April 1, 2012

Dr. Donald Wall, Director
Nuclear Radiation Center
Roundtop Drive
Washington State University
Pullman, WA 99164-1300

SUBJECT: EXAMINATION REPORT, NO. 50-027/OL-12-01, WASHINGTON STATE UNIVERSITY

Dear Dr. Wall:

During the week of February 27, 2012, the U.S. Nuclear Regulatory Commission (NRC, the Commission) administered an operator licensing examination at the Washington State University, Nuclear Radiation Center. 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 H. Eads Jr., Chief
Research and Test Reactors Oversight Branch
Division of Policy and Rulemaking
Office of Nuclear Reactor Regulation

Docket No. 50-027

Enclosures:
1. Examination Report No. 50-27/OL-12-01
2. Facility Comments with NRC Resolution
3. Written examination with facility comments incorporated

cc : Mr. Corey Hines, Washington State University

cc: w/o enclosures: See next page

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ADAMS ACCESSION #: ML12102A127 **TEMPLATE #:NRR-074**

OFFICE	DPR/PROB:CE		DIRS/IOLB:LA		DPR/PROB:BC	
NAME	GSchoenebeck		CRevelle		JEads	
DATE	04/04/2012		04/11/2012		04/01/2012	

OFFICIAL RECORD COPY

cc:

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Office of the Governor
Executive Policy Division
State Liaisons Officer
P.O. Box 43113
Olympia, WA 98504-3113

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

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

REPORT NO.: 50-27/OL-12-01

FACILITY DOCKET NO.: 50-27

FACILITY LICENSE NO.: R-76

FACILITY: WSU NRC

EXAMINATION DATES: February 28-29, 2012

SUBMITTED BY: ___________________/RA/_____ ____ _3/31/2012_
Gregory M. Schoenebeck, Chief Examiner Date

SUMMARY:

During the week of February 27, 2012, the NRC administered operator-licensing examinations to (1) Senior Reactor Operator candidate and (3) Reactor Operator candidates. All candidates passed their respective written and/or operating examination(s).

REPORT DETAILS

1. Examiner:
   Gregory Schoenebeck, NRC, Examiner

2. Results:

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

3. Exit Meeting:
   Gregory Schoenebeck, NRC, Chief Examiner
   Corey Hines, Reactor Supervisor

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
FACILITY COMMENTS ON THE WRITTEN EXAM WITH NRC RESOLUTION

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

Answer: d

Facility Comment: The facility stated that the question had caused confusion, where k_{ex} should have been written as k_{eff}. They contend that the information given in the question strictly is not enough to answer the question of what the condition of the reactor should be. The facility has recommended throwing the question out. The facility did not provide a reference to support their comment.

NRC Resolution: This question was taken directly from a scholarly reference[1] text which defines excess reactivity (k_{ex} or Δk) as the amount of reactivity (ρ) by which k_{eff} exceeds 1.000, where if the ρ is > β_{eff},
A reactor with reactivity above 1.007 is said to be prompt critical Lamarsh (2001) states that

The facility provided a copy of the Reed College Training Manual[2] where an excess multiplication factor (Δk) is defined as:

$$\Delta k \equiv k_{\mathrm{eff}} - 1$$

If Δk is > β_{eff} = 0.070, and by rearranging

Keff= 1.0070.

Given Table 9.4 in Chapter 9 of the Reed College Training Manual:

Condition	Name
$0 < k_{\mathrm{eff}} < 1$	Subcritical
$k_{\mathrm{eff}} = 1$	Delayed Critical
$1 < k_{\mathrm{eff}} < \frac{1}{1\ \beta}$	Delayed Supercritical
$k_{\mathrm{eff}} = \frac{1}{1\ \beta}$	Prompt Critical
$\frac{1}{1\ \beta} < k_{\mathrm{eff}} < \infty$	Prompt Supercritical

Table 9.4: Criticality states.

1/(1-β)= 1/(1-0.0070)= 1.0070

Therefore, it can be seen that answer "d" is the most correct for the answers given. Based on the conclusions above and without a scholarly reference from the facility to support their comment, the NRC has rejected this comment

[1] Bevelacqua, J. 2009. *Basic Health Physics.* p. 391
[2] Reed Reactor Facility. 2005. *Training Manual.* pp. 167-168

QUESTION A.5 [1.0 point]
What is β_{eff}?

a. The time required for the reactor power to change by a factor of e

b. The fraction of all fission neutrons that are born as delayed neutrons

c. The fraction of all delayed neutrons which reach thermal energy

d. The fractional change in neutron population per generation

Answer: b

Facility Comment: For the following question, the facility stated that the answers given here are incorrect. The facility stated that "Beta Effective is the fraction of fissions caused by delayed neutrons, not the fraction of delayed neutrons that reach thermal energy, as not all neutrons that reach thermal energy cause fission." The facility did not provide a reference to support their comment. The facility has recommended to throw the question out.

NRC Resolution: The *effective delayed neutron fraction (β_{eff})* is defined as the fraction of neutrons at thermal energies which were born delayed. The NRC has reviewed the question, and determined that β_{eff} was written in error and should have been β which <u>is defined as the fraction of all fission neutrons that are born as delayed neutrons.</u>[3]. The NRC examiner agrees with the facility that the question was misleading and has decided to delete the question.

[3] DOE Fundamentals Handbook Vol. 2. 1993. pp. 103-104

Question A.8 [1.0 point]
A nuclear reactor startup is in progress. Control rod withdrawal was stopped several minutes ago to assess criticality. Which one of the following is the correct set of indications which supports a declaration that the reactor has achieved criticality?

a. Period is stable at ∞; source range count rate is stable.

b. Period is stable at 60 sec; source range count rate is stable.

c. Period is stable at ∞; source range count rate is slowly increasing.

d. Period is stable at 60 sec; source range count rate is slowly increasing.

Answer: d

Facility Comment: The facility commented on the following question. The comment is as follows: Strictly speaking, with the information that the question gives, if you are critical and no blades are being moved, then the reactor CR [count rate] and period are stable and at infinity respectively. It is only after you then pull the blade AGAIN that the count rate increases linearly and the period is stable that would indicate that you *were* at critical. The facility recommended that both a and d be accepted as correct answers. The facility did not provide a reference to support their comment

NRC Resolution: This particular question comes from PWR GFE question P2968 (and is similar to P66 and P868) and is based solely on operator indications. The issue is being able to differentiate between steady indicated power due to subcritical multiplication and the same indication when the reactor is exactly critical. With a neutron startup source installed and by waiting between rod withdrawal increments during a reactor startup, the neutron population is allowed to increase through subcritical multiplication. Subcritical multiplication is the process where source neutrons are used to sustain the chain reaction in a reactor with a multiplication factor (keff) of less than one. The chain reaction is not "self-sustaining," but if the neutron source is of sufficient magnitude, it compensates for the neutrons lost through absorption and leakage. This process can result in a constant, or increasing, neutron population even though keff is less than one[4]. While answer “a” may technically describe a *critical* reactor, it also describes the condition of the reactor while in the *subcritical* state. Without being able to definitively assess the reactor *exactly critical*, the only real way is to say that the condition of the reactor is definitely *not subcritical* is by the operator’s indications for the condition of a slightly *supercritical* reactor. Therefore, answer “d” is the most correct answer in this instance.

Based on this conclusion and without a scholarly reference from the facility to support their comment, the NRC has rejected this comment to accept “a” and “d” as correct answers; “d” remains the correct answer for this question.

[4] DOE Fundamentals Handbook Vol. 2. 1993. Module 4: Reactor Theory (Reactor Operations) pp.83-128

QUESTION A.11 [1.0 point]
Which of the following statements is the most correct regarding why reactor power is controllable during a positive reactivity insertion?

a. Fission poisons (e.g., Xe and Sm) immediately add negative reactivity and slow the rise in power

b. Inherent temperature feedback mechanisms from the moderator immediately increases the reactor period and turns power

c. If the reactivity addition is ≥ β_{eff} the reactor will safely have increased neutron production that balances neutron losses and increases the neutron population

d. The rate of change of power cannot increase any more rapidly than the built-in time delay the precursor half-lives (λ) allow

Answer; d

Facility Comment: The facility commented that it was unclear if the question means during steady state or pulsing reactivity insertion. For pulsing operations, “b” is the correct answer, and for steady state, both b and d are correct. The facility recommended to accept both “b” and “d” as correct answers.

