EXAMINATION REPORT

Facility Licensee: Arkansas Power & Light
P. O. Box 551
Little Rock, Arkansas 72203

Facility Docket No.: 50-368

Facility License No.: NPF-6

Examinations administered at Arkansas Nuclear One, Unit 2, Russellville, Arkansas.

Chief Examiner: Scott McCrory 5/1/84
Stephen L. McCrory Date

Approved by: R. A. Cooley 5/2/84
R. A. Cooley, Section Chief Date

Summary

Examinations on March 20 - 22, and 27 - 29, 1984.

Written and oral examinations were administered to nine ROs, eight upgrade SROs, and one instructor certification SRO. Four upgrade SROs, one instructor certification SRO, and six ROs passed these examinations. All others failed.

ANO 2 EXAM REPORT

Report Details

1. Examination Results

SRO Candidates				RO Candidates			
Total	Pass	Fail	%	Total	Pass	Fail	%
9	5	4	55	9	6	3	66

2. Examiners

S. L. McCrory (Chief Examiner), NRC
J. Smith, PNL
R. Clark, PNL
J. Boegel, PNL

This Examination Report is composed of the sections listed below.

A. Examination Review Meeting Comment Resolution

B. Exit Meeting Minutes

C. Generic Comments

D. Examination Master Copy (SRO/RO Questions and Answers)

Performance results for individual candidates are not included in this report because, as noted in the transmittal letter attached, examination reports are placed in NRC's Public Document Room as a matter of course.

ANO 2 EXAM REPORT

Examination Review Meeting Comment Resolution

In general, editorial comments or changes made during the exam, the exam review, or subsequent grading reviews are not addressed by this resolution section. This section reflects resolution of substantive comments made during the exam review. The modifications discussed below are included in the master exam key which is provided elsewhere in this report as are all other changes mentioned above but not discussed herein. The following personnel were present for the exam review:

NRC	UTILITY
S. McCrory	J. Constantin
	L. McClure
	L. Taylor
	G. Woolf
	A. Elliot

COMMENTS

1. Q 1.9/5.9 — The shape of part B of the curve is affected by Pu build up and requires knowledge of burnable poisons which do not exist in the present ANO 2 core.

   Resp: "Pu build up" was added to the answer key for partial credit. Considering the low point value and the broad generic nature of the question, the full credit answer was not modified.

2. Q 2.1.4 — The correct answer could also be a "cylinder-double actuated air operated."

   Resp: REJECT: The control lines are clearly marked to indicate hydraulic operation.

3. Q 2.1.8 — The symbol could also be a butterfly valve.

   Resp: REJECT: "Damper" is a correct description and is included in the matching list.

4. Q 2.1.10 — The symbol could also be a pressure reducing or control valve.

   Resp: REJECT: Capillary lines are not normally used on pressure reducing valves because of the small working force transmitted.

5. Q 2.2/6.2 — (a) Key shows bus voltages.

Resp: Voltages not required in the answer.

(b) Operators are not required to memorize breaker and transformer numbers. Should delete the requirement from the key.

Resp: REJECT: These components are labeled on their control devices with the alpha-numeric designation and are procedurally referred to in this manner. The grading criteria was developed such that 80 percent of the question value could be obtained if the network was completely correct except for component numbers.

(c) Drawing too time consuming for a 6-hour exam.

Resp: REJECT: Drawings are considerably quicker and easier ways of soliciting indepth and detailed system knowledge than essay responses.

6. Q 2.3/6.3 — HPSI shut off head is 1450 psi.

Resp: ACCEPT: Key modified.

7. Q 2.4/6.4.c — DG prelube is not specifically for the turbo-charger.

Resp: ACCEPT: Key modified.

8. Q 2.4/6.4.A — Engine heating system and Jacket cooling water pressure switches are also correct.

Resp: REJECT: These are either passive or reactive to the situation stated. The answer indicated in the key is the only active force to achieve the desired result.

9. Q 2.6 — Drawing too time consuming and seismic boundaries are not considered viable objectives of the operator training program.

Resp: See response #5 concerning drawings. The answer key was modified to lower the incremental point value assigned to seismic boundary identification. However, such knowledge is considered pertinent to an operator's understanding of system survivability to casualties of a seismic nature.

10. Q 2.11 — Loss of ACW requires turbine shutdown due to loss of cooling to lube oil, starter cooling, and H_2 cooling.

Resp: ACCEPT: Key modified.

11. Q 3.1/6.1 — ESFAS actuation setpoints are different.

    Resp: ACCEPT: Key modified.

12. Q 3.3 — Safety channels have 3 detectors/channel. The source range has more than two range scale indications.

    Resp: ACCEPT: Key modified.

13. Q 3.5 — Proportional heaters to "minimum" vice "off." Additional symptoms will result from the conditions

    Resp: ACCEPT: Key modified. Symptoms were evaluated using the key as a basic guide. If a question existed about a particular response, plant reference material was reviewed to confirm the response.

14. Q 3.8/6.6.A — Key incorrect concerning SDBCS operation.

    Resp: ACCEPT: Key modified.

15. Q 4.2/7.2.B — The approved procedure states that void formation in the RV head may be detected by observance of pressurizer anomalies such as rapid increase in pressurizer level while depressurizing <u>or</u> a rapid decrease in pressurizer level while increasing pressure.

    Resp: There is no plausible situation whereby void formation would first be detected as a result of pressurizing and observing an outsurge from the pressurizer. This is a primary indication of initial void collapse or compression. This will be graded as an incorrect response to the problem stated on future exams.

16. Q 4.2/7.2 — Procedure 2203.13 indicates that a void is collapsed as soon as the outsurge from the pressurizer stops during repressurization.

    Resp: During a rapid repressurization, this premise would be true only if both charging and letdown are secured. However, the end point may not be achievable before reaching safety relief setpoints. Repressurization alone is insufficient to collapse a void in the RV head. Further, pressurizer level behavior as a result of repressurization only is inadequate indication or confirmation of complete void collapse. The wording of the question was sufficiently nonspecific to allow credit for responding per the indications of Procedure 2203.13.

17. Q 4.7/7.7 Procedure revision changed the immediate actions.

Resp: Part A became not appropriate as a result of the revision to Procedure 2202.08. The question was graded based on the responses to parts B and C only.

18. Q 4.9/7.9 Reactivity balances are only performed by the nuclear engineering department.

Resp: The question was not testing the specific ability to perform a reactivity balance, but the ability to identify reactivity changes resulting from changes to plant conditions, which is a viable requirement of operators. Using the reactivity balance forms provides the fastest and easiest means of determining the net reactivity change which must be compensated by changing the Boron concentration. The answer key identifies two methods of addressing the problem.

19. Q 4.9/7.9 Heatup/Critical ops curves and tables were needed to answer the questions correctly.

Resp: The information on these curves and tables (OP 2101.04) did not apply to the correct answer.

20. Q 8.1/8.11 (a) Too many assumptions needed for conditions given.

Resp: INVALID: Of the eight question areas, only two required any sort of an assumption. Q 8.11.C required the understanding that "loss of physical control of the facility" includes the control room. Q 8.11.D requires the reasonable and conservative assumption that radiation release in the fuel building as a result of a fuel handling accident will probably be of sufficient magnitude to call an alert condition. All other questions have specific answers per Procedure 1903.10 without any assumptions needed.

(b) Procedure 1903.10 uses mostly offsite dose projections for EAL criteria. Insufficient information was given to determine offsite dose.

Resp: INVALID: The key is based on specific criteria found in Procedure 1903.10 which do not relate directly to offsite dose projection. Several EAL criteria will result in NO offsite dose.

21. Q 8.2 Trivial question. Operators should not be required to know procedure numbering beyond the general series number.

Resp: Candidates routinely demonstrate an inability to locate or identify procedures which address emergency situations. An operator should, by virtue of training in procedures and frequent review of emergency oriented procedures, be able to go directly to the specific procedure series which contains the one needed to address a particular problem. The key was modified to give partial credit for correct general series identification.

22. Q 8.10 Control room instruments indicate CST level in percent. Operators should not have to know tank capacities.

Resp: It is reasonable to expect operators to know the capacities of major tanks related to safety as a part of basic system knowledge. Partial credit was given where candidates identified the Tech Spec limit as a function of percent.

23. General Tech Specs were asked on Special Tests section requiring memorization..

Resp: INVALID: No questions were asked about Special Tests. Question 8.8.A is the only one which may have been interpreted to relate to Special Tests and specific directions to ignore Special Tests were included in the question.

24. General Several questions require specific procedural response. Many of these procedures have been revised.

Resp: ACCEPT: Key updated to the latest procedure revision.

25. General The exam was too long and required too many drawings.

Resp: The exam was carefully reviewed as to its content and the expected completion time. Both were deemed to satisfy the requirements of 10 CFR 55. The exam process is capable of sampling only a small portion of the knowledge an operator should have. It is necessary that the exam be as comprehensive as possible within the constraints allowed. Therefore, a written exam should be challenging both in scope and length to adequately differentiate candidates of less than acceptable knowledge levels.

ANO 2 EXAM REPORT

Exit Meeting Summary

At the conclusion of each week of the exam period, examiners met with representatives of the plant staff to discuss the results of the examinations. The following personnel were present for the exit interviews:

First Week

NRC	Utility
S. McCrory	R. Wewers
	J. Vandergrift
	E. Force
	J. Constantin
	R. Hargrove
	L. McClure
	A. Elliot
	E. Wentz

Mr. McCrory started the discussion by detailing the preliminary results of the first week of oral examinations administered. There were 12 candidates, six ROs, five SROs, and one Instructor Certification. All were considered as clear passes. It was noted that these results were still subject to final review by the region.

Only one general comment of a generic nature was discussed with the facility staff. There was evidence that the candidates were unfamiliar with the expected magnitude of various plant parameters as a result of casualty type transients.

There was some discussion concerning the recent change in the facility exam review procedure. The staff indicated that they had not received a copy of the Denton letter which described the changes to the review procedure. Mr. McCrory offered to send the plant a copy of this letter by separate correspondence.

Second Week

NRC	Utility
J. Boegel (PNL)	J. Levine
	R. Wewers
	J. Constantin
	R. Hargrove

Mr. Boegel informed utility personnel that of the five candidates given oral examinations, four were clear passes. He further indicated that he observed no generic weaknesses during the examinations.

ANO 2 EXAM REPORT

Generic Comments

During the grading of the RO and SRO exams, areas of generic weakness were identified based on the responses of the candidates to specific questions. These subject areas are discussed below.

1. In question 4.9/7.9.A most of the candidates demonstrated an inability to either identify or deal with the reactivity changes resulting from the combination of rod withdrawal and simultaneous power increase to a new steady-state condition. Several candidates considered reactivity due to rods only and ignored moderator temperature and doppler reactivity effects. Others who identified the net reactivity change as positive failed to realize that negative reactivity must be added to compensate, so that the boron concentration would increase.

2. In question 4.9/7.9.B most of the candidates demonstrated a lack of understanding of the terms EFPD or EFPH. Several identified that 3 EFPH remained before Tech Spec limits would be exceeded but failed to realize that as long as power is less than 100 percent, it will take more than 3 hours to use up 3 EFPH. While most of the candidates knew that rod motion was restricted to 10"/15 min. and that normal power increases were limited to 10%/hr., few indicated awareness that normal power decreases are limited to 30%/hr. or that Tech Specs impose a 5%/hr. limit on power increase after operating below the short term rod insertion limits for more than 4 hours.

3. In question 1.3/5.3 many candidates failed to realize that the DNBR increased because the DNB or CHF limit was increased as a result of increasing the pressure.

4. Several candidates missed the radiation exposure limits asked for in question 4.3/7.3.A.

5. In question 4.5/7.5 most candidates indicated unfamiliarity with the precautions of RPP 1622.010 for minimizing internal deposition of radioactive materials as a result of decontamination efforts.

6. A chronic problem observed during grading of written exams is that candidates fail to thoroughly read a question and as a result do not answer some part of it. An unnecessary number of points were given up by candidates on this exam because they overlooked an entire category of information requested by the question. An example is a question which asks the candidate to list and explain certain information. The candidate will list the items requested but not have <u>anything</u> written for explanation.

These areas should be regarded as potential areas for emphasis in the ANO II training program. Because of the small sample size and the specificity of the remarks this analysis does not necessarily indicate a problem with the training program as a whole.

ANO II EXAM KEY

Date administered: Mrach 20, 1984
Exam type: Reactor Operator and Senoir Reactor Operator
Comments: The questions in categories 1 and 5 are the same. Categories 4 and 7 are the same except that category 4 has one more question (4.11). Category 6 is a composite of categories 2 and 3. Dual numbers are used to indicate category 6 questions.

1. Principles of Nuclear Power, Plant Operation, Thermodynamics, Heat Transfer, and Fluid Flow

1.1 A. Describe how cooldown is controlled during natural circulation. (1.0)

B. Describe and explain the major differences you would observe in the establishment of natural circulation in the following two (2) plant conditions: (1) reactor trip caused by tripping of four (4) reactor coolant pumps, and (2) reactor trip with reactor coolant pump running for ONE (1) hour and then tripping. The reactor coolant pumps are not available after being tripped. (2.0)

ANS:

A. Cooldown during natural circulation is controlled by the steam generator feed and steam rate. As steam and feed flow is increased the rate of cooldown is increased.

B. A reactor trip caused by 4 RCPs trip requires that natural circulation removes 5% to 7% of full power. A reactor trip followed by reactor coolant pump trip 1 hour later results in natural circulation removing 1% to 3% of full power. The higher power 5% to 7% will cause higher delta temperatures and flow rate causing faster setup of natural circulation. The lower power 1% to 3% will cause longer setup times.

