September 30, 2011

Dr. Kenan Unlu, Director
Radiation Science and
Engineering Center (RSEC)
Breazeale Nuclear Reactor
University Park, PA 16802-2301

SUBJECT: EXAMINATION REPORT LETTER NO. 50-005/OL-11-01,THE PENNSYLVANIA STATE UNIVERSITY BREAZEALE RESEARCH REACTOR

Dear Dr. Unlu:

During the week of August 15, 2011, the NRC administered an operator licensing examination at your Pennsylvania State University Breazeale Research Reactor facility. The examination was 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 Greg Schoenebeck at 301-415-6345 or via internet e-mail Greg.Schoenebeck@nrc.gov.

Sincerely,

/RA/

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

Docket No. 50-005

Enclosures:
1. Initial Examination Report No. 50-5/OL-11-01
2. Facility Comments with NRC Resolution
3. Written examination with facility comments incorporated
4. Facility Review of Written Examination

cc : Mr. Mark Trump, Pennsylvania State University

cc: w/o: See next page

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Engineering Center (RSEC)
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cc w/o enclosures: See next page

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Facility File (CRevelle) O7 G13

ADAMS ACCESSION #: ML112710008 **TEMPLATE #:NRR-074**

OFFICE	PROB:CE		IOLB:LA	E	PROB:SC	
NAME	GSchoenebeck		CRevelle		JEads	
DATE	09/29/2011		09/29/2011		09/30/2011	

OFFICIAL RECORD COPY

cc:

Mr. Eric J. Boeldt, Manager of
Radiation Protection
The Pennsylvania State University
304 Old Main
University Park, PA 16802-1504

Dr. Henry C. "Hank" Foley
Vice President for Research &
Dean of the Graduate School
The Pennsylvania State University
304 Old Main
University Park, PA 16802-1504

Director, Bureau of Radiation Protection
Department of Environmental Protection
P.O. Box 8469
Harrisburg, PA 17105-8469

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.: 50-005/OL-11-01

FACILITY DOCKET NO.: 50-005

FACILITY LICENSE NO.: R-2

FACILITY: Penn State Breazeale Research Reactor

EXAMINATION DATES: August 15-16, 2011

SUBMITTED BY: /RA/ 09/28/11
Gregory M. Schoenebeck, Chief Examiner Date

SUMMARY:

During the week of August 15, 2011, the NRC administered operator licensing examinations to: (1) Reactor Operator, (1) Instant Senior Reactor Operator and (1) Senior Reactor Operator upgrade candidate. Two candidates passed the written examination and all three passed the operating test.

REPORT DETAILS

1. Examiners:
Gregory Schoenebeck, NRC, Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	1/0	1/0*	2/0
Operating Tests	1/0	2/0	3/0
Overall	1/0	2/0	3/0

* Denotes: (1) SRO Instant

3. Exit Meeting:
Gregory M. Schoenebeck, NRC, Chief Examiner
Kenan Unlu, Director for Operations
Mark Trump, Associate Director for Operations

The NRC examiner thanked the facility staff for their prompt submission of written examination comments (incorporated in enclosure two to this report). The NRC Examiner thanked the facility for performing an exam review in advance of the scheduled written examination (incorporated in enclosure four to this report).

ENCLOSURE 2
<u>FACILITY COMMENTS ON THE WRITTEN EXAM WITH NRC RESOLUTION</u>

Question A5
Comment: Characteristic of a subcritical reactor – Two possible correct answers B and D.

As part of methods used at PSBR to help non-nuclear personnel develop a mental “conceptual model” we discuss critical and subcritical reactors in several ways. One of these ways discusses how the neutron production of one generation is the source neutron input for the next and the reactor is at subcritical equilibrium when these numbers are equal. Therefore the statement “a constant neutron population is achieved when the total number of neutrons produced in one generation is equal to the number of source neutrons in the next (or any other) generation is also correct.

NRC Resolution: Accepted B and D as possible answers; refer to answer key for facilities’ supplemental information in addition to the DOE Manual, *Reactor Theory (Reactor Operations) DOE-HDBK-1019/2-93 “SUBCRITICAL MULTIPLICATION”*

Reference: As stated

Question A19
Comment: No correct answer provided due to math error in key.

NRC Resolution: Students asked to calculate and provide a value during administration. Written answer was accepted by student if calculated correctly.

SDM = Critical worth – Most reactive Rod worth remaining out of core

<u>SDM = 7.97-3.90 = $4.07</u>

Reference: CCP-11 “Core Reactivity Evaluation”

Question B.13
Comment: Question was written in error and did not match the answer as specified by the key. The facility notified the examiner of the error while proctoring the exam.

NRC Resolution: The change had little impact on the exam. The question was addressed and corrected during the exam without issue by the candidates taking the exam. It now reads: “As a precaution in SOP-1, when performing a PULSE, the MINIMUM limit of reactivity is ____ with the transient rod.”

Reference: SOP-1 “Reactor Operating Procedure”, Section V.F.

Question B.19
Comment: Answer Key was incorrect; answer could reasonably be A and D. PSBR comments are in *italics.*

A. Over-heating of fuel and cladding failure with FP release. (Distracter)*This is the limiting concern address by the SAR LOCA event.*
B. Over heating fuel and Zr-hydride reaction. (Distracter) *No such reaction is postulated or supported by TRIGA analysis*.
C. Groundwater Contamination (Distracter). *While a political concern, it is not a safety issue as the pool water is near drinking water standards*.
D. Personnel Radiation exposure (Correct Answer). *While not addressed by the SAR it is a concern addressed by our procedures.*

NRC Resolution: The examiner acknowledges that the SAR analyzes the potential for a fuel accident during a total loss of cooling water accident. However, the SAR determines that air is an adequate cooling medium for TRIGA fuel to prevent fuel melt. In this case, the examiner determines that this event, involving a slow leak, has a greater consequence of a radiation hazard from the loss of biological shielding than the concern of a postulated fuel accident. Therefore, the NRC does not accept this comment.

Reference: PSBR SAR and EP-4 “Loss of Pool Water” Section D. Immediate Corrective Action

Question C.16
Comment: No completely correct answer provided due to modification of the Transient Rod drive system (worm gear replaced by drive belt). Students chose most correct answer C.

NRC Resolution: The examiner determined that there was enough information to answer the question correctly, even though the facility provided schematic had been modified. To alleviate future errors, the examiner has deleted (i.e., Strikethrough) the portion of information in this exam question which does not apply.

Reference: Conversation with PSBR Associate Director for Operations and PSBR Training Manual.

The Pennsylvania State University

NRC License Examination

Written Examination with Answer Key

8/15/2011

Enclosure 3

U. S. NUCLEAR REGULATORY COMMISSION

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

FACILITY: PENN STATE UNIVERSITY

REACTOR TYPE: POOL TYPE, MODIFIED TRIGA

DATE ADMINISTERED: 8/15/2011

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 parentheses for each question. A 70% overall is required to pass the examination. Examinations will be picked up three (3) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	CANDIDATE'S SCORE	% OF CATEGORY VALUE	CATEGORY
20.00	33.3	_______	_______	A. REACTOR THEORY, THERMODYNAMICS, AND FACILITY OPERATING CHARACTISTICS
20.00	33.3	_______	_______	B. NORMAL AND EMERGENCY OPERATING PROCEDURES AND RADIOLOGICAL CONTROLS
20.00	33.3	_______	_______	C. FACILITY AND RADIATION MONITORING SYSTEMS
60.00		_______ **FINAL GRADE**		TOTALS

ALL THE WORK DONE ON THIS EXAMINATION IS MY OWN. I HAVE NEITHER GIVEN NOR RECEIVED AID.