NRC Resolution: The NRC examiner reviewed the comment and determined that it does not understand the basis for accepting “b” as an increase in moderator temperature does not increase reactor period; a turn (i.e., reduction) in power would imply a decreasing or negative period. The question is a test of the operator’s ability to understand what makes a reactor controllable, the basis of which is governed by the following equations taken from the facility training manual which relate period and reactor power[5].

$$P(t) = P(0)e^{t/T}$$

$$\rho = \frac{\ell^{\star}}{T} + \frac{\beta_{\text{eff}}}{1 + \lambda_{\text{eff}} T}$$

Based on the conclusion above and without a scholarly reference from the facility to support their comment, the NRC has rejected this comment to accept “b” and “d” as correct answers; “d” remains the most correct answer for this question.

[5] Reed Reactor Facility. 2005. *Training Manual.* pp. 155-168

QUESTION B.1 [1.0 point]
You are the reactor operator on duty and are gathering the data required for the determination of core shutdown margin in accordance with SOP-4. Given the associated rod/blade worth curves in the **List of Figures Section** of this exam, calculate the shutdown margin given the following information:

Control Element No.	**1**	**2**	**3**	**4**	**5**
Critical Position (inches)	6.60	6.61	15.12	6.60	11.05

a. -$2.01

b. -$2.07

c. -$2.11

d. -$2.20

Answer: b

Facility Comment: The facility made the comment that the reactivity worth for the critical rod height should be given as it is difficult if not impossible to estimate to the accuracy required in the answers.

NRC Resolution: The NRC examiner has reviewed the question and determined that the facility has raised a valid concern. The NRC examiner has deleted this question. Question B.1 is deleted.

QUESTION C.9 [1.0 point]
Identify which of the following would be a correct, expected response if radiation levels at the reactor bridge exceed the preset high radiation level?

a. There will be a control blade inhibit signal will occur, preventing the outward travel of control blades

b. The ARIES system will automatically lineup the electrical distribution to power selected system components.

c. The diffuser pump will start automatically

d. The cooling tower will secure automatically

Answer: d

Facility Comment: The facility states that the question is essentially asking what happens during a scram condition (high radiation causing the scram), and thus both a and d are correct. During a scram condition the console will not allow the operator pull control elements or turn on the cooling tower until a scram reset is performed. The facility did not provide a reference to justify their comment. The facility recommends to count both “a” and “d” as correct answers.

NRC Resolution: The NRC examiner has reviewed the comment and determined that “a” was not the most correct, expected reactor system response when radiation levels at the reactor bridge exceeded the preset high radiation level. The most correct answer “d” comes from the page 5-10 of the facility Safety Analysis Report (SAR), “the pumps and cooling tower shut down automatically upon excessive radiation levels over the pool or upon building evacuation.” The question **never indicated that a reactor scram occurred**, only that excessive radiation levels existed over the pool.

Answer “a” is a distracter pertaining to the rod inhibit signals listed in the facility supplied SAR[6] which tests the operators’ knowledge (e.g., low count rate, <2 cps on Startup Channel, pulsing above 1 kW, etc.) to see if they were aware that there is not a control blade withdrawal inhibit signal that comes in when rad levels exceed a preset value.

Based on the conclusion above and without a scholarly reference from the facility to support their comment, the NRC has rejected this comment to accept “a” and “d” as correct answers; “d” remains the correct answer for this question.

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[6] WSU SAR. June 2002, Sections 7.3.1 and 13.1.2

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

FACILITY: WASHINGTON STATE UNIVERSITY

REACTOR TYPE: POOL TYPE, MODIFIED TRIGA

DATE ADMINISTERED: 2/ 28 /2012

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

Enclosure 3

Section A: ReactorTheory, Thermodynamics & Facility Operating Characteristics

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 __

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

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 __

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 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 ___	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 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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