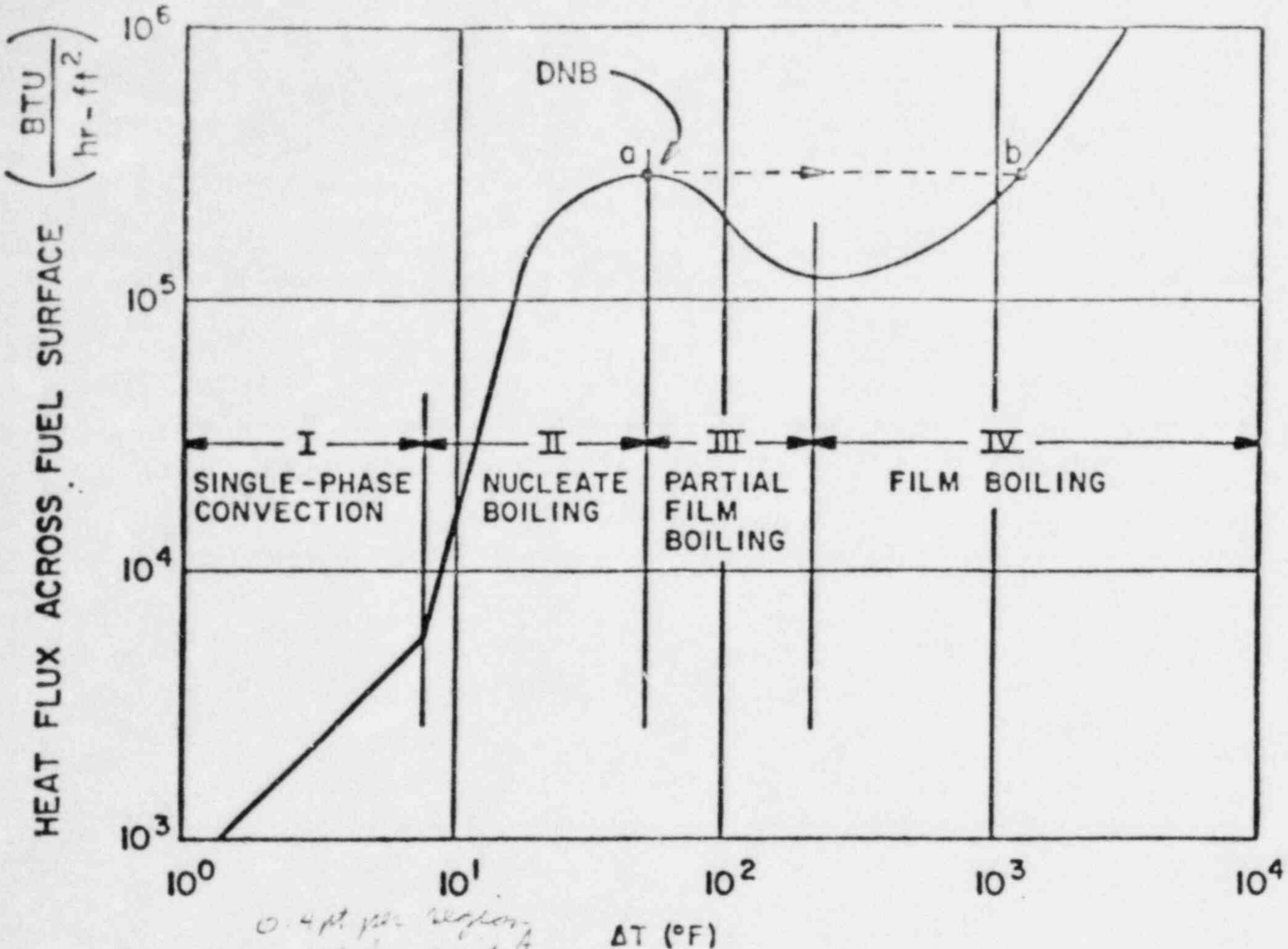
REF: Basic thermodynamics C\F

Refer to Figure 1.2 for question 1.2 and 1.3

1.2 On Figure 1.2 indicate and identify the various heat transfer or boiling regime regions. Identify point A on the curve. (2.0)

ANS: See Figure 1.2

REF: ANO Nuclear Fundamentals pgs 190-194 examine how they relate to heat transfer from a fuel rod.



0.4 pt per region
0.4 pt for point A

Departure from Nucleate Boiling Curve

Figure 92

(1) Region I - Single Phase Convection - Heat transfer ability in this region is good.

(2) Region II - Nucleate Boiling - Heat transfer ability in this region is greatly improved, as can be seen from the slope of the curve in this region. An incremental increase in heat flux in Region II will result in less of a ΔT increase than in Region I.

(3) DNB Point - Departure from Nucleate Boiling or Critical Heat Flux (point a on curve). This point is the threshold of the partial film boiling region. It is at this point where heat must be removed by passing through a larger steam bubble formation on the fuel rod surface.

1.3 Point X (Figure 1.2) identifies initial plant conditions while operating at power. RCS pressure is increased such that nucleate boiling is completely suppressed.

A. How and why is the DNBR affected? (1.0)

B. What happens to Fuel Clad surface temperature? Explain. (1.5)

ANS:

A. DNBR increases because the CHF was increased when pressure went up. (Note: Plant conditions do not move farther from the DNB point. The point is moved farther from plant conditions)

B. Using $Q = UA (T_{CLAD} - T_{MODERATOR})$
When pressure is increased to suppress nucleate boiling:

Q remains constant because it is a function of nuclear power.

A remains constant because the fuel rod does not compress significantly due to pressure increase.

$T_{moderator}$ remains constant because thermal power is not changed.

U decreases due to the loss of nucleate boiling agitation

Therefore:

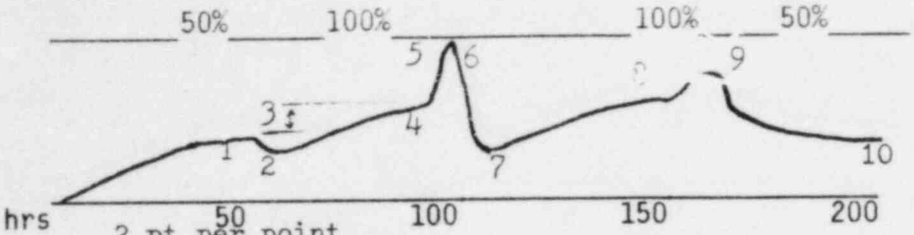
T_{CLAD} must increase (.5) ~~65~~ > to provide the necessary thermal head to remove the heat generated in the fuel.

REF: ANO Nuclear Fundamentals
Nuclear Engineering Handbook, Etherington, 1958, Section 9

1.4 Plot Xenon (Xe) for the following reactor conditions. Assuming X free initially. (Show relative magnitude and curve shape-not absolute values) (2.0)

Power level 50% for 50 hrs.
Power level 100% for next 40 hrs.
Trip power level 0% for next 8 hrs.
Power Level 100% for next 52 hrs.
Power level 50% for next 50 hrs.

ANS:



.2 pt per point
.1 pt if peak or dip relationships are incorrect

REF: Std Nuclear Theory

1.5 Figure 1.5 A-D represent the flow-head characteristics of a fluid system containing a centrifugal pump. For parts A through D below draw the new flow-head curves on Figures 1.5 A-D respectively. (2.5)

A. Power supply to the pump motor goes from 60 HZ to 63 HZ.

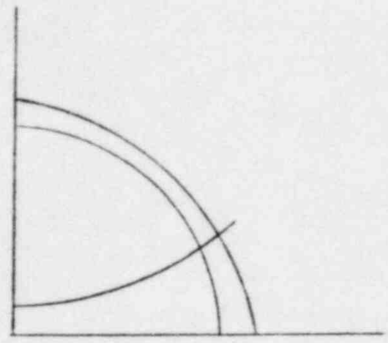
B. A venturi type flow detector is installed in downstream piping.

C. A second identical pump is installed in parallel with the existing pump.

D. A second identical pump is installed in series and the system is acid cleaned.

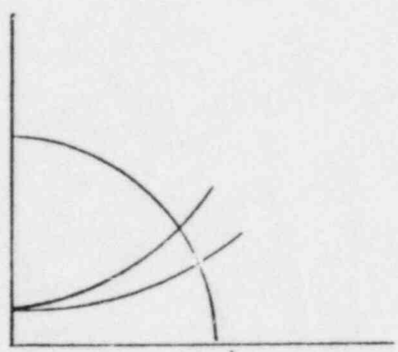
ANS: See figure 1.5

REF: Std centrifugal pump laws
CAMERON Hydraulic Data, Ingersall - Rand 1977, Section 1



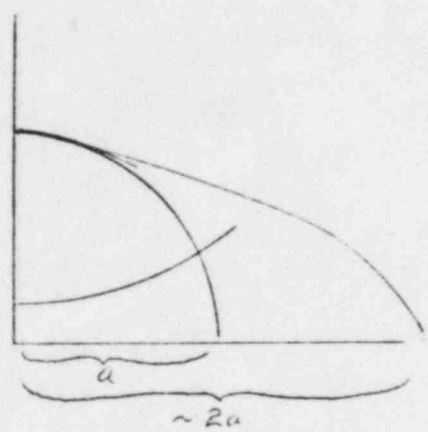
A.

0.5 pt



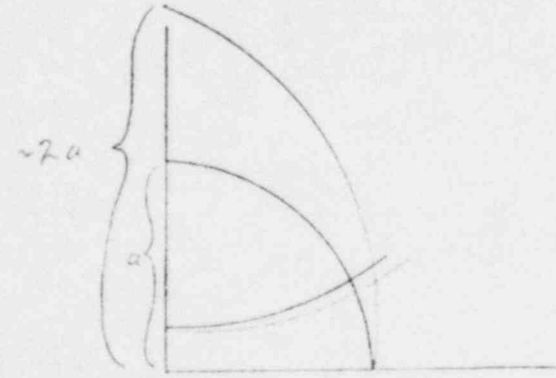
B.

0.5 pt



C.

0.5 pt for curve
0.1 pt for flow relation



D

0.4 pt curve
0.1 for [illegible] relation

Figure 15

For questions 1.6 and 1.7 refer to Figure 1.6 and the steam tables.
(1 atmosphere =29.92" Hg = 33.9' water)

1.6 The water in the condenser hotwell is _____ subcooled. (1.0)

A. Not
B. 2°F
C. 4°F
D. 8°F

ANS: C

REF: Std Thermo and Heat Transfer

1.7 The absolute pressure (psia) at the condensate pump suction is _____. (1.0)

A. 2.3 psia
B. 11.2 psia
C. 3.5 psia
D. 5.4 psia

ANS: D

REF: Std Thermo and Heat Transfer

1.8 If after operating in natural circulation for two (2) hours, an operator error (oversteaming) of the S/G causes a complete loss of natural circulation flow, how will the following parameters change (INCREASE, DECREASE, OR REMAIN THE SAME)? Briefly explain your answer. (Assume no further operator action). (2.0)

A. Core Delta T
B. Core thermocouple temperature
C. Steam generator pressure
D. Steam generator level

ANS:

A. Increase (0.2) as boiling occurs in the core. Th (0.15) will increase while Tc (0.15) remains relatively constant.

B. Increase (0.2) boiling in the core and a lesser means available to remove the heat (0.3).

C. Decrease (0.2) less primary to secondary heat transfer (0.3).

D. Increase (0.2) less steam being drawn off as the RCS cools, with constant auxiliary feed (0.3).

REF: Heat Transfer, Thermodynamics, and Fluid Flow, General Physics.

1.9 Explain briefly the basic reactivity changes responsible for the shape of the three (3) areas (A, B, and C) marked on Figure 1.9. (1.5)

ANS:

A. buildup of Samarium and other FP poisons (0.5 each)

B. depletion of burnable poisons (and Pu Build Up)

C. fuel depletion

REF: Std Rx Theory/Plant Data Book

1.10 During a reactor startup, will the actual critical position be HIGHER, LOWER, or the SAME AS the estimated critical position calculated before the following changes? EXPLAIN your choices. (Consider each change separately). (3.0)

A. The operator starts using main steam to warm the main turbine prior to reaching criticality.

B. Actual boron concentration was 30 ppm higher than the value used for figuring the ECP.

C. Startup was delayed 4 hours beyond the ECP time; a shutdown time of sixteen (16) hours was used for the ECP.

D. The pressurizer pressure setpoints are all lowered by 50 psi prior to criticality.

ANS:

A. ACP LOWER (.25) than ECP because the lowering of temperature will insert positive reactivity resulting in criticality at a lower rod height. (.5)

(Will accept SAME if RCP heating is identified as being sufficient to over come heat loss for turbine warm-up).

B. ACP HIGHER (.25) than ECP because the higher boron concentration inserts negative reactivity, resulting in a higher rod height. (.5)

C. ACP LOWER (.25) than ECP because xenon concentration will be decreasing which inserts positive reactivity. (.5)

D. ACP slightly HIGHER (.25) than ECP because negative reactivity inserted by the pressure coefficient. The moderator will be less dense and result in a higher critical rod height. (.5) (Will accept the SAME if change is considered neglible but recognized).

