July 6, 2010

Dr. Ayman I. Hawari, Director
Nuclear Reactor Program
Department of Nuclear Engineering
North Carolina State University
Campus Box 7909
2500 Stinson Drive
Raleigh, NC 27695-7909

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-297/OL-10-01, NORTH CAROLINA STATE UNIVERSITY

Dear Dr. Hawari:

During the week of May 17, 2010, the NRC administered an operator licensing examination at the North Carolina State University Reactor. 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 Patrick Isaac at 301-415-1019 or via internet e-mail Patrick.Isaac@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. 50-297

Enclosures: 1. Initial Examination Report No. 50-297/OL-10-01
2. Written examination with facility comments incorporated

cc: without enclosures: See next page

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

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

REPORT NO.: 50-297/OL-10-01

FACILITY DOCKET NO.: 50-297

FACILITY LICENSE NO.: R-120

FACILITY: North Carolina State University

EXAMINATION DATES: May 17-20, 2010

SUBMITTED BY: _____ 7/ /2010
Patrick Isaac, Chief Examiner Date

SUMMARY:

During the week of May 17, 2010, the NRC administered operator licensing examinations to six Reactor Operator candidates. Five candidates passed the written examination and five candidates passed the operating test.

REPORT DETAILS

1. Examiners:
   Gregory Schoenebeck, NRC, Examiner (In Training)
   Patrick Isaac, NRC, Chief Examiner

2. Results:

	RO PASS/FAIL	SRO PASS/FAIL	TOTAL PASS/FAIL
Written	6/1	0/0	6/1
Operating Tests	6/1	0/0	6/1
Overall	4/2	0/0	4/2

3. Exit Meeting:
   Gregory Schoenebeck, NRC, Examiner (In Training)
   Patrick Isaac, NRC, Chief Examiner
   Andrew Cook, Reactor Operations Manager
   Kerry Kincaid, Reactor Maintenance Manager
   Larry Broussard, NCSU, Chief Reactor Operator

The NRC examiner thanked the facility staff for their prompt submission of written examination comments (incorporated in enclosure two to this report). The examiner reported the following generic weaknesses:

- There was a lack of a basic understanding for the purpose of 10 CFR 50.59 and how it pertains to reactor safety.

- Although, the candidates could provide applicable dose limits, many of the candidates were unfamiliar with were these regulations resided. Familiarity with 10 CFR 20 appeared to be a consistent weakness.
- Although the candidates could reference the procedure, half of the candidates had trouble deriving the Shutdown Margin/Minimum Shutdown Margin equations to determine the value at a given point during reactor operations. It was not clear if the candidates fully understood the theory associated with Shutdown Margin.

The NRC Examiner made the observation that some of the candidates did not appear comfortable working with the Technical Specifications (TS) and Limiting Conditions for Operation (LCO).

North Carolina State University

NRC License Examination

Written Examination
with Answer Key

5/17/2010

Enclosure 2

QUESTION A.1 [1.0 point]
Which ONE of the following isotopes has the largest microscopic cross-section for absorption for thermal neutrons?

a. Sm^{149}

b. U^{235}

c. Xe^{135}

d. B^{10}

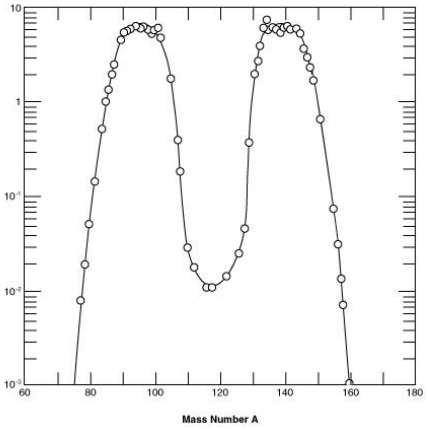
QUESTION A.2 [1.0 point]
The following graph for U-235 depicts……

a. neutron energy distribution in the moderator

b. axial flux distribution in the core

c. radial flux distribution in the core

d. fission product yield distribution



QUESTION A.3 [1.0 point]
Which factors of the six factor formula are affected by an **INCREASE** in core temperature and how are they affected?

a. $\downarrow \boldsymbol{Lf}, \downarrow \mathbf{p}, \uparrow \boldsymbol{f}$

b. $\uparrow \boldsymbol{\varepsilon}, \uparrow \boldsymbol{Lf}, \downarrow \boldsymbol{L_t}, \uparrow \mathbf{p}$

c. $\uparrow \boldsymbol{\varepsilon}, \downarrow \boldsymbol{Lf}, \downarrow \boldsymbol{L_t}, \downarrow \mathbf{p}, \uparrow \boldsymbol{\eta}, \uparrow \boldsymbol{f}$

d. $\uparrow \boldsymbol{\varepsilon}, \uparrow \boldsymbol{Lf}, \downarrow \boldsymbol{L_t}, \uparrow \mathbf{p}, \downarrow \boldsymbol{\eta}, \downarrow \boldsymbol{f}$

QUESTION A.4 [1.0 point]
You are conducting a reactor startup after installing 2 new fuel assemblies in the core. Given the following rod withdrawal data, estimate the rod position when criticality would occur. The initial count rate on the nuclear instrumentation prior to rod withdrawal is 55 cps.

a. 11 in

b. 12 in

c. 13 in

d. 15 in

Rod Withdrawal (Inches)	Count Rate (cps)
0	55
2	63
4	71
6	85
8	103
10	300

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

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

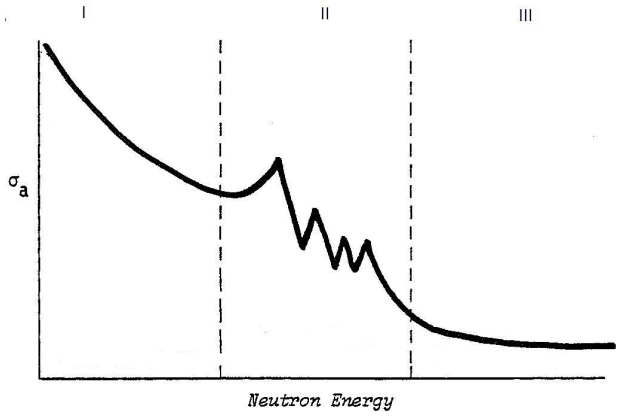
QUESTION A.6 [1.0 point]
Given the following graph, which answer best describes neutron behavior within Region II.