1 kg = 2.21 lbm

1 Horsepower = 2.54 x 10^3 BTU/hr

1 Mw = 3.41 x 10^6 BTU/hr

1 BTU = 778 ft-lbf

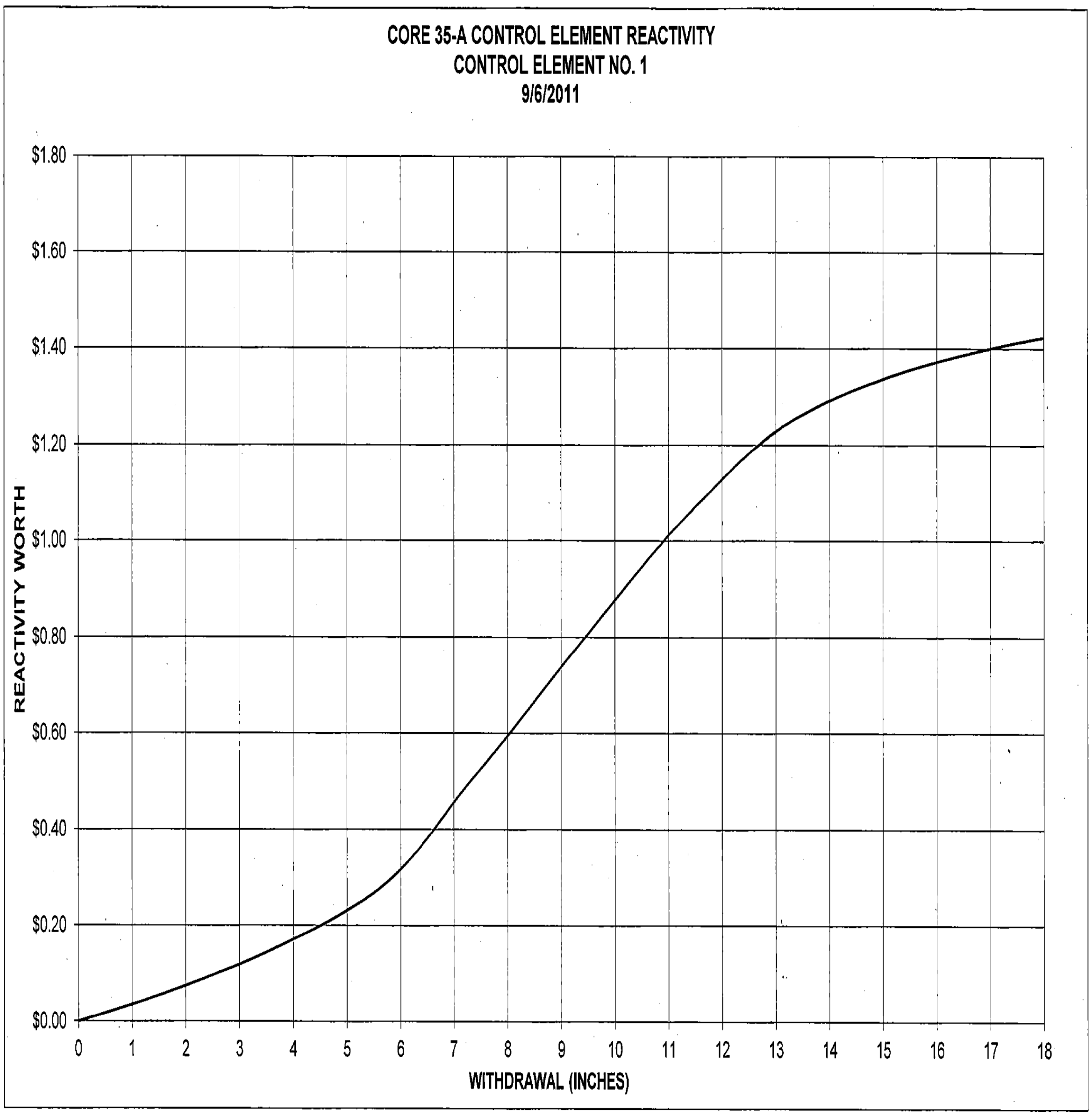
°F = 9/5 °C + 32

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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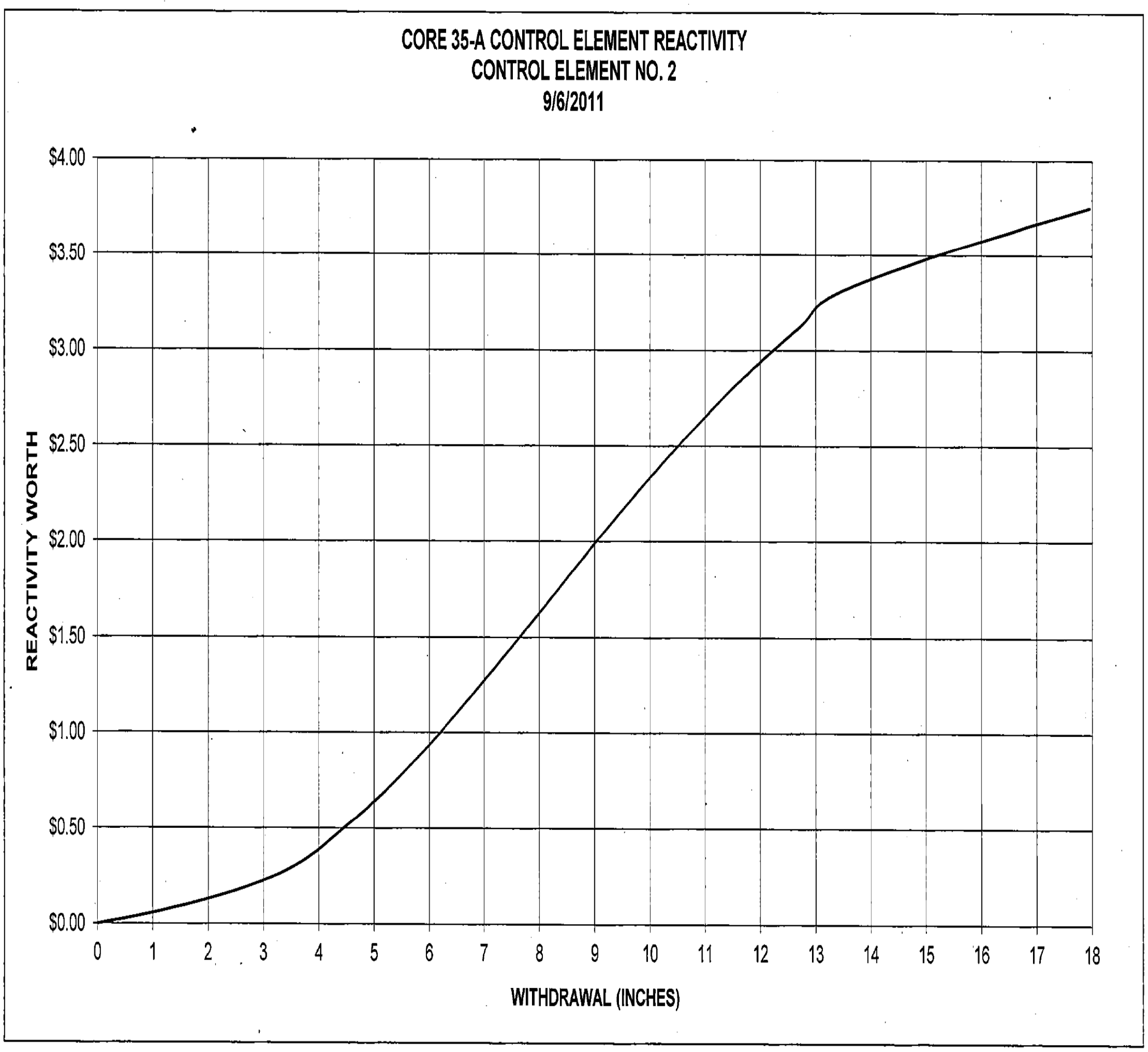
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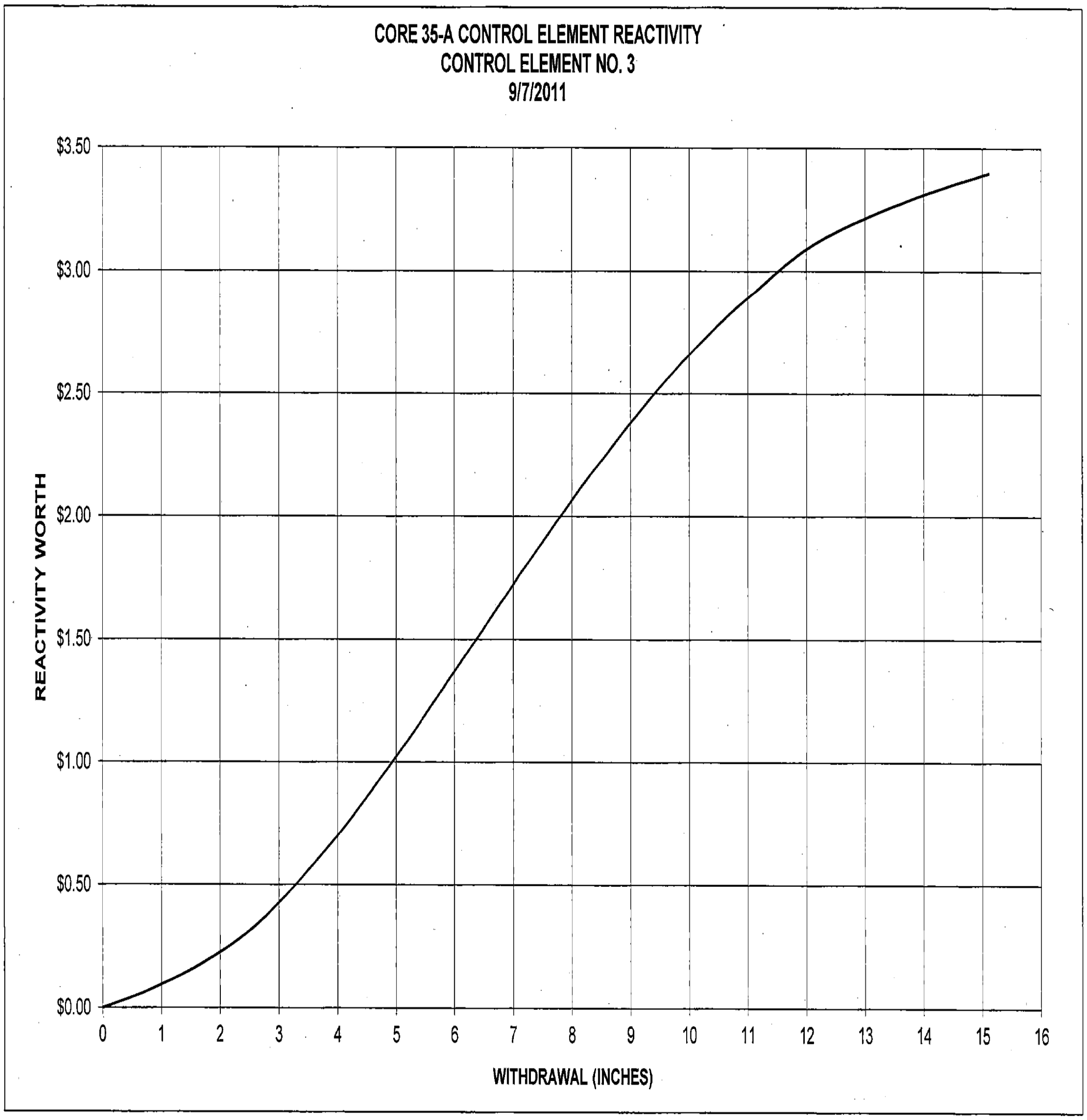
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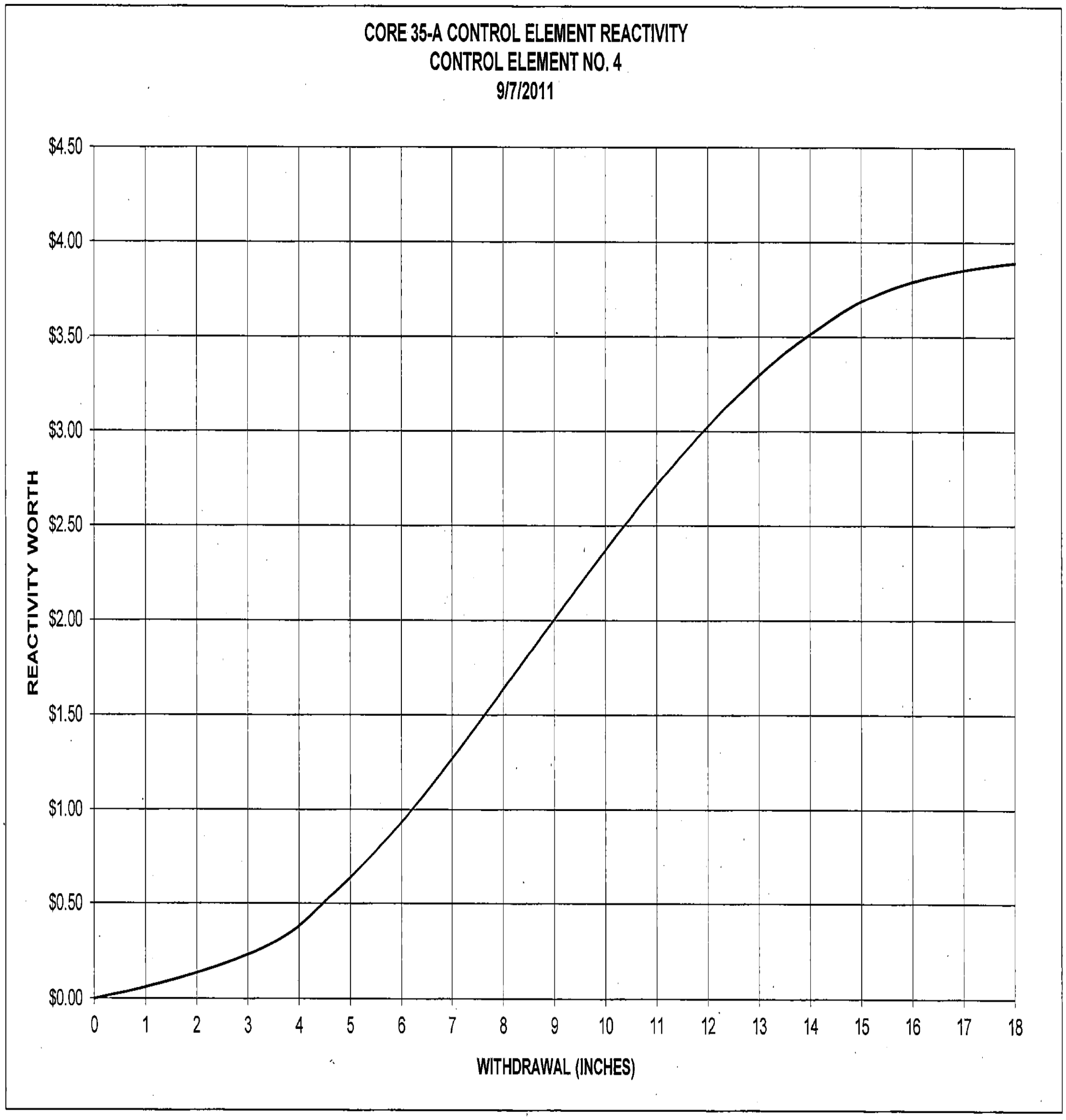

