U.S. Nuclear Regulatory Commission
Region I

OPERATOR LICENSING EXAMINATION REPORT

EXAMINATION REPORT NO:	88-03 (OL)
FACILITY DOCKET NO:	50-05
FACILITY LICENSE NO:	R-2
LICENSEE:	Pennsylvania State University
FACILITY:	Pennsylvania State Breazeale Reactor
EXAMINATION DATE:	August 30, 1988

CHIEF EXAMINER: David Wallace, Operations Engineer/Examiner — 9-28-88 Date

APPROVED BY: James A. Prell for Peter W. Eselgroth, Chief, PWR Section, Operation Branch, DRS — 9-28-88 Date

SUMMARY: A written examination (Section H only) was administered to one Senior Reactor Operator (SRO) candidate. The candidate passed the examination.

TYPE OF EXAMINATION: SRO Retake Of Section H Administered At The Region I, NRC Office

EXAMINATION RESULTS: The candidate passed the examination

1. Chief Examiner: David Wallace

2. During a telephone discussion on September 13, 1988, facility staff communicated their comments regarding the examination to the Chief Examiner.

Attachments:
1. Written Examination and Answer Key
2. Facility Comments of written examination and NRC Resolution

ATTACHMENT 1

U. S. NUCLEAR REGULATORY COMMISSION
SENIOR REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: PENNSYLVANIA STATE UNIV.

REACTOR TYPE: TRIGA III

DATE ADMINSTERED: 88/08/30

EXAMINER: ROESENER, S.

CANDIDATE

INSTRUCTIONS TO CANDIDATE:

Use separate p[illegible] for the answers. Write answers on one side only. Staple question [illegible]t on top of the answer sheets. Points for each question are i[illegible]d in parentheses after the question. The passing grade requires a[illegible]t 70% in each category. Examination papers will be picked up si[illegible]s after the examination starts.

CATEGORY VALUE	% OF TOTAL	CANDIDATE'S SCORE	% OF CATEGORY VALUE	CATEGORY
20.00	100.0			H. REACTOR THEORY
20.00			%	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. 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.

3. Use black ink or dark pencil only to facilitate legible reproductions.

4. Print your name in the blank provided on the cover sheet of the examination.

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

6. Use only the paper provided for answers.

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

8. Consecutively number each answer sheet, write "End of Category __" as appropriate, start each category on a new page, write only on one side of the paper, and write "Last Page" on the last answer sheet.

9. Number each answer as to category and number, for example, 1.4, 6.3.

10. Skip at least three lines between each answer.

11. Separate answer sheets from pad and place finished answer sheets face down on your desk or table.

12. Use abbreviations only if they are commonly used in facility literature.

13. The point value for each question is indicated in parentheses after the question and can be used as a guide for the depth of answer required.

14. Show all calculations, methods, or assumptions used to obtain an answer to mathematical problems whether indicated in the question or not.

15. Partial credit may be given. Therefore, ANSWER ALL PARTS OF THE QUESTION AND DO NOT LEAVE ANY ANSWER BLANK.

16. If parts of the examination are not clear as to intent, ask questions of the examiner only.

17. You must sign the statement on the cover sheet that indicates that the work is your own and you have not received or been given assistance in completing the examination. This must be done after the examination has been completed.

18. When you complete your examination, you shall:

a. Assemble ur examination as follows:

(1) Exa questions on top.

(2) Exam aids - figures, tables, etc.

(3) Answer pages including figures which are part of the answer.

b. Turn in your copy of the examination and all pages used to answer the examination questions.

c. Turn in all scrap paper and the balance of the paper that you did not use for answering the questions.

d. Leave the examination area, as defined by the examiner. If after leaving, you are found in this area while the examination is still in progress, your license may be denied or revoked.

QUESTION H.01 (2.00)

What is the effect (INCREASE, DECREASE or NO CHANGE) of an increase in fuel temperature on:

a. L_{th} (Thermal non-leakage probability)?

b. f (Thermal utilization factor)?

c. p (Resonance escape probability)?

d. keff?

QUESTION H.02 (2.00)

Given the following data:

All rods in: Reactor is shutdown by $5.30
Count rate is 60 counts per second

STANDBY: Transient rod at 600 units
Safety rod and shim rod at 150 units each
Regulating rod full in.

What would the count rate be with the reactor in STANDBY? Show all work. Rod worth curves are attached.

QUESTION H.03 (1.50)

State the THREE nuclear characteristics of a good moderating material.

QUESTION H.04 (2.50)

a. What are the TWO processes that produce xenon during reactor operation? (1.00)

b. What are the TWO processes that remove xenon during reactor operation? (1.00)

c. How long after a shutdown from equilibrium xenon conditions at 1 MW will the xenon peak occur?

