March 13, 2015

Dr. Hyoung K. Lee, Reactor Facility Director
Missouri University of Science
and Technology
Nuclear Engineering
222 Fulton Hall
Rolla, MO 65409-0170

SUBJECT: EXAMINATION REPORT NO. 50-123/OL-15-02, MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Dear Dr. Lee:

During the week of February 2, 2015, the NRC administered an operator licensing examination at your Missouri University of Science and Technology Reactor. The examination was conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2.

In accordance with Title 10 of the Code of Federal Regulations Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Mr. Phillip T. Young at 301-415-4094 or via e-mail Phillip.Young@nrc.gov.

Sincerely,

/RA/

Kevin Hsueh, Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-123

Enclosures:
1. Initial Examination Report No. 50-123/OL-15-02
2. Written Examination

cc w/o encl: see next page

Dr. Hyoung K. Lee, Reactor Facility Director
Missouri University of Science
and Technology
Nuclear Engineering
222 Fulton Hall
Rolla, MO 65409-0170

March 13, 2015

SUBJECT: EXAMINATION REPORT NO. 50-123/OL-15-02, MISSOURI UNIVERSITY OF SCIENCE AND TECHNOLOGY

Dear Dr. Lee:

During the week of February 2, 2015, the NRC administered an operator licensing examination at your Missouri University of Science and Technology Reactor. The examination was conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2.

In accordance with Title 10 of the Code of Federal Regulations Section 2.390, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC's Agencywide Documents Access and Management System (ADAMS). ADAMS is accessible from the NRC Web site at http://www.nrc.gov/reading-rm/adams.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Mr. Phillip T. Young at 301-415-4094 or via e-mail Phillip.Young@nrc.gov.

Sincerely,

/RA/
Kevin Hsueh, Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-123

Enclosures:
1. Initial Examination Report No. 50-123/OL-15-02
2. Written Examination

cc w/o encl: see next page

DISTRIBUTION:
PUBLIC Facility File

ADAMS Accession No.: ML15042A113 **NRR-074**

OFFICE	NRR/DPR/PROB	NRR/DPR/PROB	NRR/DPR/PROB
NAME	PYoung/pty	CRevelle	KHsueh
DATE	02/10/2015	02/27/2015	03/13/2015

OFFICIAL RECORD COPY

University of Missouri - Rolla Docket No. 50-123 cc:

Homeland Security Coordinator
Missouri Office of Homeland Security
P.O. Box 749
Jefferson City, MO 65102

Craig Reisner
University of Missoure-Rolla
Nuclear Reactor Facility
1870 Miner Circle
Rolla, MO 65409-0630

Planner, Dept of Health and Senior Services
Section for Environmental Public Health
930 Wildwood Drive, P.O. Box 570
Jefferson City, MO 65102-0570

Deputy Director for Policy
Department of Natural Resources
1101 Riverside Drive
Fourth Floor East
Jefferson City, MO 65101

A-95 Coordinator
Division of Planning
Office of Administration
P.O. Box 809
State Capitol Building
Jefferson City, MO 65101

Test, Research, and Training
Reactor Newsletter
University of Florida
202 Nuclear Sciences Center
Gainesville, FL 32611

Dr. Samuel Frimpong, Chair
Mining and Nuclear Engineering
226 McNutt Hall
Missouri University of Science and Technology
Rolla, MO 65409-0450

<u>U. S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION
REPORT</u>

REPORT NO.: 50-123/OL-15-02

FACILITY DOCKET NO.: 50-123

FACILITY LICENSE NO.: R-79

FACILITY: Missouri University of Science and Technology

EXAMINATION DATES: February 2, 2015

SUBMITTED BY: ______________________________ ____________________
Phillip T. Young, Chief Examiner Date

SUMMARY:

During the week of February 2, 2015 the NRC administered operator licensing examinations to two retake Reactor Operator applicants . Both retake applicants passed the examinations.

<u>REPORT DETAILS</u>

1. Examiners:

Phillip T. Young, Chief Examiner, NRC
Paulette Torres, Examiner Trainee, NRC

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	2/0	0/0	2/0
Operating Tests	w	0/0	0/0
Overall	2/0	0/0	2/0

3. Exit Meeting:

This was a retake examination, no exit was conducted.

ENCLOSURE 1

U. S. NUCLEAR REGULATORY COMMISSION
NON-POWER INITIAL REACTOR LICENSE EXAMINATION

FACILITY: Missouri University of Science and Technology (Rolla)

REACTOR TYPE: MTR

DATE ADMINISTERED: 2/02/2015

CANDIDATE: ______________________________

INSTRUCTIONS TO CANDIDATE:

Answers are to be written on the answer sheet provided. Attach the answer sheets to the examination. Points for each question are indicated in brackets for each question. A 70% in each section is required to pass the examination. Examinations will be picked up three (3) hours after the examination starts.