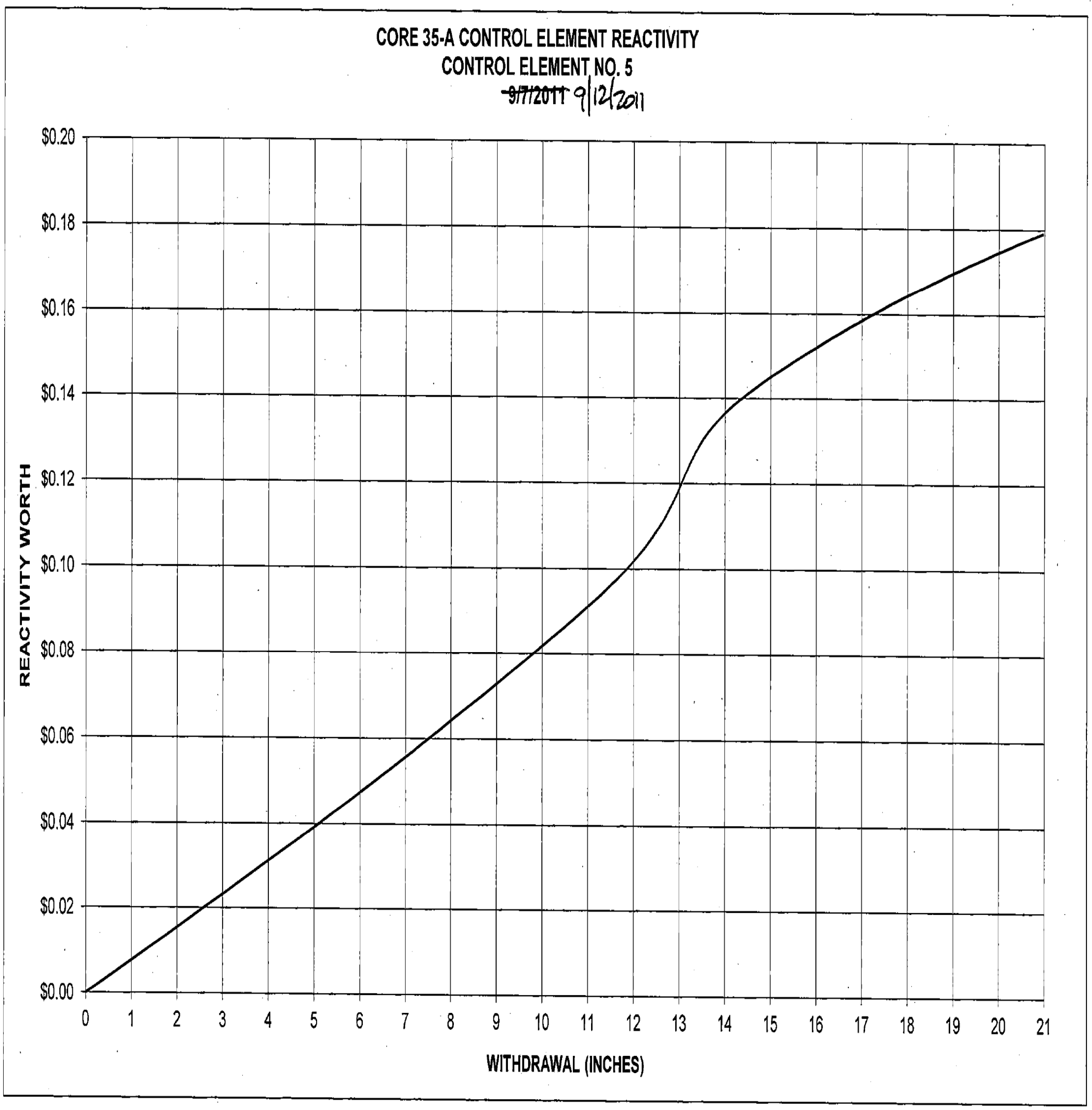
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WITHDRAWAL (INCHES)

List of Figures

QUESTION A.1 [1.0 point]
The following shows part of a decay chain for the radioactive element Radon (Rn). This decay chain is a good example of ___ decay.

$$^{222}_{86}Rn \xrightarrow{3.8\text{ d}} {}^{218}_{84}Po$$

a. Alpha

b. Beta

c. Gamma

d. Neutron

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

e. Subcritical

f. Critical

g. Within its shutdown margin requirements

h. Prompt critical

QUESTION A.3 [1.0 point]
Which of the following is the most penetrating form of radiation?

a. Alpha

b. Beta

c. Gamma

d. Neutron

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]~~ Deleted
What is β_{eff}?

a. The time required for the reactor power to change by a factor of e

b. The fraction of all fission neutrons that are born as delayed neutrons

c. The fraction of all delayed neutrons which reach thermal energy

d. The fractional change in neutron population per generation

QUESTION A.6 [1.0 point]
The following data was obtained during a nuclear reactor startup:

Control Rod Units Withdrawn	Source Range Count Rate (cps)
0	20
10	25
15	28
20	33
25	40
30	50

Assuming a uniform differential control rod worth, at what approximate control rod position will criticality occur?

a. 66 to 75 units withdrawn

b. 56 to 65 units withdrawn

c. 46 to 55 units withdrawn

d. 35 to 45 units withdrawn

QUESTION A.7 [1.0 point]
According to the WSU SAR the predominant and most significant effect that pulsing has on the reactor and/or its associated components is?

a. Higher personnel dose associated with an increase in neutron flux

b. Higher general area radiation levels associated with higher concentrations of Nitrogen-16

c. Radial differential expansion in the middle region of a new, unpulsed fuel rod

d. Uneven control blade temperatures in the core region that will cause axial strain and subsequent warping over time.

QUESTION A.8 [1.0 point]
A nuclear reactor startup is in progress. Control rod withdrawal was stopped several minutes ago to assess criticality. Which one of the following is the correct set of indications which supports a declaration that the reactor has achieved criticality?

a. Period is stable at ∞; source range count rate is stable.

b. Period is stable at 60 sec; source range count rate is stable.

c. Period is stable at ∞; source range count rate is slowly increasing.

d. Period is stable at 60 sec; source range count rate is slowly increasing.

