October 23, 2003

Mr. Ralph A. Butler, Chief Operating Officer
Research Reactor Facility
University of Missouri
Columbia, MO 65211

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-186/OL-03-02, UNIVERSITY OF MISSOURI – COLUMBIA

Dear Mr. Butler:

During the week of September 21, 2003, the NRC administered an operator licensing examination at your University of Missouri – Columbia Reactor. The examination was conducted according to NUREG-1478, "Non-Power Reactor Operator Licensing Examiner Standards," Revision 1. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with 10 CFR 2.790 of the Commission's regulations, 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 document system (ADAMS). ADAMS is accessible from the NRC Web site at (the Public Electronic Reading Room) http://www.nrc.gov/NRC/ADAMS/indesx.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 Paul Doyle at (301) 415-1058 or via internet E-mail at pvd@nrc.gov.

Sincerely,

/RA/

Patrick M. Madden, Section Chief
Research and Test Reactors Section
New, Research and Test Reactors Program
Division of Regulatory Improvement Programs
Office of Nuclear Reactor Regulation

Docket No. 50-186

Enclosures: 1. Initial Examination Report No. 50-186/OL-03-02
2. Examination and answer key (Comments incorporated)

cc w/encls:
Please see next page

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PUBLIC	RNRP\R&TR r/f	PMadden
AAdams	Facility File (EBarnhill) O-6 D-17	

ADAMS ACCESSION #: ML032760670 **TEMPLATE #:NRR-074**

OFFICE	RNRP:CE		IROB:LA	E	RNRP:SC	
NAME	PDoyle:rdr		EBarnhill		PMadden	
DATE	10/ 03 /2003		10/ 08 /2003		10/ 14 /2003	

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U. S. NUCLEAR REGULATORY COMMISSION
OPERATOR LICENSING INITIAL EXAMINATION REPORT

REPORT NO.: 50-186/OL-03-02

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: University of Missouri – Columbia

EXAMINATION DATES: September 22-23, 2003

SUBMITTED BY: ***/RA/*** 9/29/2003
Paul V. Doyle Jr., Chief Examiner Date

SUMMARY:

The NRC administered Examinations to one Reactor Operator license candidate and three Senior Reactor Operator license candidates. All four license candidates passed their respective examinations.

REPORT DETAILS

1. Examiners:
   Paul Doyle, Chief Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	1/0	0/0	1/0
Operating Tests	1/0	3/0	4/0
Overall	1/0	3/0	4/0

3. Exit Meeting:
   Paul Doyle, NRC, Examiner
   Michael Dixon, University of Missouri, MURR Assistant Reactor Manager for Operations

   The NRC examiner thanked the reactor staff for their support in the administration of the examinations. The examiner noted that there were no generic weaknesses on the part of the candidates examined, and overall the candidates were well prepared.

ENCLOSURE 1

UNIVERSITY OF MISSOURI–COLUMBIA

With Answer Key

OPERATOR LICENSING EXAMINATION

September 23, 2003

Enclosure 2

QUESTION A.1 [1.0 point, ¼ each]

Match the neutron interaction in column A with the reaction from column B.

	Column A		Column B
a.	*Inelastic Scattering*	1.	*The neutron recoils with the same kinetic energy it had prior to the collision*
b.	*Elastic Scattering*	2.	*The neutron recoils with less kinetic energy than it had prior to the collision with the nucleus emitting a gamma ray.*
c.	*Absorption*	3.	*The neutron is absorbed, with the nucleus emitting a gamma ray.*
d.	*Fission*	4.	*The neutron is absorbed, with the nucleus splitting and higher energy neutrons*

QUESTION A.2 [1.0 point]

Which ONE of the reactions below is an example of the primary neutron source for reactor startup? $_4Be^9$ +

a. $\alpha \rightarrow {}_6C^{12} + n$

b. $\beta \rightarrow {}_4Be^8 + n$

c. $\gamma \rightarrow {}_4Be^8 + n$

d. *Cosmic radiation* $\rightarrow {}_4Be^8 + n$

QUESTION A.3 [1.0 point]

During a reactor startup, the count rate is increasing linearly on a logarithmic scale, with no rod motion. This means that:

a. *the reactor is subcritical and the count rate increase is due to the buildup of delayed neutron precursors.*

b. *the reactor is critical and the count rate increase is due to source neutrons.*

c. *the reactor is subcritical and the count rate increase is due to source neutrons.*

d. *the reactor is supercritical.*

QUESTION A.4 [1.0 point]

