to absorb neutrons. We use 45 microseconds for calculations.

Examiner Response H.8(b)

Agreed. The above comment was added to the answer key.

Comment H.8(c)

Expected answer is certainly correct, but could have other correct answers.

Examiner Response H.8(c)

Disagree. The answer provided is correct and the question solicits the response provided.

Section I:

Comment I.1(c)

Changed to present CAM in use. Normally set at 5,000 cpm.

Examiner Response I.1(c)

Agreed. This was pointed out by candidate during the exam and the question changed to the CAM Unit setpoint.

Comment I.3

Question was changed since it was not applicable.

Examiner Response I.3

Agreed. The question was changed during the exam to explain the operation of the CAM Unit and the answer key changed to the correct answer.

Comment I.5(b)

Answer was in expected answer for part (a).

Examiner Response I.5

Agreed. The answer key was corrected.

Comment I.6(b)

Was not sure of source for the first expected answer. For visitors, our rule is one dosimeter for 10 individuals.

Examiner Response I.6(b)

The source of the question was the FSAR. The second comment is already in the answer key.

Comment I.8

The exhaust system was designed to remove particulates and get better dilution before reaching occupied areas. It does give values for the release of A-41, but the purpose isn't for this removal.

Examiner Response I.8

The examiner agrees the question could have been worded better, but is still applicable since it was taken from the system description provided. The candidate did well on the question.

Comment I.9

You may not get specific items in the expected answer. Basically any water on the lower level does go to the retention tank.

Examiner Response I.9

The system description listed specific sources of the water going to the retention tank, and since there is only a limited number of systems associated with the TRIGA, the candidate should know them.

Comment I.10

The question is worded incorrectly to get expected answer. The answers to the question are in 10 CFR 20 but you may get an emergency case answer of 25 rem.

Examiner Response I.10

Agreed. This question was graded very liberally based on the above comment.

Comment J.1

Might get variety of answers - do not remember question or expected answer. However, I do not believe this came from 390R notes.

Examiner Response J.1

The examiner does not understand the above comment but a review of the question and answer was performed and the question is basic theory the candidate should understand.

Comment J.2

This was true when we first did pulsed operation. At the present time, the gap stays about the same and no change in reactivity or fuel temperatures have been noted for the past 10 years.

Examiner Response J.2

Disagree. Although the above may be true, the answer in the key was from material provided to prepare the exam. The question and answer could be true and therefore is relevant. The candidate did well on the question.

Comment J.6

Question does not ask for reasons although these are given in the expected answer. Also No. (1) is not involved in the question.

Examiner Response J.7

Agreed. All the information provided in the answer is not necessary for full credit. It is only for use by the examiner and candidates answer was graded accordingly.

Comment J.8

Changed to Linear Recorder since no answer for % Power.

Examiner Response J.8

Agreed. The question was clarified during the administration of the exam.

Comment J.9

May get actual levels where scrams occur - 16" and 20" rather than distance to core. Normal distance to core is 16 feet.

Examiner Response J.9

Agreed. Additional Responses were added to the answer key.

Section K:

Comment K.6

Refer to amendment for present measurements. Item (b) in expected answer is not a surveillance requirement.

Examiner Response K.6

Agreed. The candidates response was graded according to the above comment.

Comment K.7

Actual enrichment is 8.5% and ratio is 1:1.7.

Examiner Response K.7

Agreed. The answer key was changed to incorporate the above comment.

Section L

Comment L.1(d)

Ramp rod has not been used since 1965.

Examiner Response L.1(d)

Agreed. This question was deleted from the exam.

Comment L.2

May get operating requirements instead of Technical Specification answers. These are to check the nv and temp., measure the rod worth; 15 watt rod positions for cold critical; and fuel temperature checks from 50-250 KW.

Examiner Response L.2

Disagree. Although the above comment is true, the question asked specifically for the Technical Specification requirements.