REF: C-E Reactor Theory

1.11 What happens to the moderator temperature coefficient as boron concentration is increased? Explain. (1.0)

ANS: The negative temperature coefficient becomes less negative. (0.25)

As the moderator heat increases the expansion removes boron from the core. This is a positive reactivity addition because less neutrons are absorbed. This also adds negative reactivity due to less thermalization of neutrons. (0.75)

REF: Std Reactor Theory

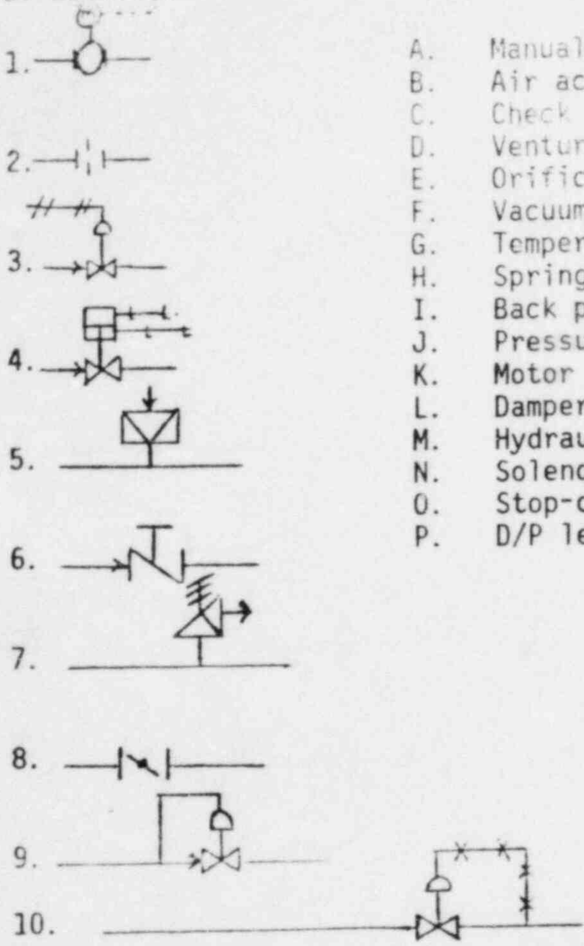
1.12 The buildup of Samarium and Plutonium after a reactor trip can, to some extent, lead to offsetting reactivity effects. Explain or show how each is PRODUCED and the REASON the reactivity effects can be offsetting. (1.0)

ANS: Fission produces Nd-149 which beta decays (1.7 hr.) to Pm-149 which beta decays (53 hrs.) to Sm-149 [0.35]. U-238 absorbs a neutron and beta decays (23 mins) to Np-239 which beta decays (55 hrs.) to Pu-239 [0.35]. Pu-239 adds positive reactivity (due to high thermal fission cross section) and Sm-149 adds negative reactivity [0.3~~5~~].

REF: C-E Reactor Theory

2. Plant Design

2.1 Match the following P&ID symbols with the name or function which best identifies the symbol. (Arrows indicate normal or design fluid flow direction). (2.0)



A. Manually operated gate valve
B. Air actuated valve
C. Check valve
D. Venturi
E. Orifice
F. Vacuum breaker
G. Temperature regulator
H. Spring loaded relief valve
I. Back pressure regulator
J. Pressure reducer
K. Motor operated ball valve
L. Damper
M. Hydrauclically controlled valve
N. Solenoid actuated valve
O. Stop-check valve
P. D/P level detector

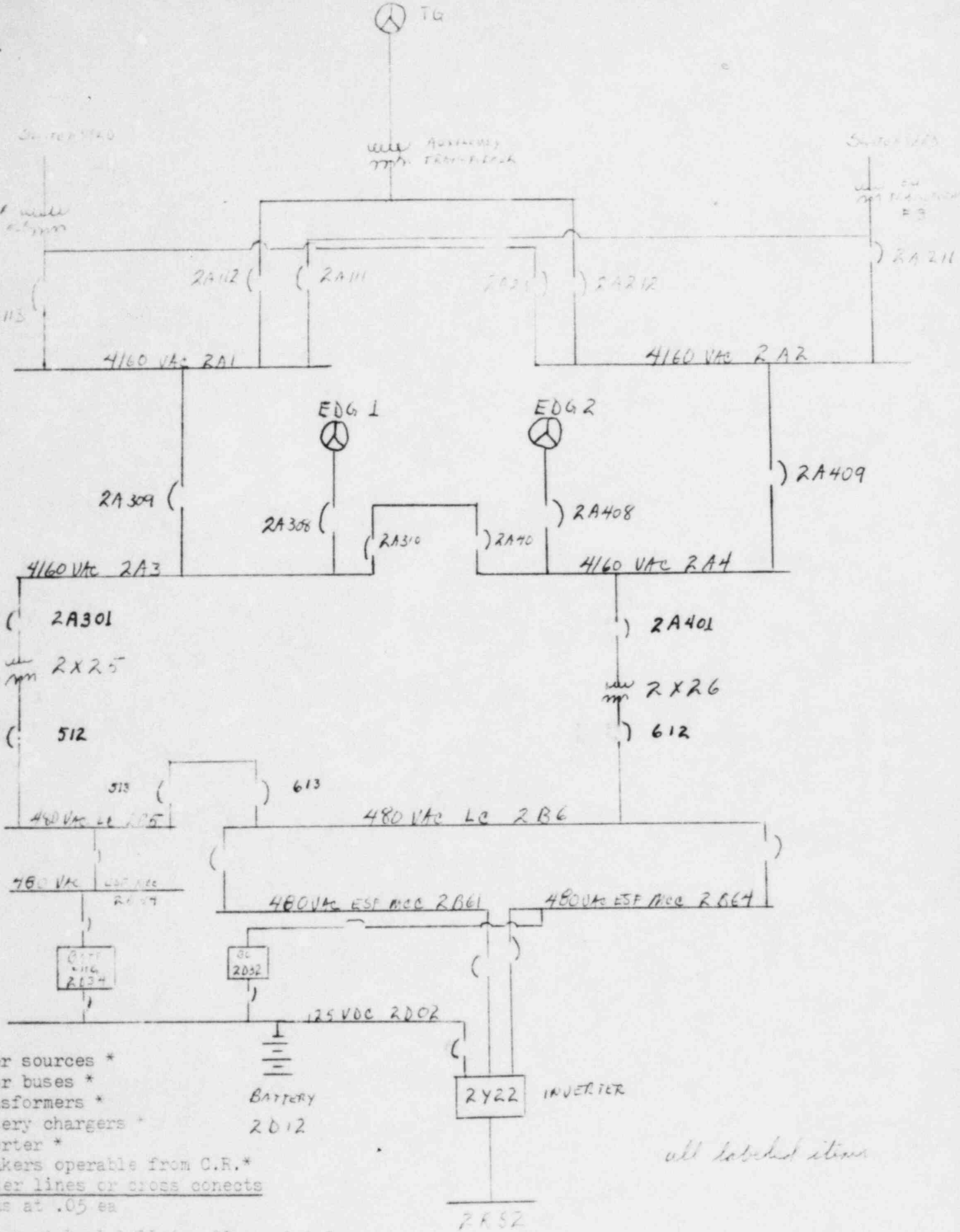
ANS: 1.K; 2.E; 3.B; 4.M; 5.F; 6.O; 7.H; 8.L; 9.I; 10.G;

REF: P&ID M-2200, 2201

2.2/6.2 Draw the electrical distribution showing all possible ways of energizing 120 VAC Vital Bus 2 RS 2. Include and identify by alpha - numeric designations all busses, breakers (that can be operated from the control room), transformers, inverters and ultimate sources. (For offsite power terminate at the switchyard connection). Ignore possible tie-in with Unit 1 and bus-linkage alterations. (4.0)

ANS: See attached figure

REF: ANO lesson plan AA-52002-007 and Figure 7.1, .5, .6, and .7



6 power sources *
10 major buses *
5 transformers *
2 battery chargers *
1 inverter *
18 breakers operable from C.R.*
<u>26 feeder lines or cross conects</u>
68 items at .05 ea

*items must be labelled, .02 per label

2.2 KEY

2.3/6.3 List the system and pressure at which injection first begins for each ECCS capable of injecting water into the RCS. (1.5)

ANS: HPSI 1450 psig
LPSI 150 - 180 psig
SIT 600 - 624 psig

REF: OP 2104.039, .040 lesson plan AA-52002-004
(Based on minimum suction pressure and DP during surveillance tests)

2.4/6.4 For the diesel design functions in Column A select the INDIVIDUAL auxiliary system/components from Column B which MOST correctly satisfies the function. EXPLAIN your choices. (3.0)

Column A		Column B	
a.	Ensures the diesel is started within 15 seconds	1.	Lube oil heaters
		2.	Pre-Lube Pump
b.	Serves as a backup speed governor	3.	Starting air receivers
c.	Minimizes engine wear when manually starting	4.	Starting air motors
		5.	Centrifugal governor
d.	Provides for easier engine starting	6.	Fuel oil day tank
		7.	Water jacket cooling pressure switches
		8.	Electro-hydraulic governor

ANS:

A. 3 [0.25] Insure reliability because each is capable of five diesel starts (0.5).

B. 5 [0.25] Takes overspeed control upon loss of electro-hydraulic governor (0.5).

C. 2 [0.25] Precoats engine bearings and parts with oil to minimize friction and thus wear [0.5].

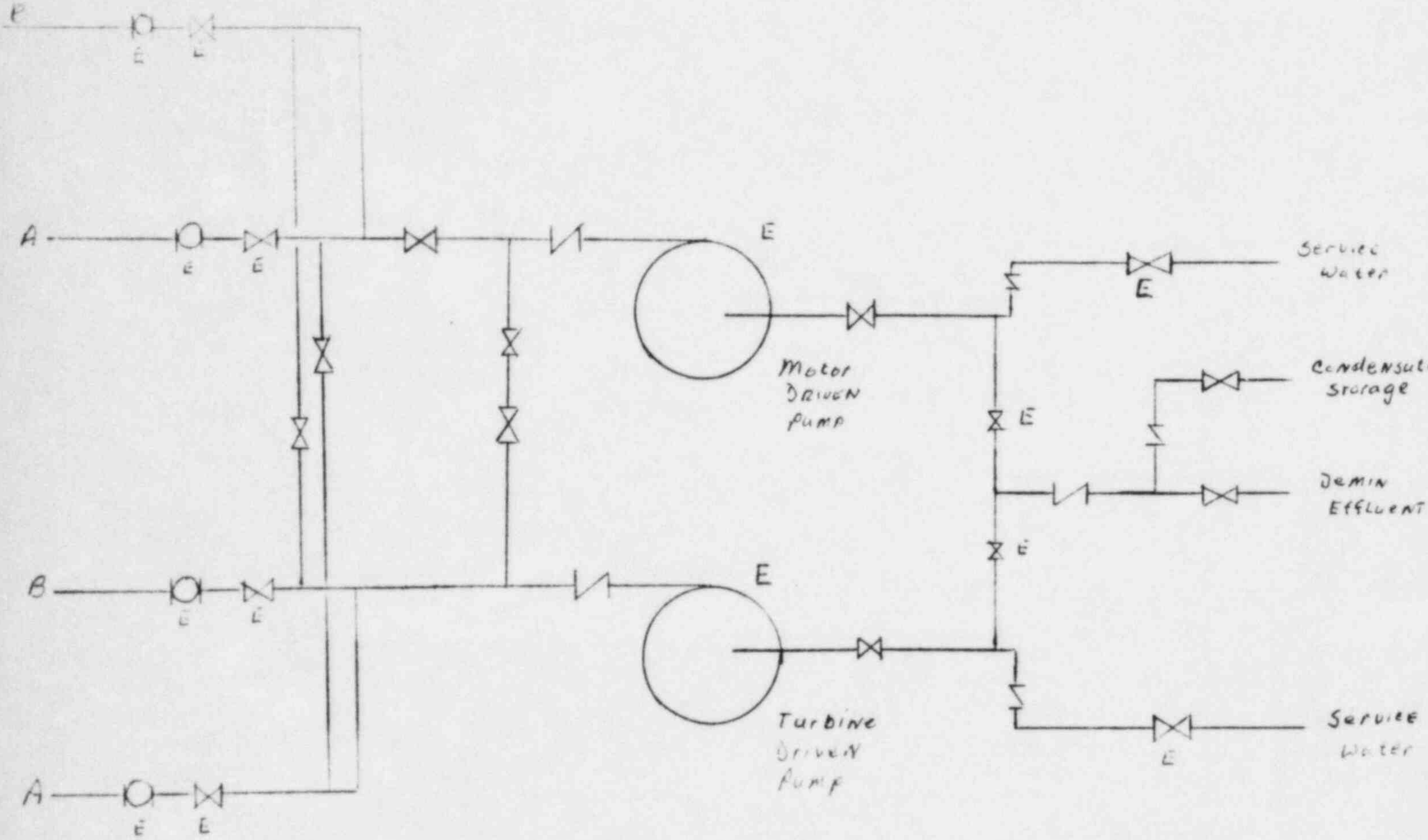
D. 1 [0.25] Lube oil heater makes the oil easier to pump and allow better lubrication (0.5).