QUESTION H.05 (2.00)

How would the following conditions change the critical rod position for a reactor startup (HIGHER, LOWER or NO CHANGE)? Consider each separately.

a. A new transient rod is installed to replace the old one.

b. The bulk pool temperature is increased 30 F.

c. Two used fuel assemblies are replaced with new assemblies.

d. An additional boron-lined neutron detector is installed near the core.

QUESTION H.06 (1.00)

TRUE or FALSE?

a. As keff approaches unity, a larger change in neutron population results from a given change in keff.

b. As keff approaches unity, a shorter period of time is required to reach the equilibrium neutron population for a given change in keff.

QUESTION H.07 (1.50)

Assume the following about the pool water heat exchanger:

The secondary side has experienced a significant build-up of corrosion products over months of operation.
The primary side has remained clean.
The primary and secondary flows have remained constant.
The secondary inlet temperature has remained constant.

State how the following parameters will have changed as the secondary side corrosion product build-up increased (INCREASE, DECREASE, or REMAIN THE SAME). IGNORE all heat losses to ambient.

a. The temperature difference between inlet and outlet on the secondary side.

b. The differential pressure across the secondary side.

QUESTION H.08 (1.00)

Explain why the safety rod is worth approximately \$1.50 more than the shim rod.

QUESTION H.09 (1.00)

Why is Beta-effective greater than Beta for the PSBR? Include in your answer the physical reason AND the term affected in the effective multiplication factor.

QUESTION H.10 (2.50)

While operating at low power, an experiment is inserted which causes the reactor power to increase. The following data are recorded:

TIME	POWER	POOL TEMPERATURE
30 seconds	100 Watts	24 C
60 seconds	630 Watts	24 C

a. What is the worth of the experiment in dollars? Assume Lambda = .1. Show all work. (1.00)

b. Using the value calculated in part a, if the reactor operator takes actions to maintain the correct neutron scaling, such that no scram occurs, but does not change rod position, at what average fuel temperature will the reactor stabilize? Assume a vlaue of -1.4 E -04 DeltaK/K/C for the temperature coefficient. Show all work. (0.50)

c. On the attached fuel cross-section drawing (Figure Q-1), sketch the temperature distribution before and after the addition of the experiment. (1.00)

QUESTION H.11 (1.00)

Given the following parameters:

Reactor power 1 Mw.
Heat exchanger flow 400 gpm.
Pool temperature 24 C.
Heat exchanger to pool return temperature of 28.9 C.
Tank constant of 178.7 kW/C/hr.
Conversion constant of 8 lbm/gal.

Calculate the temperature increase in the pool in the next hour. State all assumptions. Show all work.

QUESTION H.12 (2.00)

Assuming the following conditions:

A xenon free startup is in progress.

There has been NO rod motion for 10 minutes.

The power is approximately 10 Watts.

Complete the following table noting the behavior you would expect to observe on the startup meters (INCREASE, DECREASE, or NO CHANGE).

	Slightly Subcritical	Slightly Supercritical
Period meter.		
Count rate meter.		

(***** END OF CATEGORY H *****)
(********** END OF EXAMINATION **********)