As the reactor continues to operate over a period of a week, to maintain a constant power level the average thermal neutron flux will …

a. *decrease due to the increase in fission product poisons.*

b. *decrease because fuel is being depleted.*

c. *increase in order to compensate for fuel depletion.*

d. *remain the same.*

QUESTION A.5 [1.0 point]

An Integral Rod Worth (IRW) curve is _____, while a Differential Rod Worth (DRW) curve is _____.

a. *the total reactivity worth added by the rod at any point of withdrawal;*
   the reactivity change per unit movement of the rod at the point of withdrawal.

b. *the slope of the DRW curve at any point of withdrawal;*
   the area under the IRW curve at any point of withdrawal.

c. *the reactivity change per unit movement of the rod at any point of withdrawal;*
   the total reactivity worth of the rod at any point of withdrawal.

d. *at its maximum value when the rod is approximately half-way out of the core;*
   at its maximum value when the rod is fully withdrawn from the core.

QUESTION A.6 [1.0 point]

The reactor is operating at a constant power level with equilibrium xenon. You double Reactor power. The equilibrium xenon level at the higher power level will be …

a. *the same as at the lower power level.*

b. *higher than its value at the lower power level, but not twice as high.*

c. *twice as high.*

d. *more than twice as high.*

QUESTION A.7 [1.0 point]

The difference between K_{eff} and K_{∞} is that K_{eff} is K_{∞} corrected for …

a. *resonance escape probability*

b. *total non-leakage (fast and thermal) probabilities*

c. *U^{238} fast fissions*

d. *U^{233} thermal fissions*

QUESTION A.8 [1.0 point]

The reactor is critical at a watt with the regulating blade at position X. You withdraw the reg rod to increase power to 500 watts. To stabilize power at this level you must insert the reg rod to …

a. *a position lower than X.*

b. *position X.*

c. *a position slightly higher than X.*

d. *all the way into the core.*

QUESTION A.9 [2.0 points, 0.4 3each]

Matching - Indicate for each item in Column A the item in Column B that is associated with it.

	Column A		*Column B*
a.	*Highest σ_f for fast neutrons*	*1.*	*U^{235}*
b.	*Highest σ_f for thermal neutrons*	*2.*	*U^{238}*
c.	*Highest σ_a for thermal neutrons*	*3.*	*B^{10}*
d.	*Lowest σ_a for thermal neutrons*	*4.*	*Water*
e.	*Highest σ_s for all neutrons*	*5.*	*Graphite*

QUESTION A.10 [1.0 point]

Which ONE of the following is the correct reason burnable poison is added to the core?

a. To minimize the effects of a rod withdrawal accident.

b. To increase the power achievable for a given core size.

c. To allow addition of additional fuel to compensate for burnup.

d. To decrease the effects of Xenon and Samarium on the core.

QUESTION A.11 [1.0 point] *($\ell^* = 1 \times 10^{-4}$; $\lambda_{eff} = 0.1$; $\beta_{eff} = 0.00738\ \Delta K/K$)*

You are the reactor operator controlling the reactor in manual. An experimenter is preparing to inject an experiment worth - 1%ΔK/K into the reactor. What type of reactor period do you expect to see?

a. ≈ 2 sec.

b. ≈ 10 sec.

c. ≈ 20 sec

d. ≈ 40 sec

QUESTION A.12 [1.0 point]

You enter the control room and note that all nuclear instrumentation show a steady neutron level, and no rods are in motion. Which ONE of the following conditions CANNOT be true?

a. The reactor is critical.

b. The reactor is subcritical.

c. The reactor is supercritical.

d. The neutron source has been removed from the core.