Comment L.3

Not in Technical Specifications - Without test and answers, I am not sure what this means.

Examiner Response L.3

Disagree. This is from the Technical Specifications definitions section.

Comment L.4 (d)

Actual value is 1 KW.

Examiner Response L.4

Agreed. The answer key was corrected.

Comment L.9

Should be 10 KW and 10 MW.

Examiner Response L.9

Agreed. The additional numbers were added to the key and either answer will be acceptable.

EXAM Master

Reviewers
G. Beck
C. Pohlod

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

FACILITY: University of Illinois
REACTOR TYPE: TRIGA
DATE ADMINISTERED: July 24, 1985
EXAMINER: R. R. Ferrell
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 and a final grade of at least 70%.

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

Final Grade _______%

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

____
Applicant's Signature

H. REACTOR THEORY

H.1 The delayed neutron fractions for U-235 and U-238 are .0065 and .0157 respectively

a. How does the magnitude of your core's delayed neutron fraction compare to those stated for U-235 and U-238? 1.0 ~~(.75)~~ RRS

~~b. Express the above values in terms of delta-K per K for your core.~~ RRS ~~(.75)~~ RRS

c. How can such a small fraction of neutrons be of any significance in your core? 1.0 ~~(.75)~~ RRS

d. Why don't delayed neutrons cause fission in U-238? 1.0 ~~(.75)~~ RRS

H.2 How is B^2 (Buckling) related to driving a control rod into the core? (1.75)

H.3 With the TRIGA critical and an external source present, the power level would be increasing at a linear rate (the rate of increase depends on source strength). If the source is removed the power level would decrease. Explain. (1.75)

H.4 Define the following terms.

a. Period (1.0)

b. Poison (1.0)

c. Xenon Oscillation (1.0)

H.5 Describe what effects have and are taking place if a reactor is "prompt critical." (2.0)

H.6 Will the following items add or subtract reactivity when they are added to the reactor core?

a. Fuel Elements (1.0)

b. Moderator (1.0)

c. Control Rods (1.0)

H.7 The TRIGA has a prompt negative temperature coefficient composed of several effects. Discuss these effects. (Three required for full credit.) (2.50)

H.8 a. What is meant by neutron lifetime? (1.0)

b. How is neutron lifetime related to the composition of the reactor fuel? (1.0)

c. How does the neutron lifetime relate to the pulsing capability of the TRIGA? (1.0)

I. RADIOACTIVE MATERIAL HANDLING, DISPOSAL, AND HAZARDS

I.1 List the following normal alarm settings on radiation monitors.

a. Reactor top (.75)

b. Demineralizer (.75)

c. Reactor ~~top/ceiling~~ CAM (PORTABLE (.75)

d. Lobby (.75)

I.2 What radiation levels would you expect to find in areas marked as follows?

a. Caution, Radiation Area (1.0)

b. Caution, High Radiation Area (1.0)

I.3 The air particulate monitor is utilized for radiation detection at your reactor.

a. List the ~~two~~ alarm condition settings for the monitor. (1.0)

b. How are each of these alarm conditions indicated to the operator? (2.0)

NOTE: QUESTION TO BE APPLIED TO CAM UNIT OPERATION

I.4 What is the first isotope likely to be seen in case of a fuel element rupture? (1.0)

I.5 Define the following terms.

a. Byproduct material (1.0)

b. Rem (1.0)

c. Rad (1.0)

I.6 a. What personnel monitoring devices shall be worn by reactor staff members? (1.0)

b. How does this differ from the requirements for visitors? (1.0)

I.7 What two people (by job title) can authorize access to the reactor area for a visitor? (1.0)

I.8 What radioactive gas is the building exhaust system designed to remove? (1.0)

I.9 What four sources drain liquids into the 500 gallon retention tank located under the main floor of the lab? (2.5)

I.10 Under what conditions specified in 10 CFR 20 can a licensee permit an individual into a restricted area to receive a total occupational dose to the whole body greater than specified? (1.5)

