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

EXAMINATION REPORT NO. 50-05/84-02

FACILITY DOCKET NO. 50-5

FACILITY LICENSE NO. R-2

LICENSEE: The Pennsylvania State University
University Park, Pennsylvania 16802

FACILITY: The Pennsylvania State University

DATES: June 13, 1984

CHIEF EXAMINER: L. Whitaker — Date 9/26/84

APPROVED BY: Chief, Project Section 1D — Date 10/11/84

SUMMARY: One candidate was examined. He passed both the written and practical examination and was issued an SRO license.

REPORT DETAILS

TYPE OF EXAMS: Initial ___ Replacement _X_ Requalification ____

EXAM RESULTS:

	RO Pass/Fail	SRO Pass/Fail	Inst. Cert Pass/Fail	Fuel Handler Pass/Fail
Written Exam	/	1/0	/	/
Oral Exam	/	1/0	/	/
Simulator Exam	/	/	/	/
Overall	/	/	/	/

1. CHIEF EXAMINER AT SITE: L. Whitaker
2. OTHER EXAMINERS: None
3. PERSONS EXAMINED D. Hughes, 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.

   None

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

   None

7. Personnel Present at Exit Meeting:

   NRC Personnel

   L.Whitaker

   NRC Contractor Personnel

   None

   Facility Personnel

   S. Levine

8. Summary of NRC Comments made at exit interview:

   The examiner stated that candidate clearly passed the practical test.

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

   None

10. CHANGES MADE TO WRITTEN EXAM

See attached exam and answer sheet

Changes were made resulting from comments based on procedures or systems at the facility.

Attachment:

Written Examination and Answer Key (SRO)

Jim Rennie
(2) Terry Flinchbaugh

U. S. NUCLEAR REGULATORY COMMISSION
SENIOR REACTOR OPERATOR EXAMINATION

FACILITY: Penn State

REACTOR TYPE: TRIGA

DATE ADMINISTERED: June 13, 1984

EXAMINER: L. W. Whitaker

CANDIDATE: ________________

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Staple question sheet on top of answer sheets. Points for each question are indicated in parentheses after the question. A score of 70% or greater in each category, and 70% overall is passing.

CATEGORY VALUE	% OF TOTAL	APPLICANT'S SCORE	% OF CATEGORY VALUE	CATEGORY
25	25			H. REACTOR THEORY
15	15			I. RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS
21	21			J. SPECIFIC OPERATING CHARACTERISTICS
22	22			K. FUEL HANDLING AND CORE PARAMETERS
17	17			L. ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS
100	100.0			TOTALS:

FINAL GRADE ________________ %

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

____
Candidate's Signature

H. <u>REACTOR THEORY</u> (25 pts)

H.1 Briefly describe and/or explain the following: (8 pts) (1 each)

a. poison
b. Shutdown Margin
c. critical
d. one dollar of reactivity
e. step insertion
f. excess reactivity
g. reactor period
h. prompt critical

H.2 How may the steady state power coefficient be determined. (4 pts)

H.3 To what administrative use is put the data acquired in H-2? (4 pts)

H.4. (a) List the three most effective negative power coefficients. (3 pts)

(b) Describe the mechanisms whereby these effect reactivity. (3 pts)

H.5 If the reactor is just critical, indicating 1 watt, and the source were removed, what would happen? (3 pts)

I. RADIOACTIVE MATERIAL HANDLING, DISPOSALS, AND HAZARDS. (15 pts)

I.1. Define each of the following: (5 pts) (1 each)

a. source material
b. byproduct material
c. special nuclear material
d. contamination
e. radioactive

I.2. An experimental sample reads 10 R/hr 2 hours after removal from the sample chamber, 2 hours later (four hours after removed) it reads 1 R/hr.

a. What would the sample have read at its most radioactive time? (2.5 pts)

b. Where will the sample read 100 mr/hr? (2.5 pts)