QUESTION A.9 [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.10 [1.0 point]
You are by the pool deck in the reactor facility conducting a tour when someone from the group asks what the “blue glow” is around the reactor core 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 water 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.11 [1.0 point]
Which of the following statements is the most correct regarding why reactor power is controllable during a positive reactivity insertion?

a. Fission poisons (e.g., Xe and Sm) immediately add negative reactivity and slow the rise in power

b. Inherent temperature feedback mechanisms from the moderator immediately increases the reactor period and turns power

c. If the reactivity addition is ≥ β_{eff} the reactor will safely have increased neutron production that balances neutron losses and increases the neutron population

d. The rate of change of power cannot increase any more rapidly than the built-in time delay the precursor half-lives (λ) allow

QUESTION A.12 [1.0 point]
Which of the following is a correct definition for reactivity (p)?

a. It is the departure from criticality

b. It is the time required for power to change by a factor of “e”

c. It is the ratio of axial power distribution to active fuel height

d. It is the fraction of all fission neutrons that are born as delayed neutrons

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]
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.15 [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

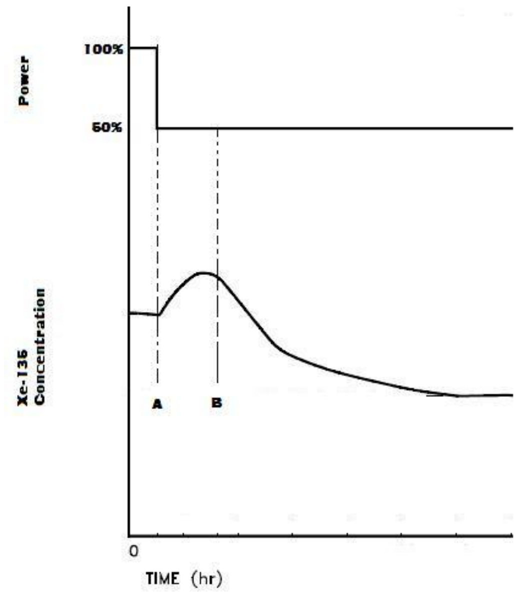
a. 18

b. 30

c. 38

d. 50

QUESTION A.16 [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.17 [1.0 point]
A nuclear reactor is subcritical with a startup in progress. Which one of the following conditions will result in a critical rod position that is lower than the estimated critical rod position?

a. A malfunction with the rod control system, where the withdrawal speed is <u>faster</u> than its typical setting

b. A malfunction with the rod control system, where the withdrawal speed is <u>slower</u> than its typical setting

c. The temperature of the secondary water supply has dropped 10 C since the last reported startup

d. A student carrying a sample containing 100 ppm boron inadvertently drops it into the pool (assume uniform dispersion)

QUESTION A.18 [1.0 point]
You are the reactor operator and are holding at an initial power level of 200 Watts. You have been asked to increase power to 10 kilowatts (kW) in preparation for a sample irradiation. In 3 minutes you would have reached 10 kW on a steady, ____ reactor period.

a. 3.6 sec

b. 12 sec

c. 46 sec

a. 60 sec

QUESTION A.19 [1.0 point]
TRIGA reactor fuel has a unique feature known as a prompt negative temperature coefficient. Which of the following best describes this unique feature that is the dominant form of negative reactivity in a TRIGA core?

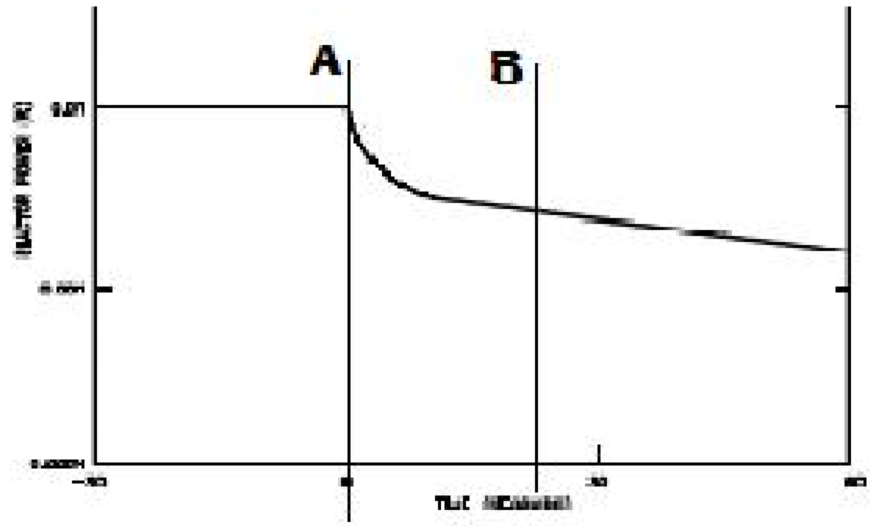
a. As the fuel heats up the resonance absorption peaks broaden and increases the likelihood of absorption in U-238 and/or Pu-240

b. As the fuel heats up a rapid increase in moderator temperature occurs through conduction and convection heat transfer mechanisms which adds negative reactivity

c. As the fuel heats up fission product poisons (e.g., Xe) increase in concentration within the fuel matrix and add negative reactivity via neutron absorption

d. As the fuel heats up the oscillating hydrogen in the ZrH lattice imparts energy to a thermal neutron, thereby increasing its mean free path and probability of escape

QUESTION A.20 [1.0 point]
The associated diagram depicts the profile of **reactor power (Y-axis) vs. time (X-axis)** 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]~~ **DELETED**
You are the reactor operator on duty and are gathering the data required for the determination of core shutdown margin in accordance with SOP-4. Given the associated rod/blade worth curves in the **List of Figures Section** of this exam, calculate the shutdown margin given the following information:

Control Element No.	**1**	**2**	**3**	**4**	**5**
Critical Position (inches)	6.60	6.61	15.12	6.60	11.05

e. -$2.01

f. -$2.07

g. -$2.11

h. -$2.20

QUESTION B.2 [1.0 point]
Which of the following would you must likely find on an NRC Form 3 "Notice to Employees"

a. A summary of operations for the year that include (not limited to): changes in facility design, experiments performed, and radioactive effluents released or discharged to the environment.

b. The requirements for when a Senior Reactor Operator is to be present at the facility

c. Occupational dose limits and radiation dose limits for individual members of the public

d. Guidance for how to report an unsafe activity or an activity which deliberately violates a license condition at the Washington State University NRC.

QUESTION B.3 [1.0 point]
A Limiting Condition for Operation (LCO) at the WSU TRIGA for pulsing operation is for the maximum reactivity inserted during pulse mode operation is to ensure the peak fuel temperature in any fuel rod does not exceed 830 °C. Which of the following is the most correct statement regarding the basis for this LCO?

a. The temperature limit as read by the instrumented fuel element prevents catastrophic fuel melt and cladding failure from excessive core temperatures.

b. When the temperature of the instrumented fuel element reaches the setting of 880°C, a reactor scram will occur to prevent exceeding the safety limit, thus there is a safety margin of 50°C

c. The temperature limit ensures that minimum departure from nucleate boiling is not exceeded during the pulse, ensuring that an adequate margin exists on the cladding surface for heat transfer

d. It is the optimal temperature for reducing the pressure buildup of H_s gas, thereby reducing the overall swelling and distortion of the cladding and entire fuel rod

QUESTION B.4 [1.0 point]
According to facility Technical Specifications, which one of the following at the WSU Nuclear Radiation Center would most likely be considered a reportable occurrence?

a. A tornado hits the University, causing a campus wide loss of electricity

b. A pneumatic sample is loaded in the core, which causes an unexplained change in a $1.50 worth of reactivity.

c. An anonymous phone caller informs you that he has witnessed people smuggling irradiated material out of the facility and into unmarked vans

d. The reactor it temporarily left unattended for five minutes while it is in an unsecured condition

QUESTION B.5 [1.0 point]
Which of the following types of events is considered an Unusual Event (Class 1 Emergency) at the WSU Nuclear Radiation Center?

a. An explosion that occurs at the reactor bay loading dock

b. An earthquake that causes structural damage to the confinement structure

c. Transient rod stuck in the UP position

d. An individual enters a high radiation area without wearing dosimetry

QUESTION B.6 [1.0 point]
What is the annual adult occupational dose limit to the whole body?

a. 5 mrem

b. 500 mrem

c. 2 rem

d. 5 rem

QUESTION B.7 [1.0 point]
_____ are administratively established constraints on equipment and operational characteristics that shall be adhered to during operation of the facility.

a. Limiting conditions for operations (LCOs)

b. Limiting safety system Settings (LSSs)

c. Safety limits (SLs)

d. Surveillance specification requirements

QUESTION B.8 [1.0 point]
How many hours per calendar quarter must you perform the functions of an RO to maintain an active RO or SRO license?

a. 4

b. 5

c. 6

d. 8

QUESTION B.9 [1.0 point]
The term, ALARA, means:

a. As Low As Reasonably Attainable

b. As Little As Reasonably Attainable

c. A Low Ambient Radiation Area

d. As Low As Reasonably Achievable

QUESTION B.10 [1.0 point]
The Nuclear Regulatory Commission requires that workers exceeding what percentage of the annual dose limit be monitored for radiation exposure?

a. 5%

b. 10%

c. 25%

d. 50%

QUESTION B.11 [1.0 point]
You are reviewing the weekly survey records performed by a qualified radiation monitor, who had performed a weekly survey at the Nuclear Radiation Center. If it was determined that there were excessive dose levels existing at the Nuclear Radiation Center, which of the following determinations would be the most correct?

