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

EXAMINATION REPORT NO. 50-170/84-03

FACILITY DOCKET NO. 50-170

FACILITY LICENSE NO. R-84

LICENSEE: Defense Nuclear Agency
Armed Forces Radiobiology Research Institute
ATTN: Colonel Bobby R. Adcock, MSC, USA
Director
Bethesda, Maryland 20014

FACILITY: AFRRI

DATES: March 5, 1984

CHIEF EXAMINER: [signature] 5/8/84
L. Whitaker — Date

APPROVED BY: [signature] 5/14/84
Chief, Project Section 1D — Date

SUMMARY: One written examination and one oral examination was administered to the candidate, who passed both sections of the examination.

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PDR ADOCK 05000170
G PDR

REPORT DETAILS

TYPE OF EXAMS: Initial X Replacement ____ Requalification ____

EXAM RESULTS:

	RO Pass/Fail	SRO Pass/Fail	Inst. Cert Pass/Fail	Fuel Handler Pass/Fail
Written Exam	/	1 /	1 /	/
Oral Exam	/	1 /	1 /	/
Simulator Exam	/	/	1 /	/
Overall	/	/	1 /	/

1. CHIEF EXAMINER AT SITE: L. Whitaker, NRC

2. OTHER EXAMINERS: R. Keller, NRC

3. PERSONS EXAMINED

   Maureen Dougherty, Instant SRO

1. Summary of generic strengths or deficiencies noted on oral exams:

   None

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

   None

3. Comments on availability and candidate familiarization with plant reference material:

   None

4. Comments on availability and candidate familiarization with plant design, procedure, T. S. changes and LERs:

   None

5. Comments on interface effectiveness with plant training staff and plant operations staff during exam period.

   Not applicable.

6. Improvements noted in training programs as a result of prior operator licensing examinations/suggestions, etc:

   None

7. Personnel Present at Exit Meeting:

<u>NRC Personnel</u>

L. Whitaker
R. Keller

<u>Facility Personnel</u>

M. Moore

8. Summary of NRC Comments made at exit interview:

Candidate seemed well prepared.

9. Summary of facility comments and commitments made at exit interview:

The facility commented that the written examination was difficult but provided no objection to the individual questions or answers.

10. CHANGES MADE TO WRITTEN EXAM

Two questions were tailored to fit AFRRI among generic Research Reactor facilities.

Attachment:

Written Examination(s) and Answer Key(s) (SRO)

U. S. NUCLEAR REGULATORY COMMISSION
SENIOR REACTOR OPERATOR [redacted] EXAMINATION

FACILITY: AFRRI

REACTOR TYPE: Critical Facility

DATE ADMINISTERED: March 5, 1984

EXAMINER: L. W. Whitaker

APPLICANT:

INSTRUCTIONS TO APPLICANT:

Use separate paper for the answers. Staple question sheet on top of the answer sheets. Points for each question are indicated in parentheses after the question.

CATEGORY VALUE	% OF TOTAL	APPLICANT'S SCORE	% OF CATEGORY VALUE	CATEGORY
25.5	24.5			H. REACTOR THEORY
15.5	15.5			I. RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS
21	21			J. SPECIAL OPERATING CHARACTERISTICS
21	21			K. FUEL HANDLING AND CORE PARAMETERS
18	18			L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS
100	100.0			TOTALS

FINAL GRADE ________________ %

H. REACTOR THEORY (24.5)

H.1 If 1% excesss reactivity is added to a reactor that is critical, the resulting period is very short. Explain in detail why the addition of 1% negative reactivity to a critical reactor results in a long stable period. (3)

H.2 While withdrawing control rods to take the reactor critical, does the start up instrumentation require the same time to level out at each subcritical level? Briefly explain. (3)

H.3 A reactor is shutdown by 5% Δk/k and has a source level of 10 CPS. The control rods are partially withdrawn and the count rate increases by a factor of 10. What is the new k-eff of the reactor? Show all work. (3)

H.4 A moveable experiment falls away from the core while the reactor is critical at a low power level incresing Δk/k by 0.2%.

a) Estimate the resulting period. (2)

b) Estimate the resulting doubling time. (1)

c) If the reactor was all ready on a 100 second period when this incident occurred, what would be the resulting period? (2)

Note: Show all work

H.5 Briefly explain how Samarium is produced in your reactor. (2)