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) are less likely to be readily absorbed than neutrons at other energy levels.

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.7 [1.0 point]
Which of the following types of neutrons has a mean neutron generation lifetime of 12.5 seconds?

a. Prompt

b. Delayed

c. Fast

d. Thermal

Question A.8 [1.0 point]
Which of the following statements is true about Xenon following a reactor scram?

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

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

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

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

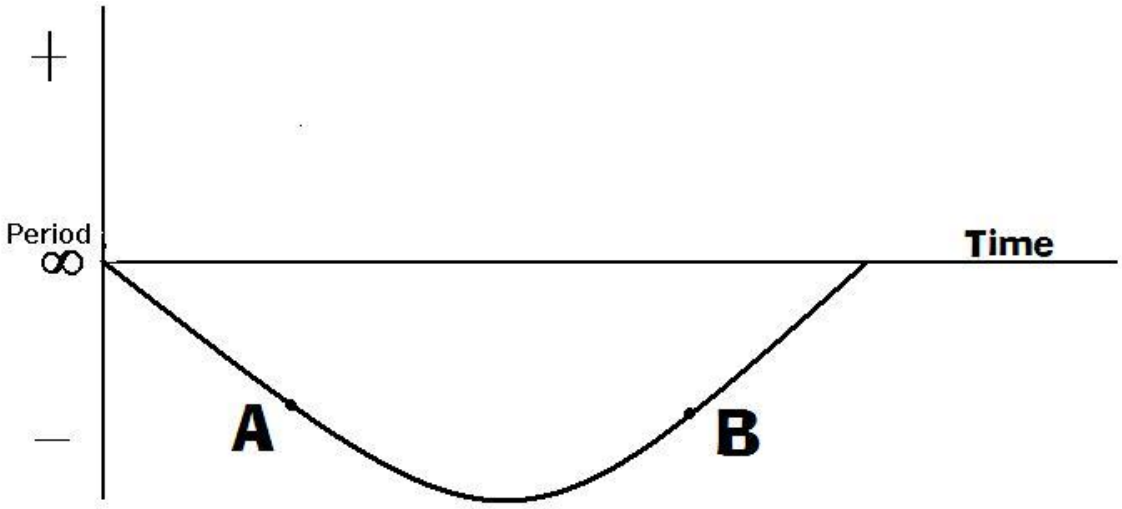
QUESTION A.9 [1.0 point]
The plot below depicts reactor period as a function of time. What best describes the behavior of **REACTOR POWER** between points A and B:

a. Constant

b. Decreasing then increasing

c. Continually increasing

d. Continually decreasing



QUESTION A.10[1.0 point]
A reactor that has a reactivity of -1671 pcm has a count rate of 50 cps on nuclear instrumentation. Calculate what the neutron level (i.e., count rate) should be after a reactivity insertion of 850 pcm from the withdrawal of the control rods.

a. 25 cps

b. 50 cps

c. 100 cps

d. 200 cps

QUESTION A.11[1.0 point]
During the time following a reactor scram, reactor power decreases on an 80 second period, which corresponds to the half-life of the longest-lived delayed neutron precursors, which is approximately

a. 80 seconds

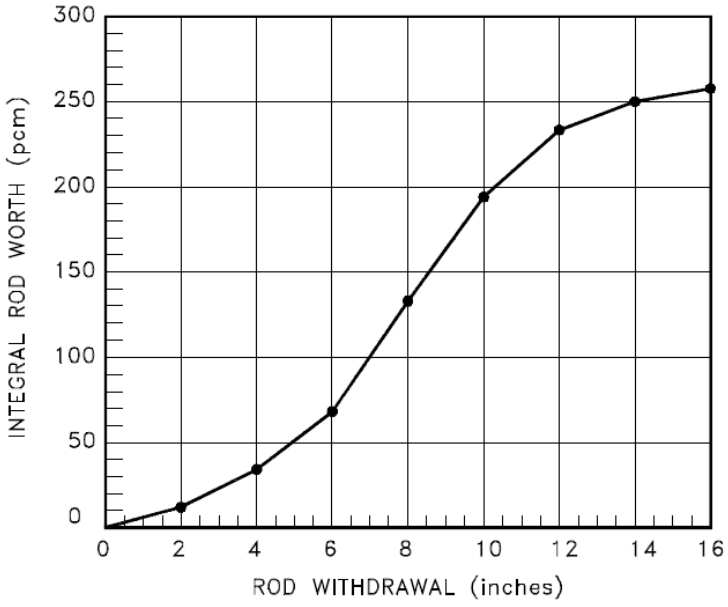
b. 55 seconds

c. 40 seconds

d. 20 seconds

QUESTION A.12[1.0 point]
The reactor is operating in the automatic mode at 750 KW, with the regulating rod at 8 inches. A malfunction of equipment in the secondary cooling system has caused primary temperature to increase by 10 °F. Disregarding any other automated system design features, find the new the position of the regulating rod given the following:

Temperature Coefficient= -4.0 pcm/F



a. 11 inches

b. 9.5 inches

c. 7 inches

d. 8.5 inches

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]
An experimenter had made an calculation error prior to loading a pneumatic sample into the core at a reactor power of 500 KW. Instead of a sample with a worth of 73 pcm, the experiment actually had a worth of **730 pcm**. The scram delay time for the reactor is 50 milliseconds. If the scram setpoint is 1.2 MW, what is the **peak reactor power** at the time of rod insertion, given the following reactor parameters?

β_{eff}= 0.0073
λ_{eff}= 0.1 sec^{-1}
~~Prompt~~ Effective generation lifetime: 2.1×10^{-4} sec (Typo, facility comment)

