March 3, 2010

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

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-186/OL-10-01, UNIVERSITY OF MISSOURI – COLUMBIA

Dear Mr. Butler:

During the week of February 1, 2010, the NRC administered operator licensing examinations at your University of Missouri – Columbia Reactor. The examinations were conducted according to NUREG-1478, "Operator Licensing Examiner Standards for Research and Test Reactors," Revision 2. 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 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. John T. Nguyen at (301) 415-4007 or via internet e-mail John.Nguyen@nrc.gov.

Sincerely,

/RA/
Johnny H. Eads, Jr., Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-186

Enclosures:
1. Initial Examination Report No. 50-186/OL-10-01
2. Written examination with facility comments incorporated

cc: John Fruits,
Assistant Reactor Manager of Operations
w/o enclosures: see next page

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<u>DISTRIBUTION</u> w/ encls.:

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ADAMS ACCESSION #: ML100480654 **TEMPLATE #:NRR-074**

OFFICE	PROB:CE		IOLB:LA	E	PROB:BC	
NAME	JNguyen:		CRevelle		JEads	
DATE	02/16/2010		03/2/2010		03/3/2010	

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

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

REPORT NO.: 50-186/OL-10-01

FACILITY DOCKET NO.: 50-186

FACILITY LICENSE NO.: R-103

FACILITY: University of Missouri-Columbia

EXAMINATION DATES: February 1 – February 2, 2010

SUBMITTED BY: ____________________________ __________
John T. Nguyen, Chief Examiner Date

SUMMARY:

During the week of February 1, 2010, the NRC administered operator licensing examinations to two Reactor Operator candidates. All applicants passed all portions of the examination

REPORT DETAILS

1. Examiners: John T. Nguyen, Chief Examiner, NRC

2. Results:

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

3. Exit Meeting:

John T. Nguyen, Chief Examiner, NRC
Les Foyto, Reactor Manager, MURR
John Fruits, Assistant Reactor Manager of Operations, MURR
Robert Hudson, Training Coordinator, MURR

At the conclusion of the site visit, the examiner met with representatives of the facility staff to discuss the results of the examinations. The examiner thanked the facility for their support of the examination.

ENCLOSURE 1

U.S.NRC
UNITED STATES NUCLEAR REGULATORY COMMISSION
Protecting People and the Environment

University of Missouri - Columbia

Operator License Examination

Written Exam with Answer Key

February 1, 2010

ENCLOSURE 2

QUESTION A.01 [1.0 point]
Which ONE of the following is the **MOST** affected factor in the six factor formula when a poison in the control rods is changed from **BORON (B)** to **CADMIUM (Cd)**?

a. Fast fission factor.

b. Reproduction factor.

c. Thermal utilization factor.

d. Fast non leakage probability.

QUESTION A.02 [1.0 point]
The injection of a sample results in a 50 millisecond period. If the scram setpoint is ***10 MEGAWATTS*** and the scram delay time is 0.1 second, which ONE of the following is the peak power of the reactor at shutdown?

a. 25 MW.

b. 60 MW.

c. 75 MW.

d. 220 MW.

QUESTION A.03 [1 point]
Which ONE of the following best describes the beta decay (β_{-1}) of a nuclide?

a. The atomic mass number unchanged, and the number of protons increases by 1.

b. The atomic mass number unchanged, and the number of protons decreases by 1.

c. The atomic mass number increases by 1, and the number of protons decrease by 1.

d. The atomic mass number increases by 2, and the number of protons increase by 1.

QUESTION A.04 [1.0 point]
During a reactor startup, criticality occurred at a **LOWER ROD HEIGHT** than the last startup. Which ONE of the following reasons could be the cause?

a. Xe^{135} increased.

b. Fuel temperature decreased.

c. Moderator temperature increased.

d. Adding an experiment with negative reactivity.