QUESTION A.13 [1.0 point]

Which ONE of the following statements concerning reactor poisons is NOT true?

a. *Following shutdown, Samarium concentration will increase to some value then stabilize.*

b. *Following shutdown, Xenon concentration will initially increase to some value then decrease exponentially*

c. *During reactor operation, Samarium concentration is independent of reactor power level.*

d. *During reactor operation, Xenon concentration is dependent on reactor power level.*

QUESTION A.14 [1.0 point]

The main source of heat in the reactor one hour after shutdown is due to …

a. *Decay of fission products*

b. *Fission due to delayed neutrons*

c. *Spontaneous fission within the core*

d. *Decay of radioactive structural materials*

QUESTION A.15 [1.0 point]

For U^{235}, the thermal fission cross-section is 582 barns, and the capture cross-section is 99 barns. When a thermal neutron is absorbed by U^{235}, the probability that a fission will occur is:

a. *0.146*

b. *0.170*

c. *0.830*

d. *0.855*

QUESTION A.16 [1.0 point]

"CORE EXCESS" is …

a. *extra reactivity into the core due to the presence of the source neutrons.*

b. *a measure of the resultant reactivity if all of the control rods and other poisons were removed.*

c. *the combined reactivity worth of control rods and chemical poison needed to keep the reactor shutdown.*

d. *the maximum reactivity insertion with the reactor shutdown with control rods fully inserted under peak Xenon conditions.*

QUESTION A.17 [1.0 point]

Thermal neutrons are …

a. neutrons possessing thermal rather than kinetic energy.

b. the primary source of thermal energy increase in the reactor coolant during reactor operation.

c. neutrons produced a significant time (on the order of seconds) after its initiating fission took place.

d. neutrons that experience no net change in energy after several collisions with atoms of the diffusing media.

QUESTION A.18 [1.0 point]

Which ONE of the following requires a control rod INSERTION to maintain reactor power constant following the change?

a. Samarium buildup

b. Primary Coolant Temperature Decreases

c. Xenon buildup

d. U^{235} concentration decrease (Fuel Burnup)

QUESTION A.19 [1.0 point]

A common method for calibrating control elements (rods, blades, etc.), is to measure doubling time then calculate period. If the doubling time is 42 seconds, which ONE of the following is the period?

a. 29 seconds

b. 42 seconds

c. 61 seconds

d. 84 seconds

QUESTION B.1 [1.0 point]

Who has responsibility for ensuring all personnel are cleared from all levels of the containment building, according to the immediate actions for a Reactor Isolation?

a. The Reactor Director

b. The Duty Health Physics person

c. The Shift Supervisor

d. The Duty Reactor Operator

QUESTION B.2 [1.0 point]

The Primary System Fuel Failure Monitor is secured due to an electrical problem. How often must the primary coolant be sampled to continue reactor operation?

a. every hour

b. every two hours

c. every four hours

d. every eight hours

QUESTION B.3 [1.0 point, ¼ each]

Match the Federal regulation in column A with the correct area covered in column B

	Column A		Column B
a.	*10 CFR 20*	*1.*	*Operator Licenses*
b.	*10 CFR 50*	*2.*	*Facility Licenses*
c.	*10 CFR 55*	*3.*	*Radiation Protection*
d.	*10 CFR 73*	*4.*	*Special Nuclear Material*

QUESTION B.4 [1.0 point]

The procedure for starting up the secondary system for 10 Mw operation requires a 5 to 10 minute delay in starting the second pump. Which ONE of the following is the correct reason for this delay?

a. To prevent an electrical overload on the system.

b. To prevent damage to the pump discharge check valves.

c. To prevent a low sump level trip.

d. To prevent water hammer damage to the heat exchangers.

QUESTION B.5 [1.0 point]

Which ONE of the following statements correctly describes the relationship between a Safety Limit (SL) and a Limiting Safety System Setting (LSSS)?

a. *The SL is a maximum operationally limiting value that prevents exceeding the LSSS during normal operations.*

b. *The SL is a parameter that assures the integrity of the fuel cladding. The LSSS initiates protective action to preclude reaching the SL.*

c. *The LSSS is a parameter that assures the integrity of the fuel cladding. The SL initiates protective action to preclude reaching the LSSS.*

d. *The SL is a maximum setpoint for instrumentation response. The LSSS is the minimum number of channels required to be operable.*

QUESTION B.6 [1.0 point]

The reactor has been shutdown for the last three hours to adjust the packing on one of the primary coolant pumps. No shutdown checksheet has been performed. Which of the following meets the MINIMUM requirements to restart the reactor?

a. *You may perform a hot startup with the SRO directing.*

b. *You may startup after performing a short form Startup Checksheet.*

c. *You may startup after ensuring the Primary system is on-line per the applicable SOP, then performing a short form Startup Checksheet.*

d. *You may startup after performing a Full Power Startup Checksheet.*

QUESTION B.7 [2.0 points, 0.5 each]

Match the Technical Specification Reactivity Limits in Column A with the correct value listed in Column B.