EQUATION SHEET

$f = ma$

$w = mg$

$E = mC^2$

$KE = \frac{1}{2}mv^2$

$PE = mgh$

$W = v\Delta P$

$\Delta E = 931\Delta m$

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

$\dot{Q} = UA\Delta T$

$Pwr = W_f\,\dot{m}$

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

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

$SUR = 26.06/T$

$T = 1.44\ DT$

$SUR = 26\left(\frac{\lambda_{eff}\rho}{\bar{\beta} - \rho}\right)$

$T = (\ell^*/\rho) + [(\bar{\beta} - \rho)/\lambda_{eff}\rho]$

$T = \ell^*/(\rho - \bar{\beta})$

$T = (\bar{\beta} - \rho)/\lambda_{eff}\rho$

$\rho = (K_{eff}-1)/K_{eff} = \Delta K_{eff}/K_{eff}$

$\rho = [\ell^*/TK_{eff}] + [\bar{\beta}/(1 + \lambda_{eff}T)]$

$P = \Sigma\phi V/(3 \times 10^{10})$

$\Sigma = N\sigma$

$v = s/t$

$s = v_o t + \frac{1}{2}at^2$

$a = (v_f - v_o)/t$

$v_f = v_o + at$

$\omega = \theta/t$

Cycle efficiency $= \frac{\text{Net Work (out)}}{\text{Energy (in)}}$

$A = \lambda N \qquad A = A_o e^{-\lambda t}$

$\lambda = \ln 2/t_{1/2} = 0.693/t_{1/2}$

$t_{1/2}(eff) = \frac{(t_{1/2})(t_b)}{(t_{1/2} + t_b)}$

$I = I_o e^{-\Sigma x}$

$I = I_o e^{-ux}$

$I = I_o\,10^{-x/TVL}$

$TVL = 1.3/u$

$HVL = 0.693/u$

$SCR = S/(1 - K_{eff})$

$CR_x = S/(1 - K_{effx})$

$CR_1(1 - K_{eff})_1 = CR_2(1 - K_{eff})_2$

$M = 1/(1 - K_{eff}) = CR_1/CR_0$

$M = (1 - K_{eff})_0/(1 - K_{eff})_1$

$SDM = (1 - K_{eff})/K_{eff}$

$\ell^* = 1 \times 10^{-5}$ seconds

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

$I_1 d_1 = I_2 d_2$

$I_1 d_1^2 = I_2 d_2^2$

$R/hr = (0.5\ CE)/d^2$ (meters)

$R/hr = 6\ CE/d^2$ (feet)

WATER PARAMETERS

1 gal. = 8.345 lbm

1 gal. = 3.78 liters

1 ft^3 = 7.48 gal.