QUESTION A.05 [1.0 point]
About two minutes following a reactor scram, the reactor period has stabilized and the power level is decreasing at a **CONSTANT** rate. Given that reactor power at time t_0 is 1000 kW, what is the time for the reactor power decreases to 100 kW from time t_0?

a. 1 minute.

b. 2 minutes.

c. 3 minutes.

d. 5 minutes.

QUESTION A.06 [1.0 point]
The FAST FISSION FACTOR is defined as a ratio of:

a. the number of fast neutrons produced by all fission over the number of fast neutrons produced by thermal fission.

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.

QUESTION A.07 [1.0 point]
Which ONE of the following is the correct amount of reactivity (Δρ) added if the multiplication factor, k, is increased from 0.700 to 0.950?

a. 0.250.

b. 0.263.

c. 0.357.

d. 0.376.

QUESTION A.08 [1.0 point]
Which ONE of the following is the time period in which the MAXIMUM amount of Xe-135 will be present in the core?

a. 7 to 11 hours after a power increase from 0% to 50%.

b. 7 to 11 hours after a power increase from 50% to 100%.

c. 7 to 11 hours after a start up to 100%power.

d. 7 to 11 hours after a scram from 100% power.

QUESTION A.09 [1.0 point]
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.

QUESTION A.10 [1.0 point]
Most text books list β for a U^{235} fueled reactor as 0.0065. However, your SAR lists β_{eff} as being 0.0074. Why is β_{eff} larger than β?

a. The fuel includes U^{238} which has a relatively large β for fast fission.

b. Some U^{238} in the core becomes Pu^{239} (by neutron absorption) which has a larger β for fission.

c. Delayed neutrons are born at lower energies than prompt neutrons resulting in a less loss due to leakage for these neutrons.

d. Delayed neutrons are born at higher energies than prompt neutrons resulting in a greater worth for these neutrons.

QUESTION A.11 [1.0 point]
Excess reactivity is the amount of reactivity …

a. associated with sample's worth.

b. needed to achieve prompt critical.

c. needed to keep a reactor shutdown when a SHIM blade is fully up.

d. available above cold criticality with all of the shim blades withdrawn from the point where the reactor is exactly critical.

QUESTION A.12 [1.0 point]
Which ONE of the following ranges in the SHIM position provides the **HIGHEST** worth during operation?

a. From 1.0 to 5.0 in.

b. From 11 to 15 in.

c. From 16 to 20 in.

d. From 22 to 26 in.

QUESTION A.13 [1.0 point]

Given the following worth: ρ_{excess} = 0.60% Δk/k, SHIM blade 1 = 0.30% Δk/k
SHIM blade 2 = 0.45 % Δk/k, SHIM blade 3 = 0.50% Δk/k
REG blade = 0.10 % Δk/k

Calculate the ***TECHNICAL SPECIFICATION LIMIT*** of 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

QUESTION A.14 [1.0 point]

A reactor has an effective delayed fraction (β_{eff}) of 0.0074. If a control rod withdrawal in this reactor increases the effective multiplication (k_{eff}) from 0.9985 to 1.0074, the reactor is:

a. subcritical.

b. exactly critical.

c. supercritical.

d. prompt critical.

QUESTION A.15 [1.0 point]

Which ONE of the following describes the term **PROMPT JUMP**?

a. A reactor is critical at 80-second period.

b. A reactor has attained criticality on prompt neutrons alone.

c. The instantaneous change in power level due to inserting a control rod.

d. The instantaneous change in power level due to withdrawing a control rod.

QUESTION A.16 [1.0 point]
The absolute value of the reactivity worth of all experiments in the center test hole shall **NOT** exceed _____ Δk/k:

a. 0.0010

b. 0.0025

c. 0.0060

d. 0.0200

QUESTION A.17 [1.0 point]
The effective target area, in cm^2, presented by a single nucleus to an incident neutron beam is defined as:

a. a neutron flux.

b. a mean free path.

c. a microscopic cross section.

d. a macroscopic cross section.

QUESTION A.18 [1.0 point]
Which ONE of the following combinations of characteristics makes a good reflector?