Column A	*Column B*
a. *Max Experiment Reactivity Worth (Absolute) (Center Test Hole).*	1. *0.098 ΔK*
b. *Max Moveable Experiment Reactivity Worth.*	2. *0.006 ΔK*
c. *Min Subcritical Margin with any one Shim blade fully withdrawn*	3. *0.025 ΔK*
d. *Maximum Core Excess*	4. *0.02 ΔK*
	5. *0.001 ΔK*

QUESTION B.8 [1.0 point]

Which ONE of the following surveillances is required (by Tech. Specs.) to be performed semi-annually?

a. *Containment Leak Test*

b. *Drop time for the Shim Blades*

c. *Operability Check for the Radiation Monitoring Instrumentation.*

d. *Operability Check of the Emergency Pool Fill System.*

QUESTION B.9 [2.0 points, ½ each]

Match type of radiation in column A with the proper penetrating power from column B.

	Column A		*Column B*
a.	*Gamma*	*1.*	*Stopped by thin sheet of paper*
b.	*Beta*	*2.*	*Stopped by thin sheet of metal*
c.	*Alpha*	*3.*	*Best shielded by light material*
d.	*Neutron*	*4.*	*Best shielded by dense material*

QUESTION B.10 [1.0 point]

The reactor is shutdown due to a loss of electrical power. In order to startup the reactor you must (per procedure) …

a. obtain LSRO permission only it the time of shutdown is less than two hours.

b. perform a short form startup checksheet if the time of shutdown is less than eight hours.

c. perform a long form startup checksheet.

d. obtain Reactor Manager permission only.

QUESTION B.11 [1.0 point]

Unless extended in writing, a Radiation Work Permits expire in:

a. 8 hours

b. 24 hours

c. 48 hours

d. one week

QUESTION B.12 [1.0 point]

If the reactor is not critical when the ECP limits are reached:

a. the ECP must be recalculated prior to any further rod withdrawal

b. the reactor must be shut down then the ECP recalculated.

c. the rods must be inserted to two inches below the ECP position and notify the LSRO.

d. after Reactor Manager approval you may continue with the reactor startup.

QUESTION B.13 [1.0 point]

The Emergency Planning Zone (EPZ) …

a. is the geographical area that is beyond the site boundary.

b. specifies contamination levels of airborne, radiological dose or dose rates that may be used as thresholds for establishing emergency classes.

c. is the geographical area that is beyond the site boundary where the Reactor Director has direct authority over all activities.

d. lies within the site boundary and is bounded by a 150 meter radius from the MURR exhaust stack.

QUESTION B.14 [1.0 point, ¼ each]

How often must data be recorded for each of the forms listed in column a per operating procedure AP-RO-110 Conduct of Operations?

a. Form FM-43, Nuclear Data	*1. 1 Hour*
b. Form FM-43, Process Data	*2. 2 Hours*
c. Form FM-55, Startup Nuclear Data	*3. 4 Hours*
d. Form FM-56, Reactor Routine Patrol	*4. Daily*

QUESTION B.15 [1.0 point]

Following an unscheduled shutdown, the operating staff has performed a thorough investigation but has not been able to determine the cause of the shutdown. All system are normal. The minimum level of management who may authorize the operating crew to restart the reactor is …

a. the Lead Senior Reactor Operator on shift.

b. the Assistant Reactor Manager-Physics

c. the Reactor Manager

d. the NRC

QUESTION B.16 [1.0 point, ¼ each]

*Identify whether Gang operation of the control blades is **ALLOWED** or is **NOT** allowed with the **reactor critical** for the listed evolutions.*

a. Reactor Shutdown

b. Normal Reactor Startup

c. Hot Reactor Startup

d. Power Recovery Startup

QUESTION B.17 [1.0 point]

*Which ONE of the following emergencies requires the console operator to scram the reactor by placing Master Control Switch (1S1) in the **TEST** position?*

a. REP-22, Emergency Core Cooling Valves 546A and 546B open during reactor operations.

b. REP-4, High Radiation Levels

c. REP-5, Nuclear Instrument Failure

d. REP-8, Control Rod Drive Mechanism Failure or Stuck Rod

QUESTION B.18 [1.0 point]

A "Knowledgeable Person" is defined as an operations trainee who has …

a. been designated by his/her shift LSRO.

b. successfully complete a 50% board.

c. successfully complete a 90% board.

d. been designated by the Reactor Manager.