H.6 Assume that the maximum excess reactivity allowed is instantly added when the reactor is at low power. Would the reactor be supercritical or prompt critical? Justify your answer. (2)

H.7 For a given power level, does the average flux in the reactor increase, decrease, or remain constant over the core life? Briefly explain. (Assume no new fuel is added.) (2)

H.8 Temperature increases from 70°F to 120°F, which of the following increase (or decrease or remain unchanged)? Briefly explain.

a) Number of neutrons absorbed in the control rods (assuming the rods do not move) (1.5)

b) Number of neutrons leaking from the core. (1.5)

c) Number of neutrons absorbed in the fuel compared to those absorbed in the moderator. (1.5)

I. RADIOACTIVE MATERIALS HANDLING, DISPOSAL AND HAZARDS (15.5)

I.1 While performing an experiment, it is determined that the reactor room air contains 4×10^{-6} μc/ml of A-41 activity. In accordance with 10 CFR 20, are there any restrictions that should be placed on the reactor room occupancy? Briefly explain. (2)

I.2 Consider two point sources each having the same curie strength (for example, 1 curie each). Source A gamma's have an energy of 1 MeV while source B gamma's have an energy of 2 MeV. You obtain a reading from the same Geiger counter 10 feet from each source. Would the reading from source A be about twice, one-half, or about the same as that from source B. Briefly explain why. (2)

I.3 a) No eating is allowed in radiation areas. If the radiation level is low enough to allow entry into the area, explain why the above prohibition is imposed. (1)

b) Discuss the radiological hazards for this prohibition. (1.5)

I.4 A small radioactive pellet (a gamma emitter) is located inside a 4-inch thick lead carrier. The dose rate at the outside surface of the carrier is 8 mr/hr. If this pellet is taken out of the carrier and held in tongs 3-feet long, how long would it take to expose the hands of the person holding the tongs to a total dose of 100 mr? (3)

(Assume the Tenth Value Layer for lead is 1 inch). Show all work and specify any assumptions.

I.5 Consider a 3 curie point source of 1 MeV gamma's

a) Determine the dose rate at 6 feet from the source assuming no shielding. Show all work. (2)

b) If the source has a half-life of 30 minutes, what is the source strength 2 hours from the time it was 3 curies? Show all work. (2)

I.6 According to 10 CFR 20, an individual in a restricted area may be allowed to receive a whole body dose of radiation greater than 1.25 rems per calendar quarter under certain conditions. Name the conditions. (2)

J. SPECIFIC OPERATING CHARACTERISTICS (21)

J.1 a) Define neutron lifetime. (1)

b) A heavy water (D_2O) tank is placed against the core in a such a manner that it replaces the light water as a reflector. Would you expect a difference in neutron lifetime? Briefly explain? (2)

J.2 During operation of your reactor, what direction of movement of control rod, if any, will be required to maintain a constant power level by the following changes. Briefly explain each answer.
(Assume each change occurs independently)

a) Operation at 100% power with the water temperature increasing from 90°F to 100°F (2)

b) Water leaks into a nitrogen-filled experimental tube placed in a vacant position within the active fuel lattice (2)

c) A moveable experiment containing boron is added to the core (1.5)

J.3 Outline how a control rod integral rod worth curve is obtained. Include the conditions before the test. (3)

J.4 What limits a power excursion of your reactor other than instrumentation initiated scrams? (Your answer should include administrative or Tech. Specs. limits as well as physical considerations) (3)

J.5 The AFRRI Reactor is operated at 100 W for 8 hours. A radioactive analysis of the reactor tank water is then performed. What are some of the radioactive isotopes you would expect to find and what is their source? (List at least 4) (1.5)

J.6 You are to supervise a temperature coefficient measurement experiment.

a) What equipment is available to introduce the temperature transient? (1)

b) What is the magnitude of the temperature transient you would use? (0.5)

c) At what rate can you change temperature? (0.5)

d) What is the corresponding reactivity magnitude and rate? (1)

e) Discuss the limitations and/or specifications involved in the experiment. (2)

K. FUEL HANDLING AND CORE PARAMETERS (17)

1. a. Define "Excess Reactivity." (1.5)

   b. What is the AFRRI license limit for excess reactivity? (0.5)