Category Value	% of Total	% of Candidates Score	Category Value	Category
18.0	33.3	______	____	A. Reactor Theory, Thermodynamics and Facility Operating Characteristics
18.0		______	____% FINAL GRADE	TOTALS

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

____
Candidate's Signature

ENCLOSURE 2

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. After the examination has been completed, you must sign the statement on the cover sheet indicating that the work is your own and you have neither received nor given assistance in completing the examination. This must be done after you complete the examination.

3. 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.

4. Use black ink or dark pencil <u>only</u> to facilitate legible reproductions.

5. Print your name in the blank provided in the upper right-hand corner of the examination cover sheet and each answer sheet.

6. Mark your answers on the answer sheet provided. USE ONLY THE PAPER PROVIDED AND DO NOT WRITE ON THE BACK SIDE OF THE PAGE.

7. The point value for each question is indicated in [brackets] after the question.

8. If the intent of a question is unclear, ask questions of the examiner only.

9. When turning in your examination, assemble the completed examination with examination questions, examination aids and answer sheets. In addition turn in all scrap paper.

10. Ensure all information you wish to have evaluated as part of your answer is on your answer sheet. Scrap paper will be disposed of immediately following the examination.

11. To pass the examination you must achieve a grade of 70 percent or greater in each category.

12. There is a time limit of three (3) hours for completion of the examination.

13. When you have completed and turned in you examination, leave the examination area. If you are observed in this area while the examination is still in progress, your license may be denied or revoked.

EQUATION SHEET's

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

$$\lambda_{eff} = 0.1 \, seconds^{-1}$$

$$SUR = 26.06 \left[\frac{\lambda_{eff} \rho}{\beta - \rho} \right]$$

$$SCR = \frac{S}{-\rho} \approx \frac{S}{1 - K_{eff}}$$

$$CR_1 (1 - K_{eff_1}) = CR_2 (1 - K_{eff_2})$$

$$CR_1 (-\rho_1) = CR_2 (-\rho_2)$$

$$M = \frac{1 - K_{eff_0}}{1 - K_{eff_1}}$$

$$M = \frac{1}{1 - K_{eff}} = \frac{CR_1}{CR_2}$$

$$P = P_0 \, 10^{SUR(t)}$$

$$P = P_0 \, e^{\frac{t}{T}}$$

$$P = \frac{\beta (1 - \rho)}{\beta - \rho} P_0$$

$$SDM = \frac{(1 - K_{eff})}{K_{eff}}$$

$$T = \frac{\ell^*}{\rho - \overline{\beta}}$$

$$T = \frac{\ell^*}{\rho} + \left[\frac{\overline{\beta} - \rho}{\lambda_{eff} \rho} \right]$$

$$\Delta \rho = \frac{K_{eff_2} - K_{eff_1}}{k_{eff_1} \, x \, K_{eff_2}}$$

$$T_{‰} = \frac{0.693}{\lambda}$$

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

$$DR = DR_0 \, e^{-\lambda t}$$

$$DR = \frac{6CiE(n)}{R^2}$$

$$DR_1 d_1^2 = DR_2 d_2^2$$

DR – Rem, Ci – curies, E – Mev, R – feet

$$\frac{(\rho_2 - \beta)^2}{Peak_2} = \frac{(\rho_1 - \beta)^2}{Peak_1}$$

1 Curie = 3.7×10^{10} dis/sec
1 kg = 2.21 lbm
1 Horsepower = 2.54×10^3 BTU/hr
1 Mw = 3.41×10^6 BTU/hr
1 BTU = 778 ft-lbf
°F = 9/5 °C + 32
1 gal (H_2O) ≈ 8 lbm
°C = 5/9 (°F - 32)
c_P = 1.0 BTU/hr/lbm/°F
c_p = 1 cal/sec/gm/°C

Section A   Reactor Theory, Thermo, and Facility Characteristics

Question A.001 [1.0 point] (1.0)
After a week of full power operation, Xenon will reach its peak following a shutdown in approximately:

a. 6 hours
b. 12 hours
c. 24 hours
d. 48 hours

Answer: A.01 b.
Reference: Burn, R., Introduction to Nuclear Reactor Operations, © 1988, §

Question A.002 [1.0 point] (2.0)
Which ONE of the following is the MAIN reason for operating with thermal neutrons instead of fast neutrons?

a. Increased neutron efficiency since thermal neutrons are less likely to leak out of the core than fast neutrons.
b. Neutron absorption in non fuel material increases exponentially as neutron energy increases.
c. The fission cross section of the fuel is much higher for thermal energy neutrons than fast neutrons.
d. Moderator temperature coefficient becomes positive as neutron energy increases.