J. SPECIFIC OPERATING CHARACTERISTICS

J.1 During the course of performing an experiment, the reactor is taken critical and leveled out at 5Kw, with a moderator temperature of 80°F. The reactor is then shutdown, the moderator heated to 140°F through application of external heat. Another startup is made, and the operator levels off once more at the same indicated levels on his instruments, as were observed in the original run. Is the actual reactor power now the same, higher or lower than when it was at 80°F ? Explain your answer. (2.0)

J.2 One characteristic of the fuel elements used in the Illinois advanced TRIGA is that the fuel temperature and loss of reactivity for a given steady-state power level show an increase after they have been pulsed a number of times. To what do you attribute this? (2.0)

J.3 How does the mode of forced cooling differ, in respect to achievable power levels, from natural convection and why? (1.5)

J.4 Assume the TRIGA reactor is operating at steady state rated power and is in auto control. What control rod response would occur and why for each of the following separately occurring events?

a. Gas emitted from an experiment bubbles up through the core. (1.0)

b. An extraneous neutron source was inadvertently brought within a distance of two feet from the core. (1.0)

J.5 Why do some nuclear instrumentation channels use a compensated ionization chamber? Sketch a compensated ionization chamber and describe its theory of operation. (3.0)

J.6 List 5 interlocks and their purpose that are incorporated into the control system to prevent overlapping operations between two modes. (4.0)

J.7 Control rod drive motors are AC powered. Normally when power is removed from a motor, it will keep rotating for a few moments. How is this feature eliminated in the TRIGA rod drive? (1.5)

J.8 When the LINEAR %Power switch is placed in the calibrate position, the meter should read: (A) 100% (B) 110% (C) 10% (D) the reading would depend on the setting of the potentiometer below the switch. (1.0)

J.9 List two (2) scrams associated with reactor water tank temperature and level. (1.5)

J.10 Describe how the operation of the flapper valves is checked for proper operation. (List the 4 steps used for full credit.) (1.5)

K. FUEL HANDLING AND CORE PARAMETERS

K.1 The following data were taken during the loading of a reactor core:

No. of Elements	Count Rate (CPS, rods out)
0	12
4	13
8	14
10	15
12	20
13	30
14	60

a. Estimate the number of fuel elements for criticality. (Use attached sheet of graph paper.) (1.5)

b. Calculate the K of the reactor after loading the 13th element. (1.0)

c. Does the shape of the reciprocal multiplication plot obtained for the loading indicate the source is too close, too far away, or at an optimum distance with respect to the detector. Explain your answer. (1.0)

K.2 What advantages, if any, are gained by adding a fuel moderator section below the poison section of a control rod? (1.5)

K.3 The manually driven rods and the transient rods (fast and adjustable) at the TRIGA contain both a poison section and a follower section.

a. Describe the composition of the rods including the follower and poison sections. (1.5)

b. What is the purpose of the follower section? (1.5)

K.4 The reactor is in auto control when the log N power indicator starts to increase while the linear power indicator starts to decrease.

What is the most likely cause of this condition? (2.0)

K.5 How is a sourceless startup prevented on your reactor? (2.0)

K.6 What are the surveillance requirements for the fuel elements for the TRIGA reactor? (4.0)

K.7 Describe the following.

a. Standard Fuel Element (2.0)

b. Low Hydride Fuel Element (2.0)

L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS

L.1 Concerning the Tech Spec limiting conditions for operation for reactivity, fill in the blanks. (0.5 each)

The reactor shall not be operated unless the following conditions exist.

a. The excess reactivity is less than ________.

b. Any experiment with a reactivity worth greater than ________ is securely fastened so as to prevent unplanned removal from or insertion into the reactor.

c. The total of the absolute values of the reactivity worth of all experiments in the reactor is less than ____________.