QUESTION C.1 [1.0 point]

Where does waste water from the primary and pool sampling station discharge to?

a. Containment Hot Sump

b. Liquid Waste Tank

c. Labyrinth Sump

d. Drain Collection Tank

QUESTION C.2 [1.0 point]

How is deicing of the cooling tower fans accomplished?

a. Open the basin steam supply valve.

b. Secure the cooling tower fan while maintaining normal CT flow.

c. Run the cooling tower fan in reverse while maintaining normal CT flow.

d. Auxiliary operator using heat guns.

QUESTION C.3 [2.0 points, 0.4 each]

List the NORMAL (10 Mwatt operation) positions (Open, Shut) for the following valves:

a. 509 (Pool Loop Isolation)

b. 545 (Pressurizer Vent)

c. 527D (2" bypass drain)

d. 547 (Reflector Convective Loop Valve)

e. 527E/F (Reactor Loop Bypass Cleanup)

QUESTION C.4 [2.0 points, 0.5 each]

For the actions in Column A select the appropriate pressurizer system pressure listed in Column B. Pressures in Column B may be used once, more than once or not at all. Only one answer may occupy each space in column A.

COLUMN A		*COLUMN B*
ACTIONS		*SETPOINTS (psig)*
a. High pressurizer Pressure scram		*1. 112.5 ± 2.5*
b. Low pressurizer pressure alarm	*2.*	*78.0*
c. Low pressurizer pressure scram		*3. 65.0*
d. Nitrogen System Low Pressure Alarm		*4. 63.0*

QUESTION C.5 [1.0 point]

Which ONE of the following Area Radiation Monitoring System Detectors is capable of causing an automatic reactor isolation?

a. Air Plenum 2

b. Fuel Vault

c. Beamport Floor North Wall

d. Room 114

QUESTION C.6 [1.0 point]

During startup, you notice that Shim Blade #1 magnet engaged light goes out. Which ONE of the following actions are allowed by the Startup Interlock?

a. Drive in Shim Blade #1, then re-engage the magnet.

b. You must scram the reactor to reset the interlock, then re-engage all magnets.

c. You may re-energize the magnet as soon as you notice the light is extinguished.

d. You must take the Master Switch to "OFF" then back to "ON" to reset the interlock. Then re-engage all magnets.

QUESTION C.7 [1.0 point]

Which one of the following describes the operation of the containment building ventilation exhaust valves on a loss of electrical power?

a. Air is applied to the close side of the east valve (16A) causing the valve to close

b. Air is applied to the close side of the west valve (16B) causing the valve to close

c. Air is vented from the open side of the west valve (16B allowing spring pressure to close the valve

d. Air is vented from the open side of the east valve (16A) allowing air pressure on the close side to close the valve

QUESTION C.8 [1.0 point]

Which one of the following is the design feature used to seal the COOLING SYSTEM WATER LINES entering the reactor building?

a. The lines enter the side of the building through a 4.6 foot water leg

b. The lines enter beneath the pool and are sealed with a packing gland

c. The lines have a 6.4 foot loop seal which extends above the active fuel

d. The lines enter the side of the building and are sealed with an inflatable gasket

QUESTION C.9 [2.0 points, 0.5 each]

For each status of the Alarm and Annunciate System indicate which of the conditions listed would result in that status.

Status Descriptions	*Conditions*
a. Illumination On Dim	*(1) Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.*
b. Illumination Flashing	*(2) Alarm was received but the operator has not yet pressed the Acknowledge pushbutton. The alarm condition has not yet cleared.*
c. Illumination On Bright	*(3) Alarm was received and the operator pressed the Acknowlege pushbutton. The alarm condition subsequently cleared but the operator has not yet pressed the Reset button.*
d. Illumination Off	*(4) Alarm was received and the operator pressed the Acknowledge pushbutton. The alarm condition subsequently cleared and the operator pressed the Reset button.*

QUESTION C.10 [1.0 point]

When setting the reactor power calculator flow potentiometer you must make a correction for cleanup flow. Which ONE of the following is the correct adjustment and reason for this adjustment? Explain why the cleanup flow is subtracted from the indicated flow in reactor loops A and B when determining the pot setting for the reactor power calculator flow potentiometer.