I.3. A sample is suspended 1 foot under the surface of a pool of water. A survey instrument at the surface reads the radiation from this sample:

a. If the meter reads 1 R, what would be the sample radioactivity on contact? (2.5 pts)

b. If the sample were shielded by a 2" lead shield, what would the meter read? (2.5 pts)

J. SPECIFIC OPERATION CHARACTERISTICS (21 pts)

J.1. Describe two make-up water systems at Penn State. (4 pts) (2 each)

J.2. Penn State has a large excess reactivity. List at least 3 reasons why this was designed. (3 pts)

J.3. Describe the sequence of events which would happen if the rods failed to scram after a pulse? A sketch should drawn. (4 pts) (2 each)

J.4. Explain how the neutron source can add positive, negative and zero reactivity at certain power levels. (3 pts)

J.5. List 5 conditions which are designed to initiate a ~~RWP~~ for one or all rods. (4 pts)

J.6. Describe the rod position indicator system. (3 pts)

K. FUEL HANDLING AND CORE PARAMETERS (22 pts)

K.1. Concerning 1/M PLOTS:

a. what circumstances dictate their use? (2 pts)
b. what information can be obtained from this plot? (2 pts)

K.2. What are the possible consequences of Power Operation with a damaged fuel element? (3 pts)

K.3. Explain the difference between integral and differential rod worth. Draw typical curves for each and label them. Numerical values are not required.
(4 pts)

K.4. Explain how fuel elements are examined to ensure they are not damaged. (3 pts)

K.5. Explain how fuel burnup compensation is achieved in each fuel element. (3 pts)

K.6. What 4 conditions must be met before removing a control rod from the core? (3 pts)

K.7. How are the operational channels used to monitor the fuel loading procedure? (2 pts)

L. ADMININSTRATIVE PROCEDURE, CONDITIONS AND LIMITATIONS (17 pts)

L.1. Define or explain: as given in TSS (.25 each) (4 pts)

a. reactor shut down
b. routine experiment
c. special experiment
d. experiment
e. reactor operation
f. major modification
g. minor modification
h. malfunction
i. RUR
j. operable
k. reactor secured
l. RRFSC
m. mode of opertion
n. channel check
o. EAS
p. ECP

L.2. What is the Tech Spec requirement for reactor room minimum free volume? (2 pts)

L.3. What are the limitations for each of the following: (5 pts) (1 each)

a. Max SS power level
b. Mas step insertion of reactivity
c. Max excess reactivity
d. Max bulk water temperature
e. Max fuel temperature

L.4. What is the function of the Reactor and Radiation Facility Safety Committee? (2 pts)

L.5. What written instructions are required by Tech specs? List 3. (2 pts)

L.6. Who must either operate or direct operation of the CET? (2 pts)

ANSWERS

PENN STATE SRO EXAM

June 13, 1984
L. Whitaker, Examiner

H.1. Briefly define and/or explain the following: (8 pts) (1 each)

a. Poison (1)

A nuclide, other than fuel, having a large absorption cross section

b. Shutdown margin (1)

How far the reactor is below cold critical

c. Critical (1)

The condition at which the reactor is undergoing a self sustaining chain reaction. K=1.

d. One dollar of reactivity (1)

That amount of reactivity which will make the reactor prompt critical

e. Step insertion (1)

An almost instantaneous insertion of reactivity

f. Excess reactivity (1)

That amount of reactivity remaining in the core greater than what is needed to bring the reactor cold critical

g. Reactor period (1)

The amount of time it takes for the reactor power to change by a factor of "e"

h. Prompt critical (1)

The reactor is critical on prompt neutrons alone.