____
CANDIDATE'S SIGNATURE

Section A: ReactorTheory, Thermodynamics & Facility Operating Characteristics

ANSWER SHEET

Multiple Choice (Circle or X your choice)
If you change your answer, write your selection in the blank.

MULTIPLE CHOICE

001 a b c d __

002 a b c d __

003 a b c d __

004 a b c d __

005 a b c d __

006 a b c d __

007 a b c d __

008 a b c d __

009 a b c d __

010 a b c d __

011 a b c d __

012 a b c d __

013 a b c d __

014 a b c d __

015 a b c d __

016 a b c d __

017 a b c d __

018 a b c d __

019 a b c d __

020 a b c d __

(***** END OF CATEGORY A *****)

Section B Normal, Emergency and Radiological Control Procedures

ANSWER SHEET

Multiple Choice (Circle or X your choice)
If you change your answer, write your selection in the blank.

MULTIPLE CHOICE

001 a b c d _	011 a b c d _
002 a b c d _	012 a b c d _
003 a b c d _	013 a b c d _
004 a b c d _	014 a b c d _
005 a b c d _	015 a b c d _
006 a b c d _	016 a b c d _
007 a b c d _	017 a b c d _
008 a b c d _	018 a b c d _
009 a b c d _	019 a b c d _
010 a b c d _	020 a b c d _

(***** END OF CATEGORY B *****)

Section C Facility and Radiation Monitoring Systems

A N S W E R   S H E E T

Multiple Choice (Circle or X your choice)
If you change your answer, write your selection in the blank.

MULTIPLE CHOICE

001 a b c d ___
002 a b c d ___
003 a b c d ___
004 a b c d ___
005 a b c d ___
006 a b c d ___
007 a b c d ___
008 a b c d ___
009 a b c d ___
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014 a b c d ___
015 a b c d ___
016 a b c d ___
017 a b c d ___
018 a b c d ___
019 a b c d ___
020 a b c d ___

(********** END OF EXAMINATION **********)

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 not received or 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.

6. Fill in the date on the cover sheet of the examination (if necessary).

7. Print your name in the upper right-hand corner of the first page of each section of your answer sheets.

8. The point value for each question is indicated in parentheses after the question.

9. Partial credit will NOT be given.

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

11. When you are done and have turned in your examination, leave the examination area as defined by the examiner.

EQUATION SHEET

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

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

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

$$P = P_0\ e^{t/\mathrm{T}}$$

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

$$\ell^* = 1\times10^{-4}\sec$$

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

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

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

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

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

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

$$M = \frac{1-K_{eff_1}}{1-K_{eff\,2}}$$

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

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

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

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

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

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

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

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

$$I = I_{oe^{-\mu x}}$$

$$DR = \frac{6\,Ci\,E(n)}{R^2}$$

$$\mu_m = \frac{\mu}{\rho}$$

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

1 Curie = 3.7 x 10^{10} dis/sec

1 kg = 2.21 lbm

1 inch=2.54 cm

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

QUESTION A.1 [1.0 point]
The delayed neutron fraction (β) for U-235 is 0.0065. However, when performing certain reactivity calculations you note the use of $\overline{\beta}_{eff}$ which has a value of 0.007 at the PSBR. Why is the value of $\overline{\beta}_{eff}$ larger than β?

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

b. Delayed Neutrons are born at lower energies than prompt neutrons resulting in less leakage during slowdown to thermal energies.

c. The fuel also contains U-238 which has a relatively large beta for fast fission.

d. U-238 in the core becomes Pu-239 (by neutron absorption), which has a higher beta for fission.

QUESTION A.2 [1.0 point]
When the excess reactivity (K_{ex}) exceeds the delayed neutron fraction (β), a reactor is said to be:

a. Subcritical

b. Critical

c. Within its shutdown margin requirements

d. Prompt critical

QUESTION A.3 [1.0 point]
You are poolside at the PSBR conducting a tour when someone from the group asks what the “blue glow” around the reactor is. Which of the following would be the most correct response?

a. It is binding energy released directly through chain reactions of the fission process

b. It is an effect where high energy, charged particles (e.g., electrons) lose and emit their energy while slowing down through the pool

c. It is an effect when high energy, charged particles (e.g., electrons) pass through the pool at a speed which is greater than the speed of light

d. It is the energy release from the interaction between a neutrino and antineutrino which is known as pair annihilation.

QUESTION A.4 [1.0 point]
A nuclear reactor startup is being performed by adding equal amounts of positive reactivity and waiting for neutron population to stabilize. As the reactor approaches criticality, the numerical change in stable neutron population after each reactivity addition __________, and the time required for the neutron population to stabilize after each reactivity addition ___________.

a. increases; remains the same

b. increases; increases

c. remains the same; remains the same

d. remains the same; increases

QUESTION A.5 [1.0 point]
Which ONE of the following statements is the most correct regarding a characteristic of subcritical multiplication?

a. The number of neutrons gained per generation doubles for each succeeding generation.

b. A constant neutron population is achieved when the total number of neutrons produced in one generation is equal to the number of source neutrons in the next generation.

c. For equal reactivity additions, it takes less time for the equilibrium subcritical neutron population level to be reached as K_{eff} approaches one.

d. Doubling the indicated power will reduce the margin to criticality by approximately one-half.

QUESTION A.6 [1.0 point]
The PSBR staff is performing its control rod calibration using the positive period method; you are the reactor operator. With the reactor power at an appropriate level you withdraw the rod of interest a small amount to establish a suitable reactor period. If the doubling time is determined to be 42 seconds, what is the reactor period **for this instance**?

a. 29 seconds

b. 42 seconds

c. 61 seconds

d. 84 seconds

QUESTION A.7 [1.0 point]
Given a critical nuclear reactor operating below the point of adding heat (POAH), what reactivity effects are associated with reaching the POAH?

a. There are no reactivity effects because the reactor is critical.

b. The increase in fuel temperature will begin to create a positive reactivity effect.

c. The decrease in fuel temperature will begin to create a negative reactivity effect.

d. The increase in fuel temperature will begin to create a negative reactivity effect.

QUESTION A.8 [1.0 point]
Which one of the following completes the following sentence as the most correct reason for having an installed neutron source within the core?

A startup without an installed neutron source...

a. could result in a very short period due to the reactor going critical before neutron population built up high enough to be read on nuclear instrumentation.

b. is impossible as there would be no neutrons available to start up the reactor.

c. would be very slow due to the long time to build up neutron population from so low a level.

d. can be compensated for by adjusting the compensating voltage on the source range detector.