*a. Subtract cleanup flow. Cleanup flow bypasses the core, but **IS** measured by the indicated flow.*

*b. Add cleanup flow. Cleanup flow also goes through the core, but **IS NOT** measured by the indicated flow.*

*c. Subtract cleanup flow. Cleanup flow also goes through the core, but **IS NOT** measured by the indicated flow.*

*d. Add cleanup flow. Cleanup flow bypasses the core, but **IS** measured by the indicated flow.*

QUESTION C.11 [1.0 point]

*Which ONE of the following reactor trips does **NOT** reset automatically?*

a. Period Scram Trip

b. Short Period Rod Run-In Trip

c. Period Automatic Control Interlock Trip

d. Period Scram Trip

QUESTION C.12 [1.0 point] ***Question Deleted (too many correct answers, should have been a "NOT" question.***

~~*What two design features of the pneumatic tube system serve to limit the radiation hazard from these tubes?*~~

~~*a. Speed at which the sample container is transported through the system.*~~

~~*b. Distance of the tubes from personnel working in the area.*~~

~~*c. When the blower switch is turned on, both blowers immediately start.*~~

~~*d. Suction of the facility exhaust fans provides a continuous flow through the system, preventing a large generation of radioactive Ar^{41} in the stagnant air in the reactor reflector irradiation position.*~~

QUESTION C.13 [1.0 point]

Which ONE of the following electrical load CANNOT be supplied by the Emergency Generator?

a. Air Locks

b. Exhaust Fan EF-13

c. Intercom System

d. Pool Pump P508A

QUESTION C.14 [1.0 point]

Which ONE of the following is the reason that the pool DI system water returns to the pool about 2 feet below the pool surface? In order to …

a. aid in the mixing of the water, which results in a more even temperature distribution.

b. create a blanket of warmer water at the top of the pool to reduce mixing, and therefore reduce the dose rate at the surface of the pool.

c. reduce pool surface temperature, since DI water is cooler than pool water.

d. reduce interference between the pool cooling system and the pool skimmer, which takes its suction at the pool surface

QUESTION C.15 [1.0 point]

Switches to initiate a facility evacuation are located …

a. the control room and the front lobby.

b. the control room and the electronics shop.

c. the reactor bridge and the front lobby.

d. the reactor bridge and the electronics shop.

QUESTION C.16 [1.0 point]

Procedure OP-RO-410 Primary Coolant System, contains a caution to immediately perform two steps to minimize the time the primary system is solid. The first step VERIFIES that Anti-Siphon Valves 543A and 543B close. Step 5.4.5 should open …

a. Pressurizer Water Addition Valve 527B

b. Pressurizer Water Drain Valve 527B

c. Primary Coolant Isolation Valves 507A/B.

d. Surge Line Isolation Valve 527C

QUESTION C.17 [1.0 point]

A high airborne activity accident in the containment has caused a reactor isolation. All personnel have evacuated containment. How can you determine whether there is still a high airborne activity?

a. Take an air sample using a connection on the containment air building leak rate system.

b. Take an air sample at the facility stack.

c. Remote readout of Stack Gas, Particulate and Iodine Monitors.

d. Remote readout of containment building exhaust #1 and #2 area radiation monitors.

A.1 a, 2; b, 1; c, 3; d, 4
REF:

A.2 c
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.3 d
REF: DOE Fundamentals Handbook, Module 4, Reactor Kinetics, page 14.

A.4 c
REF: DOE Fundamentals Handbook, Module 2, Reaction Rates, page 21.

A.5 a
REF: DOE Fundamentals Handbook, Module 3, Control Rods, page 51.

A.6 b
REF: DOE Fundamentals Handbook, Module 3, Xenon, page 37.

A.7 b
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx. See calculation on next page.

A.8 b
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx. See calculation on next page.