Density = 62.4 lbm/ft^3

Density = 1 gm/cm^3

Heat of vaporization = 970 Btu/lbm

Heat of fusion = 144 Btu/lbm

1 Atm = 14.7 psi = 29.9 in. Hg.

1 ft. H_2O = 0.4335 lbf/in^2

MISCELLANEOUS CONVERSIONS

1 Curie = 3.7×10^{10} dps

1 kg = 2.21 lbm

1 hp = 2.54×10^3 BTU/hr

1 Mw = 3.41×10^6 Btu/hr

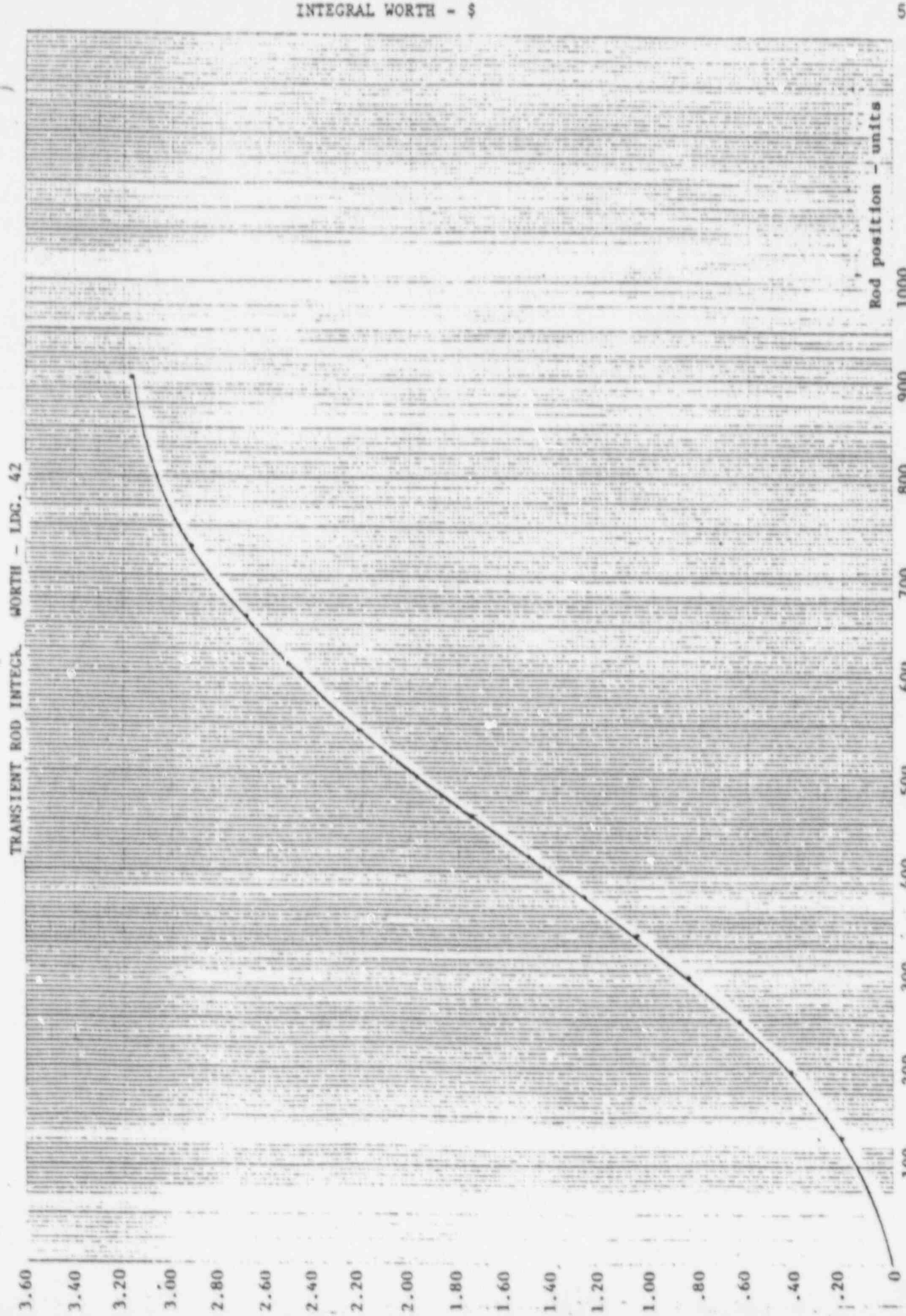
1 Btu = 778 ft-lbf