a. 1.2 MW

b. 1.4 MW

c. 2.80 MW

d. 28.0 MW

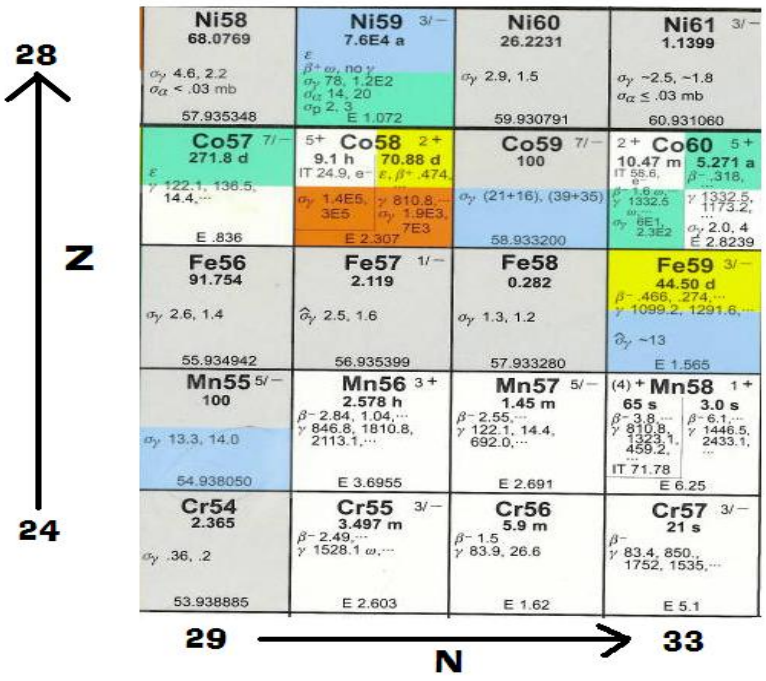
QUESTION A.15[1.0 point]
Using the applicable portion from the chart of the nuclides, what will Mn-56 decay into?

a. Mn-55

b. Co-60

c. Fe-56

d. Fe-58



QUESTION A.16[1.0 point]

What is the condition of the reactor when $k = \frac{1}{1-\beta}$?

a. subcritical

b. critical

c. prompt critical

d. prompt supercritical

Question A.17 [1.0 point]
Inelastic scattering can be described as a process whereby a neutron collides with a nucleus and:

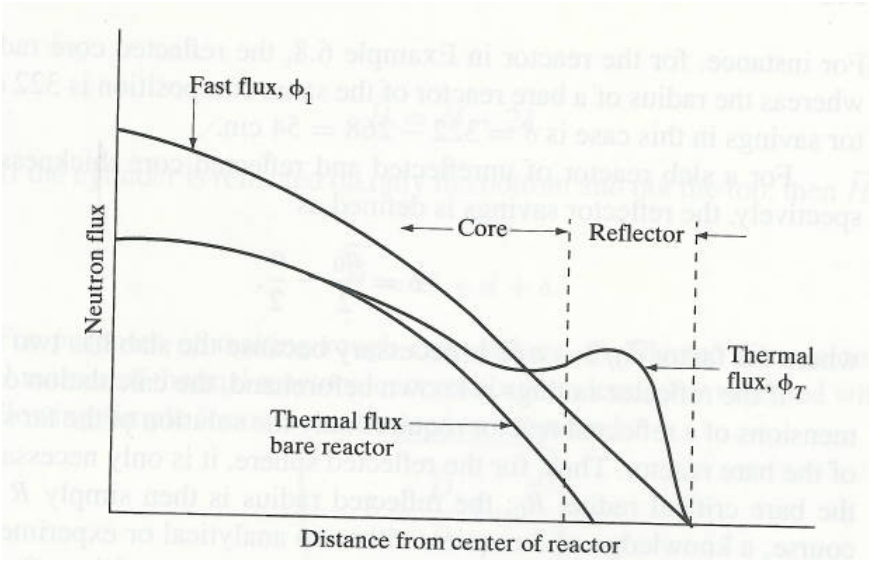
a. recoils with a lower kinetic energy, with the nucleus emitting a gamma ray.

b. recoils with the same kinetic energy it had prior to the collision.

c. is absorbed by the nucleus, with the nucleus emitting a gamma ray.

d. recoils with a higher kinetic energy, with the nucleus absorbing a gamma ray.

Question A.18 [1.0 point]
The following graph depicts fast and thermal fluxes in a reflected and non-reflected thermal reactor. Which of the following statements is true regarding a typical reflector?



a. A reflector has a high cross section for absorption which **increases** the peak power to average power ratio.

b. A reflector has a high cross section for scattering, which **increases** the peak to average power ratio

c. Thermal neutrons tend to accumulate in the reflector until they leak back into the core, escape, or become absorbed, which **reduces** the peak to average power ratio.

d. Fast neutrons become absorbed in the reflector fuel, which raises the thermal flux and **reduces** the peak to average power ratio.

Question A. 19 [1.0 point]
The reactor is critical at 10 watts, ACP= 21.0" gang. A 1.0 dpm SUR is desired. What is the peak power reached by the reactor?

Given:
$\beta_{eff} = 0.0070$
$\lambda_{eff} = 0.1$
$\alpha_{power} = -330$ pcm/MW

a. 492 kW

b. 588 kW

c. 755 kW

d. 920 kW

Question A.20 [1.0 point]

In the NC State PULSTAR Safety Analysis, it states that "a complete loss of pool water will not exceed a DNB ratio of 8." Which of the following statements of DNB is true?

a. It is the point at which a release from a failed fuel element will result in personnel exposure which exceeds Federal limits

b. It is the point which a release from a failed fuel element will result in the inhalation of airborne activity which exceeds Federal limits

c. It is the point at which heat transfer from a fuel element rapidly increases due to increased convection from air currents

d. It is the point which heat transfer from a fuel element rapidly decreases due to insulating effects of a steam blanket

QUESTION B.1 [1.0 point]
The statement from the Emergency Plan, “Events are in progress or have occurred, which involve actual or likely major failures of reactor functions needed for protection of emergency personnel and the public…..” best describes which Emergency Classification?

a. Notice of Unusual Event (NOUE)

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]
Which of the following conditions meets the Technical Specification definition for “Reactor Secured” at the NC State Pulstar reactor?

a. An experiment with a reactivity of 750 pcm is being installed in the reactor with all control rods fully inserted, Keyswitch is in OFF, and the console key is removed

b. All control rods are fully inserted and the Reactor Keyswitch in “OFF”, console key is not removed

c. One control rod drive is removed for inspection; the rod is decoupled and is fully inserted into the core, all other rods are fully inserted with the Reactor Keyswitch in “OFF” and console key is removed.

d. All control rods are fully inserted, the Reactor Keyswitch in “OFF”, console key is not removed, and fuel is being rearranged in the fuel storage racks

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

a. The relocation of an in-core experiment with worth greater than β_{eff}

b. The reactor secured, with fuel being rearranged in the storage racks

c. Recovery from an unplanned shutdown whose cause is unknown

d. The manipulation of reactor console controls by a student in training

QUESTION B.5 [1.0 point]
The special unit for absorbed dose "Rem" is defined in 10 CFR Part 20 in terms of a dose equivalent. What does the term dose equivalent relate to?