REF: ANO 2 lesson plan AA-52002-016

2.5/6.5 Sketch a one line diagram of the emergency feedwater system from the source(s) of water to the steam generators. Include pumps, major control valves, and interfaces with other plant systems. Indicate which valves and pumps would be actuated on an EFAS. (Valve numbers are not required) (3.0)

ANS: See drawing

REF: ANO 2 P&ID M-2204



0.25 pt for each water source

0.2 pt ea pump

0.077 pt ea EFAS

0.6 pt piping layout

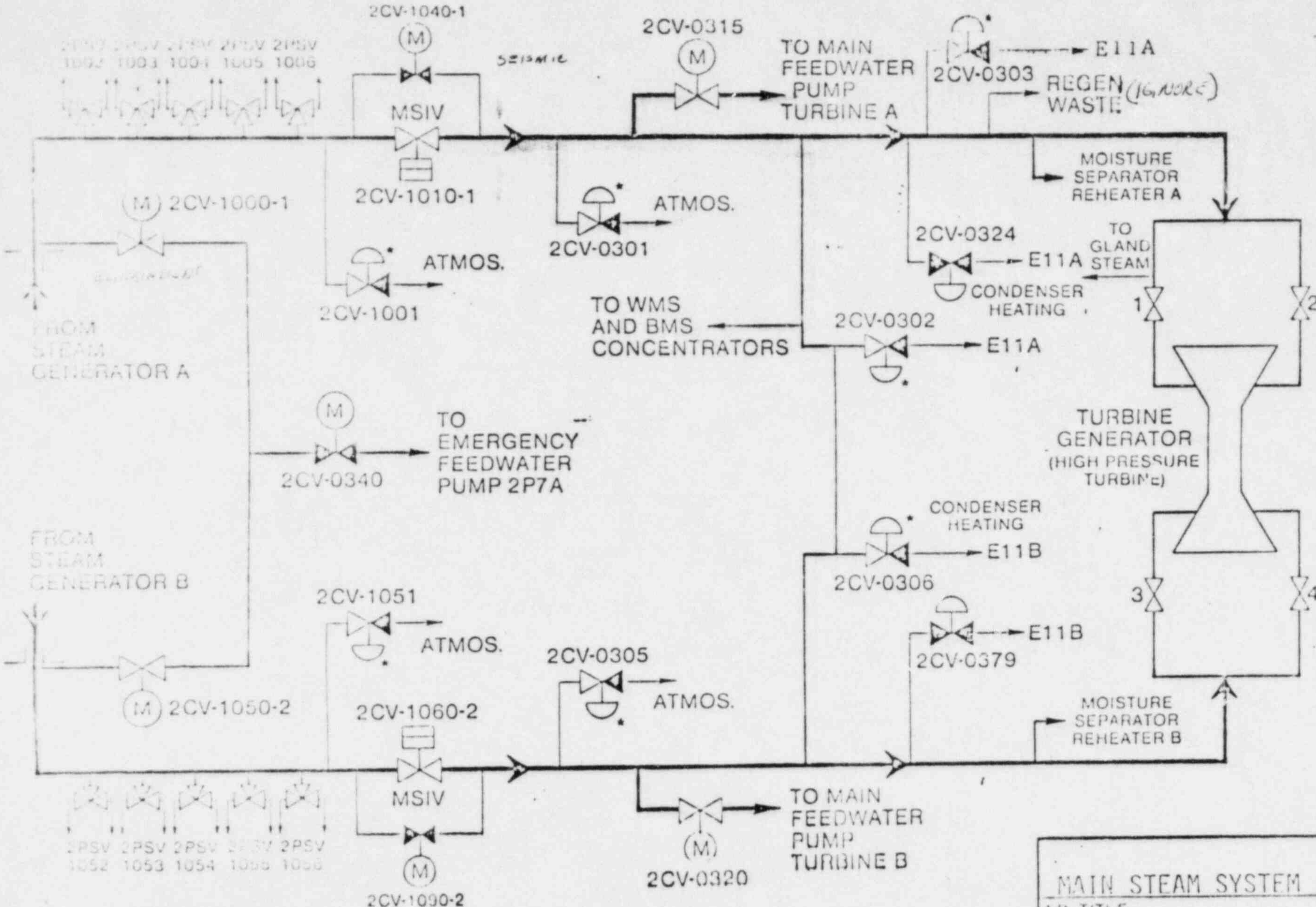
2.5 Key

2.6 Sketch one main steam line from the SG to the TG showing relative location of major components and steam takeoffs (e.g., MSIV and SGFP supply). Show containment and seismic boundaries. (2.0)

ANS: See drawing

REF: ANO 2 lesson plan AA-52002-008, Figure 8.1

FIGURE 8.1



2.6 Key

*SDBCS VALVE

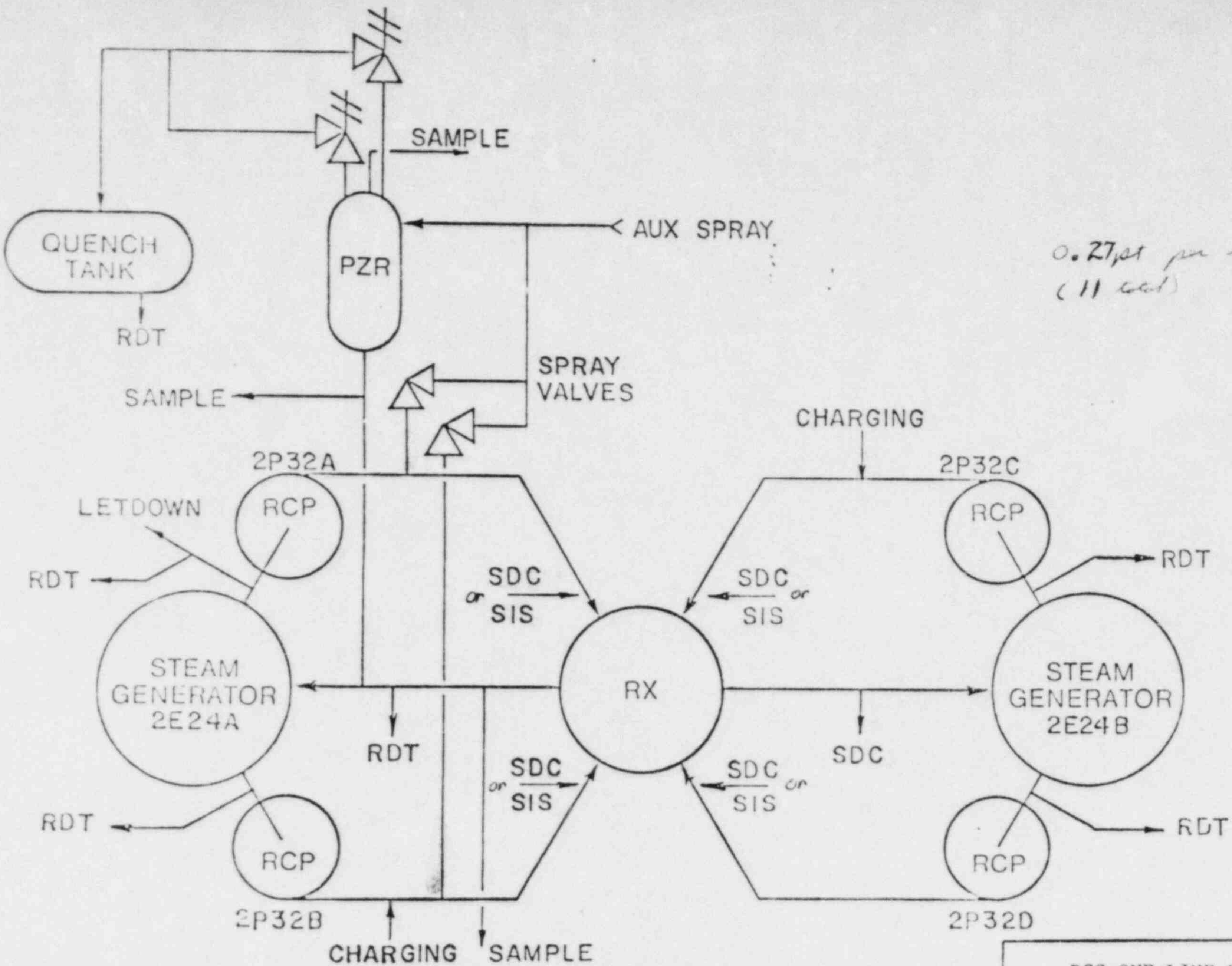
MAIN STEAM SYSTEM			
LP TITLE			
STEAM SYSTEM			
LP No.	FIGURE	DATE	REV
AA52002-008	8.1	3-82	0

2.7 Using the simplified RCS drawing provided (Figure 2.7), sketch the location of the primary system connections to the systems below. (Use abbreviations provided or define, show relative location on each leg, use each as many times as appropriate). (3.0)

Charging (CHG)
Letdown (LTDN)
Safety Injection/Shutdown Cooling Injection (SIS)
Shutdown Cooling Suction (SDC)
Pressurizer Surge Line (PZR)
Pressurizer Spray Line (SPRAY)

ANS: Key attached

REF: ANO 2 lesson plan AA-52002-001, Figure 1.2



0.27 pt per [illegible]
(11 [illegible])

REACTOR COOLANT SYSTEM

RCS ONE-LINE DIAGRAM			
LP TITLE REACTOR COOLANT SYSTEM			
LP No	FIGURE	DATE	REV

FIGURE 1.2

2.7 Key

2.8 Choose from the list below the automatic protective trip or lockout of the emergency diesel generators which is bypassed by an SIAS. (0.5)

A. Engine Overspeed
B. Generator Anti-Motoring
C. Engine Lube Oil Pressure Low
D. Generator Differential Current

ANS: B

REF: ANO 2 lesson plan AA-52002-016 pg 9

2.9 A. What interlocks must be satisfied before normal starting of a RCP? (1.0)

B. Why must RCS temperature be >500°F before starting the fourth ACP? (1.0)

ANS:

A. HP lift pump discharge pressure >400 PSI and CCW flow to the RCP >240 gpm.

B. To prevent lifting the core assembly as a result of hydraulic force imported by the coolant. (Density below 500°F is sufficient to lift core assembly w/four pumps running).

REF: RCS OP 2103.06
SAR

2.10/6.8 The radiation monitoring system provided for ANO 2 consists of two (2) subsystems. Name them and describe their primary objectives. (2.0)

ANS: Area Rad Monitoring Sys: alert local and CR personnel to abnormal rad levels in order to control exposure and release potential. Area monitors provided to supplement personnel and area radiation monitoring provisions of plant health physics program.

Process Rad Mon Sys: Processing monitoring provides means for monitoring containment atmosphere, ventilations exhause from spaces containing components for recirc. of hypothetical LOCA flushes and all other gaseous and liquid effluent paths where radionuclides could be released to enviornment.

REF: ANO lesson plan AA-52002-018 Pg 1.

2.11 True or False: Continuous full power operation is unaffected by the operational status of the auxillary cooling water system. Justify your answer. (1.0)

ANS: False. The ACWS cools the TG stator cooling subsystem. Therefore the TG will eventually exceed temp limits which will require shutdown or a power reduction. (accept also: lube oil cooling or H_2 cooling systems)

REF: EOP 2202.13 pg 2
P&ID M-2211

X

3. Instruments and Controls

3.1/6.1 List five (5) actuation signals generated by the Engineered Safety Feature Actuation System. For each, indicate the parameter(s) and setpoint value(s) which initiate the signal. (4.0)

ANS: Any five, see attached sheet

REF: ANO 2 lesson plan AA-52002-013 Table 13.2

TABLE 3.3-4

ENGINEERED SAFETY FEATURE ACTUATION SYSTEM INSTRUMENTATION TRIP VALUES

FUNCTIONAL UNIT	TRIP SETPOINT	ALLOWABLE VALUES
1. SAFETY INJECTION (SIAS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Containment Pressure - High	$\leq$ 18.4 psia	$\leq$ 19.024 psia
c. Pressurizer Pressure - Low	$\geq$ 1766 psia (1)	$\geq$ 1712.757 psia (1)
2. CONTAINMENT SPRAY (CSAS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Containment Pressure -- High-High	$\leq$ 23.3 psia	$\leq$ 23.624 psia
3. CONTAINMENT ISOLATION (CIAS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Containment Pressure - High	$\leq$ 18.4 psia	$\leq$ 19.024 psia

.33 per actuation signal
.33 signal source
.33 set point
Where more than one source or setpoint apply distribute incremental points evenly
Ignore manual trips

3.1/6.1 Key

TABLE 3.3-4 (Continued)

ENGINEERED SAFETY FEATURE ACTUATION SYSTEM INSTRUMENTATION TRIP VALUES

FUNCTIONAL UNIT	TRIP VALUE	ALLOWABLE VALUES
4. MAIN STEAM AND FEEDWATER ISOLATION (MSIS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Steam Generator Pressure - Low	$\geq$ 751 psia (2)	$\geq$ 729.613 psia (2)
5. CONTAINMENT COOLING (CCAS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Containment Pressure - High	$\leq$ 18.4 psia	$\leq$ 19.024 psia
c. Pressurizer Pressure - Low	$\geq$ 1766 psia (1)	$\geq$ 1712.757 psia (1)
6. RECIRCULATION (RAS)		
a. Manual (Trip Buttons)	Not Applicable	Not Applicable
b. Refueling Water Tank - Low	54,400 $\pm$ 2,370 gallons (equivalent to 6.0 $\pm$ 0.5% indicated level)	between 51,050 and 58,600 gallons (equivalent to between 5.111% and 6.889% indicated level)
7. LOSS OF POWER		
a. 4.16 kv Emergency Bus Undervoltage (Loss of Voltage)	3120 volts (4)	3120 volts (4)
b. 460 volt Emergency Bus Undervoltage (Degraded Voltage)	423 $\pm$ 2.0 volts with an 8.0 $\pm$ 0.5 second time delay	423 $\pm$ 4.0 volts with an 8.0 $\pm$ 0.8 second time delay

3.1/6.1 key

0001131345 4

TABLE 3.3-4 (Continued)

ENGINEERED SAFETY FEATURE ACTUATION SYSTEM INSTRUMENTATION TRIP VALUES

FUNCTIONAL UNIT	TRIP VALUE	ALLOWABLE VALUES
8. EMERGENCY FEEDWATER (EFAS)		
a. Manual (trip Buttons)	Not Applicable	Not Applicable
b. Steam Generator (A&B) Level-Low	$\geq$ 46.7% (3)	$\geq$ 45.811% (3)
c. Steam Generator ΔP-High (SG-A > SG-B)	$\leq$ 90 psi	$\leq$ 99.344 psi
d. Steam Generator ΔP-High (SG-B > SG-A)	$\leq$ 90 psi	$\leq$ 99.344 psi
e. Steam Generator (A&B) Pressure - Low	$\geq$ 751 psia (2)	$\geq$ 729.613 psia (2)

(1) Value may be decreased manually, to a minimum of > 100 psia, during a planned reduction in pressurizer pressure, provided the margin between the pressurizer pressure and this value is maintained at < 200 psi; the setpoint shall be increased automatically as pressurizer pressure is increased until the trip set-point is reached. Trip may be manually bypassed below 400 psia; bypass shall be automatically removed whenever pressurizer pressure is $\geq$ 500 psia.