1 inch = 2.54 cm

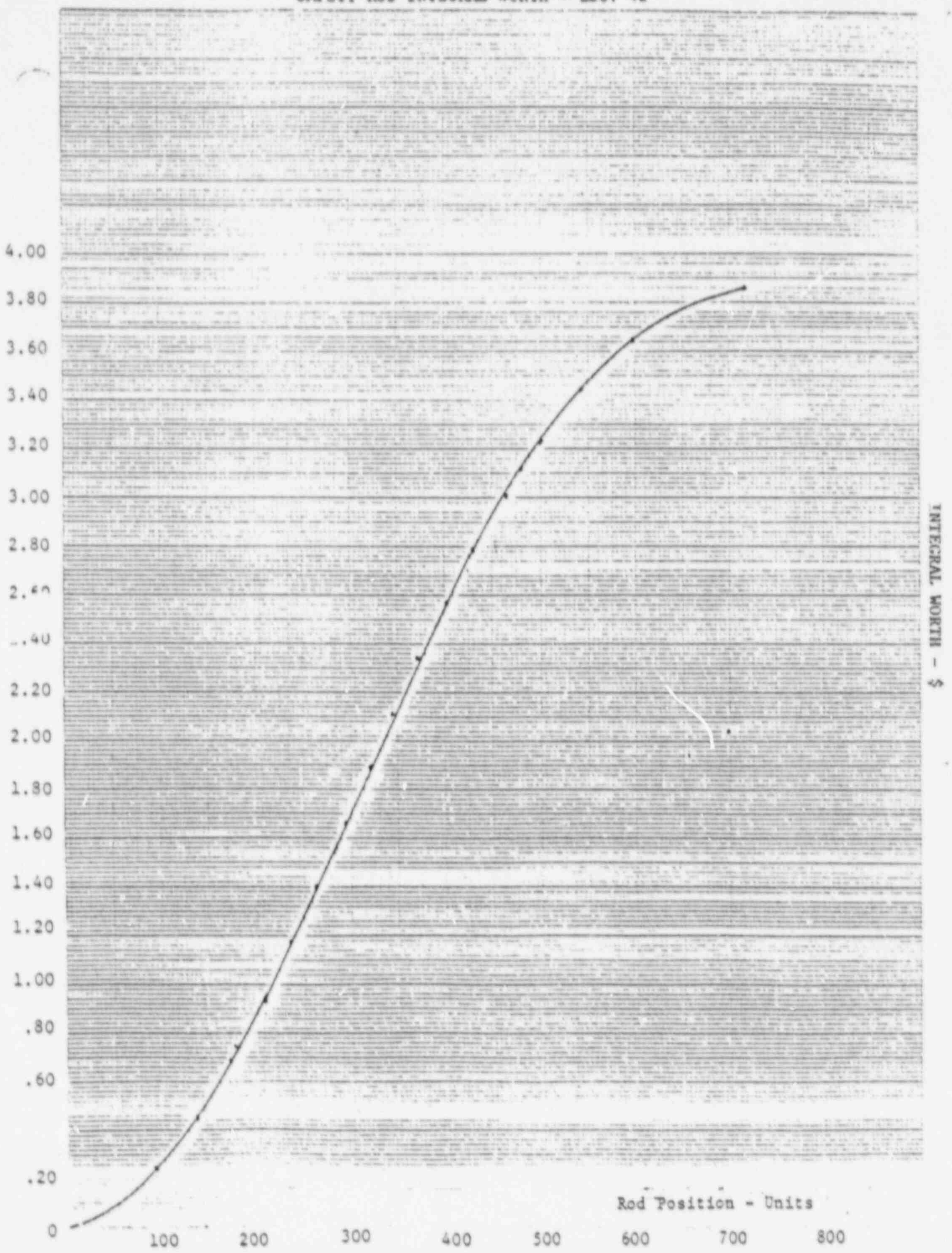
$^\circ F = 9/5\,^\circ C + 32$

$^\circ C = 5/9\,(^\circ F - 32)$

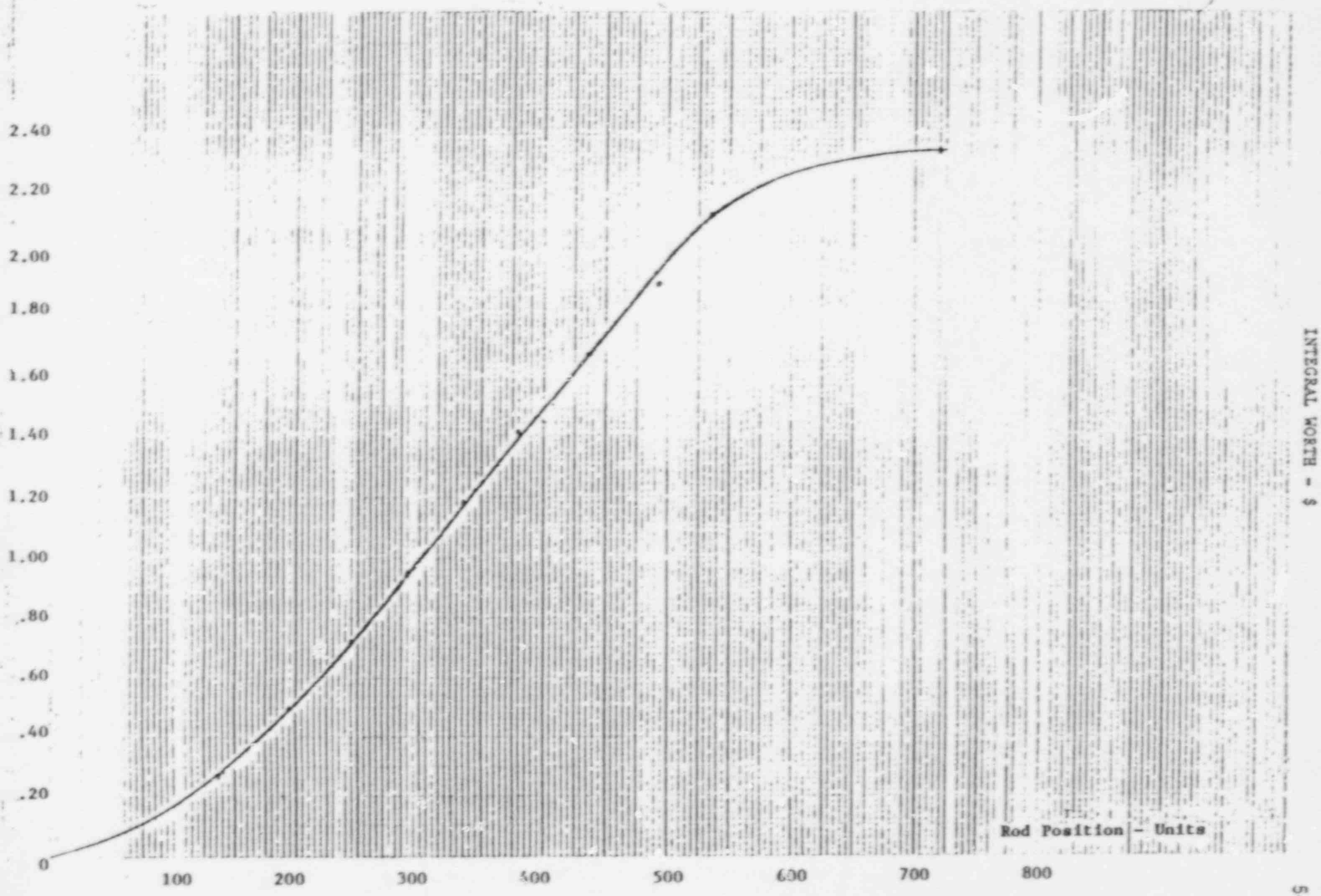
MAR /87


INTEGRAL WORTH - $
TRANSIENT ROD INTEGR. WORTH - LDG. 42
Rod position - units
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
.60
.40
.20
0
100
200
300
400
500
600
700
800
900
1000