~~d. A ramp or oscillating rod cannot be added at a rate exceeding ___________ per second.~~

e. The total reactivity worth of the two transient control rods is less than ___________.

f. The drop time of a standard control rod from the fully withdrawn position to 90 percent of full reactivity insertion is less than ____________.

g. The neutron count rate on the startup channel is greater than ___________.

L.2 The Technical Specification lists two requirements that shall be followed in order to operate the reactor in the pulse mode. What are these requirements? (Do not use those listed in Question L.1.) (2.0)

L.3 What are the conditions where the TRIGA reactor is considered "secured?" (2.25)

L.4 List three of the four interlocks associated with the TRIGA reactor listed in the technical specifications. (3.0)

L.5 What is the time interval (daily, weekly, monthly, semiannually, or annually) for the following Tech Spec surveillance items?

a. Emergency Spray Cooling System (.75)

b. Startup Instrumentation (.75)

c. Control Rod Worth (.75)

d. Radiation Monitoring Instrumentation (.75)

L.6 According to the technical specifications, what are three of the four items that must be evaluated prior to a proposed experiment being performed? (2.25)

L.7 When must the Daily Checklist be completed? (1.5)

L.8 Under what two conditions is the LOPRA considered "Inoperative?" (1.5)

L.9 What are the power level requirements that shall not be exceeded on the LOPRA for the following:

a. Steady State (0.5)

b. Peak (0.5)

Exam Master

ANSWER KEY

UNIVERSITY OF ILLINOIS

H. REACTOR THEORY

H.1 a. Triga core beta = .0073 making it larger than the B for U-235 but smaller than B for U-238

~~b. Based on .0073 B .0065/.0073 = 89¢; .0157/.0073 = $2.15 .0065 = .75% ΔK/K; .0157 = 1.5% ΔK/K~~ RR

c. The neutrons have long generation time thereby making the fission process controllable.

d. Too low on energy level for U-238 fission.

Ref: NE 390R Notes, p. 2

H.2 $B^2 \ a \ \frac{1}{(size)^2}$

As the reactor becomes effectively smaller in size, the curvature of the flux shape becomes greater and therefore buckling increases.

Ref: NE 390R Notes

H.3 Initial Decrease - Slight deficiency of the equilibrium fraction since delayed neutrons come from fission product precursors, it is necessary to build-in the precursor atoms until the rate of production is equivalent to the rate of decay. The time required for this to be accomplished is related to the half-life of the respective precursor atom. After six minutes, the longest half-life precursor (55 seconds) will be within 2% of its saturated value.

Ref: NE 390R p. 10

H.4 1. time it takes to increase the power level by a factor of e
2. material with a large cross section for absorbing neutrons, excluding fuel
3. flux shifting in core during movement of control rods causing a varying flux in different regions of the core which results in Buildup/Burnout of Xenon which will tend to shift flux again when rods are withdrawn

Ref: NE 390R p. 11, 13, 15

H.5 Keff is greater than prompt critical value chain reaction maintain on prompt neutrons alone. The reactor "outruns" the delayed neutrons and control mechanisms cannot act fast enough to prevent this. ALSO SHORT HALF-LIFE DELAYED NEUTRONS WILL BE INVOLVED IN DETERMINING THE PERIOD

Ref: NE 390R Notes, p. 2

H.6 a. Add

b. Can add or subtract depending if core is under or over moderated.

c. Subtract

Ref: NE 390R Notes

H.7 Cell effect - Increased temperature causes hardening of neutron spectrum through collisions with bound hydrogen in ZrH. Hardening spectrum results in a decrease in fission probability and an increase in the fraction of neutrons lost because of leakage from the element and parasitic capture in the core water. Also Control Rods will Absorb more neutrons; Thermal utilization ↓

Doppler effect - The capture resonances in U-238 are broadened by an increase in fuel temperature causing a decrease in the resonance escape probability.

Core leakage - When the core heats up, leakage is increased and relatively more captures occur outside the fuel (e.g., in the reflector, etc.).