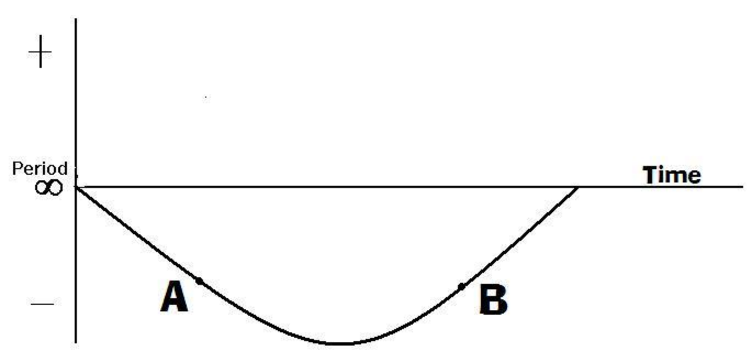
QUESTION A.9 [1.0 point]
The associated graph depicts a plot of reactor period as a function of time. What best describes the behavior of **REACTOR POWER** between points A and B:

a. Constant

b. Decreasing then increasing

c. Continually increasing

d. Continually decreasing



QUESTION A.10 [1.0 point]
Which one of the following will be the resulting stable reactor period when a \$0.25 reactivity insertion is made into an exactly critical reactor core? Neglect any effects from prompt neutrons.

Given:
$\overline{\beta_{eff}}$ =0.0070 λ=0.1

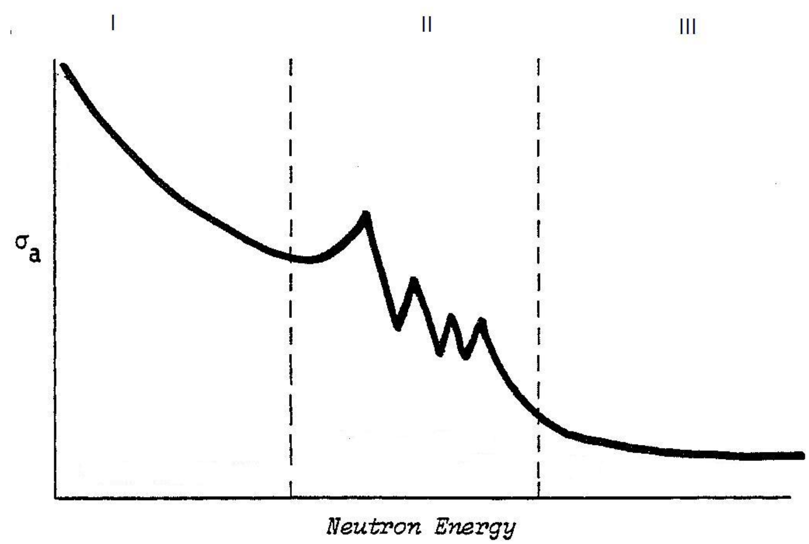
a. 18

b. 30

c. 38

d. 50

QUESTION A.11 [1.0 point]
Given the associated graph, which of the following answers best describe the neutron behavior within Region II?



a. The neutron cross section is inversely proportional to the neutron velocity (1/V)

b. The neutron cross section decreases steadily with increasing neutron energy (1/E).

c. Neutrons of specific energy levels (e.g., 50 ev, 100 kev) have a greater potential for leakage from the reactor core

d. Neutrons of specific energy levels (e.g., 50 ev, 100 kev) are more likely to be readily absorbed than neutrons at other energy levels.

QUESTION A.12 [1.0 point]
A reactor is operating in the automatic mode at 200 kW, with the regulating rod at 60% withdrawn. A malfunction of equipment in the secondary cooling system has caused primary temperature to decrease by 8˚C. Disregarding any other automated system design features, find the new position of the regulating rod using the associated rod worth curve:

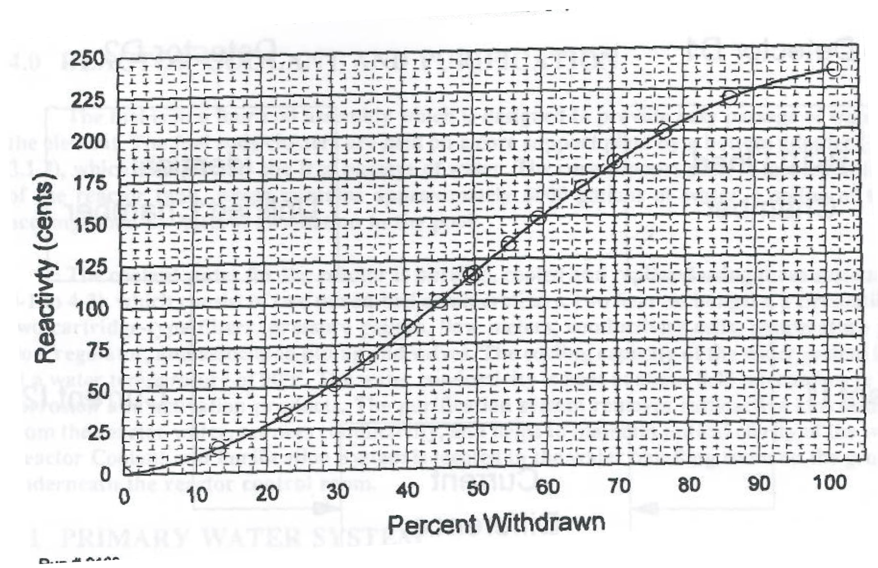
Given:
α_T= -4.9 x 10^{-4} ΔK/C
β_{eff} =0.0070

a. 44% Withdrawn

b. 50% Withdrawn

c. 66% Withdrawn

d. 80% Withdrawn



QUESTION A.13 [1.0 point]
Which ONE of the following is a correct statement of why delayed neutrons enhance the ability to control reactor power?

a. There are more delayed neutrons than prompt neutrons

b. Delayed neutrons are born at higher energy levels than prompt neutrons

c. Delayed neutrons increase the average neutron lifetime

d. Delayed neutrons readily fission in U-238

QUESTION A.14 [1.0 point]

________________ releases the most amount of energy during an average fission event.

a. Fission product recoil

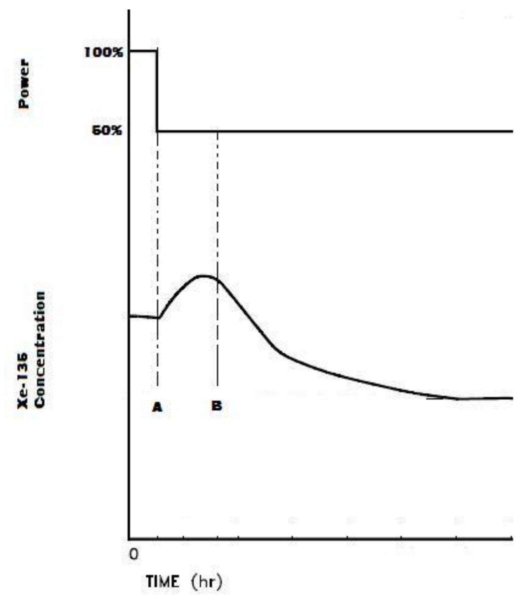
b. Fission product decay

c. Fast neutrons

d. Prompt gammas

QUESTION A.15 [1.0 point]

Using the associated graph which of the following best describes what happens to the concentration of Xenon (Xe)-135 from point A to B?



a. The concentration of Iodine-135 was at a higher equilibrium level at 100% power and is therefore producing Xe-135 at a higher rate until it reaches a maximum value 7-8 hours later.

b. The concentration of Xe-135 reaches a maximum value 40 hours after the down power transient and will decrease to a new, higher equilibrium value until it reaches a maximum value equilibrium

c. The insertion of control rods displaces the axial reactor flux causing an increased production rate of xenon gas until it reaches a maximum value 7-8 hours after the down power transient.

d. The decay rate of fission product, Cesium-135 increases due to the down power transient which increases the concentration of Xe-135 to a maximum value 40 hours later.