Ref: facility references

H.2. The procedure to determine a steady state power coefficient of reactivity is as follows: (4 pts)

1. Bring the reactor to a cold critical condition.

2. Bring reactor critical at desired higher power, measure and record the worth of control rod used to achieve this level or

2a. Using current control rod worth curves, insert a set amount of reactivity (bywithdrawing a rod to the appropriate position)

3. Plot these values on a curve of power vs. reactivity in dollars

Ref: facility references

H.3. The graph of Power vs. Reactivity is corrected using this (4 pts) data. It is very important because radiation calculations are based on this curve.

Ref: facility references

H.4. 1. Zirconium Hydride Heatup Disadvantage Factor (≈ 80%) (1)
As fuel heats up, neutrons are not longer able to transfer energy to the lattice (UZrH) to reach thermal energies. (Fast Leakage) (1)

2. Doppler Broadening (1)
As fuel heats up, Uranium atoms go into oscillation ≈20% which allows neutrons to appear in resonance energies for a longer period of time therefore increasing resonance capture and decreasing the number of neutrons which can become thermalized. (1)

3. Water density change (1)
As fuel heats up, water also heats up and density decreases which allows for less hydrogen atoms available for collisions to thermalize neutrons. (1)

Ref: facility references

H.5. If source is removed when critical at ~~1 W~~ 10 W, a slight positive period will result due to the source having a negative reactivity (about 5¢) worth at this power level (source absorbs more neutrons than producing) (3 pts)

I. RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS

I.1. Define or explain. (5 pts) (1 each)

a. Source material (1)

Uranium or thorium or any combination thereof in any physical or chemical form, or ores which contain by weight > C.05% of (a) uranium, (b) thorium, or (c) any combination of the above (does not include special nuclear material)

b. Byproduct materil (1)

Any radioactive material (except special nuclear material) yielded in or made radioactive by exposure to the radiation incident to the process of producing or using special nuclear material

c. Special nuclear material (1)

(1) plutonium, uranium 233, uranium enriched in the isotope 233 or in the isotope 235, and any other material which the Commission determines to be special nuclear material, (2) any material artifically enriched by any of the foregoing

d. Contamination (1)

Radioactive material that has been transferred or spread from a controlled area or source, and is removeable or potentially removable

e. Radioactive (1)

An unstable isotope which spontaneously decays through emission of radiation

Penn State

I.2.

$$\therefore A_o = \frac{A}{e^{-\lambda t}} = \frac{6.4}{e^{-1.11 \cdot .5}} = 1646\ R/HR$$

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

$$\ln \frac{A}{A_o} = \lambda$$

$$\frac{\ln \frac{1.6}{6.4}}{1.25}\ 1.11\ hr^{-1}$$

(2.5 pts)

b. At what time would the experiment have read 100 mR/hr?

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

$$\frac{\ln \frac{A}{A_o}}{\lambda} = t = \frac{\ln \frac{100}{1600}}{1.11} = 2.5\ hrs$$

I.3.

$\therefore$ 100 mr/hr @ 2045

a. $I_o e^{-ux}$

assume: $u\ H_2O = .07\ cm^{-1}$

$= 2.13\ ft^{-1}$

$$I_o = \frac{I}{e^{-ux}}$$

$$I_o = \frac{R/h}{e^{-(2.13)\times 2}} = 70.8\ R/hr$$

(2.5 pts)

b.

$$I = I_o e^{-ux}$$

$$= 70.8\, e^{-.91(5.08)}$$

$$= .696\ R/HR$$

(2.5 pts)

$= 696$ mr/hr

$I_o = 70.8$

$u/\rho = .08$ 2" = 5.08 cm

$u = (u/\rho)\rho = (.08)(11.34)$

$u = .91\ cm^{-1}$

9600 Gal Tank at Eng BLDG

J.1.a. ~~Still-a distillation system with an 80 gallon storage added~~ to pool by tank) (4 pts) (2 each)

Demin System of City Water

b. ~~Millipore - a filter system. Four filters to purify water~~.

c. Beam Hole - City Water

~~Both systems are gravity fed into the reactor tank~~

d. Heat Exchanger - Sec. Cool water

J.2. To compensate for negative worth experiments (3 pts)
To overcome heatup
To compensate for core burnup
For pulsing capabilites

J.3. The pulse would terminate and convert to a steady state condition the power of which would be determined by the amount inserted to cause the pulse. For example a ~~$2.90~~ $3.50 pulse would convert to 1 MW steady state run after a few seconds.

