May 22, 2002

Dr. J. Michael Rowe, Director
NIST Center for Neutron Research
National Institute of Standards
  and Technology
U. S. Department of Commerce
Gaithersburg, MD 20899

SUBJECT: INITIAL EXAMINATION REPORT NO. 50-184/OL-02-01, NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Dear Dr. Rowe:

On March 1 and April 19, 2002, the NRC administered operator licensing examinations at your National Institute of Standards and Technology Reactor. The examinations were conducted according to NUREG-1478, "Non-Power Reactor Operator Licensing Examiner Standards," Revision 1. Examination questions and preliminary findings were discussed with those members of your staff identified in the enclosed report at the conclusion of the examination.

In accordance with 10 CFR 2.790 of the Commission’s regulations, a copy of this letter and the enclosures will be available electronically for public inspection in the NRC Public Document Room or from the Publicly Available Records (PARS) component of NRC’s document system (ADAMS). ADAMS is accessible from the NRC Web site at (the Public Electronic Reading Room) http://www.nrc.gov/NRC/ADAMS/indesx.html. The NRC is forwarding the individual grades to you in a separate letter which will not be released publicly. Should you have any questions concerning this examination, please contact Paul Doyle at (301) 415-1058 or via E-mail at pvd@nrc.gov.

Sincerely,

/RA by Marvin Mendonca Acting for/

Patrick M. Madden, Section Chief
Research and Test Reactors Section
Operating Reactor Improvements Program
Division of Regulatory Improvement Programs

Office of Nuclear Reactor Regulation

Docket No. 50-184

Enclosures:
1. Initial Examination Report No. 50-184/OL-02-01
2. Facility comments with NRC resolution
3. Examination and answer key (RO/SRO)

cc w/encls: Please see next page

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cc w/encls: Please see next page

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PMadden

ADAMS ACCESSION #: ML021330702 **TEMPLATE #:NRR-074**

OFFICE	RORP:CE		IEHB:LA	E	RORP:SC	
NAME	PDoyle		EBarnhill		PMadden	
DATE	05/ 14 /2002		05/ 17 /2002		05/ 21 /2002	

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

REPORT NO.: 50-184/OL-02-01

FACILITY DOCKET NO.: 50-184

FACILITY LICENSE NO.: TR-5

FACILITY: National Institute of Standards and Technology

EXAMINATION DATES: March 1, 2002 and April 19, 2002

SUBMITTED BY: ***/RA/*** 05/07/2002
Paul Doyle, Chief Examiner Date

SUMMARY:

On March 1, 2002, the NRC administered written examinations to two Senior Operator license candidates for the National Institute of Standards and Technology Reactor. On April 19, 2002 the NRC administered operating tests to the two Senior Operator license candidates.

REPORT DETAILS

1. Examiners:
   Paul Doyle, Chief Examiner

2. Results:

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

Overall	0/0	2/0	2/0

3. Exit Meeting:
Paul Doyle, NRC, Chief Examiner
Seymour Weiss, NIST, Chief, Reactor Operations and Engineering

During the exit meeting the examiner thanked the facility for their support of the operating tests. The examiner stated that he did NOT notice any generic weaknesses on the part of the candidates.

UNITED STATES NUCLEAR REGULATORY COMMISSION

National Institute of Standards
and Technology
With Answer Key

OPERATOR LICENSING
EXAMINATION
March 1, 2002

<u>Enclosure 2</u>

QUESTION A.1 [1.0 point]
Inserting a shim arm predominantly affects K_{eff} by changing the …

a. fast fission factor

b. thermal utilization factor

c. neutron reproduction factor

d. resonance escape probability.

QUESTION A.2 [1.0 point]
You enter the control room and note that **ALL** nuclear instrumentation show a **STEADY NEUTRON LEVEL**, and no rods are in motion. Which **ONE** of the following conditions **CANNOT** be true?

a. The reactor is critical.

b. The reactor is sub-critical.

c. The reactor is super-critical.

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

QUESTION A.3 [1.0 point]
The neutron microscopic cross-section for absorption σ_a generally…

a. increases as neutron energy increases.

b. decreases as neutron energy increases.

c. increases as the mass of the target nucleus increases.

d. decreases as the mass of the target nucleus increases.

QUESTION A.4 [1.0 point]
Which ONE of the four listed factors (of the six-factor formula) is greater than one for the NIST reactor?

a. Fast Fission Factor (ε)

b. Thermal Utilization Factor (f)

c. Thermal Non-Leakage probability ($\mathfrak{L}_{th}$)

d. Resonance Escape probability (p)

QUESTION A.5 [1.0 point]
Which one of the following is the correct reason that delayed neutrons allow human control of the reactor?

a. More delayed neutrons are produced than prompt neutrons.

b. Delayed neutrons increase the mean neutron lifetime.

c. Delayed neutrons take longer to thermalize than prompt neutrons.

d. Delayed neutrons are born at higher energies than prompt neutrons.

QUESTION A.6 [2.0 points, ½ each]
Match type of radiation (Column A) with the proper penetrating power (Column B).

a. Gamma	1. Stopped by thin sheet of paper
b. Beta	2. Stopped by thin sheet of metal
c. Alpha	3. Best shielded by light (low-z) material
d. Neutron	4. Best shielded by heavy (high-z) material

QUESTION A.7 [1.0 point]
Which one of the following figures most closely depicts the reactivity versus time plot for xenon for the following series of evolutions: (See attached figures on last page of handout for choice selections.)

TIME	EVOLUTION
1	10 MW startup, clean core
2	Reduce power operate at 5 MW
3	Shutdown
4	Restart reactor operate at 5 Mw.

a. Figure a

b. Figure b

c. Figure c

d. Figure d

QUESTION A.8 [1.0 point]
Using the Integral Rod Worth Curve provided identify which ONE of the following represents K_{excess}

a. Area under curve “B”.

b. ρ_C

c. ρ_{max} - ρ_C

d. Areas under curve “A” & “B”

QUESTION A.9 [1.0 point]
Given that the NBSR is shutdown with a K_{eff} of 0.84, and β_{eff} is 0.008. Calculate the amount of reactivity required to achieve criticality.

a. 12.8$

b. 16$

c. 24$

d. 30$

QUESTION A.10 [1.0 point]
To calibrate the shim arms, you measure doubling time then calculate period. If the doubling time was 42 seconds, which ONE of the following is the period?

a. 29 seconds

b. 42 seconds

c. 61 seconds

d. 84 seconds

QUESTION A.11 [1.0 point]
Given secondary flow through HE-1A & B is 9650gpm, HE-1A & 1B (Secondary Inlet Temperature) both read 80°F, HE-1A &1B secondary Outlet Temperature both read 91°F, and the Thermal Power constants for water is 147 watts/gpm-°F (H_2O), determine the current operating power.

a. 78%

b. 71%

c. 65%

d. 59%

QUESTION A.12 [1.0 point]
Which ONE of the following is the correct definition of $\beta_{effective}$? The relative amount of delayed neutrons compared to the total number of neutrons …

a. per generation.

b. per generation corrected for leakage.

c. per generation corrected for time after the fission event.

d. per generation corrected for both leakage and time after the fission event.