QUESTION A.16 [1.0 point]
You are the reactor operator performing two pulsing operations. The first pulse had a reactivity worth of **$1.50** which resulted in a peak power of **250 MW**. If the second pulse had a reactivity worth of **$2.00**, what was the corresponding peak power?

Given:
β_{eff} =0.0070

a. 375 MW

b. 750 MW

c. 1000 MW

d. 1200 MW

QUESTION A.17 [1.0 point]
The primary coolant flow through the reactor __________________

a. becomes highly radioactive from Nitrogen (N)-16 long lived decay

b. is forced over the core using a pump located above the core.

c. flows up through large flow holes in the lower grid plate

d. cools the core by natural convection

QUESTION A.18 [1.0 point]
Refer to the associated figure which includes drawings for three 1/M plots labeled A, B, and C

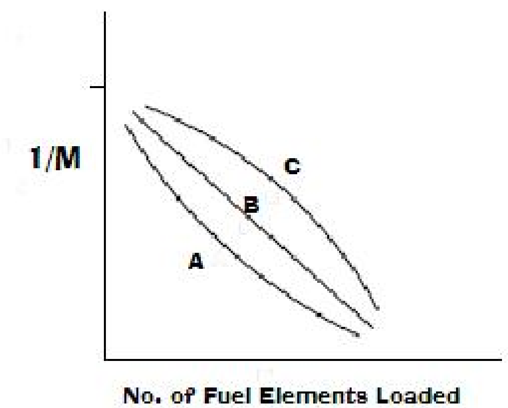
Plot B shows an ideal approach to criticality. Therefore, the least conservative approach to criticality is represented by plot _____ and could possibly be the result of recording count rates at ________ time intervals after incremental fuel loading steps compared to the situations represented by the other plots.

a. A; shorter

b. A; longer

c. C; shorter

d. C; longer



QUESTION A.19 [1.0 point]
You are performing a 50 Watt Critical Rod Position. Given the following data, calculate what the Shutdown Margin, as defined by Technical Specifications, is in a clean cold core.

a. $0.25

b. $1.48

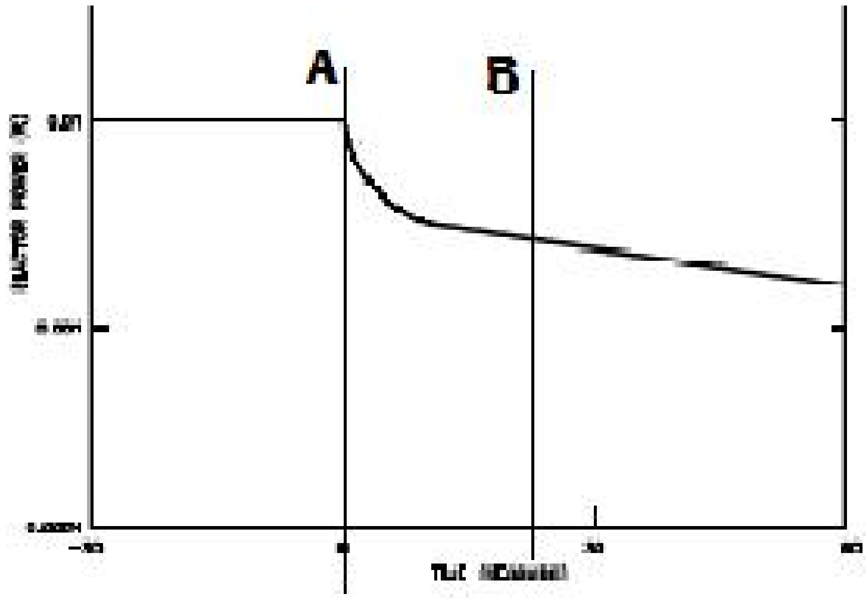
c. $5.38

d. $7.05

CCP-11
Core Reactivity Evaluation

Control Rod	Total Worth	Critical Worth
Transient	$2.94	$1.81
Safety	$3.90	$2.53
Shim	$2.91	$1.82
Regulating	$2.92	$1.81
Total	$12.67	$7.97

QUESTION A.20 [1.0 point]
The associated diagram depicts the profile of reactor power vs. time for a down power evolution. Which of the following answers best describes reactor power as it transitions from point A to B?



a. The moderator temperature coefficient adds positive reactivity in order to slow the rate of the down power

b. The rate of power change is slowed and approaches the rate determined by the longest lived neutron precursor

c. The rate of power decrease is slowed as the decay rate of iodine-135 is faster than the decay rate of xenon-135

d. Doppler broadening effects from U-238 in the fuel increases the probability of absorption which reduces the rate of power decrease

QUESTION B.1 [1.0 point]
In accordance with the facility Emergency Plan, a tornado event which damages the PSBR confinement structure is a good example of a(n) __________ type event classification.

a. Unusual Event

b. Alert

c. Site Area Emergency

d. General Emergency

QUESTION B.2 [1.0 point]
Which of the following is correct regarding NRC Form 3 "Notice to Employees"?

a. It provides guidance for filing a discrimination report

b. It provides guidance for how to report safety concerns

c. It informs you for how to get a record of your radiation exposure

d. All of the above

QUESTION B.3 [1.0 point]
The following statement from the PSBR TS is a good example of a(n) __________________ requirement.

"The maximum excess reactivity above cold, clean, critical plus samarium poison of the core configuration with experiments and experimental facilities in place SHALL be 4.9% $\Delta k/k$ (~$7.00)."

a. Surveillance

b. Limiting Safety System Settings (LSSS)

c. Administrative

d. Limiting Condition for Operation (LCO)

QUESTION B.4 [1.0 point]
Which one of the following activities at the PSBR **DOES NOT** require the presence of a Senior Reactor Operator (SRO)?

a. Shuffling fuel elements between positions within the same fuel rack

b. The relocation of an in-core experiment with reactivity worth equal to $1.20

c. Recovery from an accidental scram as a result of unintentional operator error

d. Removing the transient rod to the side of the core in order to perform an inspection

QUESTION B.5 [1.0 point]
Which of the following represents a unit of contamination?

a. Ci

b. Sieverts

c Rad

d. Roentgen

QUESTION B.6 [1.0 point]
What is the limit of radiation exposure for a member of the public (e.g., boy scout)?

a. 5 Rem

b. 2 Rem

c. 100 mrem

d. 500 mrem

QUESTION B.7 [1.0 point]

Which of the following statements is true regarding radiation safety protocol at the PSBR?

a. Category II individuals may escort a Category I individual only if they have watched the safety video first

b. Category III individuals include police officers making routine checks

c. Category II individuals may only perform work with sources of radiation only after watching the safety video.

d. Category I individuals do not have to watch the safety video and are typically escorted by Category III individuals