SAFETY ROD INTEGRAL WORTH - LDG. 42



SHIM ROD INTEGRAI :TH - LDG. 42



MAR 5/20/8

REGULATING ROD INTEG   WORTH - LDG. 42

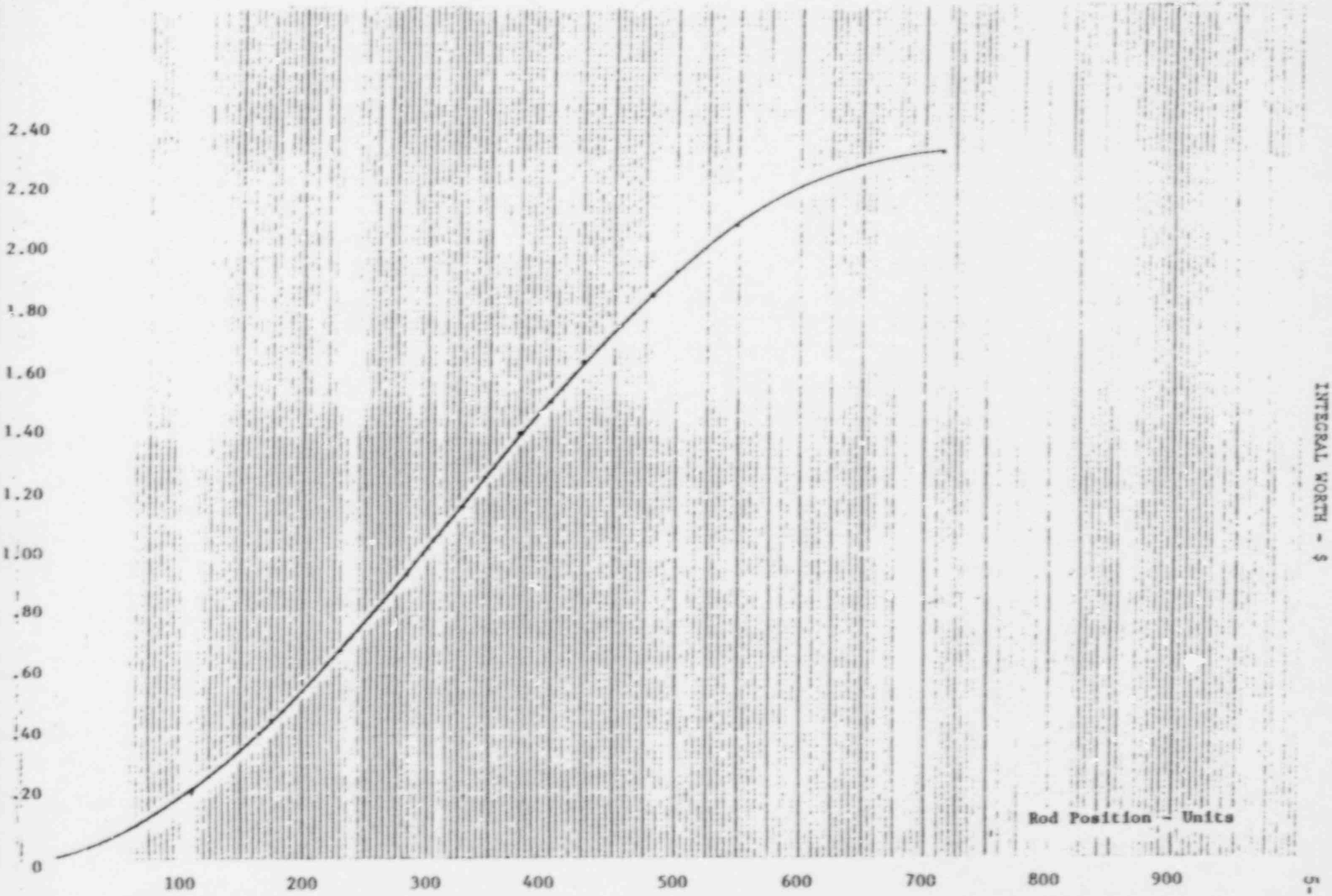
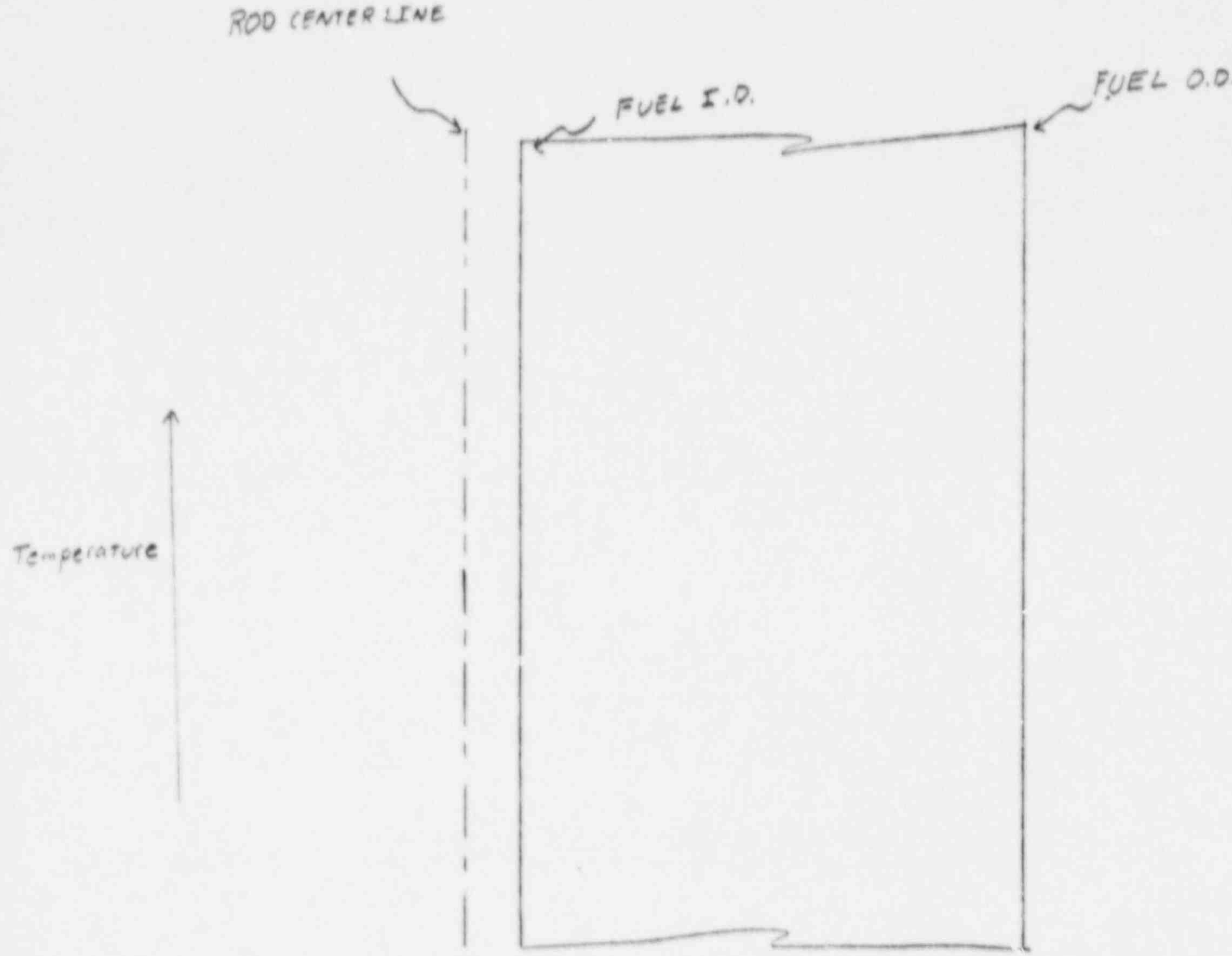