a. It is derived by accounting for the amount of radioactive material taken into the body of an adult worker by inhalation or ingestion in one year

b. It is equal to the absorbed dose (rad) multiplied by the quality factor (Q) of the radiation

c. It is equal to the absorbed dose (rad) divided by the quality factor (Q) of the radiation

d. It is the equivalent dose one would receive during the 50-year period following intake

QUESTION B.6 [1.0 point]
An example of Byproduct Material would be….

a. Pu-239

b. U-233

c. U-235

d. Co-60

~~QUESTION B.7 [1.0 point]~~ (Question deleted per facility comment. Candidates not trained on the topic)
If an average person were to receive 400 rads of radiation, what would be the most likely symptom/outcome for this stage of Acute Radiation Sickness (ACRS)?

a. Death

b. GI tract damage

c. Central Nervous System damage

d. Nausea and vomiting

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

a. 2

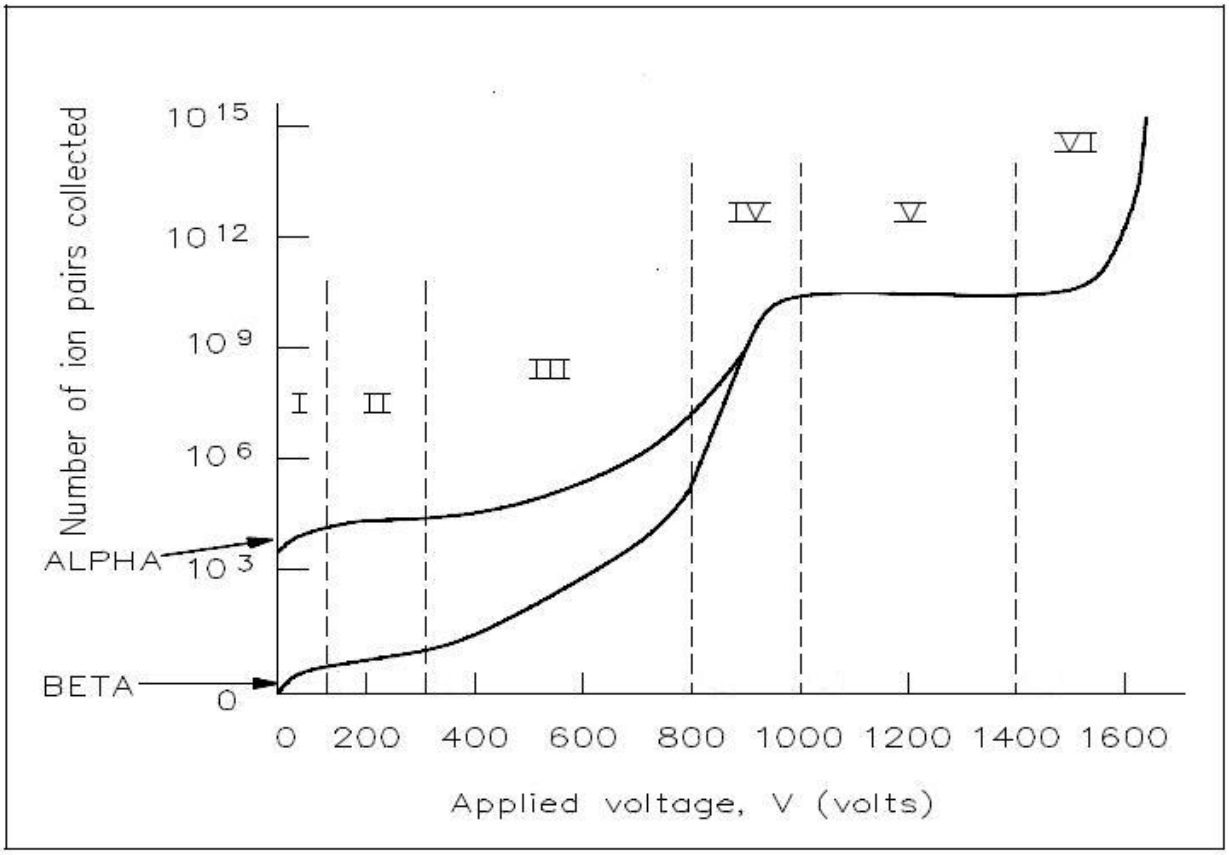
b. 4

c. 8

d. 12

QUESTION B.9 [1.0 point]

You are performing a periodic contamination survey with a Geiger-Mueller type instrument. Using the following graph, which region of the gas amplification curve does this type of meter belong to and which statement best describes this region?



a. Region V. The number of electrons produced through ionizations is **independent** of the applied detector voltage, therefore pulses **cannot** be differentiated to distinguish radiation of different energy types.

b. Region IV. The number of electrons produced through ionizations is **dependent** on the applied detector voltage, therefore pulses **can** be differentiated to distinguish radiation of different energy types.

c. Region III. Radiation interacts with a crystal center which causes electrons to be raised to an excited state. When crystal de-excites, the electron returns to ground state emitting a photon which is proportional to the intensity of the radiation.

d. Region II. The inner surface of the detector probe is covered with a thin coating of boron which aids with the detection of neutron radiation.

QUESTION B.10 [1.0 point]
Which of the following is TRUE regarding the reactivity limitation on a movable experiment at the NC State PULSTAR reactor?

a. 300 pcm or 100 pcm/sec, whichever is more limiting

b. 500 pcm or 200 pcm/sec, whichever is more limiting

c. 730 pcm or 100 pcm/sec, whichever is more limiting

d. 1000 pcm

QUESTION B.11 [1.0 point]
According to NC State PULSTAR Operating Procedures, which of the following is a responsibility of a Reactor Operator?

a. Evaluating initial experiments

b. Performing reactor building (e.g., reactor bridge) checks every 4 hours for reactor operations extending more than 8 hours

c. SCRAM or evacuating the area without waiting for supervisor approval

d. Placing the reactor control system in Automatic when making major changes in reactor power level

QUESTION B.12 [1.0 point]
The limit of 1.3 MWt (max) for forced convection flow provided in the NC State Pulstar Technical Specifications is an example of a (an)….