2. When loading a new core why is 1/M plotted rather than plotting multiplication directly? Explain. (2)

3. What is the AFRRI Technical Specification for:

   a. Shutdown margin? (1)

   b. Maximum control rod reactivity insertion rate? (1)

4. Outline the procedure you would use to verify that the maximum control rod reactivity rate is within specifications. (3)

5. What 4 parameters must be determined during the initial testing of an unknown or previously untested core configuration? (2)

6. a. Who can supervise a refueling? (1)

   b. Who has control of transfer of fuel elements from the vault? (1)

7. What are 6 rules in the operating procedures that pertain to fuel handling? (4)

L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS (18)

L.1 Indicate whether or not the following are violations of procedures and/or Technical Specifications. Briefly explain why it is or is not a violation.

a) The reactor is subcritical by 1% Δk/k with the most reactive control rod withdrawn. (1.5)

b) The reactor is started up with the log count rate channel, on linear power channel and the Log-N period channel operable. (1.5)

c) While operating at 100% power the reactor operator bypasses the Log-N period. (1.5)

d) Water level in Reactor Tank is 10.5 inches above Core Top Grid. (1.5)

e) While operating at 100% power, the continuous air monitor in the reactor room fails and the operator does not shutdown. (1.5)

L.2 Briefly explain for what purpose, under what conditions, and by whose authority the reactor door scram may be bypassed. (2.5)

L.3 In accordance with your Technical Specifications, name four types of "Reportable Occurrences." (2)

L.4 Title 10, Part 55, Operators Licenses, defines an operator as any individual who manipulates a control of a reactor.

a) Define "control." (1)

b) When can an unlicensed operator manipulate a control? (2)

L.5 Describe immediate actions required by procedures which must be performed upon learning that a group of protesters are marching to the reactor facility to attempt a sit-in. (3)

*** PRINT DIAGNOSTIC LISTING ***

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ANSWER SHEET

(SRO EXAM)

H. REACTOR THEORY

H.1 The initial change in neutron flux is determined as if all neutrons were prompt. This behavior is caused by the fact that as negative reactivity is introduced, the vast majority of neutrons absorbed are prompt. However, after this initial period, the delayed neutrons released are in direct proportion to the neutron population at an earlier time. Thus, the neutron population is being determined by the delayed neutrons alone.

The half-lives of the precursor groups 1 through 5 are substantially shorter than that for precursor group 6, the longest-lived precursor. Relative to the concentration of precursor group 6, the concentrations of the other five precursors quickly become very small. Thus the period of neutron population decrease equals the lifetime of the longest-lived precursor and corresponds to -80 seconds.

Ref: Fac Training Material (FTM)

H.2 NO, as criticality is approached the time to level out increases. The steady state multiplication of the neutrons in the system can be represented by

also electronics

$$\frac{S(1 + k_{eff} + k_{eff}^2 + \ldots)}{S}$$

Thus, as k_{eff} approaches 1.0 many more of the succeeding generations make a significant contribution to the multiplication factor.

Ref: FTM

H.3 $\frac{k-1}{k} = .05$ $\qquad k = 0.952$

$\frac{CPS_2}{CPS_1} \quad \frac{1.0 - 0.952}{1.0 - k_{eff}} = 20$ $\qquad k_{eff} = 0.9952$ $\quad \cong$

Ref: FTM

H.4 a) $\rho = .002$ $\qquad \beta_{eff} = .0078$ (.007) $\qquad \tau = 12.2$ sec $\quad \ell^* = 2 \times 10^{-4}$ sec

$$T = \frac{\ell^*}{\rho} + \frac{(\beta_{eff} - \rho)\tau}{\rho}$$

$$T = \frac{2\times10^{-4}\text{ sec}}{.002} + \frac{(.0078 - .002)\ 12.2\text{ sec}}{.002} = 34.9\text{ sec}$$

if τ is assumed to be 0.1 then answer is 28.6 sec

b) Doubling time = ln 2 x 34.9 sec = 24.2 sec

Ref: FTM

c) ρ for 100 sec

$$T = \frac{2 \times 10^{-4}}{\rho} + \frac{.0078 - \rho}{\rho} \quad 12.2$$

$$\rho 100 = 2 \times 10^{-4} + .0078 \times 12.2 - 12.2\rho$$

$$\rho = \frac{2 \times 10^{-4} + .0078 \times 12.2}{100 + 12.2} = .00085$$

$$\therefore \text{ Total } \rho = .00085 + .002 = .00285$$

$$T = \frac{2 \times 10^{-4}}{.00285} + \frac{.0078 - .00285}{.00285} \quad 12.2 = 21.3 \text{ sec}$$