a. Swipe results which measured $1x10^{-4}$ μCi/cm^2 in the radiochem lab

b. 110 mrem/hr in a posted high radiation area

c. 70 mrem/hr in a posted radiation area

d. 20 mrads/hr in a posted radiation area

QUESTION B.12 [1.0 point]
You are leading a tour of the facility for a freshman nuclear engineering class. The reactor is operating at a certain power level where radiation levels at the pool reads 5 mrem/hr by the area monitoring equipment. How long can this group stay before they exceed **<u>their</u>** 10 CFR 20 limit?

a. 100 hrs

b. 20 hrs

c. 1 hr

d. 0.4 hrs

QUESTION B.13 [1.0 point]
Which of the following answers best describes a time when an SRO is **<u>NOT</u>** required to be present at the facility?

a. Any startup after the initial startup of the day

b. Performing a reactor pulse from an initial power level of 500 kW

c. Loading six samples into the vertical rotator tubes with a combined worth of $0.75

d. Shuffling spare fuel in the storage racks adjacent to the reactor core

QUESTION B.14 [1.0 point]
Which of the following examples of experiments would **NOT** be considered an Operational Experiment?

a. Flux wire irradiations that have a dose rate of 30 mrem/hr on contact

b. A reactor power calibration with the pool divider wall installed on the East side of the pool divider

c. Calibrating a control element by a continuous pull method to determine the doubling time

d. Prompt neutron lifetime determination using the pulse method

QUESTION B.15 [1.0 point]
The guidance that discusses how access is specifically maintained at the Nuclear Radiation Center can be found in ___________.

a. Technical Specifications

b. Administrative Procedures

c. 10 CFR 50.59

d. Emergency Plan

QUESTION B.16 [1.0 point]
Which of the following would be considered the most correct method for environmental monitoring at the WSU NRC which satisfies the requirements of 10 CFR 20?

a. Continuous air monitoring for N-16 in the Exhaust Gas Monitoring System

b. Processing highly sensitive thermoluminescent dosimeters (TLDs) placed in unrestricted areas adjacent to the facility

c. Surveillance monitoring of personnel operating around exposure beam ports

d. Performing periodic pool water samples with a high purity germanium (HPGe) detector,

QUESTION B.17 [1.0 point]
The staff has just completed maintenance on a potentially contaminated system. You need to perform a survey to determine if there is any loose contamination in the vicinity that needs removal. Which of the following types of detectors would you most likely use in this instance?

a. Rem Ball

b. Scintillation Detector

c. Geiger Mueller (GM) Detector

d. Ion Chamber

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. Tritium

QUESTION B.19 [1.0 point]
Complete the following statement. Upon the completion of a reactor pulse evolution, the operator would note a value of ______ for the reactor period.

a. 0

b. 5 sec

c. -80 sec

d. ∞

QUESTION B.20 [1.0 point]
The exposure rate measured from a radioactive experiment at 1 foot is 500mrem/hr. What would be the exposure rate at 3 feet from the experiment?

a. 20.2 mrem/hr

b. 55.6 mrem/hr

c. 166.7 mrem/hr

d. 277.8 mrem/hr

QUESTION C.1 [1.0 point]
Which of the following is a correct statement regarding a function of the Wide-range safety channel?

a. Provides a scram signal in the event of the loss of voltage to the power range channels

b. Prevents pulsing the transient rod if the current reactor power (as read by the Reactor Operator) is 5 kW

c. Prevents withdrawal of standard control and regulation elements in pulse mode

d. Provides a scram signal in the event reactor period (as read by the Reactor Operator) is 2 seconds

QUESTION C.2 [1.0 point]
In the event that fuel must be unloaded from the reactor pool, two storage racks in the reactor pool are provided. Which of the following statements correctly identifies an adequate safe storage condition (by TS) of the fuel at the WSU NRC?

a. $K_{eff} = 0.5$

b. $K_{eff} = 1.0$

c. pH of the storage water= 8.0

d. storage water temperature= 60 °C

QUESTION C.3 [1.0 point]
Complete the following statement. “The normal means of de-ionized make-up water is added via a _______ located at (in) _____________.”

a. Solenoid valve, Room 201-C

b. Manual operated valve, Room 101-A

c. Fire hose, reactor pool deck

d. Solenoid valve, the recirculating pump suction

QUESTION C.4 [1.0 point]
You have just completed a power calibration and are comparing the actual and indicated power levels for the uncompensated ion detector. At what difference in reading (i.e., the margin of error) between the indicated and actual is acceptable where **no adjustment** is required?

a. 2%

b. 3%

c. 5%

d. 10%

QUESTION C.5 [1.0 point]
Which of the following control elements at the WSU NRC is considered non-scrammable?

a. Safety Blade #1

b. Safety Blade #2

c. Transient Rod

d. Regulating (control) Rod.

QUESTION C.6 [1.0 point]
The ________ detector for the WSU TRIGA contains a very thin layer of U-235 which provides an input signal to the_________.

a. Compensated Ion Chamber, Linear Power Channel

b. Ion Chamber, Safety Channel 1

c. Uncompensated Ion Chamber, Safety Channel 2

d. Fission Chamber, Log Power Channel

QUESTION C.7 [1.0 point]
You are the reactor operator with the reactor operating steady state full power. Which of the following would best describe the reactor system/ facility response if the boron neutron capture facility's treatment room access door were inadvertently opened?

a. A reactor scram will occur and the core bridge will move to the retracted position

b. The building evacuation alarm will sound, the reactor will scram and the ventilation system will line up for emergency exhaust

c. A BNC lockdown will occur, initiating a control blade withdrawal inhibit and the core bridge will move to the retracted position

d. An alarm displaying the status of the BNCF treatment room access door illuminates and sounds on the control panel, prompting you to manually scram the reactor

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

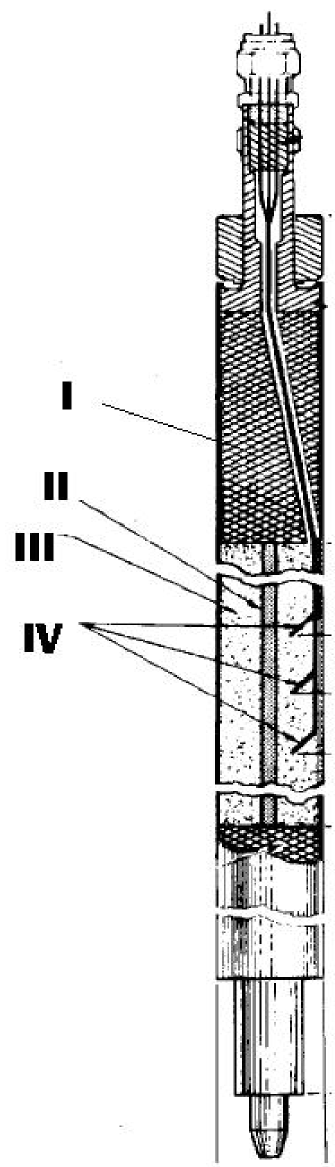
Column A	Column B
I	A. Zirconium Hydride-Uranium
II	B. Stainless steel
III	C. Erbium Burnable Poison
IV	D. Graphite Reflector
	E. Zirconium Rod
	F. Spacer
	G. Thermocouples

a. **I.C, II.F, III.A, IV.C**

b. **I.D, II.A, III.E, IV.C**

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

d. **I.C, II.B, III.E, IV.G**



QUESTION C.9 [1.0 point]
Identify which of the following would be a correct, expected response if radiation levels at the reactor bridge exceed the preset high radiation level?

e. There will be a control blade inhibit signal will occur, preventing the outward travel of control blades

f. The ARIES system will automatically lineup the electrical distribution to power selected system components.

g. The diffuser pump will start automatically

h. The cooling tower will secure automatically

QUESTION C.10 [1.0 point]
Complete the following statement. “During a reactor startup in accordance with SOP #4 if pool water becomes greater than ____, the reactor operator will rundown the reactor the reactor ?”

a. 10 C

b. 25 C

c. 50 C

d. 70 C.