a. Limiting safety system setting (LSS)

b. Safety limit

c. Limiting condition for operation (LCO)

d. Administrative Control

QUESTION B.13 [1.0 point]
According to the Technical Specifications, if one filter train in the ventilation system is down for maintenance, the other filter train must be verified operable every …

a. 8 hours

b. 12 hours

c. 24 hours

d. 48 hours

Question B.14 [1.0 point]
Which of the following statements is TRUE regarding the operability requirements for radiation monitoring equipment at the NC State Pulstar reactor?

a. The Over-the-Pool Monitor may be bypassed for < 2 minutes during pneumatic rabbit operations.

b. The Over-the-Pool Monitor may be bypassed for 30 minutes during removal of experiments from the reactor pool.

c. Particulate and gas building exhaust monitors may be bypassed for 5 minutes after starting the pneumatic blower system.

d. During periods of maintenance/repair on the Radiation Rack Recorder, not to exceed 90 days, the specified area and effluent monitor's reading are taken manually every hour

Question B.15 [1.0 point]
How are radiation levels associated with N-16 controlled during reactor operations with natural convection flow?

a. Baffling in the N-16 delay tank

b. Maintaining pool level above the Limiting Safety System Setting of 14 feet 2 inches

c. The N-16 diffuser pump

d. Placing both trains of the confinement ventilation filter system in service

Question B.16 [1.0 point]
Which of the following is **NOT** a method for controlling radiation levels at the NC State Pulstar reactor?

a. Argon purge of the Pneumatic Rabbit System when not in use

b. Draining liquid waste from the Reactor building to the sump in the floor of the Mechanical Equipment Room (MER)

c. Installing shield plugs in the valve pit adjacent to the biological shield

d. Maintaining the PULSTAR Reactor Building at a negative d/p such that effluent release is through the ventilation stack

Question B.17 [1.0 point]
You are performing a periodic radiation survey when you find a streaming source of radiation which the detector display reads 50 mr/hr on contact from a cabinet that is not posted for radiological safety. How would this area be posted in accordance with the requirements of 10 CFR 20?

a. High Radiation Area @ 30 cm from the source

b. High Radiation Area on contact w/ the cabinet

c. Radiation Area @ 30 cm from the source

d. Radiation Area on contact w/ the cabinet

.

Question B.18 [1.0 point]
In the event of a student who sustains a life-threatening head injury with contamination, which treatment facility will this individual be transported to in accordance with the NC State Pulstar Reactor E-Plan?

a. NC State Student Health Center

b. Rex Hospital

c. Duke Raleigh Hospital

d. Holly Hill Hospital

Question B.19 [1.0 point]
By technical specifications, above which power level is the N-16 Power Measuring Channel required?

a. 100 W

b. 100 kW

c. 500 kW

d. 750 kW

Question B. 20 [1.0 point]
A Startup Checklist was completed on **04/04/10** at **0715 hours**. The reactor was operated at 500 kW prior to a normal shutdown initiated at **2230 hours on 04/04/10.**. A large amount of research at the facility requires the reactor to be operated at the earliest convenience to accommodate all the runs that must be performed. Under such tight time constraints, what is the latest time that a Key-On Startup may be performed? (Assume Confinement/Evacuation system operated satisfactorily 3 days ago.)

a. 04/05/10 at 1315 hours

b. 04/05/10 at 0430 hours

c. 04/05/10 at 0715 hours

d. A Key-On Startup can not be performed as the shutdown (04/04/10) and planned startup (04/05/10) are on different days

QUESTION C.1 [1.0 point]
Which of the following best describes a correct flowpath through the Primary Coolant System?

a. Nitrogen Delay Tank, Primary Coolant Pump, Flow Orifice, Heat Exchanger

b. Pool Outlet, Nitrogen Delay Tank, Heat Exchanger, Primary Coolant Pump

c. Primary Coolant Pump, Heat Exchanger, Flow Orifice, Flow Straightening Tubes

d. Heat Exchanger, Flow Straightening Tubes, Flow Orifice, Purification System Inlet

QUESTION C.2 [1.0 point]
A complete loss of power to the Radiation Alarm Panel has just occurred. Which of the following is an expected result from this event? (Assume that there is no auxiliary power supply available)

a. Reactor scram

b. Confinement Fan No. 1 will start

c. Power to the N-16 Channel will be lost

d. A rod withdrawal inhibit bistable circuit trip will occur

~~QUESTION C.3 [1.0 point]~~ (Question deleted per facility comment. Pulsing operation has been removed at the facility)

The pulse rod at the Pulstar reactor has been installed for a control rod calibration. Which of the following statements is TRUE with regards to the Pulse Rod operation?

a. A pulse is generally performed once a year for surveillance purposes in accordance with technical specifications

b. The pulse rod is electromagnetically coupled to the drive shaft for manipulation into and out of the core

c. The pulse rod is returned to the down position by gravity when an exhaust valve is opened

d. The pulse rod may be inserted into the core without SRO approval

QUESTION C.4 [1.0 point]
The purpose of the openings on the sides of each fuel assembly box is to…..?

a. Allow coolant flow in the event the top of the fuel assembly becomes blocked by foreign material

b. Provide a surface area for the fuel handling removal tool to properly engage during reactor core modifications

c. Provide openings which mate with pins in the grid plate to prevent misalignment in the core

d. Allow for expansion of the fuel elements as the fuel pellets swell from increased temperature and fission gas expansion

QUESTION C.5 [1.0 point]
What is the composition of the regulating rod?

a. Hafnium (HF)

b. Boron Carbide (BC)

c. Silver-Gadolinium (Ag-Gd)

d. Silver-Indium-Cadmium (Ag-In-Cd)

QUESTION C.6 [1.0 point]
Which of the following is a reactor protection signal input from the Safety Channel?

a. > 9 x 10 E4 cps inhibit

b. 150 kW Trip Flow/Flapper trip

c. < 4 Watt trip

d. Inoperative trip

QUESTION C.7 [1.0 point]
Which of the following is a true statement regarding the flapper valve located on the side of the core plenum?

a. Valve position is remotely controlled by a switch on the reactor console

b. The valve is held open by differential pressure created by downward flow through the plenum

c. Upon the loss of forced flow through the plenum, the flapper will fall to a 30° open position

d. During natural convection flow the flapper valve is held shut by gravity to direct flow upward through the core during natural convection

QUESTION C.8 [1.0 point]
Which of the following temperature indications for the primary coolant does not annunciate in the control room when temperature reaches a nominal temperature of 116°F?

a. Inlet to primary side of the heat exchanger

b. Outlet from the primary side of the heat exchanger

c. Pool

d. Cold Leg

QUESTION C.9 [1.0 point]
How is streaming radiation from the reactor core prevented when the Dry Exposure Port (DEP) is installed for irradiating experiments?

a. Installed lead shield plugs

b. Baryte concrete in the reactor biological shield

c. N-16 Delay Tank

d. Curvature in the DEP tubing

QUESTION C.10 [1.0 point]
When reactor power is reduced from 1 MW to 250 kW, which of the following would be the proper response for the secondary cooling system?

a. The secondary pump will slow to reduce the amount of cooling flow through the heat exchanger

b. Cooling tower fan speed will automatically switch from high to low speed with the reduction of heat load

c. Reactor air positions the S-5 valve to direct more flow to the secondary pump suction

d. When reactor power is less than 250 kW, the secondary pump will secure automatically to coincide with the natural circulation lineup in the primary.