FIGURE Q-1



Cross-section of Fuel
(4x)

ANSWER H.01 (2.00)

a. DECREASE

b. DECREASE

c. DECREASE

d. DECREASE

REFERENCE

PSBR Training Manual, Sections 2.23.3 and 5.7.

ANSWER H.02 (2.00)

Total rod worths as follows with $1.00 equal to .007 DeltaK/K:

($2.46 + $.54 + $.52) X .007 DeltaK/K/$1.00 = .025 +/- .001 DeltaK/K

[0.25 for proper value of beta effective, 0.25 for a total rod worth of $3.52 +/- $.06, and .025 for correct equation application.]

Shutdown reactivity:

$5.30 X .007 DeltaK/K/$1.00 = -.037 DeltaK/K [0.25].

Count rate calculation:

$CR_1 (1 - K_1) = CR_2 (1 - K_2)$,

and p = (1-K)/K or K = 1/(1-p) where p = rho (reactivity).

Therefore K_1 = 1/(1 + .037) = .964 (+/- .001)[0.25]

K_2 = 1/(1 -(-.037 + .025)) = .988 (+/- .002)[0.25]

and CR_2 = 60 (1 - .964)/(1 - .988) = 180 counts per second [0.50]

REFERENCE

PSBR Training Manual, Section 8.C.
PBSR SOP-1, "Reactor Operating Procedure," step B.9.
PSBR Rod worth curves dated march 1987 and found in Training Manual, Section 5.

ANSWER H.03 (1.50)

1. High scattering cross-section.

2. High average logarithmic energy decrement.

3. Low absorption cross-section.

REFERENCE

PSBR Training Manual, Section 8.A.

ANSWER H.04 (2.50)

a. 1. Fission.
   2. Iodine decay. (1.00)

b. 1. Radioactive decay.
   2. Burnup. (1.00)

c. 9 hours (+/- 1 hour) (0.50)

REFERENCE

PSBR Training Manual, Section 2.23.2.