QUESTION C.11 [1.0 point]
The reactor is shutdown and you are assisting the SRO with the pulse rod removal for inspection and subsequent replacement? During this operation, how much (i.e., reactivity) must the reactor be kept subcritical, without xenon, and assuming that any experiment in the reactor may be removed?

a. $2.00

b. $5.00

c $6.00

d. $8.00

QUESTION C.12 [1.0 point]
The main mode of heat transfer for the reactor fuel is from the ___________?

a. Forced cooling of the primary pump

b. Secondary water system

c. Natural circulation of the pool

d. Make up water added to the pool

QUESTION C.13 [1.0 point]
Which of the following statements is correct, regarding a reactor pulse at the WSU NRC?

a. Typically, control blade #1, 2, or 4 is withdrawn to a desired power level of 2 kW

b. The magnitude of the pulse is determined by the anvil height in the rod cylinder

c. When the mode selector switch is positioned to the “Pulse” mode, only the standard control blades are inhibited from being withdrawn.

d. A transient rod scram occurs 20 seconds on a preset timer once the reactor operator initiates the “fire” button

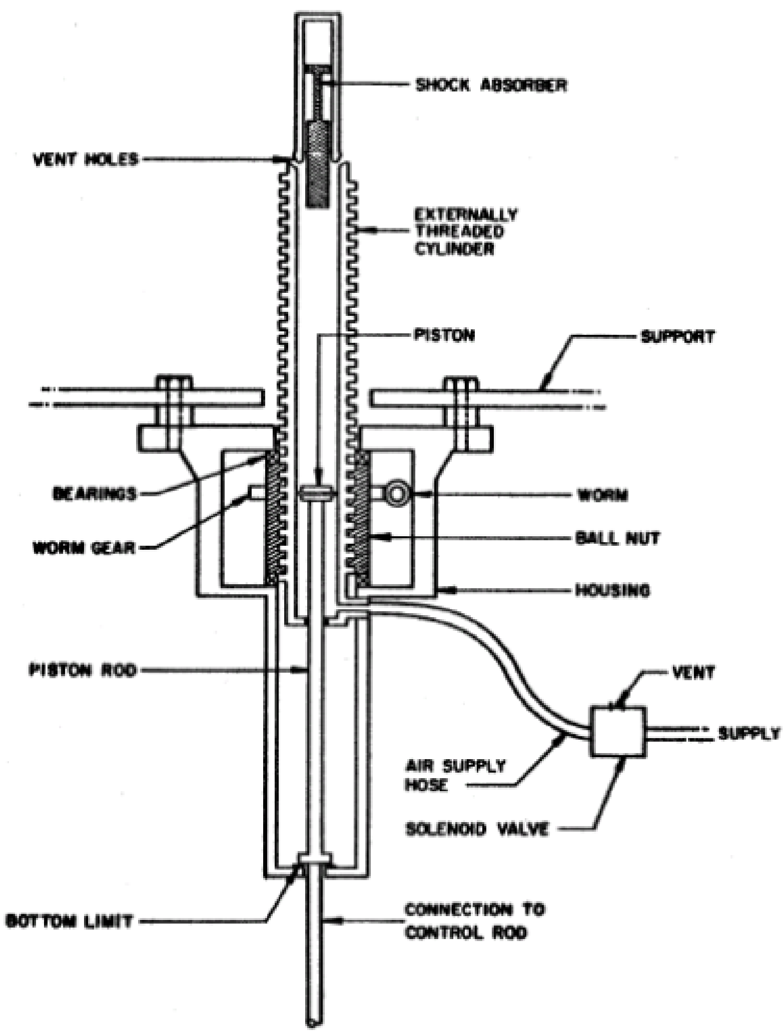
QUESTION C.14 [1.0 point]
Using the associated diagram, which of the following answers best describes a correct functional process of the transient rod drive mechanism and its associated components?

a. Once the transient rod has been pulsed, the three-way solenoid valve is de-energized and the rod is driven to the bottom limit by the worm gear motor and worm assembly.

b. If power is de-energized to the three-way 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 motor thereby raising or lowering the cylinder independently of the piston and control rod.

d. The indicator for the down position of the transient rod is actuated when the small bar attached to the bottom of the air cylinder comes in contact with the down limit switch.



QUESTION C.15 [1.0 point total, 0.125 each]
The Figure of Core 35-A a current layout for WSU NRC's TRIGA core. Given the description of the component (e.g., No. 2 Linear UIC), determine an appropriate grid location (i.e., A1) in the figure.

1) A location you would expect to find a fuel element that contained 8.5% wt percent U-235
Answer:_____

2) A location that you would expect a high temperature scram signal to originate
Answer:_____

3) A location that you would expect an isotope to be produced for well-logging
Answer:_____

4) A location that you would find material that improves neutron economy
Answer:_____

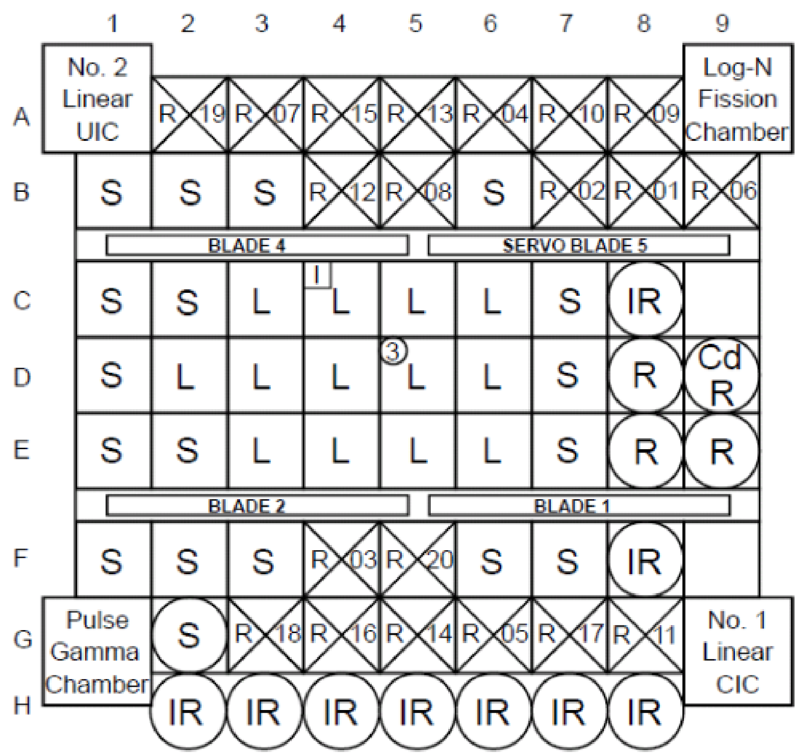
5) A location you would expect to find the neutron startup source
Answer:_____

6) A location you would expect to find the least reactive control element
Answer:_____

7) A location you may find a reactor scram signal originate if power is >125% of licensed power
Answer:_____

8) A location you would most likely expect to find sample irradiations being performed for the purposes of neutron activation analysis
Answer:_____

CORE 35-A



QUESTION C.16 [1.0 point]
The reactor is shutdown and you are the reactor operator assisting the Reactor Supervisor with the installation of a brand new experiment rig being installed into the reactor core. After the rig is installed, the reactor is to be started up to perform full power irradiations. As you are putting the rig into the core, you realize that this is an experiment setup that you have never seen before and you ponder its safety aspects. Which of the following would be the most correct response to determine the safety of the newly installed experimental rig?

a. You could ask the Reactor Supervisor if he had performed Administrative Procedure #3 for a 10 CFR 50.59 determination.

b. You can contact the Nuclear Regulatory Commission to have an inspector assess the experimental rig in accordance with 10 CFR 50.59

c. You can perform the start-up checklist in accordance with SOP#4 to verify that no change in reactor conditions has occurred, satisfying the requirements for a safety evaluation and safe reactor operation

d. You could check to ensure that the experimental rig was approved by the Nuclear Regulatory Commission because ALL changes must be approved prior to making a modification at the facility

QUESTION C.17 [1.0 point]
Which of the following is **NOT** a mode of operation for the pool room and air handling system at the WSU NRC?

a. Normal

b. Isolation

c. Evacuation

d. Dilute

QUESTION C.18 [1.0 point]
If a rupture occurred in the pool water outlet pipe, what would prevent all the water from draining out of the pool?

a. A check valve at the outlet to the primary pump

b. Water from the primary make-up water system

c. A siphon break

d. The minimal elevation difference between the pipe and top of the pool

QUESTION C.19 [1.0 point]
In the event of a loss of power at the WSU NRC, which of the following is a system/component that will be provided power from the ARIES system?

a. Primary pump

b. Beam Room Area Monitor

c. Pool level monitor

d. Irradiation Room (Cave) motion sensors

QUESTION C.20 [1.0 point]
Which of the following alarms/indications WILL directly require a reactor scram?

a. Red HIGH ALARM and light from the Continuous Air Monitor (CAM)

b. Low Pool Water Level

c Alarm on the Exhaust Gas Monitor

d. < 2 cps on the wide range power instrumentation

Question:

A.1
Answer: a
Reference: Nuclides and Isotopes: Chart of the Nuclides. Lockheed Martin 16th Ed.