	Scattering Cross Section	Absorption Cross Section
a.	High	High
b.	Low	High
c.	High	Low
d.	Low	Low

QUESTION A.19 [1.0 point]
A reactor is critical at 4.5 MW power. The SHIM blades with a worth of 0.1 Δk/k is rapidly inserted into the reactor core. Calculate the power level after immediate insertion of the control blades to the reactor core. Given βeff = 0.0078.

a. 125 KW.

b. 225 kW

c. 325 kW

d. 5.50 MW

QUESTION A.20 [1.0 point]
Which ONE of the following is the principle source of heat in the reactor after a shutdown from extended operation at 10 MW?

a. Decay of fission products.

b. Spontaneous fission of U^{238}.

c. Production of delayed neutrons.

d. Production of prompt gamma rays.

***************** End of Section A ********************************

QUESTION B.01 [1.0 point]
Which ONE of the following types of experiments shall **NOT** be irradiated at MURR?

a. The experiment contains 15 milligrams of explosive materials.

b. The movable experiment has a reactivity worth of – 0.002 Δk/k.

c. The secured experiments have a reactivity worth of 0.005 Δk/k.

d. The secured experiment placed in the center test hold has a reactivity worth of -0.005 Δk/k.

QUESTION B.02 [1.0 point, 0.25 each]
Match the type of radiation in column A with their quality factor in column B. Items in column B is to be used once, more than once or not at all.

	Column A	Column B	
a.	Beta	1.	1
b.	Gamma	2.	5
c.	Alpha particles	3.	10
d.	Neutrons of unknown energy	4.	20

QUESTION B.03 [1.0 point]
A radioactive source reads 65 Rem/hr on contact. Four hours later, the same source reads 2.5 Rem/hr. How long is the time for the source to decay from a reading of 65 Rem/hr to 100 mRem/hr?

a. 6.0 hours.

b. 8.0 hours.

c. 9.0 hours.

d. 10.0 hours.

QUESTION B.04 [1.0 point]
Given that the following emergency conditions occur at the MURR reactor facility:

(a) Low level of coolant alarms
(b) Particulate monitor alarms
(c) Radiation levels at the nearest site boundary indicate 100 mRem for one hour.

Which ONE of the following is the appropriate Emergency Classification?

a. Notification of Unusual Event.

b. Alert.

c. Site Area Emergency.

d. General Emergency.

QUESTION B.05 [1.0 point]
A radioactive material is **DECAYING** at a rate of 20% per hour. Determine its half-life?

a. 1.5 hours.

b. 2.0 hours.

c. 3.0 hours.

d. 5.0 hours.

QUESTION B.06 [1.0 point]
During a reactor startup, the reactor operator calculates that the maximum excess reactivity for reference core conditions is 0.1 $\Delta k/k$. For this excess reactivity, which ONE of the following is the best action?

a. Continue to operate because the excess reactivity is within TS limit.

b. Increase power to Mode III operation and verify the excess reactivity again.

c. Shutdown the reactor; immediately report the result to NRC due to excess being above TS limit.

d Continue operation, but immediately report the result to the supervisor since the excess reactivity is exceeding TS limit.

QUESTION B.07 [1.0 point]
An area in which radiation levels could result in an individual receiving a dose equivalent in excess of 100 mRem/hr is defined as:

a. Radiation area.

b. Restricted Area.

c. High Radiation Area.

d. Very High Radiation Area.

QUESTION B.08 [1.0 point]
A Radiation Work Permit (RWP) is required if the non-routine work is being performed with anticipated rates of greater than…

a. 50 mRem/hr.

b. 100 mRem/hr.

c. 200 mRem/hr.

d. 500 mRem/hr.

QUESTION B.09 [1.0 point]
Which ONE of the following is the MINIMUM staffing requirement when a **HOT REACTOR STARTUP** is required?

a. 1 RO in the control room and 1 SRO in his office.

b. 1 RO and 1 staff member in the control room.

c. 1 RO and 1 SRO in the control room.

d. 2 SRO in the control room.