Answer: A.02 c.
Reference: Burn, R., *Introduction of Nuclear Reactor Operations*, © 1982, Figure 2.6, page 2-39

Question A.003 [1.0 point] (3.0)
A thermal neutron is a neutron which:

a. is produced as a result of thermal fission.
b. possesses thermal rather than kinetic energy.
c. has been produced several seconds after its initiating fission occurred.
d. experiences no net change in its energy after several collisions with atoms of the diffusing medium.

Answer: A.03 d.
Reference: Burn, Introduction to Nuclear Reactor Operations, Pages 2-36, 2-45.

Question A.004 [1.0 point] (4.0)
Which ONE of the following factors in the six-factor formula is the simplest to vary by the operator?

a. reproduction factor.

b. thermal utilization factor.

c. thermal non-leakage factor.

d. resonance escape probability.

Answer: A.04 b.
Reference: Burn, Introduction to Nuclear Reactor Operations, Page 3-19.

Question A.005 [1.0 point] (5.0)
About two minutes following a reactor scram, period has stabilized, and is decreasing at a CONSTANT rate. If reactor power is 10^{-5}% full power what will the power be in three minutes.

a. 5×10^{-6} % full power

b. 2×10^{-6} % full power

c. 10^{-6} % full power

d. 5×10^{-7} % full power

Answer: A.05 c.
Reference: $P = P_0 e^{-T/\tau} = 10^{-5} \times e^{(-180sec/80sec)} = 10^{-5} \times e^{-2.25} = 0.1054 \times 10^{-5}$
$= 1.054 \times 10^{-6}$

Question A.006 [1.0 point] (6.0)
An experiment to be placed in the central thimble has been wrapped in cadmium. Which one of the following types of radiation will be most effectively blocked by the cadmium wrapping?

a. Thermal neutrons

b. Fast neutrons

c. Gamma rays

d. X-rays

Answer: A.06 a.
Reference: NRC Standard Question.

Question A.007 [1.0 point] (7.0)
Which ONE of the following is the MOST affected factor in the six factor formula due to fuel burnup?

a. Fast fission factor.
b. Reproduction factor.
c. Thermal utilization factor.
d. Resonance escape probability.

Answer: A.07 c.
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.2.2, page 3-18.

Question A.008 [1.0 point] (8.0)
The injection of a sample results in a 50 millisecond period. If the scram setpoint is ***300 KILOWATTS*** and the scram delay time is 0.1 seconds, which ONE of the following is the peak power of the reactor at shutdown?

a. 250 kW
b. 600 kW
c. 900 kW
d. 2200 kW

Answer: A.08 d.
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982,
$P = P_0\ e^{t/\tau}$, $P = 300$ kilowatts $\times\ e^{0.1/0.05} = 300 \times e^2 = 2216.7$ kilowatts

Question A.009 [1.0 point] (9.0)
In a just critical reactor, adding one dollar worth of reactivity will cause:

a. A sudden drop in neutron flux.
b. The reactor period to be equal to $(\beta-\rho)/\lambda\rho$.
c. All prompt neutron term to become unimportant.
d. The resultant period to be a function of the prompt neutron lifetime.

Answer: A.09 d.
Reference: Introduction to Nuclear Operation, Reed Burn, 1988, Sec 4.2, page 4-4

Section A Reactor Theory, Thermo, and Facility Characteristics

Question A.010 [1.0 point] (10.0)
The RESONANCE ESCAPE PROBABILITY is defined as a ratio of:

a. the number of thermal neutrons absorbed in fuel over the number of thermal neutrons absorbed in fuel and core materials.

b. the number of fast neutrons produced by fission in a generation over the number of total neutrons produced by fission in the previous generation.

c. the number of fast neutrons produced by U-238 over the number of thermal neutrons absorbed in fuel.

d. the number of neutrons that reach thermal energy over the number of fast neutrons that start to slow down.

Answer: A.10 d.
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.1, page 3-16.

Question A.011 [1.0 point] (11.0)
Which ONE of the following statements is the definition of REACTIVITY?

a. A measure of the core's fuel depletion.

b. Equal to 1.00 ΔK/K when the reactor is critical.

c. The factional change in neutron population between generations.

d. The number of neutrons produced by fission in a generation over the number of neutrons produced by fission in the previous generation.