QUESTION A.13 [1.0 point]
Which ONE of the following reactor changes require a control rod INSERTION to return reactor power to its initial level following the change?

a. Formation of N^{16} in the coolant.

b. Removal of an experiment with positive reactivity from the reactor.

c. Buildup of Xe^{135}

d. A fault in the automatic system resulting in a primary coolant temperature decrease.

QUESTION A.14 [1.0 point]
Which ONE of the following is the reason that Xenon Peaks after a shutdown?

a. Iodine decays faster than Xenon decays

b. Promethium decays faster than Xenon decays

c. Xenon decays faster than Iodine decays

d. Xenon decays faster than Promethium

QUESTION   A.15   [1.0 point]
The number of neutrons passing through a one square centimeter of target material per second is the definition of which one of the following?

a. Neutron Population (np)

b. Neutron Impact Potential (nip)

c. Neutron Flux (nv)

d. Neutron Density (nd)

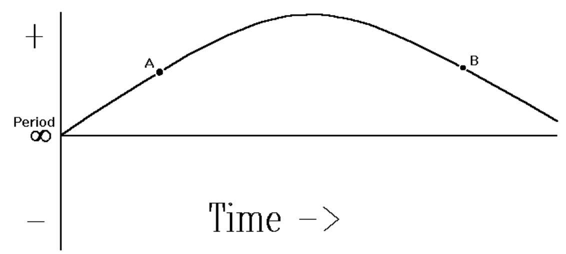
QUESTION   A.16   [1.0 point]
Shown below is a trace of reactor period as a function of time. Between points A and B reactor power is:

a. continually increasing.

b. continually decreasing.

c. increasing, then decreasing.

d. constant.



QUESTION A.17 [1.0 point]
Which ONE of the following factors is the most significant in determining the differential worth of a control rod?

a. The rod speed.

b. Reactor power.

c. The flux shape.

d. The amount of fuel in the core.

QUESTION A.18 [1.0 point]
To make a just critical reactor ***"PROMPT CRITICAL"***, by definition you must add reactivity equal to …

a. τ_{eff}

b. λ_{eff}

c. β_{eff}

d. K_{eff}

QUESTION A.19 [1.0 point]
K_{eff} is K_{∞} times the

a. fast fission factor (ε)

b. reproduction factor (η)

c. total non-leakage factor ($\mathcal{L}_f \times \mathcal{L}_{th}$)

d. resonance escape probability (p)

QUESTION B.1 [1.0 point]
You've detected a stuck regulating rod. Which ONE of the following is your immediate action(s) according to Annunciator Instruction 0.3?

a. Attempt to drive the regulating rod in until power decreases by 2%.

b. Drive all shim arms in verifying the stuck regulating rod fails to move.

c. Scram the reactor, noting the position of the stuck rod.

d. Control reactor power using the shim arms.

QUESTION B.2 [1.0 point]
Which ONE of the following Reactor Run-Downs is ***REQUIRED*** by Technical Specifications?

a. High Thermal Power (BTUR)

b. High Reactor Outlet Temperature

c. Low Reactor Vessel Level.

d. Low Thermal Shield Cooling System Flow.

QUESTION B.3 [1.0 point]
ANNUAL maintenance was last performed on a system on **July 31, 2001.** The last date annual maintenance may be performed on the system without being late is …

a. July 31, 2002

b. August 31, 2002

c. September 30, 2002

d. October 31, 2002

QUESTION B.4 [2.0 points, 0.5 each]
Identify the source (Irradiation of Air, Coolant (D_2O) or Fission Product (FP)) for each of the radioisotopes listed below.

a. Xe^{135}

b. Ar^{41}

c. N^{16}

d. H^3

QUESTION B.5 [2.0 points, ½ point each]
Match each of the Technical Specification Limits in column A with its corresponding value in column B. (Each limit has only one answer, values in Column B may be used more once, more than once or not at all.)

	Column A	Column B
a.	Minimum negative reactivity added by moderator dump	15% $\Delta\rho$
b.	Absolute worth of any individual experiment	4.0% $\Delta\rho$
c.	Maximum Core Excess Reactivity	2.6% $\Delta\rho$
d.	The sum of the absolute Value of all experiments	1.0% $\Delta\rho$
		0.5% $\Delta\rho$

QUESTION B.6 [2.0 points, ½ each]
Identify each of the following Technical Specification Requirements as being either a Safety Limit (SL) Limiting Safety System Setting (LSSS) or a Limiting Condition for Operation (LCO).

a. Minimum Coolant Flow (inner plenum) 60 gpm/MW

b. The reactor may be operated at power levels of up to 10 kW with reduced flow (including no flow) if decay heat is insufficient to cause significant heating of the reactor coolant.

c. The reactor shall not be operated unless at least one shutdown cooling pump is operable.

d. The reactor shall not be operated unless all four shim safety arms are operable.

QUESTION B.7 [1.0 point]
According to the Administrative Rules, the ***MINIMUM*** number of nuclear instruments required for refueling is …

a. one on-scale instrument with trip safety function

b. two on-scale instruments with trip safety function

c. one on-scale instrument

d. two on-scale instruments

QUESTION B.8 [1.0 point]
Although Tritium (H^3) has a radioactive half-life of 12 years, the relative damage to the body is less than many other radioisotopes with this long a half-life because …

a. it is a beta emitter.

b. it has a short (12 day) biological half-life.

c. it is not readily absorbed by the body.

d. it is an alpha emitter.