QUESTION B.10 [1.0 point]
Which ONE of the following materials **shall be** doubly encapsulated at MURR?

a. A flammable material.

b. A corrosive material.

c. An explosive material.

d. A material with a pressure buildup.

QUESTION B.11 [1.0 point]
Which ONE of the following definitions is the Total Effective Dose Equivalent (TEDE) as specified in 10 CFR Part 20?

a. The sum of thyroid dose and external dose.

b. The sum of the external deep dose and the organ dose.

c. The sum of the deep dose equivalent and the committed effective dose equivalent.

d. The dose that your whole body is received from the source, but excluded from the deep dose.

QUESTION B.12 [1.0 point]
Select the list that gives the order of types of radiation from the **LEAST** penetrating to the **MOST** penetrating (i.e. travels the further in air).

a. neutron, gamma, beta, alpha.

b. alpha, beta, neutron, gamma.

c. beta, alpha, gamma, neutron.

d. alpha, neutron, beta, gamma.

QUESTION B.13 [1.0 point]
If an emergency situation requires personnel to search for and remove injured person(s), a planned emergency exposure to the whole body could be allowed up to ____ to save a life.

a. 25 rem

b. 50 rem

c. 75 rem

d. 100 rem

QUESTION B.14 [1.0 point]
While the reactor is OPERATING, a routine patrol of the facility should be completed every ____ hours.

a. 2

b. 4

c. 6

d. 8

QUESTION B.15 [1.0 point]
The drop-time of each of the four shim blades shall be measured:

a. monthly.

b. quarterly.

c. semi-annually.

d. annually.

QUESTION B.16 [1.0 point]
A two curie source, with a 1.8 Mev gamma, is to be stored in the reactor building. How far from the source should a HIGH RADIATION AREA sign be posted?

a. 4 feet.

b. 15 feet.

c. 22 feet.

d. 66 feet.

QUESTION B.17 [1.0 point]
Unless extended in writing, a Radiation Work Permits expires in:

a. 8 hours.

b. 24 hours.

c. a week.

d. a month.

QUESTION B.18 [1.0 point]
The four parameters used to evaluate the safety limits are:

a. reactor power level, core flow rate, reactor inlet water temperature, and water tank level.

b. reactor power level, core flow rate, reactor inlet water temperature, and pressurizer pressure.

c. reactivity, reactor power level, reactor inlet water temperature, and pressurizer pressure.

d. reactor power level, core flow rate, reactor outlet water temperature, and pressurizer pressure.

QUESTION B.19 [1.0 point]
When the reactor power level is above 100 kW, the reactor shall be operated so that the maximum distance between the highest and lowest shim blades shall NOT exceed:

a. 0.5 inch.

b. 1.0 inch.

c. 1.5 inches.

d. 2.0 inches.

QUESTION B.20 [1.0 point]
During a reactor startup, the reactor operator finds a discrepancy in the Estimated Critical Position (ECP). For this discrepancy, which ONE of the following is the best action?

a. Shutdown the reactor; then recalculate the ECP.

b. Continue operation, but immediately report the result to the supervisor.

c. Continue to operate because the ECP is NOT required during startup.

d Withdraw the control blades to critical, and then use 1/M to predict the ECP.

****************************** End of Section B ********************************

QUESTION   C.01   [2.0 points, 0.25 each]
Match the input signals listed in column A with their respective responses listed in column B. (Items in column B is to be used more than once or not at all.)

Column A		Column B
a.	11-sec period.	1. Indication only.
b.	Primary coolant flow = 1700 gpm.	2. Indication and rod prohibit.
c.	Pressurize pressure = 65 psig.	3. Indication and rod run-in.
d.	15 Vdc at Signal Processor # 1 failed.	4. Indication and reactor scram.
e.	Channel 1 count rate = 10 cps.	
f.	100 kW power at Mode II.	
g.	Bridge radiation monitor = 60 mRem/hr. (up scale position)	
h.	Drawer module is removed.	