(4 pts-2 for words)
(2 for sketch)

J.4. Source is positive reactivity at low power levels (~< 500 mW) (1)
it is adding 3 z 10^6 neutrons cm^2.s which is more than is being absorbed

At approximately 500 mW the source is absorbing the same ϕ it is supplying therefore the source is worth zero. (1)

At > 500 mW the core flux is greater and the source is absorbing more neutrons than it adds therefore it has a negative reactivity worth (1)

J.5. (4 pts)
- HV loss on source or fission chamber
- fast period 3 sec
- ~~pool water temp 50°C~~ alarm @ 110°F
- source level (~~RWP~~ unless operational channel sees source level neutrons) Rod lockout < 1KW (no SCRAM)
- 1KW interlock - no air to trans rod
- operational calibrate - if operational channel is in any mode except operate

J. (cont.)

J.6. By the digital indicators on the console which read in ~~% of~~ units rod withdrawn. The signal comes from a pot which is connected to the motor and rack & pinion drive. As the pot turns it changes the voltage applied to the console digital readouts. The voltage span are calibrated to be a percentage of the rod travel.

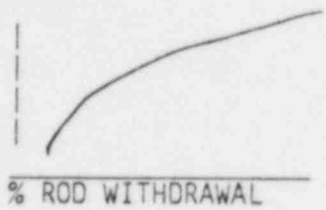
(3 pts)

K.1. a. A graph plotting the inverse multiplication factor vs. the number of elements placed in core or the units of reactivity inserted. (2)

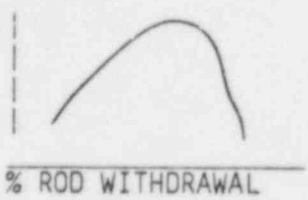
b. It predicts the critical loading as k approaches unity. (2)

K.2. Highly radioactive fission product released into the water and air (gaseous fission products) (3)

K.3. Integral rod worth curve: cumulative worth for each "pull" (4)



Differential rod worth curve: each "pull" value is plotted individually.



K.4. Fuel element removed from core following guidelines NRC licensed SRO, other person must be present. (3)

Element is placed in measuring tool for elongation and lateral bending.

Element is inspected for visible flaws or damage, serial number is checked, and element is returned to core.

K.5. The samarium wafer is a burnable poison and each element has two wafers (one on each end of the fuel slug) as the fuel burns up so does the poison thereby equalizing the element worth. (3)

no burnable poison — so rods must be raised incrementally higher as fuel burns out.

K.6. 1. Reactor will be in a shutdown condition (3)
2. Minimum of three individuals will be presnet, 2 of 3 are NRC licensed.
3. One licensed operator will observe the core nuclear instrumentation.
4. The minimum shutdown margin provided by the remaining contro' rods w/the most reactive control rod fully removed shall be ~~$1.00~~ $ .57 (0.4% k/k).

K.7. The neutron startup source is placed next to the detector (2) to insure entire channel operation, before the refueling operation starts.