Ref: NE390 R Notes

H.8 a. The time between birth of a neutron from fission and death by absorption or leakage.

b. Fuel and moderator are in an intimate mixture means the neutron will be thermalized quickly and be in close proximity to fuel for fissioning as opposed to leaving the fuel, being moderated and returning to fuel in normal fuel/moderator configuration. (Neutron lifetime in TRIGA ~ ~~39~~ 45 microseconds.)

c. Shorter lifetimes, larger peak pulses attainable before negative coefficient shuts it down.

Ref: NE 390R Notes

Answer Key - University of Illinois

I. RADIOACTIVE MATERIAL HANDLING, DISPOSAL, AND HAZARDS

I.1 a. $\leq$ 200 mr/hr

b. $\leq$ 100 mr/hr

c. ~~50 mr/hr~~ 5000 CPM ON THE X10 RANGE

d. 20 mr/hr

Ref: TS, Section 3.0

I.2 a. Major portion of body receive in one hour a dose > 5 mr.

b. Major portion of body receive in one hour a dose > 100 mr.

Ref: 10 CFR 20

I.3 a. alarm - ~~100,000~~ 5,000 cpm ON THE X10 SCALE
~~alert - 10,000 cpm~~

b. ~~alarm - continuous pulsing of the bell and red lights~~
~~alert - several pulses from a bell,~~
~~- red light on air particulate monitor~~
~~- red light on reactor console followed by a flashing yellow light in both directions~~

PUMP → FILTER → GM-TUBE → INTEGRATER → BISTABLE → BELL/ALARM LIGHT

Ref: FSAR, Section XI

I.4 rubidium-88

Ref: FSAR, Section XI

I.5 a. Any radioactive material yielded in or made radioactive by exposure to the radiation incident to the process of producing or utilizing special nuclear material (measure of the dose of any ionizing radiation to body tissues in terms of its estimated biological effect relateive to a dose of 1 roentgen or X-rays.) } PART OF b.

b. Rad x QF

c. absorbed energy - 100 ergs/gm measure of the dose of any ionizing radiation in terms of the energy absorbed per unit mass of the tissue.

Ref: 10 CFR 20

I.6 a. Film badges and self reading pocket dosimeters.

b. < 8 hrs/week - issued pocket dosimeter
Visiting groups - 1 dosimeter/every 10 people

Ref: TS XI-26

I.7 Reactor Supervisor
Reactor Health Physicist

Ref: XI-26

I.8 Ar-41

Ref: TS XI-6

I.9 4 floor drains
1 trench drain
cleanup shower
cleanup sink

Ref: TS XI-3

I.10 1. Dose to whole body shall not exceed 3 rems
2. Shall not exceed 5(N-18)
3. Form 4 completed

Ref: 10 CFR 20.101

J. SPECIFIC OPERATING CHARACTERISTICS

J.1 Lower (0.5). The instruments are now seeing more leakage neutrons due to less dense moderator. Therefore they read higher at lower actual power.

Ref: NE 390R Notes

J.2 Attributed to the formation of a slight gap between fuel and cladding causing poorer heat conduction from the fuel-moderator to the cladding.

Ref: NE 390R Notes

J.3 Forced circulation affords higher achievable power levels due to lower fuel temperatures and thereby lower fuel temperature defect.

Ref: NE 390R Notes

J.4 a. The bubbles would be treated as voids and since TRIGA has a negative void coefficient the rods would be pulled to maintain power constant.

b. The effect from an extraneous neutron source would be negligible and no control rod action would take place.

Ref: NE 390R Notes

J.5 See attached sketch.

Ref:

J.6 (1) The simultaneous withdrawal of more than two motor-driven rods in the steady-state mode. This prevents the insertion of reactivity at a rate where control of the power level may be lost by the operator. This is especially true during operations previous to the appearance of the reactor period information, which occurs at about one watt.