QUESTION B.8 [1.0 point]
If you **ARE NOT** active watchstander, by the Requalification Plan, how many hours of licensed RO or SRO activity must you perform to become current?

a. 2

b. 4

c. 6

d. 8

QUESTION B.9 [1.0 point]
You are handling irradiated samples and you decide to expedite the process by not adhering to standard PSBR procedures and precautions. One irradiated sample you pull directly from the core measures **100 Rem/hr at 1 meter**. If you moved **10 meters** away how long before you would exceed your 10 CFR 20 limit for whole body radiation exposure?

a. 0.5 hr

b. 1 hr

c. 2 hrs

d. 5 hrs

QUESTION B.10 [1.0 point]
In case of major medical emergencies, the ___________ is the nearest medical facility has agreed to accept patients from radiation accidents at the university:

a. Mount Nittany Medical Center

b. Lewiston Hospital

c. The University Health Clinic

d. Hershey Medical Center

QUESTION B.11 [1.0 point]
The safety system channels required to be operable in all modes of operation are:

a. Fuel temperature, High Power, Detector Power Supply

b. Fuel temperature scram, Scram Button Console, Watchdog Circuit

c. High Power, Detector Power Supply, Preset Timer

d. Source level, Pulse Mode Inhibit, Transient Rod

QUESTION B.12 [1.0 point]
The _________ is responsible for the termination of an emergency.

a. Reactor Operator

b. Senior Reactor Operator

c. Emergency Director

d. Facility Manager

QUESTION B.13 [1.0 point]
As a precaution in SOP-1, when performing a PULSE, the MINIMUM limit of reactivity is ____ with the transient rod.

a. $\bar{\beta}$

b. $1.50

c. $2.50

d. $3.00

QUESTION B.14 [1.0 point]
Which of the following is the most correct statement regarding the use of the **X-SCRAM Bypass (F1)?**

a. Performing Wide Range Monitor Checks in accordance with SOP-2 does not require express Facility Director's approval.

b. Each time X-Scram Bypass (F1) is to be used, the Reactor Operator must have the express Facility Director's approval.

c. If you are performing a CCP with the reactor at power which requires X-Scram Bypass (F1), the Reactor Operator must have the express Facility Director's approval before proceeding.

d. If you are handling highly radioactive samples by the pool deck during reactor power operations, X-Scram Bypass (F1) may be authorized by the Facility Director for up to 1 minute in order to preclude an inadvertent scram from an evacuation signal.

QUESTION B.15 [1.0 point]
Complete the following statement:

It is permissible to move the secured reactor when it is not coupled to an experimental facility assuming the reactor is not moved closer than _________ to any object, unless a closer proximity is allowed by the _______________.

a. 1 foot, approved experiment authorization

b. 2 feet, Limiting Condition for Operation in PSBR Technical Specifications

c. 4 feet, Duty Shutdown Reactor Operator authorization

d. 10 feet, Limiting Safety Setting in PSBR Technical Specifications

QUESTION B.16 [1.0 point]
What is the dose rate after shielding a Cs-137 source that emits 1 MeV photons if the unshielded dose rate is 100 mrem/hr and the source is shielded by ½ inch lead? Given:

Density: 11.35 g/cm^3
Mass Attenuation Coefficient: 0.0708 cm^2/g

a. 13.3 mrem/hr

b. 36.2 mrem/hr

c. 50.0 mrem/hr

d. 91.4 mrem/hr

QUESTION B.17 [1.0 point]
According to 10 CFR 20, the NRC requires that workers exceeding what percentage of the annual dose limit be monitored (i.e., issued dosimetry) for radiation exposure?

a. 5%

b. 10%

c. 20%

d. 50%

QUESTION B.18 [1.0 point]
In the event of a suspected fuel leak from a 30/20 TRIGA element, which of the following nuclides would most likely be found in an **Air Particulate** Sample?

a. Cs-138

b. Rn-226

c. Xe-133

d. Co-60

QUESTION B.19 [1.0 point]
The PSBR facility pool wall is breached and there is significant leakage, resulting in the lowering of pool level at a rate of 1 cm/minute. Which of the following is the greatest issue/concern as a result of this event?

a. Overheating the TRIGA fuel, resulting in clad failure and fission product release

b. Overheating the TRIGA fuel, resulting in Zirconium-Hydride reaction which releases explosive hydrogen gas

c. Groundwater contamination to the surrounding water table

d. Increased personnel exposure to higher amounts of radiation

QUESTION B.20 [1.0 point]
You are manually increasing power from 10 W to 1 MW on the regulating rod. At what power level would the Fuel Doppler Effect likely become first evident?

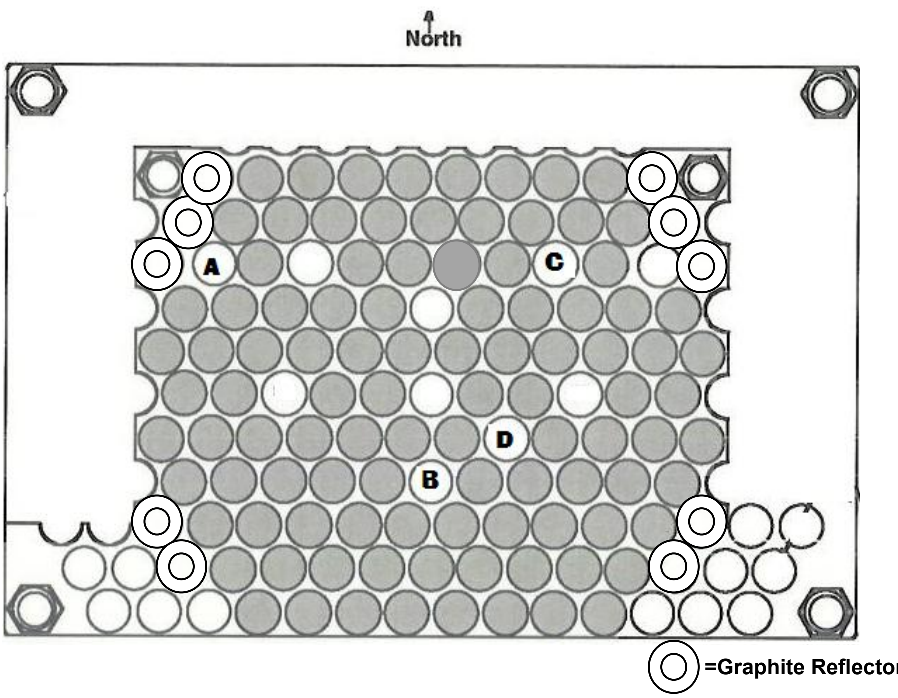
a. 100 W

b. 1 kW

c. 100 kW

d. 900 kW

QUESTION C.1 [1.0 point]
Using the following cross section of the PSBR core match the letter (i.e., A through D) with the correct component (i.e., 1 through 11) from the right column? (NOTE: You are **NOT** matching a grid position)



1. Safety Control Rod
2. Shim Control Rod
3. Regulating Rod
4. Transient Control Rod
5. Central Thimble
6. Instrumented Fuel Element 15
7. Instrumented Fuel Element 16
8. Pneumatic Transfer System
9. Neutron Startup Source
10. Dry Tube Irradiator 1
11. Dry Tube Irradiator 2

a. A-8; B-5; C-9; D-6

b. A-10; B-1; C-11; D-9

c. A-10; B-4; C-9; D-7

d. A-2; B-5; C-6; D-3

QUESTION C.2 [1.0 point]
Which of the following is considered the principal biological shield for the PSBR reactor?