(2) Value may be decreased manually during a planned reduction in steam generator pressure, provided the margin between the steam generator pressure and this value is maintained at < 200 psi; the setpoint shall be increased automatically as steam generator pressure is increased until the trip setpoint is reached.

(3) % of the distance between steam generator upper and lower level instrument nozzles.

(4) Inverse time relay set value, not a trip value. The zero voltage trip will occur in 0.75 ± 0.075 seconds.

3.1/6.1 Key

3.2 What are four (4) of five (5) core operating limits monitored by COLSS? (2.0)

ANS: any four (4)

(0.5 each)

1. Peak Linear Heat Rate (LPD)
2. Margin to DNB (DNBR Margin)
3. Total Core power
4. Azimuthal tilt
5. Axial Shape Index

REF: ANO 2 I&C OP 2105.13 pg 2
Tech Specs 3.2.1, 3.2.3, 3.2.4, 3.2.7

3.3 The excore nuclear instrumentation consists of three (3) subsystems. List them, the type, and quantity of detectors each uses, and the prinicple purpose and range of each. (4.5)

ANS:

Name	Startup (0.3)	Control (0.3)	Safety (0.3)
#Detectors	2/ch 4 total (0.3)	1/ch 2 total (0.3)	3/ch 12 total (0.3)
Type	Fission (0.3)	Fission (0.3)	Fission (0.3)
Range	0.1 → 10^5 CPS or 0 → 200% or 10^{-8}% → 200% (0.3)	1% → 125% or 0% (0.3)	log $2x10^{-8}$% → 200% or linear 1% → 200% (0.3)
Purpose	SUR/power level below C/S range (0.3)	input for Rx Reg SYS (0.3)	power input to PPS (0.3)

REF: ANO 2 lesson plan AA-52002-014

3.4 List ten (10) signals to the turbine trip system which will cause a turbine trip by closing all turbine steam valves (setpoints <u>not</u> required). (2.5)

ANS: and ten

1) Overspeed (110% of rated speed)
2) Backup overspeed trip (112% of rated speed).
3) Low vacuum (<7.5 psia)
4) Excessive thrust bearing wear (<13 psig)
5) Reactor trip
6) Generator lockout trip
7) Manual trip from Control Room
8) Excessive vibration (>14 mls.)
9) Manual trip at turbine
10) High exhaust hood temperature (>225°F)
11) MSR high level
12) Loss of stator coolant
13) Low hydraulic fluid pressure (<1100 psi)
14) Loss of both speed signals.
15) Low bearings oil pressure (<13 psi)
16) Shaft pump discharge pressure low (<105 psi)
17) Loss of DC to EH controller
18) 500 KV breaker 5130/5134 failure
19) Computer trip of turbine

REF: ANO 2 lesson plan AA-52002-009 pgs 13-14

3.5 Assume the pressure channel input on service to the pressurizer control system (PPCS) failed high. Describe controlled component response to this failure and five alarms or indications in the control room symptomatic of this failure. (2.0)

ANS: Component Response: Spray valves full open (0.33)
Proportional htrs. to minimum (0.33)
B/U htrs. de-energized (0.33)

Symptoms: Pzr. Press. Hi-Lo alarm (5/7 @ 0.2 ea)
Spray valves full open
Proportional heaters to minimum
B/U htrs off w/press >2220 psi

Pzr Press Lo Pretrip alarm
SIAS received
Rx trip on low pressure

REF: ANO 2 RCS OP 2103.05

3.6 Choose from the list below the main control room indication most appropriate to confirm rod insertion after an automatic reactor trip. (0.5)

A. CEA Rod Bottom ~~lights illuminated~~ lower electrical limit

B. RPS trip path actuated alarm

C. Reactor trip breaker TCB 1 switchgear trip alarm

D. CEA group indications reading zero

ANS: A

REF: ANO 2 EP 2202.04

3.7 A. With the CEA control system in automatic sequential (AS), how can power be reduced from 100% to 80% without producing CEA motion? (0.5)

B. What inputs and calculations does the Reactor Regulating System (RRS) use to produce a CEA motion demand signal? (1.5)

ANS:

A. Reduce reactor power by decreasing steam demand [0.25] and at the same time reduce Tavg by borating [0.25].

B. T.G. 1st stage press, is used to calculate Tref and T.G. power. Th and Tc are used to calculate Tavg. A rate of power change error is calculated from T.G. power and reactor power. A temperature error is calculated from Tref and Tavg. The errors are combined to produce CEA motion demand. (.3 per sentence.)

REF: ANO 2 lesson plan AA-52002-034

3.8/6.6 A. How would the Steam Dump and Bypass Control System (SDBCS) valves respond to a turbine trip (without a reactor trip) while at 100% power? Rod Control in Auto (1.0)

B. What signals determine this response? (1.0)

C. How would the SDBCS respond differently if: (1.5)

1. A reactor trip caused the turbine trip?

2. Circ water were lost at the time of the turbine trip?

(Discuss only <u>initial</u> system response - within first minute).

ANS:

A. The steam dump and bypass valves would <u>Quick Open</u> to establish no load temperature and pressure in the RCS and SGs.

B. Low steam flow (rapid large drop in flow)(.5)or high pressure (rapid large rise) generate the Q.O. signal. (.5)

C. 1. A reactor trip blocks the Q.O. signal to 2 up stream and 1 downsteam dump valves.

2. All valves receive Q.O. initially. As condenser vacuum decreases the bypass valves will shut leaving only the dump valves open.

REF: ANO 2 lesson plan AA-52002-011

3.9 With the unit at 80% power, a steam generator tube leak develops which rapidly escalates to 110 gpm in less than five (5) minutes.

A. Explain what available instrumentation will enable the operator to confirm the emergency is a tube failure rather than a primary leak to the containment. (1.0)

B. Explain the instrument response which enables the operator to determine the affected steam generator. (1.0)

ANS:

A.

S/G Tube Rupture	Leak to Containment
Sample Monitor	Containment Monitors
Vacuum Pump DISCH Monitor	Containment Press
Steam Line Monitor	Sump Level
(Steam/Feed Mismatch too small)	Containment Temp
	Containment Humidity

B. Steam Line Monitor or Blowdown line
EFW feed demand signal

REF: EP 2202.06, 2202.23

3.10/6.7 How would the following indications be affected (INCREASE, DECREASE OR NO CHANGE) by the associated condition change listed below? Consider each indication separately and EXPLAIN your answer. (3.0)

	INDICATION	CONDITION CHANGE
A.	Nuclear Wide Range Instrument	Cold leg temperature increases 50 degrees F at constant true nuclear power.
B.	Pressurizer level	Differential pressure transmitter reference leg temperature increases 10 degrees F. (No change in actual steam flow)
C.	Steam Generator level	Control steam flow signal increases (No change in acutal steam flow)

ANS:

A. Increase [0.5] Increased neutron leakage to detector [0.5]

B. Increase [0.5] reduced density of water in reference leg decreases differential pressure signal resulting in an apparent increase in level [0.5]

C. Increase [0.5] feed flow would increase to attempt to match the steam flow until the level error signal overrides the mismatch and reduces flow. (Final level is slightly higher than initial)

(accept NO CHANGE if answer says level control only looks at feed flow-steam flow mismatch rate which rapidly decays away on a step change followed by a constant mismatch).

REF: A&B Standard Reactor Theory and Fluid Mechanics
C ANO 2 lesson plan AA-52002-015

4. Procedures - Normal, Abnormal, Emergency, and Radiological Control

4.1/7.1 Refer to Figure 4.1 for this question.

A. What are the required immediate actions if the H_2/O_2 analyzer reading for the Waste Gas Surge Tank is at point 1 ? (1.0)

B. What further immediate actions are required if the situation degrades to the indication at point 2 ? (1.0)

C. Why is the mixture at point 3 impossible? (1.0)

ANS:

A. 1. Change H_2/O_2 analyzer lineup to monitor the waste gas decay tank in service. (.33 ea)

2. Have Radchem Dept perform H_2/O_2 samples on all affected components.

3. Take action to reduce concentrations to be within Region A within 24 hours.

B. 1. Secure all vent, purge and vacuum degas operations. (.25 ea)

2. Place Waste Gas Compressors in "Pull to Lock".

3. Continue H_2/O_2 sampling by Radchem.

4. Take action to reduce concentrations

C. The mixutre is impossible because the only O_2 source for the systems monitored by the H_2/O_2 analyzer is air which is 79% N_2. Therefore, a mixtrue of 80% H_2 will have about 4% O_2 and 16% N_2.

REF: AOP 2203.10 pgs 1&6

4.2/7.2 A. How is the reactor vessel head cooled during natural circulation? Briefly describe the actions necessary to achieve the most effective cool down method for the RV head. (1.0)

B. What are the principle indications of void formation in the RCS when in natural circulation? (1.0)

C. Generally describe what is done to collapse void in the RCS when in natural circulation. What are the indications of void collapse. (Do not consider use of the vessel head vent system). (1.5)

ANS:

A. The vessel head is cooled by ambient loss and conduction from the head and flange to the nozzle belt region. A large ^T (~350) is created between the vessel head and Th by rapid cooldown using the SGs.

B. 1. An otherwise unaccountable increase in pressurizer level. or

2. Inability to reduce pressure with spray. or

3. Rapid increase while depressuring.

C. 1. Stop depressurizing (secure spray). (.2)

2. Energize pzr heaters to increase press (.2)

3. Increase press (pzr level drop - indicates void compression/partial collapse.) (.2)

4. Over pressurize 50psi to ensure pzr press control. (.2)

5. Soak to allow RCS structure to cooldown before continuing depressurization. (Ensures complete void collapse) (.2)

Complete void collapse is indicated by observing normal pressurizer level and pressure response to charging and spray after a soak period following repressurization. (.5)

REF: AOP 2203.13 pgs 1-3

4.3/7.3 A. State the ANO weekly, quarterly, and annual exposure limits for personnel with complete exposure records. (1.0)

B. What is the highest weekly exposure allowed without the General Manager's approval? (0.5)

ANS:

A. 300 MREM/wk
2500 MREM/qtr
5000 MREM/yr
(all subject to ≤5(N-18) REM accumulated)

B. Up to 1000 MREM/wk (HP superintendent approved)

REF: RPP 1622.011 pg 3

4.4/7.4 List five (5) symptoms or indications of uncontrolled/inadvertent moderator dilution. (2.0)

ANS:

1. Power level and/or Tavg increase w/CEDMCS Manual
2. Decrease in Boron concen on meter or by sample
3. Increase in VCT press or level
4. Bororometer high/lo alarm
5. Boron dilution monitor alarm

REF: EP 2202.07 pg 1

If answer power level increases (only) must qualify by indicating power less than 1% otherwise, deduct 0.1 pt.

4.5/7.5 Upon exiting a contaminated area, you find that your hands and shirt sleeves appear to be contaminated. Describe in moderate detail the survey and decontamination procedures you expect HP personnel to perform on you. Additionally, give three (3) specific precautions to minimize the potential for internal deposition of radioactive material due to decontamination efforts. (2.5)

ANS:
1. Detailed whole body frisk
2. Check for skin cuts, abraisons, etc.
3. Remove clothing
4. Second frisk after clothing removed
5. Dress in clean anti-c or surgical greens and procede to decon area
6. Wash affected areas with soap and water

(Look to see that most of these are covered in a common sense manor.)

precautions (any 3) (.5 ea)

1. Cover skin cuts or abraisions not contaminated with water proof dressing
2. Do not use stiff brushes or other items which may abrade skin
3. Use anti-cs and respirators as needed to reduce contamination spread
4. Water should be about body temp.
5. Do not use industrial or waterless hand cleansers.

(Give 1/2 credit for "good sense" actions whicn do not fit there.)

REF: RPP 1622.010 pgs 3-5

4.6/7.6 List the immediate actions for a steam generator tube rupture which exceeds charging pump capacity but is within HPSI pump capacity. Include <u>all actions</u> required by section II of EOPs 2202.06 and 2202.23. (3.0)

ANS: See attached sheets

REF: EOP 2202.23 pg 3, 2202.06 pg 8

SECTION II: TUBE LEAKAGE GREATER THAN CHARGING CAPACITY

1.0 SYMPTOMS

1.1 Symptoms of a loss of coolant accident (i.e., pressurizer levels decreasing with no coincident T_{AVE} drop, and with maximum charging & minimum letdown) in conjunction with . . .

1.1.1 Steam generator sample radiation monitor alarm.

1.1.2 Condenser vacuum pump suction radiation monitor alarm.

1.1.3 High radiation indication from Main Steam Radiation Monitors 2RI-1007 for 2SG 2E24A or 2RI-1057 for SG 2E24B as read on Panel 2C336-2 in the Control Room.

2.0 IMMEDIATE ACTIONS

0.4 pt 2.1 Trip the reactor; verify reactor-turbine trip.

0.15 pt 2.2 Verify the valve permissive switches for the atmospheric dumps are in the "OFF" position.

2.3 Initiate OP 2202.06, Section II (LOCA, small break) <u>in conjunction with</u> this procedure.

0.15 pt 2.4 Monitor steam generator levels, pressures, & F.W. flows; Secure both normal & emergency F.W. to the steam generator with the highest level & pressure, and the lowest F.W. flow.

0.4 pt 2.5 Commence an immediate cooldown to 475°F T_{AVE} via turbine bypasses; depressurize RCS to $\leq$ 1000 psia.