Ref: FTM

H.5 Sm-149 is produced from fission fragments of Neodymium and β decay via promethem to Sm

Ref FTM

H.6 Maximum excess reactivity is 0.5 %Δk/k or .005 Δk/k which is far less than β_{eff} of .0078. Therefore, the reactor would be super critical. PROMPT @ ARRS (PULSES & SQUARES)

Ref: FTM

H.7 Increases. The fission rate must remain constant for constant power; therefore, since Σ_f decreases as fuel is used up, the average flux must increase.

Ref: FTM

H.8 All increase as water temperature increases its density decreases and thus its absorption of neutrons decreases. In addition, the slowing down length and diffusion length increase, therefore more neutrons leak out and are absorbed in the fuel and control rods.

Ref: FTM

what much temp would require rods to be pulled out of core thereby increasing the amount of rod in core to absorb n's.

I. RADIAOCTIVE MATERIALS HANDLING, DISPOSAL AND HAZARDS

what table ? ②

I.1 4×10^{-6} μc/ml is twice 10 CFR 20 limits for restricted area (Standard Exam Table provided with exam). This limit is for 40 hour occupancy. Thus occupancy would be restricted to 20 hrs/week in the reactor building.

Ref: CFR's

I.2 About the same, GM's are not energy dependent (by 6 CEN = R/hr @ 1 ft R would double)

Ref: ~~Ftm~~ Fac. info accepted ⟶

I.3 a) Due to the hazard of introducing removable contamination into the body via eating

b) Ingesting radioactive particles is dangerous because it concentrates in certain areas of the body and there is no shielding to minimize ionization damage.

Ref. Ftm

I.4 Assume pellet at inside of wall

4" = 4 TVL's or 8 mr/hr x 10^4 = 80,000 mr/hr @ 4'

$$\text{Dose at 3 ft} \; \frac{D_1}{\text{ }} = \frac{D_2}{\text{ }} = \frac{80R}{(36)^2} = \frac{D_2}{r^2} = 988 \text{ mr} \sim 1R$$

$$\frac{100 \text{ mr}}{1000 \text{ mr/hr}} = 0.1 \text{ hrs} = 6 \text{ minutes}$$

Ref: CALC

I.5 a) $\frac{R}{Hr} @ 6 \text{ ft} = \frac{6 \text{ CEN}}{(6)^2} = \frac{6 \times 3 \times 1 \times 1}{36} = 0.5 \text{ R/hr}$

b) $A = A_o e^{-0.693t/T_{1/2}}$ $\qquad \frac{t}{T_{1/2}} = \frac{2 \text{ hrs.}}{0.5 \text{ hrs}} = 4$

$A = 3\ e^{-.693x4}$

$A = 3 \times e^{-2.772} = 3 \times .0625 = .188$ curies

Ref: CALC

I.6 Provided that (1) he does not exceed 3 rem per quarter

(2) his radiation history is known and recorded on the proper form ([redacted])

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

J. SPECIFIC OPERATING CHARACTERISTICS

J.1 a) The average time a neutron exists in the reactor from the time it is born until it is absorbed or it leaks out

b) The neutron life is increased since there is less absorption by the heavy water when compared to light water and more are reflected back into the core

Ref: [illegible] manuals

J.2 a) Because the moderator temperature coefficient is negative, as the pool temperature increases, the control rod will have to be withdrawn

b) Since water is a better moderator than nitrogen and since the void coefficient must be negative to satisfy Tech. Specs. The reactivity would increase. Therefore, rods will have to be inserted.

c) Since boron has a large absorption cross-section when compared to water, negative reactivity would be added and thus the rods will have to be withdrawn

Ref: FRM

J.3 Conditions before test - Reactor Critical rods banked
By using the positive period method obtain a differential rod worth curve. In the positive period method, criticality is achieved at a low power level, the rod to be calibrated is withdrawn such that a reasonable period is obtained and measured. The other rods are then inserted to achieve criticality and the process is repeated over the length of the rod. A differential rod worth curve is plotted, i.e., ρ/unit travel vs. unit travel. This curve is then integrated (usually graphically) and an integrated rod worth curve is obtained.