a. The concrete pool wall

b. The N-16 diffuser pump

c. The reactor pool water

d. The fuel cladding

QUESTION C.3 [1.0 point]
What is the basis for the safety limit “a standard TRIGA fuel element shall not exceed 1150°C under any condition of operation”?

a. This limit is set to prevent exceeding conditions for fuel melt

b. Prevents the element “warping” from high temperatures experienced during pulsing operations.

c. Avoids “ballooning” effects and possible failure of the fuel element cladding from hydrogen gas during the dissociation of zirconium hydride

d. Precludes temperatures which are favorable for hydrogen embrittlement of the fuel cladding

QUESTION C.4 [1.0 point]
The following reaction ($^{10}B + {}^{1}_{0}n \rightarrow {}^{7}_{3}Li + \alpha$) can best be found in the ____________

a. Biological Shield

b. Reflector

c. Power range nuclear instrumentation

d. Regulating Rod

QUESTION C.5 [1.0 point]
Which of the following is an **INCORRECT** statement regarding the instrumentation and control systems at the PSBR?

a. The RSS is designed to provide all reactor protection, control and monitoring functions necessary for safe operation.

b. DCC-Z is the monitoring computer and does not perform any control actions.

c. The RSS is completely hardwired and does not contain any software programmable devices or actuation functions.

d. The PCMS will fail conservatively if the watchdog is not reset.

QUESTION C.6 [1.0 point]
Which of the following best describes the status of the control rods in the “2 Rod Auto” mode?

a. Shim and transient rods banked for automatic control and the safety rod “shimmed”

b. Shim and regulating rods banked for automatic control and the safety rod “shimmed”

c. Regulating and safety rods banked for automatic control and the shim rod “shimmed”

d. Regulating, shim, and safety rods banked for automatic control and no “shimming” rod

QUESTION C.7 [1.0 point]
Which of the following events would most likely lead to a reactor stepback at the PSBR?

a. N-16 diffusion pump failure at 250 kW

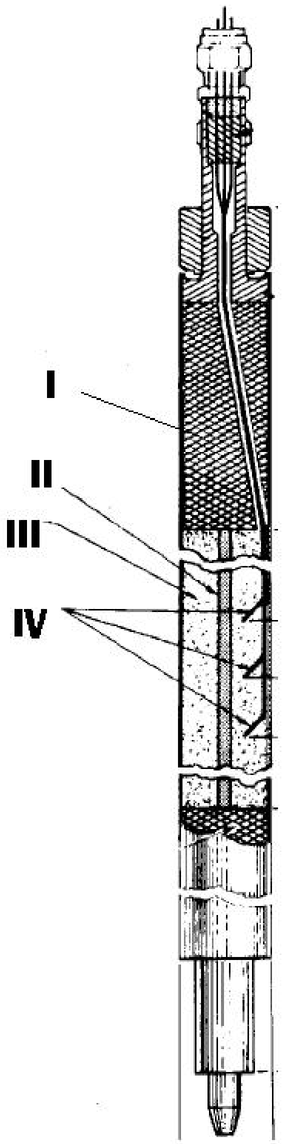
b. Instrumented fuel element temperature reading of 505°C

c. A wide range power level indication of 500 kW with a power range indication of 150 kW

d. Level of the reactor pool drops to 20 feet

QUESTION C.8 [1.0 point]
Using the associated diagram of an instrumented fuel element match the correct position locator (Column A) to the correct component (Column B).

Column A	Column B
I	A. Zirconium Hydride-Uranium
II	B. Stainless steel
III	C. Erbium Burnable Poison
IV	D. Graphite Reflector
	E. Zirconium Rod
	F. Spacer
	G. Thermocouples



a. I.A, II.E, III.C, IV.G

b. I.D, II.G, III.A, IV.F

c. I.D, II.E, III.A, IV.G

d. I.C, II.A, III.B, IV.G

QUESTION C.9 [1.0 point]
When the reactor is moved against the D_2O tank there is a substantive increase in the shutdown or standby wide range channel reading due to….

a. increased fission from the fissile material in the D_2O tank

b. greater neutron absorptive capture in D_2O than H_2O which subsequently releases more capture gammas

c. the activity of an experiment in the beamhole laboratory that increases the reactor period, producing a change on the order of 10% of the indicated power level

d. greater neutron reflection back into the core

QUESTION C.10 [1.0 point]
Which of the following may be a likely result from a Reactor Pool Level Low (1) alarm?

a. A call or visit from the Penn State University Police Service

b. The N-16 pump will automatically trip

c. The reactor will scram

d. A rod withdrawal inhibit will be locked in until the condition clears

QUESTION C.11 [1.0 point]
With regards to the regulating control rod, which of the following is **NOT** a DCC-X indication the reactor operator has at the PSBR control panel?

a. When the rod is in the DOWN position

b. When the rod is in the UP position

c When the drive is in the UP position

d. When the drive is in the DOWN position

QUESTION C.12 [1.0 point]
Which of the following is (are) considered the Engineered Safety Feature at the PSBR?

a. The reactor overpower trip

b. The primary heat exchanger

c. The emergency exhaust system

d. The emergency fill connection from the city water supply

QUESTION C.13 [1.0 point]
The purpose of the PSBR's N-16 pump is to……..

a. Provide assistance with natural circulation through the reactor core

b. Reduce radiation levels at the pool surface

c. Sweep away fission products in order to prevent them from reaching the pool surface

d. Take a suction on the primary pool and discharge it to the purification system to remove activated impurities

QUESTION C.14 [1.0 point]
You are performing a radiation survey around the reactor pool using a Geiger Mueller detector. Which of the following is a **disadvantage** of using this type of detector?

a. It is sensitive to light

b. It is unable to electronically discriminate different types of radiation

c. It has a separate alpha and beta plateau curve which must be accounted for

d. It has a short resolving time when detecting radiation

QUESTION C.15 [1.0 point]
Which one of the following will initiate a Reactor Scram AND a Reactor Operation Inhibit?

a. High Radiation Co-60 Lab Monitor

b. High pool temperature.

c. Reactor Bay Truck Door open.

d. Both East and West Bay Radiation Trips defeated.