(2) The removal of either transient rod with the other rods removed from their down position in the steady-state move. This prevents undesired transients that result from an operational error. Although the system would be protected by the power level and period scrams, the information recorded for transients would be lacking and hence the results would be unknown.

(3) The application of air to the adjustable transient rod unless the rod cylinder is fully inserted int he steady-state mode. This limits the rate of reactivity insertion during startup in to its maximum up position. The second rod (adjustable transient) must be mechanically removed with the rod cylinder.

(4) The movement of any control rod except the transient rods in the pulse mode. This is a safety feature that prevents insertion of additional reactivity just previous to a transient. When the reactor is placed in the pulse mode, information on the power level is lost until a power level in the megawatt region is obtained and the first indications of increases in the fuel temperature appear. Without the interlock, it is conceivable that a manually operated rod could be withdrawn accidentally and thereby result in a transient considerably higher than expected.

(5) The performance of a pulse or the initiation of a square wave with the steady state reactor power able 250 kilowatts. This prevents an occurrence where the maximum fuel temperature might exceed the safety limit. The present limit of 250 kilowatts allows some flexibility for transient operation, while still assuring that excessively high temperature won't occur even if a maximum transient is operated from this level.

Ref: NE 390R Notes

J.7 Electrical dynamic and static braking on motors provide fast stops and to limit coasting or over travel.

Ref: FSAR

J.8 % power switch - calibrate - reads 100%

Ref: FSAR

J.9 a. Rx water tank level scram if level above top grid plate if core is less than 14 feet. (16" AND 20" - normall is 16ft)

b. Water temperature scram if bulk water temperature in tank or exit coolant temperature $\geq$ 120°.