A.9 a. 2; b. 1; c. 3; d. 5; e. 4
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.10 c
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.11 c
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

$$\tau = \frac{\ell^*}{\rho} + \left[\frac{\bar{\beta}-\rho}{\lambda \rho}\right] \qquad \tau = \frac{1 \times 10^{-4}}{-1 \times 10^{-2}} + \left[\frac{0.00738 - -0.01}{0.1 * -0.01}\right]$$

$$\tau = -0.01 + \left[\frac{0.01738}{-0.001}\right] = -0.01 - 17.38 = -1.739\text{sec}$$

A.12 c
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.13 c
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.14 a
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.15 d *Probability = $\sigma_f/(\sigma_f + \sigma_a)$ = 582/(528 + 99) = 582/681 = 0.855*
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.16 b
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.17 d
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.18 b
REF: DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

A.19 c
REF: Standard NRC Question[1]. Also: period = (doubling time) ÷ (ln(2)) = 42/0.693 = 60.6 ≈ 61
DOE Fundamentals Handbook, Module X, ~~Reactor Kinetics~~, page xx.

B.1 d
Ref: FEP-2, page 2 of 4.

B.2 c
Ref: Technical Specifications, § 3.9, Coolant System, page 1 of 3.

B.3 a, 3; b, 2; c, 1; d, 4
Ref: Code of Federal Regulations Title 10.

B.4 c
Ref: EQB question 9045, also OP-RO-480, Secondary Coolant System

B.5 b
Ref: T.S. § A Definitions

B.6 d
Ref: SOP I.4.3.F.1 Startup Checksheet §§ a & b

B.7 a, 2; b, 5; c, 4; d, 1
Ref: T.S. § 3.1 Reactivity

B.8 d
Ref: T.S. §§ 5.1, 5.3, 5.4 & 5.6

B.9 a. 4 b. 2 c. 1 d. 3
Ref: Basic Nuclear Concepts, p. 7.4.2

B.10 c
Ref: FEP

B.11 b
Ref: AP-HP-105

B.12 c
Ref: OP-RO-210, Reactor Operations

B.13 d
Ref: E-Plan Definitions 9.8

B.14 a, 1; b, 2; c, 4; d, 3
Ref: AP-RO-110 Conduct of Operations

B.15 c
Ref: AP-RO-110 Conduct of Operations,

*B.16 a, **ALLOWED**; b, **NOT**; c, **ALLOWED**; d, **NOT***
Ref: AP-RO-110 Conduct of Operations, § 6.6.6 Control Blade Operation.

B.17 d
Ref: REO-RO-100, REP-4, REP-5, REP-8 and REP-22

B.17 d
Ref: AP-RO-110 Conduct of Operations, §

C.1 d
Ref: Training Manual for Reactor Operators, Page I-75

C.2 c
Ref: OP-RO-480, Secondary Coolant System, page 8

C.3 a. Open b. Shut c. Shut d. Open e. Open
Ref: MURR Training Manual pages I-59 through I-65.

C.4 a. 2 b. 3 c. 4 d. 1
Ref: AP-RO-110, Table 10.2

C.5 a
Ref: FEP-2 p. 1. Also Training Manual for ROs § II.9 Area Radiation Monitoring System.

C.6 a
Ref: HSR Chapter 9.0 Instrumentation and Control, § 9.5 Startup Interlocks

C.7 b
Ref: MURR Training Manual for Reactor Operators Section I.11 pp I

C.8 b
Ref: MURR Hazards Summary Report Section 1.4.5

C.9 a, 3; b, 2; c, 1; d, 4
Ref: Training Manual, p. II-68, Hazards Summary Report, p. 9-19

C.10 a
Ref: OP-RO-350 Reactor Power Calculator Flow Potentiometer Adjustment.

C.11 a or d
Ref: MURR Training Manual, p. II-30, II-31, II-32.

~~*C.12 e Question Deleted, too many correct answers (should have been a NOT question)*~~
~~*Ref: REF: Hazards Summary 8-25. Letter from the University of Missouri, Columbia, to the NRC Division of Reactor Licensing, dated 10/6/70. Letter from the University of Missouri, Columbia, to the NRC Directorate of Reactor Licensing, dated 4/18/75.*~~

C.13 d
Ref: Training Manual for Reactor Operators, § III.1 Electrical Power Distribution and § III.3 Emergency Electrical System

C.14 b
Ref: MURR HSR, § 7.1.10 p. 7-20.

C.15 a
Ref: Training Manual for Reactor Operators § II.10, p. II.10.1. Also 02/92 NRC examination.