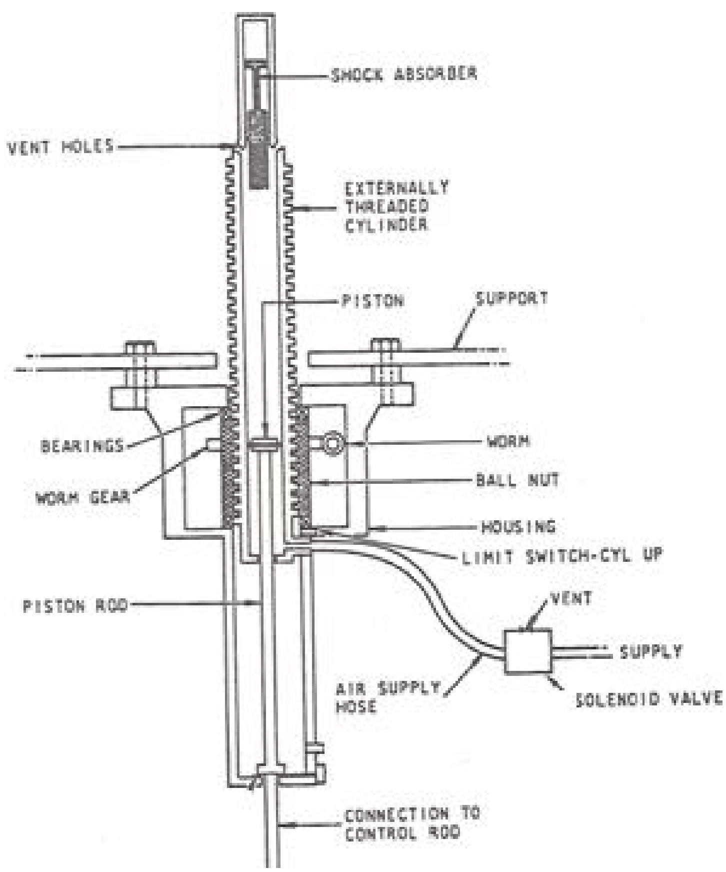
QUESTION C.16 [1.0 point]
Using the associated diagram, which of the following answers best describes a correct functional process of the transient rod drive mechanism and its associated components?

a. The transient rod is raised or lowered by air supplied through a solenoid valve which turns a belt/ball-nut drive that drives the externally threaded cylinder up or down.

b. If power is de-energized to the solenoid valve, the air supply valve shuts and the pressure in the cylinder relieves through vent holes at the top of the cylinder

c. The ball-nut assembly is rotated by a ~~worm gear driven~~ (belt driven) motor thereby raising or lowering the cylinder independently of the piston and control rod.

d. Adjustments to the air supply pressure and shock absorber height controls the upper limit of piston travel and hence controls the amount of reactivity inserted for a pulse or square wave.



QUESTION C.17 [1.0 point]
The purge gas for the pneumatic transfer system is…..?

a. Compressed air

b. Compressed Nitrogen

c. Compressed CO_2

d. Compressed Argon

QUESTION C.18 [1.0 point]
Which of the following components/systems at the PSBR would you most likely find tritium during normal operation?

a. D_2O tank

b. Ion exchange resin

c. TRIGA Fuel

d. Continuous Air Monitor

QUESTION C.19 [1.0 point]
Which of the following sources of electrical power is considered a limiting condition for operation (LCO) in PSBR Technical Specifications when the reactor is secured?

a. University Power Supply

b. Diesel Generator

c. Uninterruptable Power Supply (UPS)

d. There is no LCO which require any of the above components when the reactor is secured.

QUESTION   C.20 [1.0 point]
When energized, flow through the Emergency Exhaust System is verified by:

a. a DCC-X message indicating “Emerg Ventilation Flow On”.

b. the Absolute Filter pressure gauge reads 0.2 inches H_2O.

c. the red power-on light on the Cobalt-60 lobby control panel.

d. the red pilot light on the circuit box on the east wall of the reactor bay.

Section A: Reactor Theory, Thermodynamics, and Facility Operating Characteristics

Question:

A.1
Answer: b
Reference: Reactor Theory (Neutron Characteristics) DOE-HDBK-1019/1-93 PROMPT AND DELAYED NEUTRONS

A.2
Answer: d
Reference: Bevelacqua, J. 2009. *Basic Health Physics*. p.391

A.3
Answer:c
Reference: PSBR Training Manual, Chapter 1.8 “Bremstrahlung and Cerenkov Effect”

A.4
Answer: b
Reference: Question ID #P1766, ***NRC Generic Fundamentals Examination Question Bank—PWR2010***

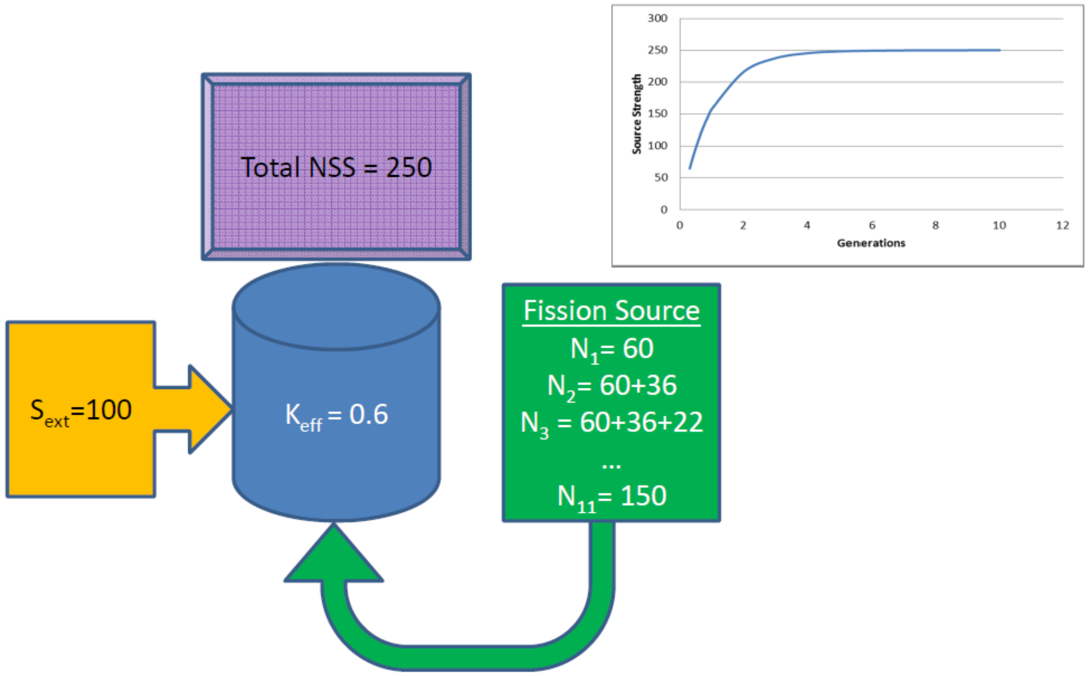
A.5
Answer: b and d (based on facility comment)

$$\frac{CR_1}{CR_2} = \frac{1-k_2}{1-k_1}$$

If CR_2 is twice CR_1, then to be equal, (1-$Keff_2$) must be half of (1-$Keff_1$).

Reference.
DOE Handbook, Vol 2, Section 2.0

Additional Reference Material (Supplied by PSBR)



Total Neutron Source Strength = S_{ext} + $S_{fission}$

S_{ext} is constant, $S_{fission}$ increases from 60 to 150 as the system reaches equilibrium as t → ∞, NSS → 250, the equilibrium value at which the NSS is constant over time.