ANSWER H.05 (2.00)

a. HIGHER
b. HIGHER
c. LOWER
d. HIGHER

(***** CATEGORY H CONTINUED ON NEXT PAGE *****)

REFERENCE

PSBR Training Manual, Sections 2.20 to 2.23.

ANSWER H.06 (1.00)

a. TRUE

b. FALSE

REFERENCE

PSBR Training Manual, Section 2.18.

ANSWER H.07 (1.50)

1. REMAIN THE SAME.

2. INCREASE.

REFERENCE

PSBR Training Manual, Section 3.11.
Murray, R. L.; Nuclear Energy p. 138.

ANSWER H.08 (1.00)

Because the safety rod is located in a region of higher flux as compared to the shim rod.

(***** CATEGORY H CONTINUED ON NEXT PAGE *****)

REFERENCE

PSBR Training Manual, Sections 2.21 & 2.22.

ANSWER H.09 (1.00)

Because delayed neutrons are born at lower energies than prompt neutrons [0.50] and therefore have a greater fast non-leakage probability [0.50].

REFERENCE

PSBR Training Manual, Section 2.12.

ANSWER H.10 (2.50)

a.

$T = t / \ln(P_1 / P_0)$ = 30 seconds / ln(630/100) = 16.3 seconds (+/- .5 sec)

p(reactivity) = \$1/(1 + T*Lambda) = \$1/(1 + 16.3 * .1) = \$0.38

[0.50 for correct period (T), 0.50 for correct use of reactivity equation based on ca di'ates calculated period].

b.

$T_2 = T_1$ + (Change in reactivity/The negative temperature coefficient)

= 24 C + (-.0038 DeltaK/K / - 1.4 E -04 DeltaK/K/C) = 51 C.

[0.50 point for correct use of NTC equation based on candidates result for part a.]

c. Answer should show a straight line for the before sketch [0.20] and a convex line with the peak at the inside diameter for the after [0.20] sketch. The after sketch should be greater at ALL points than the before sketch [0.20]. The peak value should be greater than the average calculated in part b [0.20] and the value at the O.D. of the fuel should be less than that calculated in part b [0.20].

(***** CATEGORY H CONTINUED ON NEXT PAGE *****)

REFERENCE

PSBR Training Manual, Sections 2.10, 2.16, 2.17, 2.23.3.
Thermal-hydraulic Principles and Applications to the Pressurized Water Reactor, Chapter 3.

ANSWER H.11 (1.00)

Heat removal by heat exchanger:

$\dot{Q} = \dot{m}c_p(Tout - Tin) =$

400 gal/min * 8 lbm/gal * 1 min/60 sec * 1 Btu/lbm/F * (28.9 C - 24 C) * 9 F/ 5 C =

470 BTU/sec * 1.0548 kW/Btu/sec = 496 kW

Therefore, heat being added to pool is 504 kW

504 kW / 178.7 kW/C/hr = 2.8 C (5.1 F) +/- .2 C (.4 F)

[0.50 for correct calculation of heat removed by heat exchanger, 0.50 for correct calculation of temperature rise in pool based on candidates value of heat deposited in pool].

REFERENCE

PSBR Training Manual, Sections 3.11.
PSBR CCP-2, Reactor Thermal Power Calibration".
Thermal-hydraulic Principles and Applications to the Pressurized Water Reactor, Chapter 3.

ANSWER H.12 (2.00)

	Slightly Subcritical	Slightly Supercritical
Period meter.	NO CHANGE	INCREASE
Count rate meter.	NO CHANGE	INCREASE

REFERENCE

PSBR Training Manual, Sections 2.18.

(***** END OF CATEGORY H *****)
(********** END OF EXAMINATION **********)

ATTACHMENT 2

FACILITY COMMENTS AND NRC RESPONSE FOR
SRO SECTION H EXAMINATION ADMINISTERED ON AUGUST 30, 1988

Question H.07a

Facility Comment: Buildup of crud in the heat exchanger will decrease the heat transfer and therefore the change in temperature on the secondary side will decrease.

NRC Response: Comment noted. The question has been deleted because the answer is dependent on the rate of crud buildup and the length of time over which the temperature transient is considered.

Question H.12 The facility interprets the question to be referring to a constant period startup since a startup is in progress and no rod motion has occurred. Under this condition, in a slightly supercritical condition, the period meter will remain steady.

NRC Response: The comment is valid. Additional review has resulted in the question being deleted, since source strength is not addressed, and the term "slightly subcritical" is too vague to convey a period of time that will permit subcritical multiplication to cause a steady countrate.