QUESTION   C.02   [1.0 point]
Which ONE of the following Area Radiation Monitoring System is capable of causing automatic reactor isolation?

a. Fuel Vault.

b. Room 114.

c. Air Plenum # 2.

d. East Beamport Wall.

QUESTION C.03 [1.0 point]
Which ONE of the following best describes the reason for the high sensitivity of Geiger-Mueller tube detector?

a. Coating with U-235.

b. A longer length tube, so target is larger for all incident events.

c. Lower voltage applied to the detector helps to amplify all incident events.

d. Any incident radiation event causing primary ionization results in ionization of entire detector.

QUESTION C.04 [1.0 point]
Which ONE of the following represents the normal flow rate of the ENTIRE primary coolant system at 10 MW power?

a. 1000 gpm.

b. 1800 gpm.

c. 2500 gpm.

d. 3600 gpm.

QUESTION C.05 [1.0 point]
To isolate the electrical distribution to the reactor cooling pumps, the MURR staff can turn off the breakers located at…..

a. Motor Control Center -1.

b. Motor Control Center -3.

c. Motor Control Center -4.

d. Motor Control Center -5.

QUESTION C.06 [1.0 point]
Which ONE of the following conditions will cause the reactor to change from automatic mode to manual mode?

a. Reactor power exceeds 10 MW.

b. The reactor period exceeds 50 seconds.

c. The regulating blade reaches less than 10% withdrawn.

d. The shim blade position reaches 24 inches of withdrawal.

QUESTION C.07 [2.0 points, 0.25 each]
Match each monitor and instrument (channel) listed in column A with a specific purpose in column B. Items in column B are to be used only once.

Column A	Column B
a. Intermediate Range Monitor 2.	1. Monitor radiation level in the reactor bridge.
b. Power Range Monitor 4.	2. Detect radioisotopes released due to fuel failure.
c. Wide Range Monitor.	3. Calculate safety limit.
d. Portable monitor.	4. Survey of laboratory.
e. Source Range Monitor 1.	5. Monitor neutron level during the reactor startup.
f. Area radiation monitor.	6. Provide a period scram.
g. Core Inlet Temperature.	7. Provide a high power level scram.
h. Particulate monitor.	8. Permit reactor power to be automatically controlled during the steady state mode.

QUESTION C.08 [1.0 point]
Which ONE of the following describes the operation of the Reactor Inlet and Outlet Isolation valves (507A & 507B)?

a. Air open, air close.

b. Air open, spring close.

c. Motor-operated (open and close).

d. Spring open, air close.

QUESTION C.09 [1.0 point]
Which ONE of the following is the MAXIMUM capacity of the MURR liquid waste disposal?

a. 5,000 gallons (five tanks with 1,000 gallons capacity each).

b. 10,000 gallons (two tanks with 5,000 gallons capacity each).

c. 15,000 gallons (three tanks with 5,000 gallons capacity each).

d. 25,000 gallons (five tanks with 5,000 gallons capacity each).

QUESTION C.10 [1.0 point]
Which ONE of the following is the actual design feature which prevents siphoning of primary water on a failure of the primary piping?

a. A valve upstream of the primary pump will shut automatically.

b. The Emergency Fill system will automatically maintain tank level.

c. A valve, when open, allows the water from the reactor pool to the reactor loop.

d. A valve, when open, allows air into the reactor loop at the highest point in the invert loop.

QUESTION C.11 [1.0 point]
Which ONE of the following is NOT required for the Estimated Critical Position (ECP) Corrections?

a. Pool water level.

b. Pool inlet temperature.

c. Flux trap loading worth.

d. Primary core inlet temperature.

QUESTION C.12 [1.0 point]
On a loss of normal electrical power, which ONE of the following systems is NOT supplied by the Emergency Generator?

a. Exit Signs.

b. Normal Laboratory Air Compressor.

c. Evacuation Alarm System.

d. Reactor Control Room Instrumentation.