A.6
Answer: c
Reference: PSBR Training Manual, Chapter 2.22

A.7
Answer: d
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.8
Answer: a
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.9
Answer: d

Ref: From point A to B, reactor period is negative, and since $Pf=Poe^{\frac{t}{T}}$, power will continue to decrease.
DOE Manual Vol. 1, Section 2

A.10
Answer: b

$$\tau = \frac{\ell^*}{\rho} + \frac{\bar{\beta}_{eff} - \rho}{\lambda_{eff}\,\rho + \dot{\rho}}$$
$$\begin{pmatrix}\text{prompt}\\ \text{term}\end{pmatrix} \quad \begin{pmatrix}\text{delayed}\\ \text{term}\end{pmatrix}$$

Neglecting the prompt term and since the reactor was exactly critical; the rate of reactivity in the reactor was zero. Therefore, the inhour equation reduces to the following:

$$\tau = \frac{\bar{\beta}_{eff} - \rho}{\lambda_{eff}\,\rho}$$

Ref: This question can be answered in two ways. One way is through the equations as shown below, or two, use a rule of thumb that if the reactor moves halfway from its subcritical state towards criticality, the count rate will double.

Where,
$\rho(\$)=\rho/\beta$
$p_1=(0.0070)x(\$0.25)= 0.00175$

$\tau = \frac{0.0070-0.00176}{0.1(0.00175)}$ = 30 sec

Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.11
Answer: d
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.12
Answer: a
The decrease in temperature has added 0.392 %ρ of reactivity which must be accounted for by the regulating rod to maintain 200 kW. Therefore, the reg rod must be inserted -0.392 %ρ worth.
Converting -0.392 %ρ to $= $\rho(\$)=\rho/\beta \rightarrow 0.00392/0.0070= -56$ cents
Using the integral rod worth curve, with the reg rod initially at 60% (150 cents), the new rod height at 150 – 56=94 cents **(44% withdrawn).**

Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.13
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.14
Answer: a
Reference:
PSBR Training Manual, Chapter 2 “Principles of Reactor Operation”, p.2

A.15
Answer: a
Reference:
DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.16
Answer: c
$\Delta\$prompt = \rho - \beta$ where β= $1.00 of reactivity
P_1=250 MW
ρ_1=$0.50
$P_2=X_2$=$1.00

$(250\text{ MW})/(0.5)^2=(x)(1)^2= 1000\text{MW}$

Reference: Reactor Physics of Pulsing: Fuchs-Hansen Adiabatic Model
http://www.rcp.ijs.si/ric/pulse_operation-s.html

A.17
Answer: d
Reference: PSU Exam Reference Material, “Exam Questions”, Part A Question #26

A.18
Answer: c.
Reference: PSU Training Manual, Section 2.7 “Critical Mass Experiment”

A.19

Answer: ~~b~~ Answer accepted based on written answer on answer sheet.

~~SDM= TRW+ Excess Reactivity = ($12.67)-($7.29)→$5.38~~
~~MIN SDM= $5.38-$3.90 (most reactive rod)= $1.48~~

SDM = Critical worth – Most reactive Rod worth remaining out of core

SDM = 7.97-3.90 = $4.07

CCP-11
Core Reactivity Evaluation

Control Rod	Total Worth	Critical Worth
Transient	$2.94	$1.81
Safety	$3.90	$2.53
Shim	$2.91	$1.82
Regulating	$2.92	$1.81
Total	$12.67	$7.97

Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2 and* PSU Exam Reference Material

A.20

Answer: b
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

Section B: Normal Emergency Procedures & Radiological Controls

Question:

B.1
Answer: b
Reference: EP-1, “PSBR Emergency Procedure”, Rev. 15

B.2
Answer: d
Reference: NRC Form 3. http://www.nrc.gov/reading-rm/doc-collections/forms/form3_us.pdf

B.3
Answer: d
Reference: AP-5 PSBR TS, Section 2.0

B.4
Answer: a
Reference: AP-5 PSBR TS, Section 6.0

B.5
Answer: a
Reference: 10 CFR 20

B.6
Answer: c.
Reference: 10 CFR 20

B.7
Answer d.
Reference: AP-8 “Radiation Protection Orientation Requirements”

B.8
Answer: c
Reference:10CFR55.53(e)

B.9
Answer: a
Reference: 10 CFR 20

B.10
Answer: a
Reference: EP-6, “Medical Emergencies”

B.11
Answer: b
Reference: PSBR Technical Specifications 3.2.4 (table 2)

B.12
Answer: c
Reference: EP-1 “Emergency Preparedness Plan Implementation”

B.13
Answer: b
Reference: PSBR SOP-1, Rev. 18

B.14
Answer: a
Reference: PSBR SOP-1, Rev. 18

B.15
Answer: a
Reference: SOP-1 “Reactor Operating Procedure”

B.16
Answer: b
Reference: $I = I_{oe^{-\mu x}}$ and $\mu_m = \frac{\mu}{\rho}$
Solving for μ=μ_m x ρ= (0.0708 cm^2/g from table) x (11.35 g/cm^3) = 0.8 cm^{-1}
x = 0.5 inches x 2.54 cm/in = 1.27 cm
$I = 100 mrem/hr_{e^{-(0.8)(1.27)}}$= **36.2 mrem/hr**
Reference: 10 CFR 20

B.17
Answer: b
Reference: 10 CFR 20; Bevelacqua, J. *Basic Health Physics*.

B.18
Answer: a
Reference: PSBR SAR and Operator Training Manual

B.19
Answer: d
Reference: SOP-1 “Reactor Operating Procedure”

B.20
Answer: b
Reference: PSBR Student Training Manual

Section C: Facility and Radiation Monitoring Systems

Question:

C.1
Answer: c
Reference: PSBR SAR Section 4.0 “Reactor Description”

C.2
Answer: c
Reference: PSBR SAR Section 4.3 “Reactor Pool”

C.3
Answer: c
Reference: TS for the PSBR, Section 2.0, November 2009

C.4
Answer: d
Reference: PSBR Training Manual

C.5
Answer: a
Reference: PSBR SAR Section 7.2 “Design of Instrumentation and Control Systems”

C.6
Answer: b
Reference: PSBR SAR Section 7.3 “Reactor Control System”

C.7
Answer: c
Reference: PSBR Training Manual Section B Reactor Pool and Water Systems

C.8
Answer: c
Reference: PSBR Training Manual Chapter 3 “Features of Facility Design Including Safety and Emergency Systems”, Figure 3-5

C.9
Answer: d
Reference: PSBR Training Manual Chapter 5 “General Operating Characteristics”

C.10
Answer: a
Reference: PSBR Training Manual Chapter 4 “Instrumentation and Control”

C.11
Answer: b
Reference: PSBR Training Manual Chapter 4 “Instrumentation and Control”

C.12
Answer: c

Reference: PSBR SAR Section 6.0 “Engineered Safety Features”

C.13
Answer: b
Reference: PSBR Training Manual Chapter 3 “Features of Facility Design Including Safety and Emergency Systems”

C.14
Answer: b
Reference: PSBR Training Manual Chapter 4.6 “Geiger Mueller Detectors”

C.15
Answer: c
Reference: PSBR Training Manual, Chapter 4.20.6.1b

C.16
Answer: c
Reference: PSBR Training Manual Chapter 4.22 “Transient Rod Control”

C.17
Answer: c
Reference: ENNU 320 Vol.2, pg. 5-2

C.18
Answer: a
Reference: PSBR Training Manual Chapter 3.22 “D_2O Tank”

C.19
Answer: d
Reference: PSBR SAR, Section 8, “Electrical Systems

C.20
Answer: a
Reference: PSBR Training Manual Chapter 3.17

Enclosure 4
Facility Review of Written Examination