CAUTION
MSIS actuation setpoints must be periodically reset during cooldown to prevent isolation of the "operable" steam generator.

4.6 key (7.6)

SECTION II - BREAK WITHIN HPSI PUMP CAPACITY

1.6.4 Combination of RCS temperatures and pressurizer pressures falling into the "Restricted Region" of Figure 1 (Saturation Curve).

1.6.5 Incore instrument temperatures $\geq T_{sat}$ for existing pressurizer pressure

1.6.6 Oscillations in excore power channels due to steam formation

1.6.7 T_H increasing (>570°F) and diverging from T_C and $T_H - T_C \geq 50°F$ if on natural circulation

2.0 IMMEDIATE ACTIONS

2.1 Verify reactor and turbine tripped.

CAUTION

DO NOT DELAY SIAS ACTUATION BY DEPRESSING THE PRESSURIZER PRESSURE SETPOINT RESET PUSHBUTTONS.

*2.2 Verify proper ESFAS actuation, as follows:

*2.2.1 Indicating lamps on ESFAS actuated components correspond to the color of the switch nameplates.

A. Red - Valve open or equipment running.

B. Green - Valve closed or equipment stopped.

*2.2.2 Verify HPSI injection flow when RCS pressure <1450 psia.

2.3 Manually actuate ESFAS at limits below if automatic actuation does not occur.

*2.3.1 SIAS and CCAS - containment pressure $\geq$18.4 psia or RCS pressure $\leq$1766 psia

*2.3.2 CIAS - containment pressure $\geq$18.4 psia

*2.3.3 CSAS - containment pressure $\geq$23.3 psia

*2.3.4 MSIS - steam generator pressure $\leq$751 psia

*2.3.5 RAS - RWT <5.5%

SECTION II - BREAK WITHIN HPSI PUMP CAPACITY

.4 2.4 Trip all RCP's after the reactor has been tripped for five seconds.

• •
•   CAUTION   •
• LIMIT FEED-RATE TO PRECLUDE EXCEEDING COOLDOWN •
• LIMIT OF 100°F/hr. •
• •

.15 2.5 Verify emergency feedwater actuated and restoring S/G levels.

.15 2.6 Verify diverse containment isolation. [illegible]

.4 2.7 Isolate letdown by closing letdown isolation valve (2CV-4820-2).

.4 2.8 Isolate SG blowdown.

3.0 FOLLOWUP ACTIONS

3.1 Notify the Duty Emergency Coordinator.

> NOTE
>
> Reverify asterisked parameters in immediate actions using available instrumentation, preferably those POST-LOCA qualified.

> NOTE
>
> Abnormally high containment building temperatures will affect pressurizer and steam generator level indication due to changes in the density of water in the reference legs. Refer to Attachments 1 and 2 for steam generator and pressurizer level indication correction factors and reactor building temperature computer points (T5601-1, T5602-2, T5603-3, T5604-4, T5605-5, and T5606-6).

> NOTE
>
> If <20°F margin to saturation is maintained for ≥5 minutes, I^{131} ≥1 mci/gm, or plant transient occurs which causes an ECCS actuation, refer to 1903.10 for determination of emergency action level.

3.2 Monitor pressurizer pressure, RCS temperatures and margin to saturation; maintain at least 50°F margin to saturation by holding RCS pressure near the maximum allowable pressure within the cooldown pressure temperature curve (Figure 2) if possible.

• •
•   CAUTION   •
• DO NOT RESET SIAS AFTER BONA-FIDE ACTUATION UNTIL PLANT IS •
• COOLED DOWN AND DEPRESSURIZED; PREMATURE RESETTING COULD •
• RESULT IN LOSS OF ALL PREVIOUSLY ACTUATED COMPONENTS IN THE •
• EVENT OF LOSS OF POWER UNTIL REACTUATED AND START TIME DELAYS •
• HAVE ELAPSED. •
• •

4.7/7.7 SIAS and RAS occur simultaneously while at power. Excluding response to the reactor trip:

A. What is the immediate action for this situation?
(Deleted as result of recent procedure change)

B. Describe how the SIAS is validated for one of the four (4) emergency conditions which initiate SIAS. (1.5)

C. If the SIAS is determined to be invalid, what immediate recovery actions are required? (1.5)

ANS: See attached sheets

REF: EOP 2202.08 pgs 2&3

1.0 SYMPTOMS

1.1 RPS/ESF pretrip/trip alarm(s)

1.2 Safety Injection System actuation alarm(s)

1.3 Possible annunciator alarms associated with reactor trips:

1.3.1 RPS/ESF pretrip/trip channel alarm(s)

1.3.2 RPS actuation channel alarm(s)

1.3.3 PPS channel trip alarm(s)

1.3.4 Reactor trip breaker switchgear trip alarm(s)

1.4 Pretrip/trip indication on PPS insert on 2C03

1.5 SIAS lamps on PPS de-energized

1.6 SIAS actuated pumps, valves and/or components in their SIAS position

2.0 IMMEDIATE ACTIONS

2.1 If the reactor has tripped, carry out the "Reactor Turbine Trip" procedure.

2.2 Determine validity of SIAS signal as follows:

2.2.1 Pressurizer pressure and level decreasing

S/G pressure approximately normal

any one

Containment Building pressure, temperature, humidity and sump levels increasing

SIAS is valid: follow "Loss of Reactor Coolant"

2.2.2 Pressurizer pressure and level decreasing

S/G pressure abnormally low

Containment Building pressure, temperature, humidity and sump levels increasing

RCS Temperature abnormally low

SIAS is valid: follow "Steam Supply System Rupture" (steam rupture inside containment building)

2.2.3 Pressurizer pressure and level decreasing

S/G pressure abnormally low

any one

Containment Building pressure, temperature, humidity and sump levels constant

RCS Temperature abnormally low

SIAS is valid: follow "Steam Supply System Rupture"

2.2.4 Pressurizer pressure and levels decreasing

Radiation Monitors associated with Primary to Secondary leak increasing

SIAS is valid: carry out "S/G Tube Rupture"

2.3 If SIAS is determined invalid; verify >50°F margin to saturation and secondary decay heat removal and secure inadvertent SIAS by:

.25 per part

2.3.1 Place HPSI pump(s) handswitches in "Pull to Lock".

2.3.2 Place LPSI pump(s) handswitches in "Pull to Lock".

2.3.3 Place Boric Acid pump(s) handswitches in "Pull to Lock".

2.3.4 Place standby charging pump(s) handswitches in "Stop".

3.0 FOLLOWUP ACTIONS

CAUTION

IF EQUIPMENT CANNOT BE RETURNED TO NORMAL CONFIGURATION CAPABLE OF AUTOMATIC ACTUATION WITHIN ONE HOUR, IMMEDIATELY INITIATE A COOLDOWN TO COLD SHUTDOWN AT THE MAXIMUM ALLOWABLE RATE.

3.1 Determine and correct cause of inadvertent actuation, reset the affected systems and return all handswitches to normal.

3.2 If RAS actuated inadvertently, return to RWT suction as follows:

3.2.1 Reset the RAS actuation.

3.2.2 Close a set of containment sump suction valves (2CV-5649 and 2CV-5650 or 2CV-5647 and 2CV-5648).

3.2.3 Open RWT suction valves (2CV-5630 and 2CV-5631).

4.8/7.8 Per ANO Procedure 1622.003 what radiation levels and conditions require posting as:

A. Radiation Area
B. High Radiation Area

(List all possible conditions) (1.5)

ANS:

A. ≥2.5 mR/hr inside controlled access area (and Rad waste storage buildings)
≥0.8 mR/hr outside the above areas

B. Any area where (accessible whole body) dose rate is ≥100 mR/hr.

REF: G-RWP 1622.003

4.9/7.9 The reactor has been operating at the conditions of point 1 on Figure 4.9.1 for six (6) hours.

A. Using the data on Table 4.9.1 what will be the final boron concentration if the plant condition is changed to point 2 of Figure 4.9.1. Show all calculations (Figures 4.9.2 through 4.9.9 and reactivity balance work sheets are provided to assist calculations). (2.0)

B. If the total accumulated operating time to the right of line A on Figure 4.9.1 is 4.875 EFPD for the month, which of points 2, 3, or 4 can be attained without violating tech specs? The OP 2102.04 procedural guidelines and requirements for rod motion and rate of change of power apply. For each point describe the method you would use to get there and the time it would take. Explain how you comply with tech specs (if at all) for changing to the condition for each point. (2.0)

ANS:

A. 450 ppm (see reactivity forms)

B. Point 2 - yes ~8-10.5 hr
By boration and rod withdrawal, rd ht. can be raised above the limit (long term) in 2.5 hr while holding power constant. This will only burn up 1.5 EFPH of the 3 remaining. Then power assention to 100% in limited to less than 5%/hr so that just over 8 hours are required to get to 100% power.

Point 3 - yes ~3.5 hr
Use same method as for point 2 but do not increase power. Rod motion is limited to 10 in/15 min through out the withdrawal. The long term limit is achieved in the same time as for point 2 with the same EFPH burn up.

Point 4 - yes 1.5 hr
By increasing boron by about 70 ppm power can be reduced below 20% as fast as the turbine can be unloaded while maintaining Tavg = Tref. Admin. limits for power reduction are 30%/hr

REF: OP 2103.15, 2102.04
Tech Spec 3.1

for A: portial credit evaluation shoulld be based on

1. If reactivity balance forms are used: end point valves should be entered for HFP, ARO, XeFree & Eq SM.

ρ fuel = ρ Boron, all other ρ = 0

4.5% $\Delta K/K$ = 4.02 % $\Delta K/K$ (uncorrected) X 1.12 (correction factor)

4.02 $\Delta K/K$ Boron => 450 ppm from graph or 2. $\Delta \rho_{Boron} = -[+\rho_{rods} - \rho_{MTC} - \rho_{doppler}]$

$= -[.65 - .17 - .28]$

$= -.2\ \%\Delta K/K$ if 100 ppm B $= -1\%\Delta K/K$

then $-.2 \times 100$ ppm$/-1 = 20$ ppm INCREASE

Since the final condition is HFP, ARO, Eq Xe and Sm it is only necessary to use the ... to compute the burnup compensated B worth and then uncompensate to determine actual concentration required.

ARKANSAS POWER & LIGHT COMPANY
Arkansas Nuclear One

TITLE: WORK SHEET A-1 | FORM NO. 2103.15A | REV. # 11 PC #

Work Sheet A-1 Reactivity Balance During Critical Operations to Analyze for Reactivity Anomolies

Reference Conditions: 100%FP, 583°F, 2250 psia, no Xenon, no Boron, HFP equilibrium Samarium

Data Needed for Calculation:

Cycle Burnup 300 EFPD ; RCS Boron Conc. X (450) ppm

*RCS T_{avg} 580 °F ; Heat Balance Power Level 100 %FP

*NOTE: Use average of CPC Channel A PID 160 & PID 162 for T_{avg} (or an equivalent indication) From: SEL |___|, Other ________

CEA Grp. 1 150 in wd., CEA Grp. 2 150 in wd., CEA Grp. 3 150 in wd

CEA Grp. 4 150 in wd., CEA Grp. 5 150 in wd., CEA Grp. 6 150 in wd

PLCEA Grp 150 in.wd.

1. From Attachment A-1:

   ρ(Fuel) = 4.5 % Δk/k

2. From Attachment A-2: ρ(Boron) = y % Δk/k

   From Attachment A-3: Boron Worth Burnup Correction = 1.12

   From Attachment A-4: Boron Worth Temp. Correction = 1.0

   ρ(Boron)* = ρ(Boron) x Burnup Correction x Temperature Correction

   ρ(Boron)* = y (4.02) %Δk/k x 1.12 x 1.0

   $\frac{4.5}{1.12} = 4.02$

   ρ(Boron)* = (*4.5*) % Δk/k

3. If T_{avg} = 580°F ± 2°F, neglect temperature correction, ρ(Temp) = 0, otherwise, from Attachment A-5:

   $\alpha temp(Tavg) =$ ________ $\times 10^{-4} \frac{\Delta k}{k°F}$

   $\alpha temp(580°F) =$ ________ $\times 10^{-4} \frac{\Delta k}{k°F}$

   $$\rho(Temp) = \frac{\alpha temp(Tavg) + \alpha temp(580°F)}{2} \times (Tavg - 580°F) \times 100\%$$

   $$= \frac{\_\_\_\_ + \_\_\_\_}{2} \times 10^{-4} \frac{\Delta k}{k°F} \times \_\_\_\_ °F \times 100\%$$

   ρ(Temp) = 0 %Δk/k

4. From Attachment A-6 (Interpolate between parametric burnup curves):

   a) For present controlling CEA group position ρ(CEAs) = 0 %Δk/k

ARKANSAS POWER & LIGHT COMPANY
Arkansas Nuclear One

TITLE: WORK SHEET A-1 | FORM NO. 2103.15A | REV. # 11 PC #

b) From Attachment A-7:
Additional worth due to PLCEAs = Ø %Δk/k

c) Sum of 4a and 4b: ρ(CEAs) + ρ(PLCEAs) = Ø % Δk/k

d) From Attachment A-8:

Temperature Correction Factor (TCF) = ________

e) ρ(CEAs net) = [ρ(CEAs) + ρ(PLCEAs)] x TCF

| ρ(CEAs net) = Ø % Δk/k |

5. From Attachment A-9 (Interpolate between parametric Burnup Curves)

| ρ(Power) = Ø %Δk/k |

6. From: SAXON2 [ ], Other ________ (Indicate Method)

| ρ(Xenon) = Ø % Δk/k |

7. If samarium is at HFP equilibrium, neglect additional samarium worth, ρ(Samarium) = 0

Otherwise, From: SAM2 [ ], Other ________ (Indicate Method)

| ρ(Samarium) = Ø % Δk/k |

8. Sum the following:

ρ(Net) = ρ(Fuel) - ρ(Boron)* ± ρ(Temp) - ρ(CEAs net) + ρ(Power) - ρ(Xenon) - [± ρ(Samarium)]

| ρ(Net) = +4.5 %Δk/k |

If ρ(Net) exceeds ± 0.5%Δk/k refer to Section 4.0, Limits and Precautions.