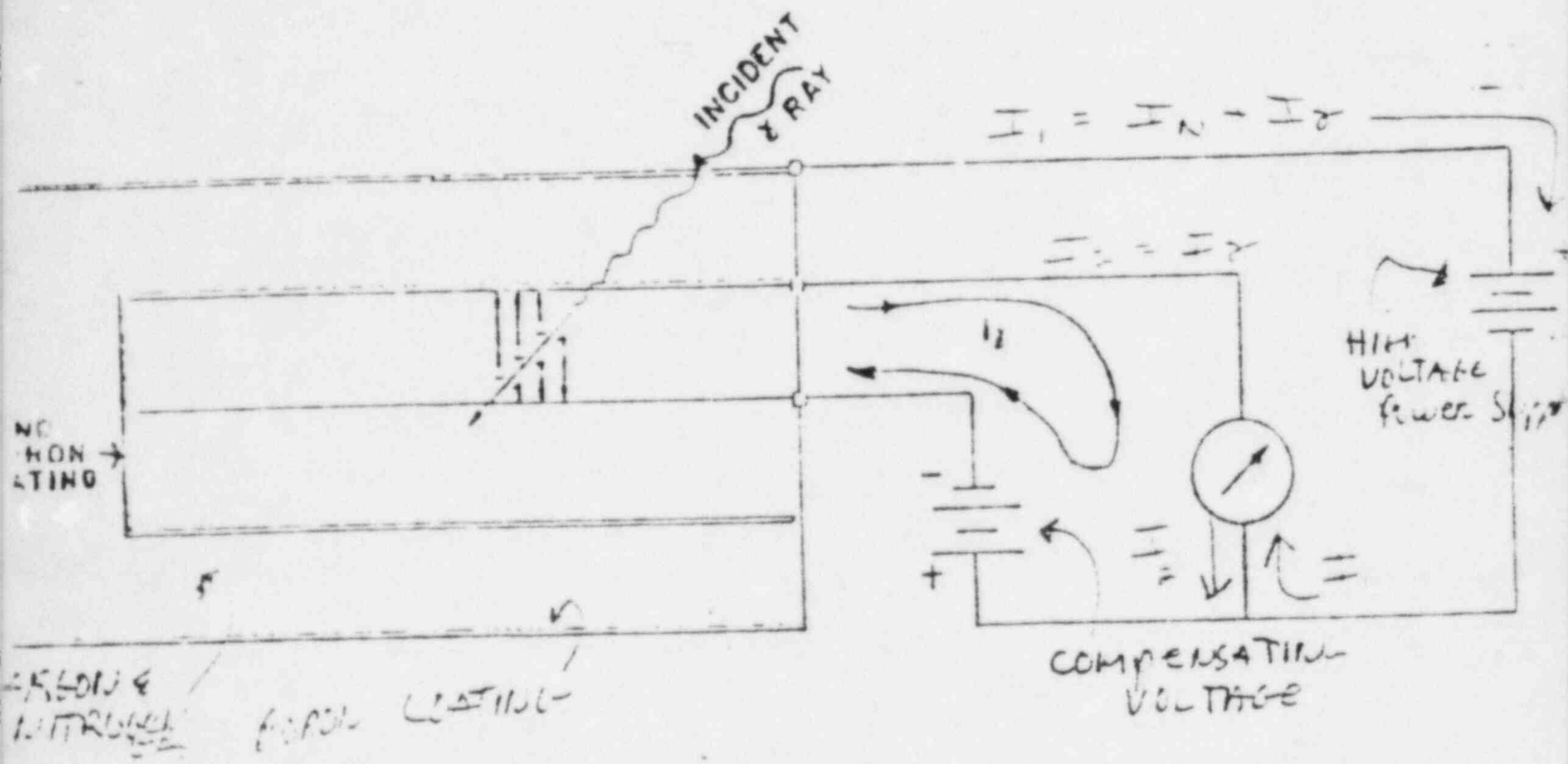
Ref: FSAR

J.10 Reactor checkout procedure

11.e - Start primary pump
11.g - Check Flapper Valve is closed
11.h - Stop primary pump
11.j - Check Flapper Valve is open

Ref: FSAR

J.5



[illegible] chamber is coated with boron enriched in the B^{10} isotope and is sensitive to neutrons and gamma radiation. The second chamber is uncoated and is sensitive only to gamma. By connecting the two chambers so that their output currents buck (the currents electrically oppose each other) then the net electrical output or current from the chamber will be the algebraic sum of the two ionization currents.

[illegible] = [illegible] - I_γ
[illegible] $I_n + I_\gamma$
[illegible] = I_γ

Intermediate ranges are generally undercompensated (~95% compensated

[illegible] = $I_n + I_\gamma$
[illegible] = .95 I_γ

This means current from boron lined chamber is greater than current from unlined chamber in a gamma field.

K. FUEL HANDLING AND CORE PARAMETERS

K.1 a. 15 elements

b. K = .6 by $\frac{1}{1-K}$; $M = \frac{1}{1-K}$, $\frac{.12}{30} = \frac{1}{1-K}$, $2.5 = \frac{1}{1-K}$

$K = \frac{1.5}{2.5} = .6$

c. Too close; the multiplication in the reactor is initially being masked by the strength of source neutrons

Ref: NE 390R Notes

K.2 Allows smaller overall dimensions of core and prevents flux peaking; increases worth.

Ref: NE 390R Notes

K.3 a. Control rod - Fuel follower - air void, borated graphite, fuel, air void

Fast Transient rod - (borated graphite double section), air void

Adjustable transient rod - borated graphite, air void

b. The air follower serves to diminish the flux peaking that would occur in the water filling the region when the rod is withdrawn.

Ref: FSAR

K.4 Linear Power Instrument failed low, log N seeing increase in power since rod is being withdrawn by the linear power instrument.

Ref: FSAR

K.5 By the use of a source interlock on the startup detector requiring minimum counts.