QUESTION B.9 [1.0 point]
Rescue personnel, are authorized to receive a pre-established radiation exposure WITHOUT Emergency Director (ED) approval in order to save someone's life. Assuming rescue personnel have reached this limit, how much ADDITIONAL radiation exposure can the ED authorize for LIFESAVING ACTIONS during that same emergency?

a. 25

b. 50

c. 75

d. 100 Rem

QUESTION B.10 [1.0 point]
Which ONE of the following experiments does NOT require double encapsulation or a doubled walled container?

a. Fueled Experiment

b. Explosive experiment

c. Material corrosive to reactor

d. Material corrosive to experimental coolant

QUESTION B.11 [1.0 point]
A radiation survey instrument was used to measure an irradiated experiment. The results were 100 mrem/hr with the window open and 60 mrem/hr with the window closed. What was the beta dose?

a. 40 mrem/hr

b. 60 mrem/hr

c. 100 mrem/hr

d. 140 mrem/hr

QUESTION B.12 [1.0 point]
Which ONE of the following correctly completes the sentence. While the reactor is OPERATING, the process test switch may be placed in the "2 of 2" position …

a. for not longer than 8 hours to allow the checking of a channel's operability.

b. indefinitely if power is reduced below 10 MW before changing the selector's position.

c. up to a maximum of 12 hours if no experiments are inserted into the reactor.

d. while maintaining a steady power level but must be returned to the "1 of 2" position prior to changing power.

QUESTION B.13 [1.0 point]
A Radiation Work Permit (RWP) has been written to perform a non-repetitive task on potentially contaminated equipment. How long will this RWP remain in effect?

a. Until the job is completed.

b. 8 hours or until the end of the current shift.

c. A maximum of 24 hours.

d. Indefinitely, if reviewed daily by Health Physics.

QUESTION B.14 [1.0 point]
Per Annunciator Procedure 0.1 *“D_2O System Rupture”*, Immediate Action, you would stop and isolate the shutdown cooling pumps and initiate top feed if vessel level falls below …

a. 60 inches.

b. 100 inches.

c. 140 inches.

d. 180 inches.

QUESTION B.15 [1.0 point]
In regards to Emergency Health Physics Equipment located at the control room area, you would expect to find all of the following **EXCEPT**

a. a personnel decontamination kit.

b. portable emergency radios.

c. protective clothing.

d. Air Sampler

QUESTION B.16 [1.0 point]
Which **ONE** of the following statements correctly defines the term "Channel Test?"

a. The introduction of a signal into a channel and observation of the proper channel response.

b. An arrangement of sensors, components and modules as required to provide a single trip or other output signal relating to a reactor or system operating parameter.

c. The qualitative verification of acceptable performance by observation of channel behavior.

d. The adjustment of a channel such that its output corresponds with acceptable accuracy to known values of the parameter which the channel measures.

QUESTION B.17 [1.0 point]
If estimated critical position differs from actual critical position by more than one degree you must:

a. stop and recalculate the estimated critical position prior to further rod withdrawal.

b. shut down the reactor.

c. notify the Reactor Supervisor.

d. notify the Chief Nuclear Engineer.

QUESTION C.1 [1.0 point, ¼ point each]
Using the simplified diagram of the pneumatic tube (rabbit) system provided, identify the position of valves A through D (Open or Closed), on a sample ***INSERTION***.

a. A

b. B

c. C

d. D

QUESTION C.2 [1.0 point]
A ventilation Radiation Monitor located on the B1 level is supplied with air drawn by a blower from 10 points within the ventilation system. The primary purpose of this monitor is to monitor the concentration of

a. H^3

b. Ar^{41}

c. $Xe^{1331\text{-}135}$ (Fission Gases)

d. N^{16}

QUESTION C.3 [2.0 points, ½ each]
Match each type of gas listed with its correct purpose.

	Gas		Purpose
a.	Air	1.	Gas used in the Pneumatic Tube (Rabbit) System.
b.	CO_2	2.	Used to operate ventilation system butterfly valves.
c.	N_2	3.	Cover gas on primary system to prevent loss of D_2O.
d.	He	4.	Backup to operate ventilation system butterfly valves.

QUESTION C.4 [1.0 point]
The ***MAIN*** purpose of the activated charcoal filters in the emergency exhaust systems is to absorb radioactive …

a. Tritium

b. Iodine

c. Argon

d. Nitrogen

QUESTION C.5 [2.0 points, ½ point each]
Identify the type of detector (B^{10} Proportional Counter (**B^{10}**), Fission Counter (**FC**), Compensated Ion Chamber (**CIC**) or Uncompensated Ion Chamber(**UIC**)) utilized by each of the Nuclear Instrumentation channels listed below. (Note detector types may be used more than once or not at all.)

a. Source Channels 1& 2

b. Intermediate Range (Log-N) Channels 3 & 4

c. Linear Power and Automatic Regulating Rod Control Channel 5

d. Power Range Channels 6, 7 & 8.

QUESTION C.6 [1.0 point]
Which ***ONE*** of the following signals does ***NOT*** generate a ***MAJOR SCRAM***?

a. High Irradiated Air Monitor Activity Level

b. High Normal Air Monitor Activity Level

c. High Stack Monitor Activity Level

d. High Fission Products Monitor Activity Level

QUESTION C.7 [1.0 point]
You discover several scratches on the outer plate of a fuel element. You inform the Reactor Supervisor who decides to use the element. The decision to use this element was

a. appropriate because the outer plates contain no fuel.

b. appropriate because the outer two plates are thicker than the inner plates, due to thicker cladding.

c. inappropriate because it could lead to fission product release from the plate due to reduced cladding.

d. inappropriate because of the higher fuel loading of the outer plates.

QUESTION C.8 [1.0 point]
Following a major scram the ventilation system lineup …

a. must be reconfigured manually, the operator must start the dilution fan to maintain confinement pressure at no less than 0.25 inches negative.

b. must be reconfigured manually, the operator must secure the normal ventilation and start the emergency exhaust system which maintains confinement pressure at no less than 0.25 inches negative.

c. reconfigures automatically, the dilution fan energizes to maintain confinement pressure at no less than 0.25 inches negative.

d. reconfigures automatically, normal ventilation secures, and the emergency exhaust system maintains confinement pressure at no less than 0.25 inches negative.

QUESTION C.9 [1.0 point]
Operation with the shim safety arms less than 12° is prohibited because …

a. the worth of the shim arms below this level is insignificant

b. the scram spring force is insufficient to overcome shock absorber resistance.

c. there is too much stress on the shim arm below this angle.

d. the scram spring force is insufficient to overcome the pressure differential due to full core flow.