Performed By ________________________

Date ________________ Time ________________

Reviewed By ________________________
Nuclear Engineer or Nuclear Support Supervisor

4.10/7.10 What are the immediate actions for a Waste Gas Discharge Line High Radiation alarm? (1.0)

ANS: 1. Secure any vent operations in progress

2. Verify 2 CV-2428(2C-14) waste gas discharge trip valve closed.

REF: AOP 2203.006

4.11 A. List the plant operator's immediate actions/duties when control room evacuation and remote shutdown are required. (1.5)

B. During remote shutdown what is required to prevent inadvertent initiation of SIAS, MSIS, or CCAS? (1.0)

ANS: See attached sheets

REF: EOP 2202.33 pgs 1&7

8. Administrative Procedures, Conditions and Limitations

8.1 A. What are the four (4) Emergency Action Levels (EAL) specified in the EAL response procedure? (1.0)

B. The subcooled condition of the RCS can degrade to the point that an EAL may be entered. Identify the degraded subcooled condition which satisfies the classification criteria for entry into the lowest EAL. Continue to degrade this condition and indicate the criteria which escalate the emergency to each subsequent EAL. (3.0)

ANS:

A. Unusual Event (.25 ea)
Alert
Site Emergency
General Emergency

B. 1. Margin to saturation <20°F for >5 min unusual event (1 ea)

2. Margin <20°F for >10 min (w/o indication of immediate recovery) alert

3. At saturation - Site Emergency no higher level

REF: EPP 1903.10 pgs 3, 4, 5, 14 & 26

D.2 What series numbers apply to the following procedural area (example: Training Admin Procedure - 1063) (2.0)

A. Radiation Protection Procedure
B. Abnormal Operating Procedure (Unit 2)
C. Emergency Operating Procedure (Unit 2)
D. Emergency Plan Implementing Procedure
E. Offsite Dose Projection Procedure

ANS:

A. 1622 series -.4 if either of first 2 number wrong
B. 2203 -.2 if either of last 2 number wrong
C. 2202
D. 1903
E. 1904

REF: EP 1903.01 pg 1

8.3 A. List five (5) categories or types of temporary modifications which are governed by the Jumper and Lifted Lead Control Procedure (OPA 1000.28) (2.5)

B. What temporary modifications are exempt from this procedure? (1.0)

ANS:

A. 1. Install/remove electrical jumpers
2. Lifting electric leads
3. Install/remove mechanical bypasses, spool pieces
4. Alter mechanical configuration
5. Install/remove blind or blank flanges
6. Rotate spectacle flanges

B. 1. Temporary modifications covered by approved procedures or work plans

2. Install/remove hand held jumpers

REF: OPA 1000.28

8.4 When should HOLD cards be issued in the name of the Maintenance Supervisor? (1.5)

ANS: 1. Jobs extending beyond one shift which will require multiple crews.

2. When assignment of lead individual is expected to change during the course of the job.

REF: OPAP 1000.27 pg 6

8.5 True or False. It is permissible to intentionally enter technical specification action statements for routine maintenance if the Maintenance Superintendent's permission is obtained. (0.5)

ANS: False - permission must come from the Operations Superindentent or Operations Manager.

REF: OPAP 1000.27 pg 10

8.6 Give five (5) examples of <u>serious injury</u> which by definition envoke the Personnel Emergency Procedure EP 1903.23. (2.5)

ANS: any five (5)

1. Loss of consciousness (more than momentary)
2. Fracture (actual or suspected)
3. Head injury
4. Injury that may have damaged internal organs
5. Serious burn
6. Hemorrhaging (bleeding)
7. Large dose of radiation (>50R)

REF: EP 1903.23 pg 2

8.7 What three (3) symtoms are sufficient to order a plant evacuation? (3.0)

ANS: 1. Unevaluated general area radiation levels exceeding 2.5 mRem/hr outside of the controlled access areas which are not attributed to any cause other than a possible radiological incident.

2. Unevaluated airborne radioactivity in excess of 1×10^{-9} uCi/cc measured outside of the controlled access areas.

3. An uncontrolled toxic gas leak where the hazard is not confined to a local area and the conditions continue to increase in severity.

REF: EPP 1903.30 pg 3

8.8 A. What is the minimum Tavg allowed by Tech Specs while critical? (Exclude special tests) (0.5)

B. What action(s), including time limits, is/are required if Tavg goes below the limit while critical? (1.0)

ANS: A. 525°F

B. be above 525°F in 15 min. (.5) or be in HOT STANDBY in next 15 min. (.5)

REF: T.S. 3.1.1.5 pg 3/4 1-6

8.9 Which of the following items are addressed by Technical Specifications? Answer YES if the item is, and NO if the item is not addressed in the Technical Specifications.

		ANS:
A.	Primary containment humidity	yes 3.6.1.4
B.	Offsite power feeds	yes 3.8.1.1
C.	Plant computer	no
D.	Service water pumps	yes 3.7.3.1
E.	CCW pumps	no
F.	Ex core nuclear instrumentation	yes 3.3.1.1
G.	CVCS volume control tank	no
H.	Secondary chemistry (-.125/for yes-Activity or Rad. Chem)	no
I.	Lake Dardanelle Level	yes 3.7.5.1
J.	Spent fuel pool building crane	yes 3.9.7

REF: ANO Unit 2 TS

8.10 List the affected system and state whether it would be considered operable or inoperable per Technical Specifications (i.e., outside an LCO-entered action statement) for each of the following conditions (unless otherwise specified, plant is at 100% power and all other conditions normal): (4.0)

A. Level instrumentation for one safety injection tank failed.
B. Condensate storage tank inventory of 150,000 gal. total
C. During normal refueling, one airlock door seal damaged so as to prevent proper sealing.
D. During low power physics testing, average reactor coolant temperature is 400°F and reactor critical.
E. Control room air temperature reaches 130°F while Hi radiation alarm exists.
F. Only one heat and two smoke detectors are found operable in EDG room 2093
G. The last two monthly surveillance tests of a diesel generator have each been performed 6 days late
H. The bulk temperature of the spent fuel pool is 135°F.

ANS:

A. ECCS/SI INOP (0.5 each)
B. EFW (CST) INOP (3.7.1.3) .25 sys, .25 OP/INOP
C. Airlock/Containment OP (3.6.1.3)
D. Reactor Core OP (3.10.5)
E. Control Room Emergency Ventilation INOP (3.7.6.1)
F. Fire Detection Inst OP 3.3.3.8
G. DG INOP 4.0.2, 4.8.1.1.2
H. SFPC/Fuel Storage OP (3.9 Series)

REF: FCS TS

for B If answer says that 80% is the limit but does not state whether 150,000 gal is equal to, less than, or greater than 80% deduct .125

8.11 Classify each of the following conditions to the appropriate emergency action level in accordance with Emergency Plan Implementing Procedure Emergency Action Level Response (1903.10) (3.0)

A. Reactor coolant activity greater than Technical Specification limits.

B. Loss of all annunciators.

C. Security threat resulting in loss of physical control of the facility.

D. Fuel handling accident with radiation released to fuel building

E. Multiple steam generator tube failure beyond make up capacity coincident with high primary system activity.

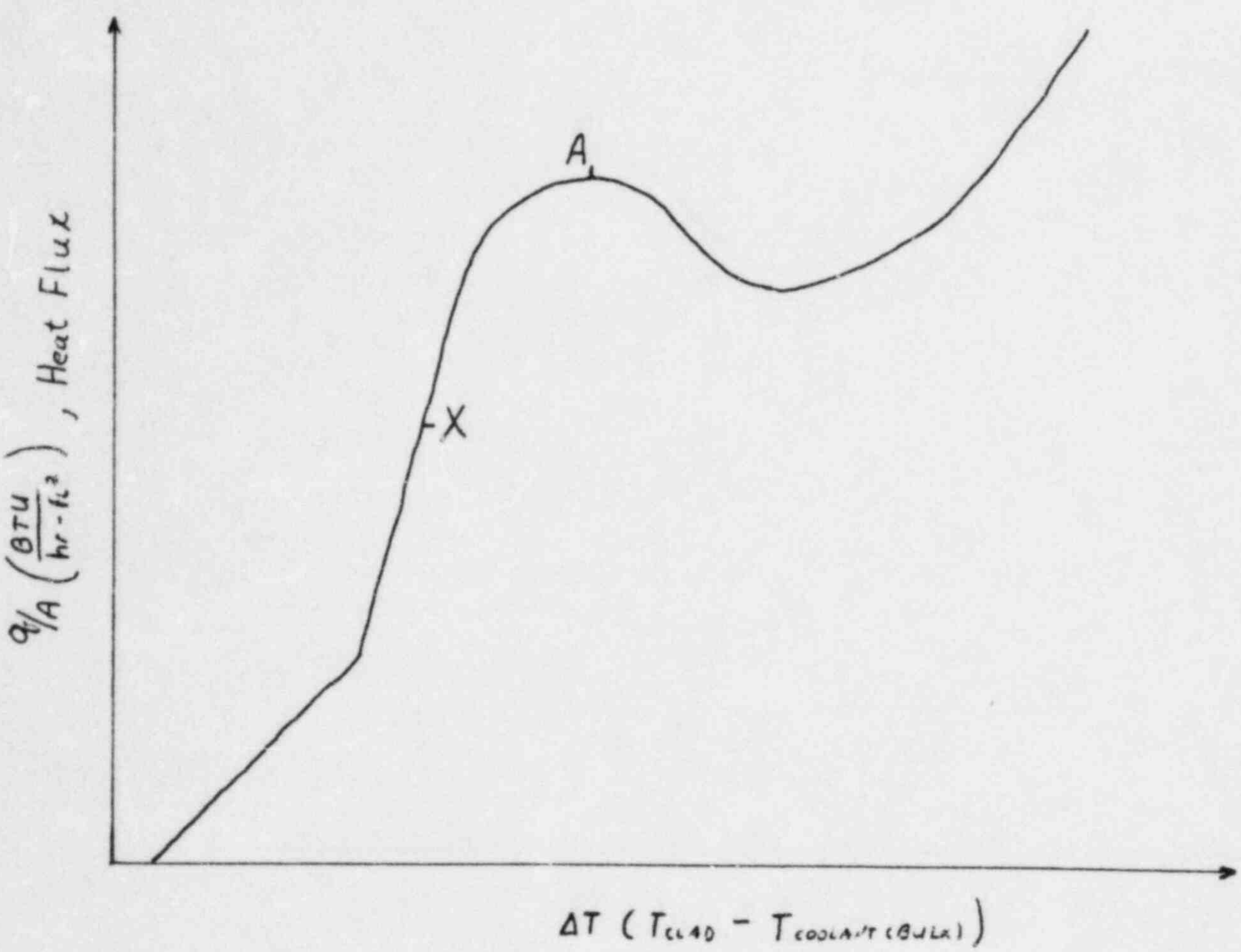
F. Loss of all offsite power.

ANS:

A. Unusual event	D. Alert	(0.5 each)
B. Alert	E. Alert	-.25 for 1 too hi
C. General Emergency	F. Unusual Event	-.4 for 2 too hi
		-.5 all other