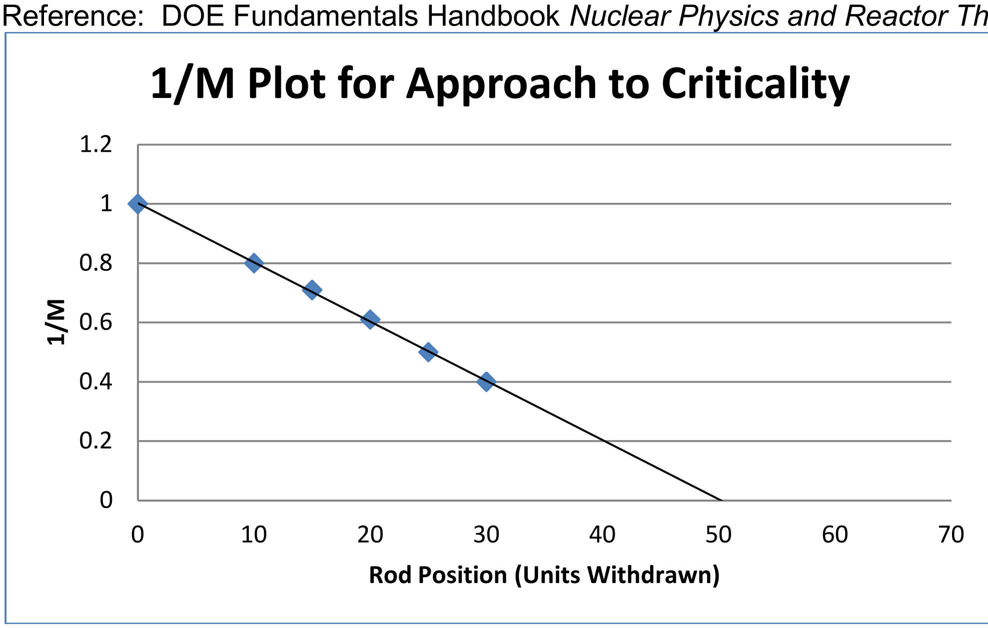
A.2
Answer: d
Reference: Bevelacqua, J. 2009. *Basic Health Physics*. p.391

A.3
Answer: c
Reference: Bevelacqua, J. 2009. *Basic Health Physics*. p.391

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

A.5
Answer: b
Reference.
Effective delayed neutron fraction is the fraction of all delayed neutrons which reach thermal energy.
DOE Handbook, Vol 2, Section 2.0

A.6
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*



A.7
Answer: c
Reference: WSU SAR, Section 6.0 Safety Analysis

A.8
Answer: d
Reference: Question ID #P1766, ***NRC Generic Fundamentals Examination Question Bank—PWR2010***

A.9
Answer: a
DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.10
Answer: c
Reference: Definition of "Bremstrahlung and Cerenkov Effect"

Given the TRW, solving for SDM=
SDM= TRW-Excess Reactivity =($5.05-$1.20)=$3.85
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

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

A.12
Answer: a
Reference:
DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.13
Answer: c
Reference: DOE Manual, Section 3

A.14
Answer: c
Using the formula from the equation sheet:

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

Δ$prompt = ρ - β where β= $1.00 of reactivity
P_1=250 MW
ρ_1=$0.50
P_2=X_2=$1.00

(250 MW)/$(0.5)^2$=(x)$(1)^2$= 1000MW

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

A.15
Answer:
Answer: b

$$\tau = \underbrace{\frac{\ell^*}{\rho}}_{\text{(prompt term)}} + \underbrace{\frac{\bar{\beta}_{eff} - \rho}{\lambda_{eff}\,\rho + \dot{\rho}}}_{\text{(delayed term)}}$$

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,
ρ($)=ρ/β
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.16
Answer: a
Reference:
DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

A.17
Answer: c
Reference: DOE Handbook Vol II

A.18
Answer: c.
Reference:

$$P = P_o e^{t/T}$$

WSU Training Manual P. 151

A.19
Answer: d
Reference: Gavrilas, M. PhD. University of Maryland Reactor Operations Manual: ENNU 320 Vol. 2. P 3-5.

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~~ DELETED
Answer: b
Reference:

Control Element No.	1	2	3	4	5
Critical Position (inches)	6.60	6.61	15.12	6.60	11.05
Current Reactivity Worths	$1.42	$3.75	$3.40	$3.90	$0.18
Critical Position Reactivity Worths	$0.39	$1.14	$3.40	$1.13	$0.09
Excess Reactivity	$1.03	$2.61	$0.00	$2.77	$0.09

Shutdown Margin= (Core Excess – Total Rod Worths of Blades 1,2,3)= -$2.07

Data taken from WSU Core Reactivity Parameters (10/2011) and Rod Calibration Data (9/2011)

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: WSU TS 3.1.2

B.4
Answer: b
Reference: WSU TS Definition of “Reportable Occurrence”

B.5
Answer: b
Reference: WSU E-Plan Implementing Procedures

B.6
Answer: d
Reference: 10 CFR 20

B.7
Answer a.
Reference: ANSI/ANS-15.1-2007. The development of technical specifications for research reactors.

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

B.9
Answer: d
Reference: 10 CFR20

B.10
Answer: b
Reference: 10 CFR 20 and Bevelequa, J. 2009.*Basic Health Physics.*

B.11
Answer: c
Reference: SOP-10 "Standard Procedure for Health Physics Surveys"

B.12
Answer: d
No member of the public can receive more than 2.0 mrem in any one hour, so this limit would be reached first.100 mrem dose limit to members of the public (10 CFR 20)
2 mrem/(5 mrem/hr)= 0.4 hrs
Reference: 10 CFR 20

B.13
Answer: c
Reference: SOP No. 4

B.14
Answer: a
Reference: SOP No. 3

B.15
Answer: b
Reference: AP No.4

B.16
Answer: b
Reference: SOP No. 20

B.17
Answer: c

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

B.18
Answer: a
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

B.19
Answer: c
Reference: DOE Fundamentals Handbook *Nuclear Physics and Reactor Theory Vol. 2*

B.20
Answer: b
$(500 \text{ mrem/hr})(1 \text{ ft})^2 = (x)(3 \text{ ft})^2 = 55.6 \text{ mrem/hr}$
Reference: Radiation Protection Training

Section C: Facility and Radiation Monitoring Systems

Question:

C.1
Answer: b
Reference: WSU SAR. June 2002, Section 7.4

C.2
Answer: a
Reference: WSU TS, April 26, 2002, Sections 3.3 and 5.5,

C.3
Answer: d
Reference: WSU SAR. June 2002, Section 5.5

C.4
Answer: c
Reference: SOP 13 “Standard Procedure for Performing Reactor Power Calibrations”

C.5
Answer: d
Reference: WSU SAR. June 2002, Section 4.2.2

C.6
Answer: d
Reference: WSU SAR. June 2002, Section 7.3.1

C.7
Answer: a
Reference: WSU SAR. June 2002, Appendix 16A

C.8
Answer: c
Reference: NRC Reference Material for a Standard TRIGA Instrumented Fuel Element

C.9
Answer: d
Reference: WSU SAR. June 2002, Page 5-10, and Sections 7.3.1, 13.1.2

C.10
Answer: c
Reference: SOP #4, Rev. 10/4/10

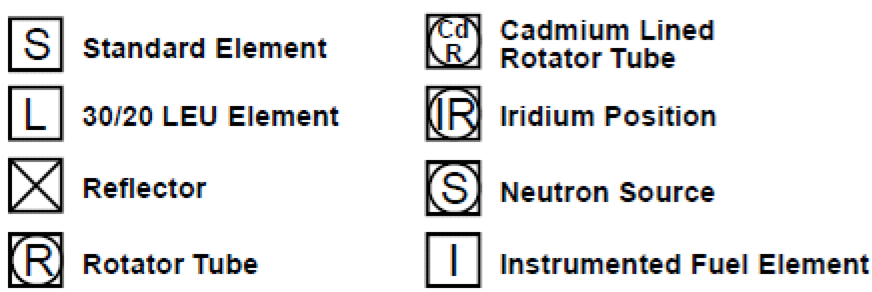
C.11
Answer: b
Reference: SOP # 8 Rev. 8/21/07

C.12
Answer: c
Reference: WSU SAR. June 2002, Section 3.1

C.13
Answer: b
Reference: SOP #4, Rev. 10/4/10

C.14
Answer: c
Reference: WSU SAR. June 2002, Section 4.2.2

C.15
Answer: Based on student response using the following information from Core-35A:



Reference: Core 35-A diagram, WSU SAR. June 2002, Section 4 and 10

C.16
Answer: a
Reference: WSU NRC AP#3

C.17
Answer: c
Reference: WSU SAR. June 2002, Section 7.4.6

C.18
Answer: c
Reference: WSU SAR. June 2002, Section 13.1.4

C.19
Answer: c
Reference: WSU SAR. June 2002, Section 7.4.6

C.20
Answer: b
Reference: WSU SAR, June 2002, Table 7.2-2