QUESTION C.11 [1.0 point]
Which of the following is a correct statement regarding interlocks which restrict Fission Chamber movement? Movement is allowed only if……

a. The Gang Drive switch is in the mid position

b. No Source Channel or Inhibit present

c. The Ganged Insert switch be in the OUT position

d. The LOG N OPERATIVE is depressed after reaching 4 Watts.

QUESTION C.12 [1.0 point]
When is automatic control of the Regulating Rod allowed?

a. ~~CDRM~~ (CRDM, typo) is withdrawn 12.5 inches rod height

b. FC ABS DEV is + or – 10%

c. Gang Drive switch is in the neutral (mid) position

d. All of the above

QUESTION C.13 [1.0 point]
Reactor Procedure NRP-OP-103, states that when increasing reactor power above 900 kW to full power, pool temperature will normally stabilize between 100°F and 105°F, where nuclear instruments are adjusted to agree with the N-16 Channel. Which of the following is an equivalent **ΔT** between T_5 and T_6 at 1 MW?

a. 5°F

b 13.8°F

c. 27.7°F

d. 50.5°F

QUESTION C.14 [1.0 point]
If a reactor is operating at low power levels (e.g., 200 W), what is a potential consequence for applying too much compensating voltage to the Linear Channel detector?

a. Actual core power may be **higher** than indicated power level

b. Actual core power may be **lower** than indicated power level

c. There will be no effect, as the neutron flux signal will dominate the gamma flux signal at this power level

d. There will be no effect, the Linear Channel detector is an uncompensated ion chamber.

QUESTION C.15 [1.0 point]
You are sitting at the control panel as the reactor operator when RUR authorized personnel are transporting an irradiated experiment through the control room. What is the maximum radiation level would you expect the sample to read during this scenario?

a. 2 mrem/hr at 30 cm

b. 5 mrem/hr at 30 cm

c. 10 mrem/hr at 30 cm

d. 20 mrem/hr at 30 cm

QUESTION C.16 [1.0 point]
At 1 MW, by procedure, how long are sample allowed to be irradiated for if they are placed in polyethylene containers?

a. 8 hrs

b. 12 hrs

c. 24 hrs

d. 48 hrs

QUESTION C.17 [1.0 point]
WHICH ONE of the following detectors is used primarily to measure Ar^{41} release to the environment?

a. Area Radiation Monitors above the Pool

b. Air Particulate Monitor

c Continuous Air Radiation Monitor

d. Stack Gas Monitor

~~QUESTION C.18 [1.0 point]~~ (The question was deleted, per comment from the facility. Answers b and c are essentially the same)
You are performing a routine water chemistry analysis and you note that unusual activity with higher than normal concentrations from this sample. Additionally, you note that the demineralizer activity has doubled since the last time a radiation survey had been performed. After reviewing pre-critical startup logs and normal reactor operating logs you note that over the course of several weeks that reactor pool level has been trending downward during periods of < 150kW and when the reactor is secured. What is most likely the cause of this abnormal condition in the facility?

a. A fuel element failure has occurred

b. There is a pressure boundary breach on the primary side of the heat exchanger caused

c. There is a pressure boundary breach on the secondary side of the heat exchanger

d. Temperature Control Valve (S-5) has failed, causing more primary coolant to bypass the primary heat exchanger, and is directing more to the Purification System which is damaging the Purification System Ion Exchanger resin.

QUESTION C.19 [1.0 point]
Which of the following is the maximum credible accident for an excursion type accident associated with the NCSU Pulstar Reactor?

a. A Double Ended Guillotine break of one tube in the heat exchanger with the primary pump operating

b. A fuel assembly dropped from a height of > 2 ft above the core, positioning into an optimum position of an optimal core configuration in a critical reactor

c. Continuous rod withdrawal of all three control rods from a subcritical core through criticality up to shutdown by the high level neutron flux SCRAMs

d. A slug of primary coolant < 27°F injected into the reactor core which is operating at < 150kW

QUESTION C.20 [1.0 point]
Using the following diagram match the correct position locator (Column A) to the correct experiment facility (Column B) with for the NC State Pulstar Reactor.

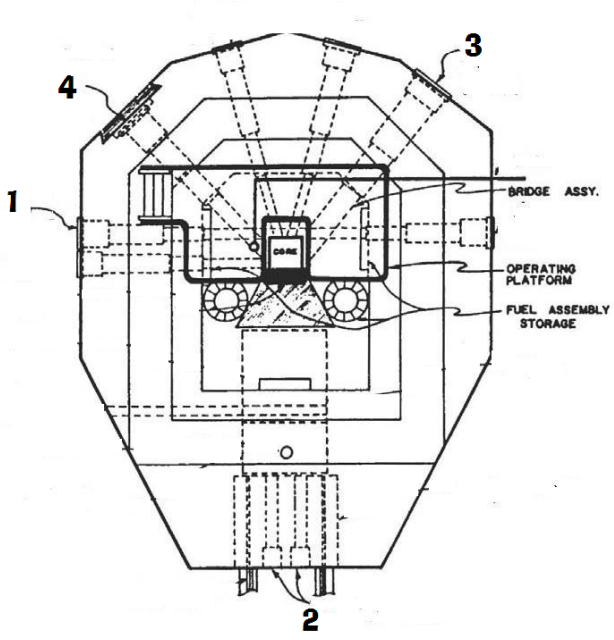
Column A	Column B
1	A. Beam Tube #3 (Cave)
2	B. Thermal Column
3	C. Pneumatic Transfer
4	D. Thru Tube
	E. Beam Tube #5
	F. Thermal Irradiation Port
	G. Beam Tube #6 (Square)

#1 D, #2 B, #3 E, #4 G

A. #1 C, #2 A, #3 G, #4 A

B. #1 C, #2 F, #3 E, #4 G

C. #1 D, #2 B, #3 G, #4 A



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

Question:

A.1
Answer: c
Sm^{149} (41,000 b); U^{235} (687 b); Xe^{135} (2.65×10^6 b); B^{10} (3840 b)
Reference: Lamarsh, J. "Introduction to Nuclear Engineering" p. 738

A.2
Answer: d
Reference: DOE Manual Vol. 1, pg. 57

A.3
Answer: a
Reference:

As reactor core temperature increases, the moderator to fuel ratio will decrease due to the decrease in density of the water. Therefore, due to this fact:

↓*Lf (Fast Non-Leakage Factor):* is the probability that neutrons will not leak out while still fast. Therefore, with less moderator in the core, the probability that they will not leak out decreases.