QUESTION C.13 [1.0 point]
Exposing a check source to the particulate detector to verify whether it is operable is considered to be:

a. a channel test.

b. a channel check.

c. a channel calibration.

d. a channel verification.

QUESTION C.14 [1.0 point]
Which ONE of the following is the solution added to the secondary water system to maintain the pH level?

a. Carbonic Acid.

b. Sulfuric Acid.

c. Copper Sulphate.

d. Sodium Chlorine.

QUESTION C.15 [1.0 point]
Which ONE of the following is the design features for the MURR fuel?

a. Each fuel element contains 20 fuel-bearing plates with a nominal active length of 24 inches.

b. Each fuel element contains 24 fuel-bearing plates with a nominal active length of 20 inches.

c. Each fuel element contains 24 fuel-bearing plates with a nominal active length of 24 inches.

d. Each fuel element contains 24 fuel-bearing plates with a nominal active length of 26 inches.

QUESTION C.16 [1.0 point]
Which ONE of the following radiation monitor channels contains a charcoal cartridge?

a. The gas channel.

b. The iodine channel.

c. The particulate channel.

d. The Air Plenum # 1 channel.

QUESTION C.17 [1.0 point]
During reactor startup, a thermal column door open alarm will …

a. have no effect on the operation of the reactor.

b. prevent withdrawal of control blades.

c. cause a rod run in.

d. cause a reactor scram.

QUESTION C.18 [1.0 point]
Which ONE of the following is the correct statement regarding the materials used to construct five control blades at MURR?

a. All five are stainless steel.

b. All five are boron carbide clad in aluminum.

c. The SHIM blades are boron carbide clad in aluminum, the REGULATING blade is stainless steel.

d. The SHIM blades are boron carbide clad in stainless steel, the REGULATING blade is aluminum.

******************* End of Section C *****************************
******************* End of the Exam ***************************

A.01 c
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.2, page 3-19.

A.02 c
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982
$P = P_0 e^{t/\tau}$, $P = 10$ Megawatts × $e^{0.1/0.05} = 10 \times e^2 = 73.9$ Megawatts

A.03 a
REF: Chart of the Nuclides

A.04 b
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 8.4, page 8-9.

A.05 c
REF: $P = P_0 e^{-T/\tau}$, 100 kW = 1000 kW $\times e^{(X/-80sec)}$, X = ln(0.1) $\times$ 80 sec ; X = 180 sec. or 3 min

A.06 a
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.1, page 3-16.

A.07 d
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 3.3.3, page 3-21.
The applicant can use one of the following methods:
a) At k=0.7; ρ = ΔKeff/Keff or ρ = Keff-1/Keff = -0.3/0.7 =-0.429. At k=0.95, ρ =-0.05/0.95 ρ = -0.053. The difference between ρ is the answer, i.e. -0.053-(-0.429) =0.376
b) Δ ρ = ρ1 – ρ2 where ρ1 = Keff1-1/Keff1 and ρ2 = Keff2-1/Keff2. Substitute ρ1 and ρ2 with Keff1 and Keff2 into the equation above, the result is Δρ = keff1-keff2/(keff1 x keff2)
Δρ = k1-k2/(k1 x k2) ; Δρ = 0.95-0.70/(0.95 x 0.70) =0.376

A.08 d
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Sec 8.4, page 8-9.

A.09 a
REF 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

A.10 c
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, § Section 3.3, page 3-14

A.11 d
REF: MURR TS 1.0

A.12 b

REF: MURR Worth Curve (note: center of Shim blade provides the highest worth)

A.13 a
REF: Total rod worth – (excess + most active SHIM blade + REG blade)
(0.30+0.45+0.5+0.1) %Δk/k –(0.6+0.5+0.1) %Δk/k =(1.35 -1.2) %Δk/k = 0.15 %Δk/k

A.14 d
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Section 4.2, page 4-1.

A.15 d
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Page 4-21.