QUESTION C.10 [1.0 point]
Which ONE of the following is the material used as a neutron poison in the Regulating Rod?

a. Erbium

b. Cadmium

c. Aluminum

d. Boron

QUESTION C.11 [2.0 points, 0.5 each]
Identify each of the essential electrical loads listed as being powered by AC Only (AC), DC Only, (DC) or AC or DC (AC/DC).

a. Emergency Cooling Sump

b. D_2O Shutdown Pumps

c. Emergency Exhaust Fans (EF 5 and EF 6)

d. Annunciator Power and Evacuation Alarm

QUESTION C.12 [1.0 point]
Which ONE of the following Reactor Rundown Signals can NOT be bypassed?

a. Cold Source flow

b. Cold Source pressure

c. Reactor Outlet Temperature

d. Reactor Thermal Power.

QUESTION C.13 [1.0 point]
WHICH ONE of the listed components within the Helium Sweep Gas system is responsible for the recombination of disassociated D_2 and O_2?

a. The ¼” thick aluminum vessel containing alumina-palladium pellets.

b. The 304 Stainless Steel cold Trap.

c. The ¼” aluminum plate tank containing an activated charcoal filter.

d. The 6061 aluminum cylinder Gas Holder.

QUESTION C.14 [1.0 point]
Which ONE of the following is the method used to get rid of radioactive liquid waste? Radioactive liquid waste is sent to Health Physics where it is

a. held, for decay of short lived isotopes then sampled for 10CFR20 limits and if satisfactory, pumped to the sewer system.

b. put through evaporators, filters ion exchangers, reducing the liquid waste to proper solid form.

c. diluted to less than 10CFR20 limits, then pumped to the sewer system.

d. tested for 10CFR20 limits, then pumped to the sewer system.

QUESTION C.15 [1.0 point]
The Compensated Ion Chambers used at NIST do not have the compensating voltage connected. The reason that compensating voltage is not required in your reactor is because …

a. The Deuterium in the primary absorbs many gammas (gamma-neutron reaction).

b. The Tritium in the primary absorbs many gammas (gamma-neutron reaction).

c. There are lead windows located between the core and the detectors which absorb many gammas.

d. A D_2O moderated core must be larger than an H_2O moderated core resulting in greater self-shielding of gammas.

QUESTION C.16 [1.0 point]
Identify each of the parts of the Thermal Column from the figure provided. (Note: Ignore cooling gap.)

	Column A		Column B
a.	A	1.	Bismuth
b.	B	2.	Boral
c.	C	3.	D_2O
d.	D	4.	Graphite
		5.	H_2O

A.1 b REF: Standard NRC Question[1]

A.2 c REF: Standard NRC Question[1]

A.3 b REF: Standard NRC Question[1]

A.4 a REF: Standard NRC Question[1]

A.5 b REF: Standard NRC Question[1]

A.6 a. 4; b. 2; c. 1; d. 3 REF: Standard NRC Question[1]

A.7 a REF: Standard NRC Question[1]

A.8 c REF: Standard NRC Question[1]

A.9 c REF: Standard NRC Question[1].
Also: $\rho = (K_{eff} - 1)/K_{eff}$ $(0.84 - 1)/0.84 = -0.16/0.84 = -0.19\ \Delta K/K$. $0.19/0.008 = \$23.809$ or \$24

A.10 c REF: Standard NRC Question[1].
Also: period = (doubling time) ÷ (ln(2)) = 42/0.693 = 60.6 ≈ 61

A.11 a REF: NRC Exam administered 02/1991
Also: $9650\text{gpm} \times 11°\text{F} \times 142\ \text{watt/gpm}°\text{F} = 15.6 \times 10^6$ watts; $15.6 \times 10^6 \div 20.0 \times 10^6 = 0.78 = 78\%$

A.12 b REF: Standard NRC Question[1]

A.13 d REF: Standard NRC Question[1]

A.14 a REF: Standard NRC Question[1]

A.15 c REF: Standard NRC Question[1]

A.16 a REF: Standard NRC Question[1]

A.17 c REF: Standard NRC Question[1]

A.18 c REF: Standard NRC Question[1]

A.19 c REF: Standard NRC Question[1]

[1] NOTE: NIST does not supply a Text for Reactor Theory Training.

B.1 d
REF: Annunciator Instruction 0.3.

B.2 b
REF: NBSR Requalification Examination administered March 1996. Also T.S. § 2.2, p. 4.

B.3 d
REF: T.S. 5.0 Time period definitions.

B.4 a, FP; b, Air; c, D_2O; d, D_2O
REF: Standard NRC Question

B.5 a, 4% Δρ; b, 0.5% Δρ; c, 15% Δρ; d, 2.6% Δρ
REF: Technical Specifications § 4.0 (1) & (2), 3.3 (2)(b) and 3.4 Bases

B.6 a, LSSS b, SL c, LCO; d, LCO
REF: Technical Specifications, 2.1 2nd specification, 2.2 3rd specification 3.2 1st specification and 3.4 1st specification.

B.7 d
REF: Administrative Rule 3.0, § III.A, also Administrative Rule 6.0 § I.B.

B.8 b
REF: Rewrite of NBSR Requalification Examination question administered April 1998.

B.9 c
REF: Emergency Instructions Manual, E.I. 1.5, "General Information", Page 5 of 5

B.10 a
REF: Technical Specifications, § 4.0, Specifications (3) and (4).

B.11 a
REF: Instrument reads only γ dose with window closed. Instrument reads both β and γ dose with window open. Therefore, β dose is window open dose less window closed dose.

B.12 a
REF: Operation Instructions Manual, O.I. 5.7. "Operation of the Process Instrumentation Safety System", Page 2 of 3

B.13 a
REF: Health Physics Procedures, H.P. 2.4, "Radiation Work Permit (RWP), Page 1 of 2

B.14 c

REF: Annunciator Procedures, A.P. 01 § III.A.

B.15 c or d Second choice added per facility comment.
REF: Emergency Instructions E.I. 4.4, § II.C.

B.16 a
REF: TS, § 1.1.2

B.17 c
REF Rewrite of NBSR Requalification Examination administered 1996, also OI 1.1 § II.I p. 4

C.1 A, Closed; B, Open; C, Open; D, Closed
REF: NBSR Reactor Operations Training Guide, Figure 8.3

C.2 a
REF: NBSR Reactor Operations Training Guide, §6.4.7, page 52.