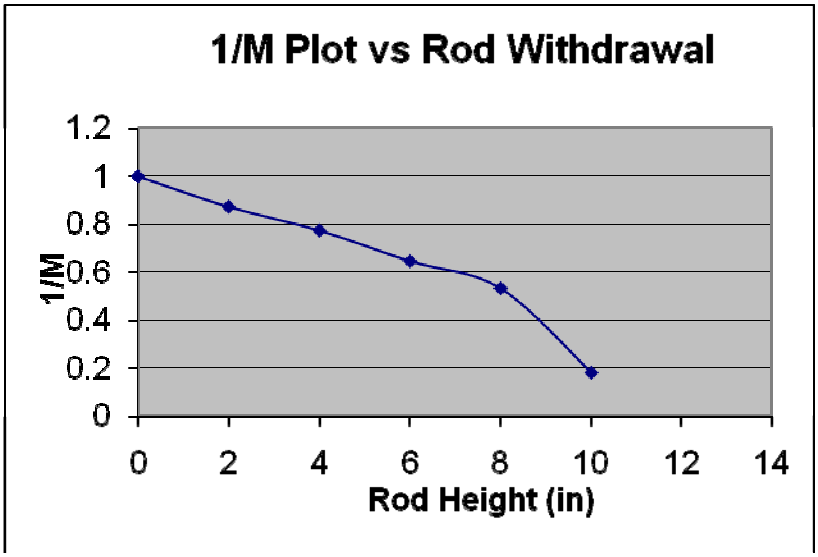
↓p*(Resonance Escape Probability)*: is the probability that a neutron will be reduced to thermal energy levels without being absorbed by U-238. Due to the increase in temperature and Doppler Broadening effects, the probability of escape decreases.

↑***f*** *(Thermal Utilization Factor)*: is the ratio of absorption in fuel to the amount absorbed in the core (e.g., fuel, moderator, control rods, etc.). When the temperature rises, the water moderator expands, and a significant amount of it will be forced out of the reactor core. This means that N_m, the number of moderator atoms per cm^3, will be reduced, making it less likely for a neutron to be absorbed by a moderator atom. This reduction in N_m results in an increase in thermal utilization as moderator temperature increases because a neutron now has a better chance of hitting a fuel atom.

DOE Manual Vol 2, Section 1.0

A.4
Answer: a
Reference:

$\frac{CR_1}{CR_2} = \frac{1}{M}$, Where CR_1= reference count rate (i.e., 55 cps) and CR_2= current count rate.



DOE Handbook Vol. 2, NC State Pulstar Trainee Manual Chapter 1

A.5
Answer: c
Reference.
DOE Handbook, Vol 2, Section 2.0

A.6
Answer: d.
Reference: Resonance Escape Region
DOE Manual Vol 1, Section 2, and Pulstar Reactor Trainee Manual, Chapter 1

A.7
Answer: b
Reference: DOE Handbook Vol 1 Section 3.0

A.8
Answer: b
Reference: Following a reactor shutdown, xenon-135 concentration will increase due to the decay of the iodine inventory of the core.
DOE Handbook, Vol 2, Section 4 and NC State Pulstar Trainee Manual Chapter

A.9
Answer: d

Reference: 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: c
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.

$$\frac{CR_1}{CR_2}=\frac{1-k_2}{1-k_1} \text{ --> } CR_2 = CR_1\frac{1-k_1}{1-k_2} = 50 \text{ cps} \left(\frac{1-0.984}{1-0.992}\right) = 100$$

Where,

1 pcm= $0.00001\frac{\Delta K}{K}$

p_1= -0.01671, p_2= -1671+850= 821 pcm--> -0.00821

$$k_1=\frac{1}{1-p_1}=\frac{1}{1+0.01671}=0.984$$

$$k_2=\frac{1}{1-p_2}=\frac{1}{1+0.00821}=0.9919$$

DOE Manual Vol. 2, Section 1, NC State Pulstar Trainee Manual Chapter 1

A.11
Answer: b
Reference: Group 1 is the longest-lived delayed neutron precursor for thermal fission in U-235, with a half-life of 55.72 sec.
Lamarsh, J. "Introduction to Nuclear Engineering" p. 88

A.12
Answer: b
Reference:
The increase in temperature has added -40 pcm of reactivity which must be accounted for by the regulating rod to maintain 750 kW. Therefore, the reg rod must be withdrawn 40 pcm worth. Using the integral rod worth curve, with the reg rod initially at 8 in (≈130 pcm), the new rod height at 170 pcm is ≈9.5 in.
DOE Manual Vol. 2 Section 3

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

A.14
Answer: c
Reference:
The candidate should recognize that reactivity has approached $\beta_{eff,}$ therefore the delayed term cancels from the period equation, with only the prompt term dominating.