C.16 d
Ref: OP-RO-410 Caution following step 5.4.2.

C.17 a
Ref: SV-HP-135

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

FACILITY: University of Missouri-Columbia

REACTOR TYPE: TANK

DATE ADMINISTERED: 2003/08/23

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
20.00	33.3	_____	____	A. Reactor Theory, Thermodynamics and Facility Operating Characteristics
20.00	33.3	_____	____	B. Normal and Emergency Operating Procedures and Radiological Controls
19.00	33.3	_____	____	C. Facility and Radiation Monitoring Systems
59.00		_____	____% FINAL GRADE	TOTALS

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

_____
Candidate's Signature

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

2. 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 only 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

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

$$P_{\max} = \frac{(\rho-\beta)^2}{2\alpha(k)\ell}$$

$$\ell^* = 1 \times 10^{-4}\ seconds$$

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

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

$$R_1(1-K_{eff_1}) = CR_2(1-K_{eff_2})$$
$$CR_1(-\rho_1) = CR_2(-\rho_2)$$

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

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

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

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

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

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

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

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

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

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

$$T_{1/2} = \frac{0.693}{\lambda}$$

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

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

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

$$DR_1 d_1^{\,2} = DR_2 d_2^{\,2}$$

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 x 10^{10} dis/sec

1 kg = 2.21 lbm

1 Horsepower = 2.54 x 10^3 BTU/hr

1 Mw = 3.41 x 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

A.1a 1 2 3 4 ___

A.1b 1 2 3 4 ___

A.1c 1 2 3 4 ___

A.1d 1 2 3 4 ___

A.2 a b c d ___

A.3 a b c d ___

A.4 a b c d ___

A.5 a b c d ___

A.6 a b c d ___

A.7 a b c d ___

A.8 a b c d ___

A.9a 1 2 3 4 5 ___

A.9b 1 2 3 4 5 ___

A.9c a b c d ___

A.9d a b c d ___

A.9e a b c d ___

A.10 a b c d ___

A.11 a b c d ___

A.12 a b c d ___

A.13 a b c d ___

A.14 a b c d ___

A.15 a b c d ___

A.16 a b c d ___

A.17 a b c d ___

A.18 a b c d ___

A.19 a b c d ___

B.1 a b c d ___

B.2 a b c d ___

B.3a 1 2 3 4 ___

B.3b 1 2 3 4 ___

B.3c 1 2 3 4 ___

B.3d 1 2 3 4 ___

B.4 a b c d ___

B.5 a b c d ___

B.6 a b c d ___

B.7a 1 2 3 4 5 ___

B.7b 1 2 3 4 5 ___

B.7c 1 2 3 4 5 ___

B.7d 1 2 3 4 5 ___

B.8 a b c d ___

B.9a 1 2 3 4 ___

B.9b 1 2 3 4 ___

B.9c 1 2 3 4 ___

B.9d 1 2 3 4 ___

B.10 a b c d ___

B.11 a b c d ___

B.12 a b c d ___

B.13 a b c d ___

B.14a 1 2 3 4 ___

B.14b 1 2 3 4 ___

B.14c 1 2 3 4 ___

B.14d 1 2 3 4 ___

B.15 a b c d ___

B.16a ALLOWED NOT ___

B.16b ALLOWED NOT ___

B.16c ALLOWED NOT ___

B.16d ALLOWED NOT ___

B.17 a b c d ___

B.18 a b c d ___

C.1 a b c d ___

C.2 a b c d ___

C.3a OPEN SHUT ___

C.3b OPEN SHUT ___

C.3c OPEN SHUT ___

C.3d OPEN SHUT ___

C.3e OPEN SHUT ___

C.4a 1 2 3 4 ___

C.4b 1 2 3 4 ___

C.4c 1 2 3 4 ___

C.4d 1 2 3 4 ___

C.5 a b c d ___

C.6 a b c d ___

C.7 a b c d ___

C.8 a b c d ___

C.9a 1 2 3 4 ___

C.9b 1 2 3 4 ___

C.9c 1 2 3 4 ___

C.9d 1 2 3 4 ___

C.10 a b c d ___

C.11 a b c d ___

C.12 a b c d ___

C.13 a b c d ___

C.14 a b c d ___

C.15 a b c d ___

C.16 a b c d ___

C.17 a b c d ___