Ref: FSAR

K.6 a. The standard fuel elements shall be measured for length and bend at intervals separated by not more than 500 pulses of magnitude greater than $1.00 of reactivity. Fuel elements in the B and C hexagonals shall be measured at intervals not to exceed 12 months. Low hydride fuel elements shall be measured at intervals separated by not more than 50 pulses or 12 months if they are used for pulsed operating in the TRIGA core.

b. A fuel element indicating an elongation greater than 1/4 of an inch over its original length or a lateral bending greater than 1/16 of an inch over its original bending shall be considered to be damaged and shall not be used in the core for further operation.

c. Fuel elements in the B- and C- hexagonals shall be measured for possible distortion in the event that there is indication that fuel temperatures greater than the limiting safety system setting on temperature may have been exceeded.

Ref: TS, 4.0

K.7 a. Standard Fuel Element: The standard fuel element shall contain uranium-zirconium hydride, clad in 0.020 inch of 304 stainless steel. It shall contain a maximum of ~~9.0~~ 8.5 weight percent uranium which has a maximum enrichment of 20 percent. There shall be ~~1.55 to 1.80~~ 1.7 hydrogen atoms to 1.0 zirconium atom.

b. Low Hydride Fuel Element: This fuel element shall contain uranium-zirconium hydride, clad in 0.030 inch of aluminum or 0.020 inch of 304 stainless steel. It shall contain a maximum of ~~8~~ 8.5 weight percent uranium which has a maximum enrichment of 20 percent. There shall be ~~0.9 to 1.54~~ 1.7 hydrogen atoms to 1.0 zirconium atom.

Ref: TS, 5.0

L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS

L.1 a. $8.00

b. $1.00

c. $5.00

d. $10.00

e. $5.00

f. 1 second

g. 1 cpm

Ref: TS Section 3.1

L.2 a. Transient rods are set such that their reactivity worth upon withdrawl is not greater than $4.60.

b. Temperature of the fuel immediately prior to the pulse is less than 250°C as measured in the thermocoupled fuel element in the B-hexagonal or 235°C in the C-hexagonal or 211°C in the D-hexagonal.

Ref: TS Section 3.3

L.3 a. The reactor is shutdown.

b. Power to the control rod magnets and actuating solenoids has been switched off, the key removed.

c. No work in progress involving fuel or in core experiments or maintenance of the core structure, control rods or Control Rod Drive Mechanisms.

Ref: TS, XV-2

L.4 3/4 at .75 each

a. In the manual or "steady-state" mode only two control rods may be raised at any one time.

b. Except for the pulse mode, the transient rods cannot be raised with any of the other mechanical control rods above the fully inserted position.

c. Mechanically driven control rods cannot be withdrawn with less than 1 cps on the startup channel.

d. A pulse cannot be initiated when the power level exceeds ~~250~~ 1 Kw. Ref

(Any three 1.0 each)

Ref: TS XV-13

L.5 a. Weekly

b. Daily

c. Semiannually

d. Weekly

Ref: TS, XV

L.6 3/4 @ .75 each

a. Reactivity worth of the experiment

b. Integrity of the experiment including the effects of changes in temperature, pressure or chemical composition.

c. Any physical or chemical interaction that could occur with the reactor components.

d. Any radiation hazard that may result from the activation of materials or from external beams.

Ref: TS XV-29

L.7 a. Prior to each day operation

b. 100 hrs of extended operation

Ref: Written Procedures - Daily Checklist

L.8 a. Sufficient fuel has been removed from the assembly to assure that Keff < 0.99 with all safety rods, poison rod, and measuring devices removed from the core region.

b. The LOPRA has been decoupled from the TRIGA by placing a neutron absorbing curtain, equivalent to 20 mils of boral, between the assembly and the graphite column and/or by moving the assembly away from the graphite column to provide at least the equivalent effect.

Ref: FSAR Section 10

Safety Limit — Safety System Setpoint

L.9 a. 250 Kw (10KW) } either one

b. 1000 Mw 10MW

Ref: TS, Section 2.1