Ref: FTM

?

J.4 Negative temperature coefficient, negative void coefficient if boiling occurs, maximum core reactivity as limited by Tech. Specs.

Ref: FTM

This method used for above critical height; the rest of the curve is obtained by rod drop method (amplitude obtained); shape is obtained via subcritical multiplication method.

J.5 Should see Ci^{38}, Ha^{24}, Fe^{59}, Cu^{64} etc....CAF
Ref: FTM

?

L Na^{24}, A^{41},

J6 - CAF

a Electrical Heater - core itself

b 1.47°C/100 kw-hr

c. see b

d ≅ .5¢/oC - to α and 5.5 Weq temp coef curve

K

1.a the available above a cold clean critical configuration which may be added by manipulation of controls
Ref: FTM

1.b ~~3.9%~~ ΔK/K 3.5%
Ref: FTM

2. 1/M is a linear function that PREDICTS criticality where it crosses zero and if it is non-linear indicates problems with counting setup. M is non-linear function that is tending to ∞ and is very difficult to analyze.
Ref: FTM

3.a Subcritical by > 0.~~5~~1% ΔK/K with most reactive control rod withdrawn
Ref: CALC.

3.b < 0.084% ΔK/K up to 10x source level and < 0.033% ΔK/K at higher levels. (NOW)
Ref: CALC.

4. Several methods will work, CAF for standard method.

5. a. control rod bank and worth

b. temp and void coeff.

c. reactor power

d. shutdown margin
REF: FTM

6. a. SRO

b. Reactor Supervisor (no vault)
Ref: FTM

7. (OP Fuel handling)
ALSO: CAF

L. ADMINISTRATIVE PROCEDURES, CONDITIONS, AND LIMITATIONS

.7

L.1 a) No violation - Reactor must be subcritical by more than 0.5% Δk/k with the most reactive control rod fully withdrawn

b) Violation - 2 Linear Power Channels are needed

c) Violation - unless the reactor supervisor has given him permission —

d) Violation - Water level must be less than ~~10 inch~~ 14 ft above Core Top Grid) —

e) Violation ~~unless replaced by~~ a ~~suitable portable instrument~~

Ref: Tech Specs

L.2 During maintenance checks and radiation surveys with the specific permission of the Operations Supervisor provided that no other scram channels are bypassed

Ref: Fac. OPR PROC. —(CAF)

L.3 Name any four

The occurrence of any facility condition that:

a) causes a Limiting Safety System Setting to exceed its established Tech. Spec. setting

b) Exceeds a Limiting condition for Operation established by Tech. Specs.

c) Causes any uncontrolled or unplanned release of radioactive material from the restricted area of the facility

d) Results in safety system component failures which could, or threaten to, render the system incapable of performing its intended safety function as defined in Tech. Specs or SAR

e) Results in abnormal degradation of one of the several boundaries which are designed to contain the radioactive materials resulting from the fission process

f) Results in uncontrolled or unanticipated changes in reactivity of greater than ~~0.5%~~ Δk/k 3.00

g) Causes conditions arising from natural or off-site manmade events that affect or threaten to affect safe operation of the facility

Ref: FTM + TECH SPECS

h) Results in observed inadequacies in the implementation of administrative or procedural controls such that the inadequacy causes or threatens to cause the existence or development of an unsafe condition in connection with the operation of the facility.

Ref: FTM

L.4 a) Control means apparatus and mechanisms the manipulation of which directly affect the reacitivity or power level of the reactor

ITH

b) Any individual may manipulate the controls of a facility as a part of his training to qualify for an operator license under the direction and in the presence of a licensed operator or senior operator, <u>or</u> as part of his training as a student in a nuclear engineering course under the direction and in the presence of a licensed operator or senior operator.

Ref: CAF

L.5 a) The reactor will be shut down and secured
b) The [redacted] Staff, Operations Supervisor and the Facility Director will be notified immediately
c) All outside doors and gates will be inspected and locked closed
d) The guard force of [redacted]. will be notified along with the [redacted] Police Dept. Their assistance will be requested immediately

Ref: FTM

Class Φ emergency
Possible class 1 see EM plan.