T= $\frac{l^*}{p} + \frac{\bar{\beta}_{eff} - p}{\lambda_{eff} p - p} \longrightarrow \frac{l^*}{p} = \frac{2.1x10^{-4}}{.0073}$ = 29 millisecond

$P_f = P_0 e^{\frac{t}{T}} = 0.5e^{\frac{50}{29}}$ = 2.80 MW

Lamarsh, J. 2001. Introduction to Nuclear Engineering 3rd Ed.. P. 331, DOE Fundamentals Handbook.Vol.2 Section 4, and Pulstar Reactor Trainee Manual Chapter 2

A.15
Answer: c
Reference:
Mn-56 is beta decay, which is the conversion of a neutron into a proton and electron.
Baum, E., Knox, H., and Miller, T. 2002. Nuclides and Isotopes 16th Ed. p. 28

A.16
Answer: c
Reference: The multiplication factor (k) is proportional to the total number of neutrons, prompt and delayed, emitted per fission. However, since only the fraction (1-β) of the fission neutrons are prompt, the fraction of prompt neutrons from with regards to the multiplication factor is (1-β)k. Therefore, when (1-β)k=1, the reactor is critical on prompt neutrons alone, and the reactor is said to be prompt critical. If you rearrange (1-β)k=1 it will read $k = \frac{1}{1-\beta}$.
Lamarsh, J. 2001. Introduction to Nuclear Engineering 3rd Ed.. pp.340-341

A.17
Answer: a
Reference: DOE Handbook Vol I, pg. 45

A.18
Answer: c.
Reference: The thermalized neutrons are not absorbed as quickly in the reflector as neutrons thermalized in the core since the reflector, being unfueled, has a much smaller absorption cross-section. The thermal neutrons tend to accumulate in the reflector until they leak back into the core, escape from the outer surface of the reflector, or are absorbed.

Lamarsh, J. 2001. Introduction to Nuclear Engineering 3rd Ed.. p. 305.

A.19
Answer: b

Reference: $\rho = \frac{SUR\beta_{eff}}{26.1\lambda_{eff} + SUR} = \frac{1.0(700)}{26.1(0.1)+1.0}$ =193.9 pcm

As long as $\rho_{net} > 0$, there will be a positive SUR and reactor power will continue to increase. When peak power is reached $\rho_{net}=0$.

$$\Delta\rho_{net} = \Delta\rho_{rods} + \Delta\rho_{power}$$
$$\Delta\rho_{power} = -\Delta\rho_{rods} = -193.9 \text{ pcm}$$
$$\rho_{power} = \alpha_{power} * \Delta Power$$
$$\Delta Power = \rho_{power} / \alpha_{power} = 0.588 \text{ MW}$$

Pulstar Reactor Trainee Manual Chapter 2

A.20
Answer: d
Reference: Definition of Departure from Nucleate Boiling.
NRC Website

Section B: Normal/Emergency Procedures & Radiological Controls

Question:

B.1
Answer: c
Reference: NC State E-Plan, Rev. 8, dated July 19, 2006

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

B.3
Answer: c
Reference: NC State TS 1.20b(iii) states as a requirement for the reactor to be secured, "No work is in progress involving core fuel, core structure, installed control rods, or control rod drives unless they are physically decoupled from the control rods."
TS for the NC State University Pulstar Reactor, Amendment 15

B.4
Answer: d.
Reference: Under 10 CFR Part 55, The regulations in this part do not require a license for an individual who- "Under the direction and in the presence of a licensed operator or senior operator, manipulates the controls of a research or training reactor as part of the individual's training as a student"
10 CFR Part 55.13

B.5
Answer: b
Reference: 10 CFR Part 20.1003 and NRC Training Material

B.6
Answer: d.
Reference: Byproduct material is radioactive material made radioactive by the process of using special nuclear material
10 CFR Part 20.1003

~~B.7~~(Deleted)
Answer d.
Reference: Answer based on the 5 stages of Acute Radiation Syndrome
CDC website http://www.bt.cdc.gov/radiation/arsphysicianfactsheet.asp

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

B.9
Answer: a
Reference: DOE Fundamentals Handbook-1013/2-92, pg. 42

B.10
Answer: a
Reference: NRP-OP-104, pg. 4

B.11
Answer: c
Reference: NRP-OP-103 Reactor Operations

B.12
Answer: a
Reference: NC State Tech Specs. 10 CFR 50.36

B.13
Answer: c
Reference: NC State Technical Specifications, Section 3.6

B.14
Answer: a
Reference: NC State Technical Specifications, Section 3.5

B.15
Answer: b.
Reference: SAR 10.3.1.2

B.16
Answer: a
Reference: NC State Pulstar SAR. Section 10.3.2 Argon-41 Production

B.17
Answer: c
Reference: 10 CFR 20

B.18
Answer: b
Reference: NC State E-Plan, Section 3.3.1

B.19
Answer: c
Reference: NC State TS Section 3.4

B.20
Answer: b. A Key-on Startup may be performed if reactor key switch has been turned off for less than six hours. 6 hrs + 2230 hrs= 2830 hours--> 2830hrs – 2400 hrs = 0430 hrs on 4/5/2010.
Reference: NRP-OP-101, Section 4.1

Section C: Facility and Radiation Monitoring Systems

Question:

C.1
Answer: d
Reference: NC State Pulstar SAR Figure 4-1A

C.2
Answer: b.
Reference: Automatic initiation signal for confinement
NC State Pulstar SAR Section 5.2

~~C.3 (Question Deleted)~~
Answer: c
Reference: NC State Pulstar SAR Section 3.2

C.4
Answer: ~~c~~ ,a (Typo)
Reference: NC State Pulstar SAR, Section 3

C.5
Answer: d
Reference: NC State Pulstar SAR. Section 3

C.6
Answer: b
Reference: NC State Pulstar SAR, Section 7

C.7
Answer: c
Reference: NC State Pulstar SAR section 4.2.1

C.8
Answer: a
Reference: SAR, Section 4.2.5

C.9
Answer: ~~b~~, d (Typo)
Reference: SAR, Section 14.4.5

C.10
Answer: c
Reference: NC State Pulstar SAR 4.2.2

C.11
Answer: a
Reference: SAR Section 7.5.1
C.12

Answer: c
Reference: SAR Section 7.5.1

C.13
Answer: b
Reference: NRP-OP-103, Section 4.3

C.14
Answer: a
Reference: DOE Fundamentals Handbook 1013, Section 2.4

C.15
Answer: a
Reference: NRP-OP-104

C.16
Answer: c
Reference: NRP-OP-104

C.17
Answer: d
Reference: NC State Pulstar SAR Section 5.2.2

~~C.18~~ (Question Deleted)
Answer: c
Reference: If a pressure boundary breach were to suddenly appear during power operations, secondary water would enter the primary system. This type of leak is easily identified since secondary water contaminants would be activated and collected in the primary demineralizer system causing an abnormal radiation level increase. If a pressure boundary breach during low power operation when the secondary system in not operating or while the reactor is secured would result in a primary to secondary leak.
NC State Pulstar SAR, Section 13.2.1.6

C.19
Answer: b
Reference: SAR, Section 13.2

C.20
Answer: d
Reference: SAR, Section 14