C.3 a, 2; b, 1; c, 4; d, 3
REF: NBSR Reactor Operations Training Guide,

C.4 b
REF: Rewrite NBSR Requalification Examination question administered March, 1998.

C.5 a, B^{10} Counter; b, CIC; c, CIC; d, UIC
REF: NBSR Reactor Operations Training Guide,

C.6 d
REF: Rewrite of NBSR Requalification Exam administered April 1998.

C.7 a
REF: NBSR Requalification Exam administered April 1998.

C.8 d
REF: NBSR Reactor Operations Training Guide, § 4.10.3 1st & 2nd ¶s.

C.9 b
REF: NBSR Reactor Operations Training Guide, § 1.3.5 4th ¶.

C.10 c
REF: NBSR Reactor Operations Training Guide, § 1.1.5 2nd ¶.

C.11 a, AC; b, AC/DC; c, AC/DC; d, DC
REF: NBSR Training Guide, § 5.4, pp. 42-4328.

C.12 c
REF: NIST Requalification Examination question administered January, 2000.

C.13 a
REF: NBSR Training Guide, § 4.7.2, pp. 27-28.

C.14 b
REF: NBSR Training Guide, § 4.1.2.2. 3rd ¶.

C.15 c
REF: NBSR Training Guide, §§ 6.2.3 and 6.2.4, p. 46

C.16 a, 3; b, 1; c, 2; d, 4
REF: NBSR Training Guide, Figure I.2.

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

FACILITY: National Institute of Standards and Technology

REACTOR TYPE: NBSR

DATE ADMINISTERED: 2002/03/01

REGION: I

CANDIDATE: ________________________________

INSTRUCTIONS TO CANDIDATE:
Write answers on the answer sheet provided. Attach answer sheets to the examination. Points for each question are indicated in brackets. 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	33.3	_____	_____	A. Reactor Theory, Thermodynamics, and Facility Operating Characteristics
20	33.3	_____	_____	B. Normal and Emergency Operating Procedures and Radiological Controls
20	33.3	_____	_____	C. Plant and Radiation Monitoring Systems
60		_____	_____	TOTALS
			FINAL GRADE	

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

Candidate's Signature

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.
2. After the examination has been completed, you must sign the statement on the cover sheet indicating that the work is your own and you have neither received nor given assistance in completing the examination. This must be done after you complete the examination.
3. Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.
4. Use black ink or dark pencil <u>only</u> to facilitate legible reproductions.
5. Print your name in the blank provided in the upper right-hand corner of the examination cover sheet and each answer sheet.
6. Mark your answers on the answer sheet provided. USE ONLY THE PAPER PROVIDED AND DO NOT WRITE ON THE BACK SIDE OF THE PAGE.
7. The point value for each question is indicated in [brackets] after the question.
8. If the intent of a question is unclear, ask questions of the examiner only.
9. When turning in your examination, assemble the completed examination with examination questions, examination aids and answer sheets. In addition turn in all scrap paper.
10. Ensure all information you wish to have evaluated as part of your answer is on your answer sheet. Scrap paper will be disposed of immediately following the examination.
11. To pass the examination you must achieve a grade of 70 percent or greater in each category.

12. There is a time limit of three (3) hours for completion of the examination.

13. When you have completed and turned in you examination, leave the examination area. If you are observed in this area while the examination is still in progress, your license may be denied or revoked.

REACTIVITY VALUES		
Total worth of 4 shim arms	25.6%	$32
Worth of single shim arm	6.4%	$8
Worth of regulating rod	0.64%	$0.8
Maximum Reactivity Insertion Rate	-0.04%/sec	$0.05/sec
Temp Coefficient (Operating temp. ~107°F)	-0.016%/°F	-$0.02/°F
Void Coefficient (fuel region)	-0.064%/liter	-0.08/liter
Upper Reflector Worth		
Rods In	4%	$5
Rods Out	10%	$12.5
Typical Beam Port Flooding		
D_2O	0.2%	$0.25
H_2O	-0.016%	$0.02
Equilibrium Xenon	~3%	$3.75
Equilibrium Samarium	~1%	$1.25
Peak Xenon (above Samarium	~12%	$15

CURRENT APPROXIMATE REACTIVITY BALANCE	
Temperature	$5
Xenon – Samarium	$5

Lifetime	\$4.5
Experiments	Negligible
Control at End-of-Life	Negligible
Total Excess Reactivity	\$10

Formulas

$$\rho = \frac{\Delta K}{K} = \frac{K-1}{K} = \frac{K_2 - K_1}{K_1 K_2}$$

$$M = \frac{C_t}{C_i} = \frac{1}{1-K}$$

$$\frac{1}{M} = \frac{C_i}{C_t} = 1 - K$$

$$\frac{C_{t_2}}{C_{t_1}} = \frac{1-K_1}{1-K_2}$$

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

$$\tau = \frac{\ell^*}{\rho} \qquad \rho \geq \$1$$

$$\tau = \left(\frac{\beta_{eff} - \rho}{\rho}\right)\bar{\lambda} = \frac{\beta_{eff} - \rho}{\rho\bar{\lambda}} \qquad \rho < \$1$$

$$\tau = \frac{\ell^*}{\rho - \beta} \; (\mathit{Instantaneous}) \qquad \rho > \$1$$

$$K = \varepsilon \mathscr{L}_f p \mathscr{L}_{th} f \eta$$

$$\Sigma = \sigma N$$

$$\rho = \frac{\ell^* + \beta_{eff}\bar{\lambda}}{\tau + \bar{\lambda}}$$

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

$$P = \bar{\phi}_{th} \times \frac{M}{\rho_{th}} N_0 \times \sigma_f \times 3.2 \times 10^{-11} = \bar{\phi}_{th} \times V \times \Sigma_f \times 3.2 \times 10^{-11}$$

$$I = I_0 e^{-\mu x} = I_0 10^{\frac{-X}{TVL}}$$

$$TVL = \frac{2.3}{\mu} \qquad HVL = \frac{0.693}{\mu}$$

$$I_1 D_1^2 = I_2 D_2^2$$

$$X = X_0 e^{-\lambda t} \quad \textit{Where X can be A(activity), I(intensity), or N(number)}$$