A.16 c
REF MURR TS 3.1, page A-15

A.17 c
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, Section 2.51, page 2-36.

A.18 c
REF: Standard NRC Question

A.19 c
REF: $P1 = P0 (\beta_{eff} \times (1 - \rho))/(\beta_{eff} - \rho)$
$P1 = 4.5$ MW $(.0078 \times (1 - (- 0.1)/ (0.0078 - (- 0.1)$
$P1 = 4.5$ MW $\times (0.072)$; $P1 = 325$ kW

A.20 a
REF: Burn, R., *Introduction to Nuclear Reactor Operations,* © 1982, page 4-33

B.01 b
REF: Technical Specifications § 3.1 & 3.6

B.02 a(1) b(1) c(4) d(3)
REF: 10 CFR 20

B.03 b
REF: $DR = DR_{\circ} * e^{-\lambda t}$
2.5 rem/hr =65 rem/hr* $e^{-\lambda(4hr)}$
Ln(2.5/65) = -λ*4 --> λ=0.8145; solve for t: Ln(.1/65)=-0.8145 *t → t=7.95 hours

B.04 c
REF: EP-RO-011

B.05 c
REF: $DR = DR_{\circ} * e^{-\lambda t}$
20% is decayed, so 80% is still there
80% =100%* $e^{-\lambda(1hr)}$
Ln(80/100) = -λ*1 -->λ=0.223 t1/2=Ln(2)/ λ -->.693/.223 t=3.1 hours

B.06 c
REF: TS 3.1.f

B.07 c
REF: 10 CFR 20

B.08 b
REF: AP-HP-105, Sec 4.1.

B.09 c
REF: AP-RO-110, Sec 6.6.9

B.10 b
REF: TS 3.7.2, page 16

B.11 c
REF: 10 CFR 20.1003.

B.12 b
REF: NRC standard question

B.13 c
REF: EP-RO-018, Sec 1.0

B.14 b
REF: AP-RO-110, Sec 6.5.7

B.15 b
REF: TS 4.3.a

B.16 b

REF: 6CEN = R/hr @ 1 ft. -> 6 x 2 x 1.8 x 1 = 21.6 R/hr at 1ft. $I_0D_0^2 = I*D^2$
21.6 R/hr*1 ft = 0.1 R/hr $*D^2$
D= √(21.6/0.1) = 14.7 ft.

B.17 b
REF: AP-HP-105, RWP Instruction Sheet.

B.18 b
REF: TS 2.1

B.19 b
REF: TS 4.3.a

B.20 a
REF: AP-RO-110, Sec 6.6.5

C.01	a(3)	b(4)	c(4)	d(4)	e(2)	f(1)	g(1)	h(4)

REF: TS 2.2 and MURR Training Manual

C.02 c
REF: MURR Training Manual, Reactor Isolation and Facility Evacuation.

C.03 d
REF: Standard NRC question

C.04 d
REF: MURR SAR 5.1

C.05 d
REF: MURR Training Manual, Normal Electrical Distribution

C.06 c
REF: SAR 9.6.2

C.07	a(6)	b(7)	c(8)	d(4)	e(5)	f(1)	g(3)	h(2)

REF: TS 2.2 and MURR Training Manual, Nuclear Instrumentation

C.08 b
REF: MURR Training Manual, Primary Coolant Loop

C.09 c
REF: MURR SAR 7.3.3, Liquid Waste Disposal

C.10 d
REF: MURR SAR 5.2, Siphon Break System

C.11 a
REF: OP-RO-210, ECP Corrections & Critical Data

C.12 b
REF: MURR SAR 7.1.4, Emergency Power System.

C.13 a
REF: TS, Definition

C.14 b
REF: MURR Training Manual, Second Coolant System

C.15 c
REF: MURR TS 5.4, Reactor Core and Fuel

C.16 b
REF: MURR Training Manual, Stack Monitor - Eberline

C.17 b

REF: MURR SAR 9.5, Startup Interlocks

C.18 c
REF: MURR SAR, Control Elements