Answer: A.11 c.
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.3, page 3-20.

Question A.012 [1.0 point] (12.0)
A reactor has an effective delayed fraction (β_{eff}) of 0.0065. If a control rod withdrawal in this reactor increases the effective multiplication (k_{eff}) from 0.998 to 1.005, the reactor is:

a. subcritical.

b. exactly critical.

c. supercritical.

d. prompt critical.

Answer: A.12 c.
Reference: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Section 4.2, Page 4-1. **Note**: For prompt critical, k_{eff} has to be ≥ 1.0065

Question A.013 [1.0 point] (13.0)
A reactor is SHUTDOWN by 8.6 % Δk/k. When a control rod with a worth of -3.1 % Δk/k is removed from the core, a rate of 1000 counts per second (cps) is measured. What was the previous count rate (cps)? Given βeff = 0.0078.

a. 660.

b. 750.

c. 850.

d. 1170.

Answer: A.13 a.
Reference: ρ_1=-0.086; K_{eff1}=1/1- ρ_1
K_{eff1} =1/(1-(-.086)) —>K_{eff1}= 0.9208,
Remove –3.1 % Δk/k from the core, means adding 3.1 % Δk/k to the core when removing the rod; new worth = -0.086 + 0.031= -0.055, K_{eff2} = 1/1+0.055; —>0.948
$Count_1$*(1-K_{eff1}) = $Count_2$*(1-K_{eff2}) $Count_1$*(1-0.9208) = $Count_2$*(1-0.948)
$Count_1$*(1-0.9208) = 1000(1-0.948); Count $_1$ = 657 cps

Question A.014 [1.0 point] (14.0)
Given the following:

ρ_{excess} = 0.60% Δk/k,

control rod 1 = 0.30% Δk/k

control rod 2 = 0.45% Δk/k,

control rod 3 = 0.50% Δk/k

Calculate the ***TECHNICAL SPECIFICATION LIMIT*** for Shutdown Margin for this core.

a. 0.15% Δ k/k

b. 0.65% Δ k/k

c. 1.25% Δ k/k

d. 1.75% Δk/k

Answer: A.14 a.
Reference: Total rod worth – (excess + most active control rod)
(0.30+0.45+0.5) %Δk/k –(0.6+0.5) %Δk/k =(1.25 -1.1) %Δk/k = 0.15 %Δk/k

Question A.015 [1.0 point] (15.0)
Which ONE of the following conditions will INCREASE the shutdown margin of a reactor?

a. Lowering moderator temperature (Assume negative temperature coefficient).

b. Insertion of a positive reactivity worth experiment.

c. Burnout of a burnable poison.

d. Fuel depletion.

Answer: A.15 d.
Reference: Standard NRC question

Question A.016 [1.0 point] (16.0)
Which ONE of the following is the MAJOR source of energy released during SHUTDOWN?

a. Energy of prompt gamma rays.

b. Energy of the decayed fission fragments.

c. Kinetic energy of the fission neutrons.

d. Kinetic energy of the fission fragments.

Answer: A.16 b.
Reference: Introduction to Nuclear Operation, Reed Burn, 1988, Sec 3.2, page 3-5

Question A.017 [1.0 point] (17.0)
Which of the following statements is true about Xenon following a reactor scram?

a. The concentration of ^{135}Xe will decrease due to reduced nuclear flux

b. The concentration of ^{135}Xe will decrease by natural decay into ^{135}I

c. The concentration of ^{135}Xe will increase due to the decay of the ^{135}I inventory.

d. The concentration of ^{135}Xe will remain constant until it is removed via neutron burnout during the subsequent reactor startup.

Answer: A.17 c.
Reference: Following a reactor shutdown, xenon-135 concentration will increase due to the decay of the iodine inventory of the core. DOE Handbook, Vol. 2, Section 4

Question A.018 [1.0 point] (18.0)
Given the following Core Reactivity Data:

Control Rod	Total Worth (%dk/k)	Worth Removed (%dk/k)
Safety Rod 1	2.70	1.68
Safety Rod 2	3.20	2.60
Safety Rod 3	2.60	1.52
Regulating Rod	0.40	0.40

Which one of the following is the calculated shutdown margin that would satisfy the Technical Specification Minimum Shutdown Margin? **Assume that all control rods are scramable.**

a. 2.70
b. 3.00
c. 5.70
d. 6.20

Answer: A.18 b.
Reference: SDM = Ʒ(B) - Max. (A) = 6.20%dk/k – 3.20%dk/k = 3.00 %dk/k