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

$$\frac{R}{hr} = \frac{6\,C\,E}{d^2(\textit{in feet})} = \frac{0.5\,C\,E}{d^2(\textit{in meters})}$$

$$C = \textit{Curies} \quad \textit{and} \quad E = \gamma \textit{ energies}$$

$$\frac{P}{P_0} = \frac{\beta_{eff} + \beta_{eff}\rho}{\beta_{eff} + \rho} (\textit{for large } \rho, \textit{ i.e., rod drop})$$

$$P\,(watts) = Flow\left(\frac{gal}{\text{min}}\right) \times \Delta t(^\circ F) \times C\ \ (constant)$$

$$C(D_2O) = \frac{60 \times 9.2 \times 1}{3.413} = 162$$

$$C(H_2O) = \frac{60 \times 8.34 \times 1}{3.413} = 147$$

CONSTANTS

<u>WATER (@STP)</u>

1 gal (H_2O)	8.34 lb
1 gal (D_2O)	9.2 lb
1 ft^3	7.48 gal.
Density (H_2O)	62.4 lb/ft^3 or 1.0 g/cm^3
Density (D_2O)	68.95 lb/ft^3 or 1.105 g/cm^3
C_P (H_2O and D_2O)	1.0 cal/g-°C

<u>POWER AND ENERGY</u>

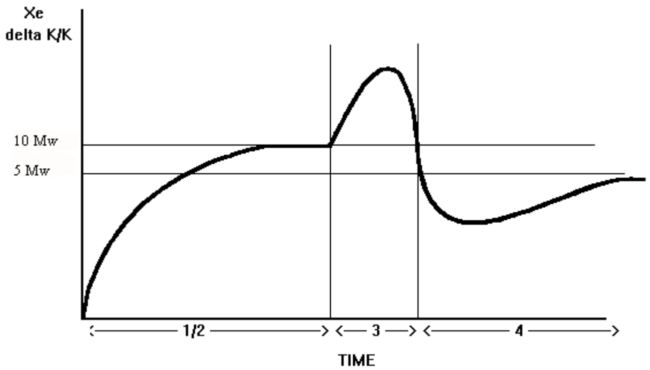
1 watt	1 Joule/sec or 3.413 BTU/hr
1 calorie	4.183 joules
1 BTU	1054 joules
1 Hp	2.54×10^3 BTU/hr
Thermal Power (H_2O)	147 watt/gpm-°F
Thermal Power (D_2O)	162 watt/gpm-°F

<u>REACTOR (NBSR)</u>

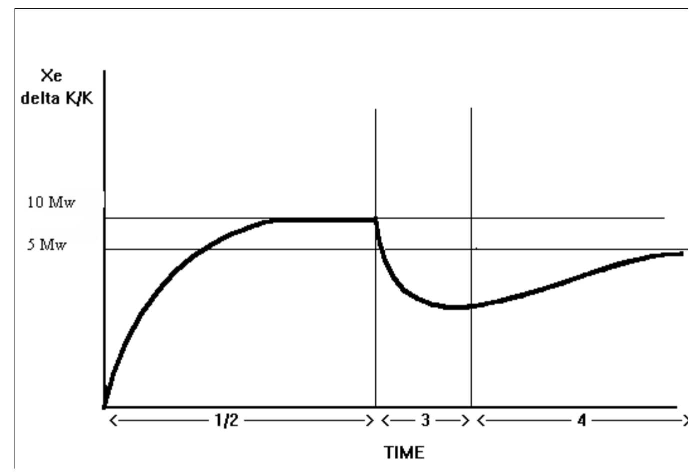
ℓ^*	7×10^{-4} sec
β	0.0064
β_{eff}	0.008
τ_{bar}	10 sec
λ_{bar}	0.1 sec^{-1}

<u>ACTIVITY</u>

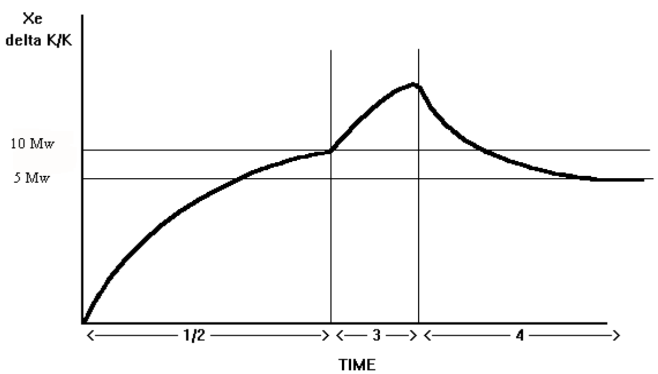
1 curie	3.7×10^{10} disintegrations per second or 2.22×10^{12} disintegrations per minute