L.1. Define or explain (4 pts) (.25 each)

a. Reactor shutdown (.25)

The reactor is at least $1.00 subcritical

b. Routine experiment (.25)

Experiments safely performed at least once and issued routine authorization by the Reactor and Radiation Facility Safety Committee

c. Special experiment (.25)

A new experiment or experiments not included in a Routine Reactor Authorization. Shall be performed under direct supervision of the PIC of the reactor or his designee

d. Experiment (.25)

Any apparatus, device, or material placed in the reactor core region, in an exposure facility, or in line with a beam of radiation originating from the reactor core. Also, any operation designed to measure reactor parameters or characteristics

e. Reactor operation (.25)

Any condition wherein the reactor is not secured

f. Major modification (.25)

Any physical change in either the components or the design of the reactor system or its associated equipment that will require an amendment to the existing Technical Specifications of the Reactor License (R-84) and therefore approval by the U.S. Nuclear Regulatory Commission (USNRC).

g. Minor modification (.25)

Any physical change other then direct replacement or equivalent substitution, in either the components or the design of the reactor system or its associated equipment that will not require an amendment to the existing Technical Specifications of the Reactor License (R-84). Require notification and concurrence of the RRFSC and are authorized by the PIC. Documented in a Minor Modification Log and reported to the USNRC per 10 CFR 50.59 and in the annual report.

L. (cont.)

h. Malfunction (.25)

The failure of a component of a reactor system that will prevent the system from either operating in its normal manner or from its intended function.

i. RUR (.25)

Reactor Use Request

j. Opearable (.25)

A system or device shall be considered operable when it is capable of performing its intended functions in a normal manner

k. Reactor secured (.25)

When all of the following conditions are met:

1. Reactor is shutdown
2. Console key is removed and no power is supplied to the magnets
3. No conditions exists whereby the shutdown margin of reactivity could be reduced to less than ~~$1.00~~ 2%Δk/k (#2,36)
4. No maintenance or work is in progress that involves movement of fuel elements in the core or movement of any control rod

l. RRFSC (.25)

Reactor and Radiation Facility Safety Committee

m. Mode of operation (.25)

There are two modes:

1. Steady state opeation: either in manual or automatic operatin of the control rods at power levels up to MW. (Also square wave)

2. Pulse: The reactor is intentionally placed on power excursion by making a step insertion of reactivity above critical with the transient rod.

n. Channel check (.25)

(Same Check)

A qualitative vertification of acceptable performance by observation of channel behavior

L. (cont.)

o. EAS (.25)

Emergency Action Station

p. ECP (.25)

Emergency Command Post

Ref: Tech Specs

L.2. What is the tech spec requirement for reactor room minimum free volume? (2)

~~22,000Ft³~~ 90,000 ft³

Ref: Tech Specs

L.3. a. 1MW (110% Power) (1)

b. What is the maximum step insertion of reactivity?

~~$3.28 = 2.3% k/k~~ 2.38 Δk/k ($3.40)

c What is the maximum excess reactivity (1)

~~$5.00 = 3.5% k/k~~ 4.9% Δk/k $7.00

d. What is the maximum bulk water temperature? (1)

~~60°C TX 50° C RSD~~ 110 °F

e. What is the maximum fuel temperature? (1)

~~500°C RSD 600°C TS~~ 800 °C

~~Ref: AFRRI~~ Oper~~ations~~ Manual

L.4. To review all radiological health and safety matters concerning the reactor and its associated equipment, the reactor room, the reactor console, the exposure rooms, the pneumatic transfer system, the roped off prep area, the fuel element shipping casks, the reactor fuel and its storage area (in addition to other AFRRI major radiation sources) (2)

Will review and authorize all proposed changes to [redacted]'s Reactor Facility License.

L.5. 1. Surveillance and calibration of reactor instrumentation (2)
2. Surveillance of the area radiation monitors
3. Reactor startup and reactor shutdown
4. Emergency and abnormal conditions, including evacuation, re-entry, and recovery
5. Utilization of exposure rooms including the opening and closing of exposure room plug doors
6. Loading and unloading fuel
7. Operation of the pneumatic tubes
8. Removal of control rods
9. Any operation deemed necessary by the Staff Scientist, Research Program, Coordinating Office, the Reactor PIC and the RRFSC

Surveillance of Rod Drives

(CHOOSE ANY THREE)

(AP 5)

L.6. A licensed operator of the reactor branch will operate or directly supervise the opertion of the CET (2)