Xe
delta K/K
10 Mw
5 Mw
1/2
3
4
TIME

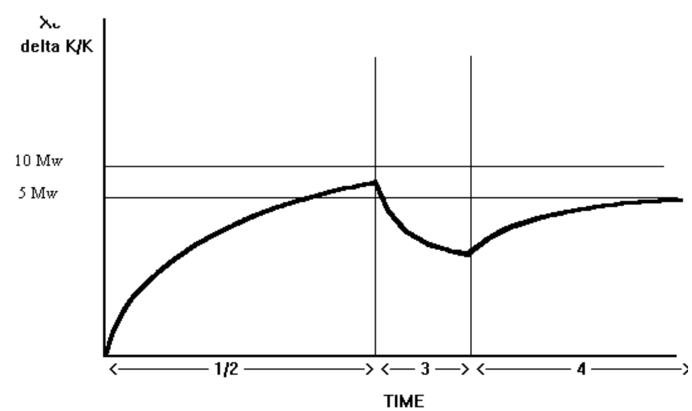
a


Xe
delta K/K
10 Mw
5 Mw
1/2
3
4
TIME

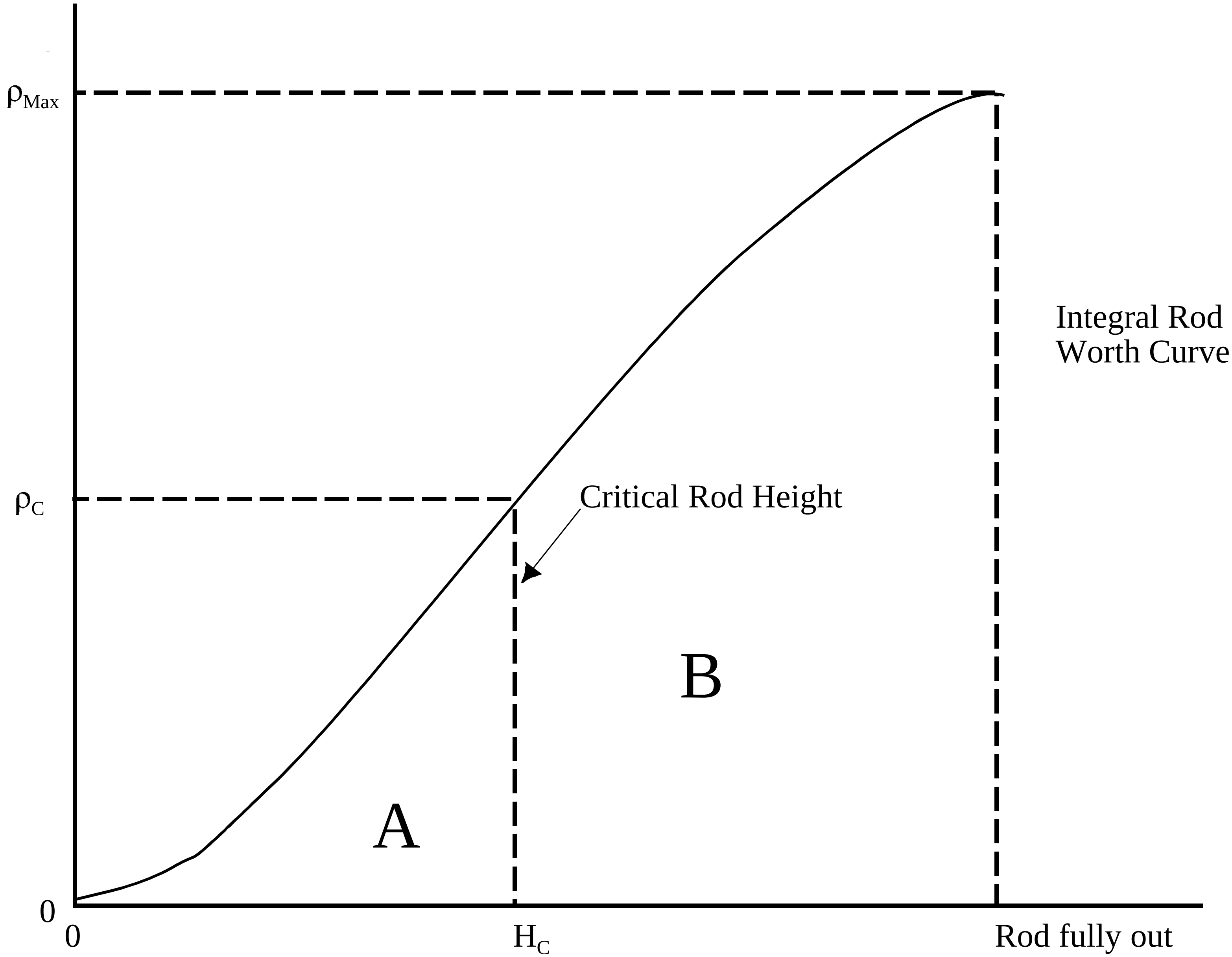
b


Xe
delta K/K
10 Mw
5 Mw
1/2
3
4
TIME

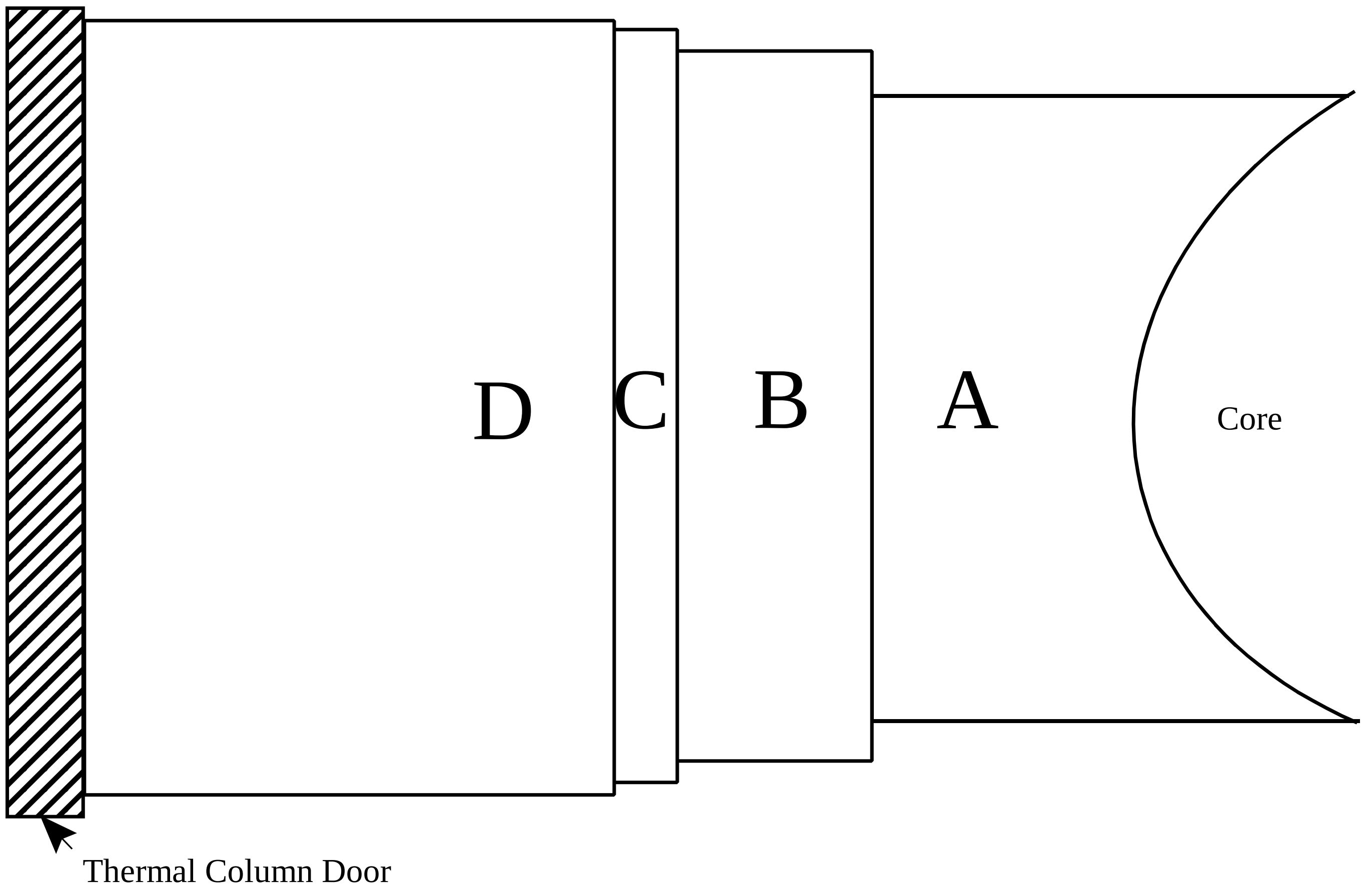
c


delta K/K
10 Mw
5 Mw
1/2
3
4
TIME

d

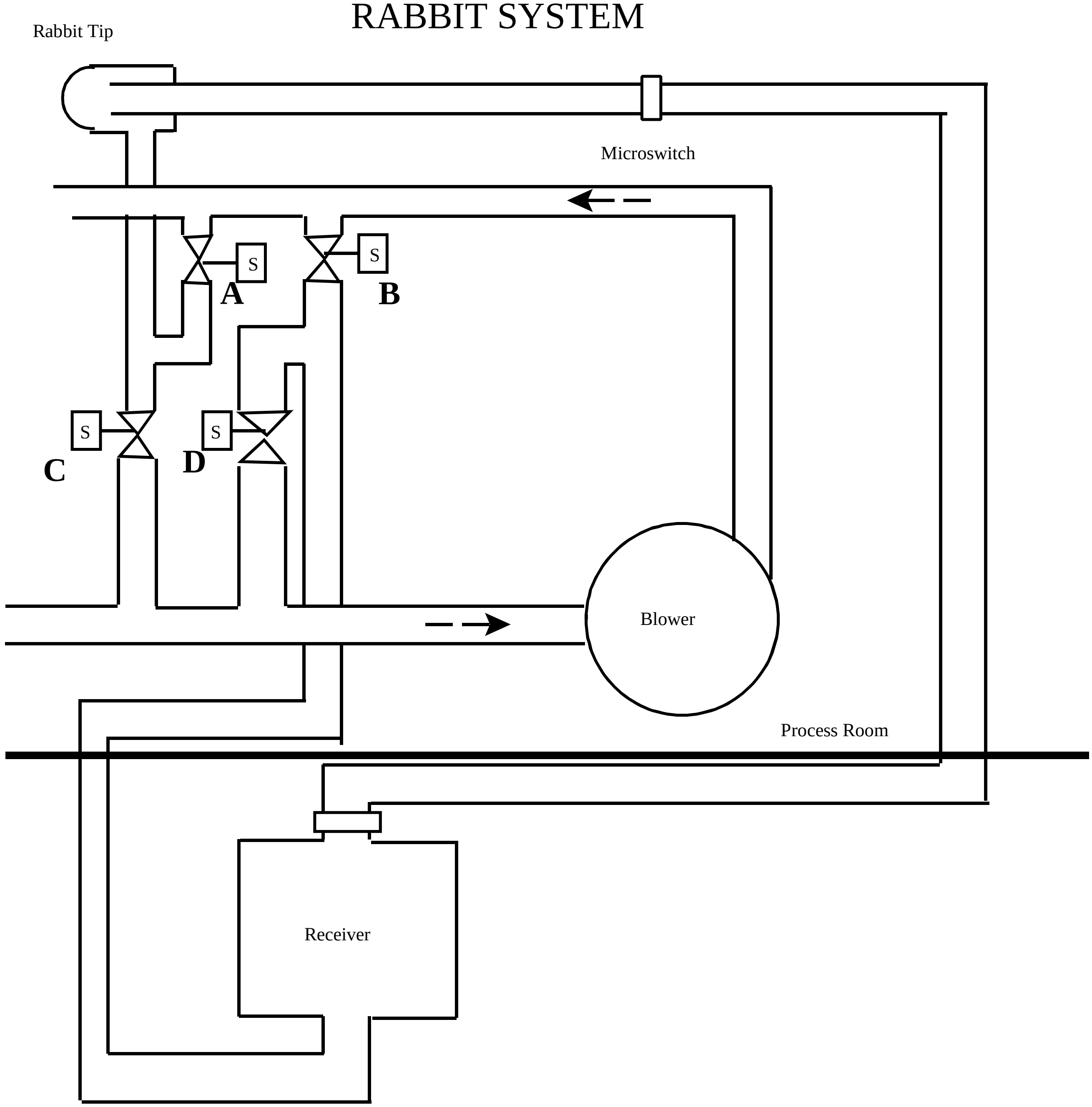


ρ_{Max}
ρ_C
0
0
H_C
Rod fully out
Integral Rod Worth Curve
Critical Rod Height
A
B



Thermal Column Components

RABBIT SYSTEM



A.8 A.7 A.6d A.6c A.6b A.6a A.5 A.4 A.3 A.2 A.1 Section

a b c d a b c d 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 a b c d a b c d a b c d a b c d a b c d a b c d

A N S W E R

A.19 A.18 A.17 A.16 A.15 A.14 A.13 A.12 A.11 A.10 A.

a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c

B.6b B.6a B.5d B.5c B.5b B.5a B.4d B.4c B.4b B.4a B.3 B.2 B.1 Section

SL LSSL LSSL 4.0 0.25 6410.0 256410.0 256410.0 2065 D.0 A0.5 FP O Air FP O Air FP a O b FP c d a b c d a b c d

A N S W E R

B.17 B.16 B.15 B.14 B.13 B.12 B.11 B.10 B.9 B.8 B.7 B.6d

a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c d a b c d SL

Section

C.7 C.6 C.5d C.5c C.5b C.5a C.4 C.3d C.3c C.3b C.3a C.2 C.1d C.1c C.1b C.1a

a b c d a b c d B 10 FC BUIC FC BUIC FC BUIC FC a UIC a b c d 1 2 3 4 1 2 3 4 1 2 3 4 1 2 3 4 a b c d Open Closed Open Closed Open Closed Open Closed

A N S W E R

C.16c C.16b C.16a C.16a C.15 C.14 C.13 C.12 C.11d C.11c C.11b C.11a C.10 C.

1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 1 2 3 4 5 a b c d a b c d a b c d a b c d AC DC AC DC AC DC AC DC AC DC AC DC a b AC