REF: EPP 1903.10 pgs 5, 15, 26, 38

TABLES AND FIGURES



Typical Departure from Nucleate Boiling Curve

Figure 1.2

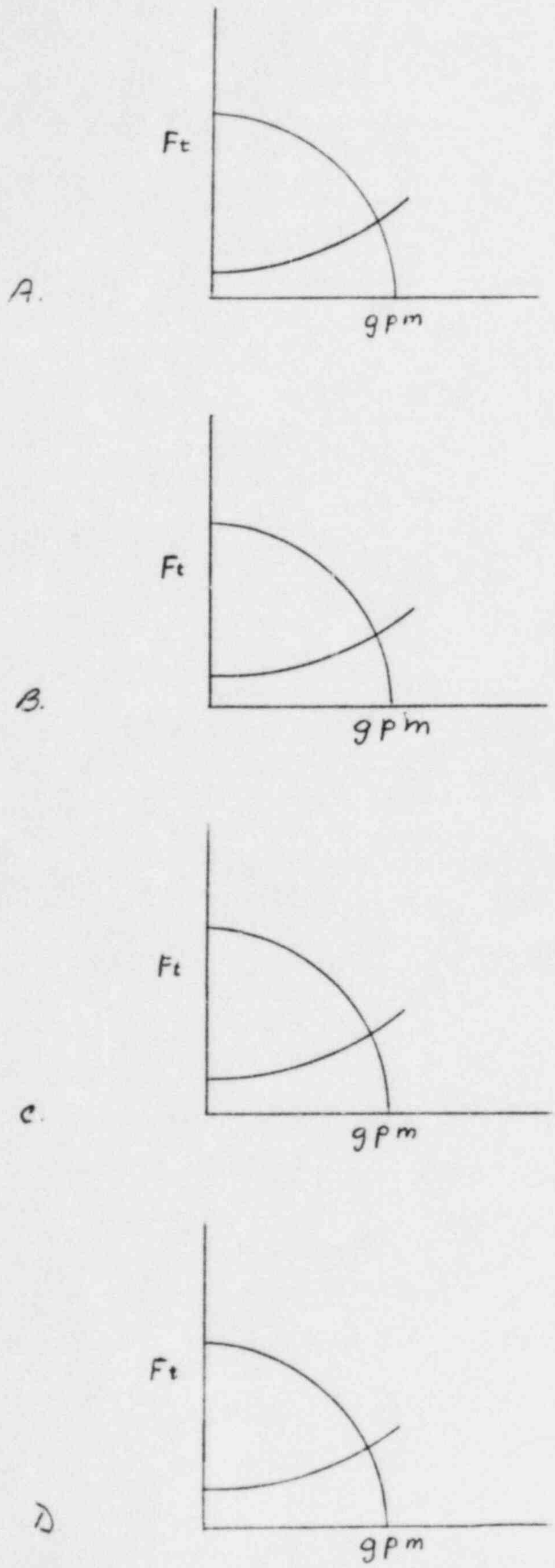


Figure 1.5

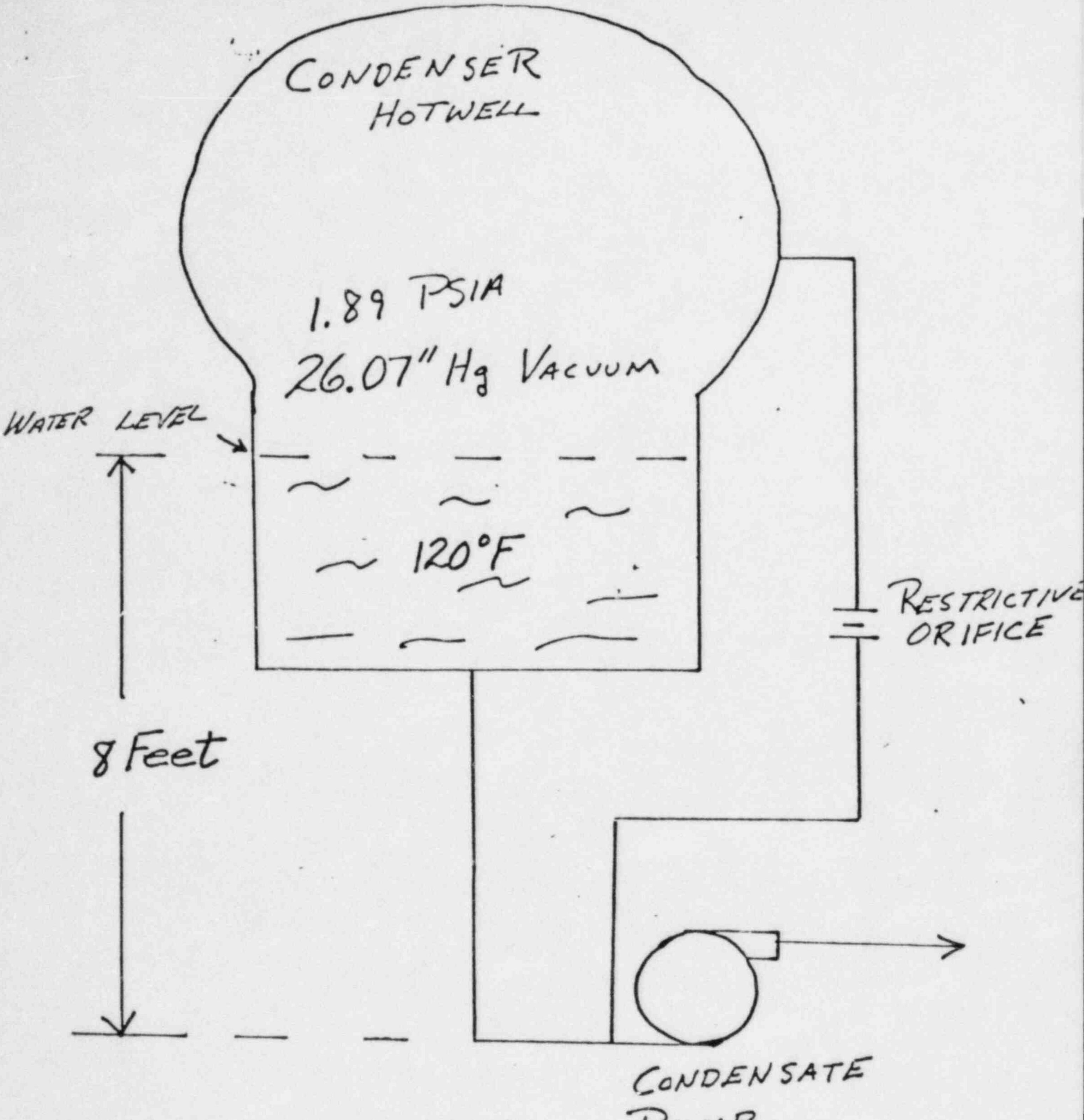

CONDENSER
HOTWELL
1.89 PSIA
26.07" Hg VACUUM
WATER LEVEL
120°F
8 Feet
RESTRICTIVE
ORIFICE
CONDENSATE
PUMP

FIG 1.6

Table 2: Saturated Steam: Pressure Table

Abs Press. Lb/Sq In p	Temp Fahr t	Specific Volume: Sat. Liquid v_f	Specific Volume: Evap v_{fg}	Specific Volume: Sat. Vapor v_g	Enthalpy: Sat. Liquid h_f	Enthalpy: Evap h_{fg}	Enthalpy: Sat. Vapor h_g	Entropy: Sat. Liquid s_f	Entropy: Evap s_{fg}	Entropy: Sat. Vapor s_g	Abs Press. Lb/Sq In p
0.08865	32.018	0.016022	3302.4	3302.4	0.0003	1075.5	1075.5	0.0000	2.1872	2.1872	0.08865
0.25	59.323	0.016032	1235.5	1235.5	27.382	1060.1	1087.4	0.0542	2.0425	2.0967	0.25
0.50	79.586	0.016071	641.5	641.5	47.623	1048.6	1096.3	0.0925	1.9446	2.0370	0.50
1.0	101.74	0.016136	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	1.0
5.0	162.24	0.016407	73.515	73.532	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	5.0
10.0	193.21	0.016592	38.404	38.420	161.26	982.1	1143.3	0.2836	1.5043	1.7879	10.0
14.696	212.00	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	14.696
15.0	213.03	0.016726	26.274	26.290	181.21	969.7	1150.9	0.3137	1.4415	1.7552	15.0
20.0	227.96	0.016834	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	20.0
30.0	250.34	0.017009	13.7266	13.7436	218.9	945.2	1164.1	0.3682	1.3313	1.6995	30.0
40.0	267.25	0.017151	10.4794	10.4965	236.1	933.6	1169.8	0.3921	1.2844	1.6765	40.0
50.0	281.02	0.017274	8.4967	8.5140	250.2	923.9	1174.1	0.4112	1.2474	1.6586	50.0
60.0	292.71	0.017383	7.1562	7.1736	262.2	915.4	1177.6	0.4273	1.2167	1.6440	60.0
70.0	302.93	0.017482	6.1875	6.2050	272.7	907.8	1180.6	0.4411	1.1905	1.6316	70.0
80.0	312.04	0.017573	5.4536	5.4711	282.1	900.9	1183.1	0.4534	1.1675	1.6208	80.0
90.0	320.28	0.017659	4.8779	4.8953	290.7	894.6	1185.3	0.4643	1.1470	1.6113	90.0
100.0	327.82	0.017740	4.4133	4.4310	298.5	888.6	1187.2	0.4743	1.1284	1.6027	100.0
110.0	334.79	0.01782	4.0306	4.0484	305.8	883.1	1188.9	0.4834	1.1115	1.5950	110.0
120.0	341.27	0.01789	3.7097	3.7275	312.6	877.8	1190.4	0.4919	1.0960	1.5879	120.0
130.0	347.33	0.01796	3.4364	3.4544	319.0	872.8	1191.7	0.4998	1.0815	1.5813	130.0
140.0	353.04	0.01803	3.2010	3.2190	325.0	868.0	1193.0	0.5071	1.0681	1.5752	140.0
150.0	358.43	0.01809	2.9958	3.0139	330.6	863.4	1194.1	0.5141	1.0554	1.5695	150.0
160.0	363.55	0.01815	2.8155	2.8336	336.1	859.0	1195.1	0.5206	1.0435	1.5641	160.0
170.0	368.42	0.01821	2.6556	2.6738	341.2	854.8	1196.0	0.5269	1.0322	1.5591	170.0
180.0	373.08	0.01827	2.5129	2.5312	346.2	850.7	1196.9	0.5328	1.0215	1.5543	180.0
190.0	377.53	0.01833	2.3847	2.4030	350.9	846.7	1197.6	0.5384	1.0113	1.5498	190.0
200.0	381.80	0.01839	2.2689	2.2873	355.5	842.8	1198.3	0.5438	1.0016	1.5454	200.0
210.0	385.91	0.01844	2.16373	2.18217	359.9	839.1	1199.0	0.5490	0.9923	1.5413	210.0
220.0	389.88	0.01850	2.06779	2.08629	364.2	835.4	1199.6	0.5540	0.9834	1.5374	220.0
230.0	393.70	0.01855	1.97991	1.99846	368.3	831.8	1200.1	0.5588	0.9748	1.5336	230.0
240.0	397.39	0.01860	1.89909	1.91769	372.3	828.4	1200.6	0.5634	0.9665	1.5299	240.0
250.0	400.97	0.01865	1.82452	1.84317	376.1	825.0	1201.1	0.5679	0.9585	1.5264	250.0
260.0	404.44	0.01870	1.75548	1.77418	379.9	821.6	1201.5	0.5722	0.9508	1.5230	260.0
270.0	407.80	0.01875	1.69137	1.71013	383.6	818.3	1201.9	0.5764	0.9433	1.5197	270.0
280.0	411.07	0.01880	1.63169	1.65049	387.1	815.1	1202.3	0.5805	0.9361	1.5166	280.0
290.0	414.25	0.01885	1.57597	1.59482	390.6	812.0	1202.6	0.5844	0.9291	1.5135	290.0
300.0	417.35	0.01889	1.52384	1.54274	394.0	808.9	1202.9	0.5882	0.9223	1.5105	300.0
350.0	431.73	0.01912	1.30642	1.32554	409.8	794.2	1204.0	0.6059	0.8909	1.4968	350.0
400.0	444.60	0.01934	1.14162	1.16095	424.2	780.4	1204.6	0.6217	0.8630	1.4847	400.0
450.0	456.28	0.01954	1.01224	1.03179	437.3	767.5	1204.8	0.6360	0.8378	1.4738	450.0
500.0	467.01	0.01975	0.90787	0.92762	449.5	755.1	1204.7	0.6490	0.8148	1.4639	500.0
550.0	476.94	0.01994	0.82183	0.84177	460.9	743.3	1204.3	0.6611	0.7936	1.454[illegible]	550.0
600.0	486.20	0.02013	0.74962	0.76975	471.7	732.0	1203.7	0.6723	0.7738	1.4461	600.0
650.0	494.89	0.02032	0.68811	0.70843	481.9	720.9	1202.8	0.6828	0.7552	1.4381	650.0
700.0	503.08	0.02050	0.63505	0.65556	491.6	710.2	1201.8	0.6928	0.7377	1.4304	700.0
750.0	510.84	0.02069	0.58880	0.60949	500.9	699.8	1200.7	0.7022	0.7210	1.4232	750.0
800.0	518.21	0.02087	0.54809	0.56896	509.8	689.6	1199.4	0.7111	0.7051	1.4163	800.0
850.0	525.24	0.02105	0.51197	0.53302	518.4	679.5	1198.0	0.7197	0.6899	1.4096	850.0
900.0	531.95	0.02123	0.47968	0.50091	526.7	669.7	1196.4	0.7279	0.6753	1.4032	900.0
950.0	538.39	0.02141	0.45064	0.47205	534.7	660.0	1194.7	0.7358	0.6612	1.3970	950.0
1000.0	544.58	0.02159	0.42436	0.44596	542.6	650.4	1192.9	0.7434	0.6476	1.3910	1000.0
1050.0	550.53	0.02177	0.40047	0.42224	550.1	640.9	1191.0	0.7507	0.6344	1.3851	1050.0
1100.0	556.28	0.02195	0.37863	0.40058	557.5	631.5	1189.1	0.7578	0.6216	1.3794	1100.0
1150.0	561.82	0.02214	0.35859	0.38073	564.8	622.2	1187.0	0.7647	0.6091	1.3738	1150.0
1200.0	567.19	0.02232	0.34013	0.36245	571.9	613.0	1184.8	0.7714	0.5969	1.3683	1200.0
1250.0	572.38	0.02250	0.32306	0.34556	578.8	603.8	1182.6	0.7780	0.5850	1.3630	1250.0
1300.0	577.42	0.02269	0.30722	0.32991	585.6	594.6	1180.2	0.7843	0.5733	1.3577	1300.0
1350.0	582.32	0.02288	0.29250	0.31537	592.3	585.4	1177.8	0.7906	0.5620	1.3525	1350.0
1400.0	587.07	0.02307	0.27871	0.30178	598.8	576.5	1175.3	0.7966	0.5507	1.3474	1400.0
1450.0	591.70	0.02327	0.26584	0.28911	605.3	567.4	1172.8	0.8026	0.5397	1.3423	1450.0
1500.0	596.20	0.02346	0.25372	0.27719	611.7	558.4	1170.1	0.8085	0.5288	1.3373	1500.0
1550.0	600.59	0.02366	0.24235	0.26601	618.0	549.4	1167.4	0.8142	0.5182	1.3324	1550.0
1600.0	604.87	0.02387	0.23159	0.25545	624.2	540.3	1164.5	0.8199	0.5076	[illegible]	1600.0
1650.0	609.05	0.02407	0.22143	0.24551	630.4	531.3	1161.6	0.8254	0.497[illegible]	1.3225	1650.0
1700.0	613.13	0.02428	0.21178	0.23607	636.5	522.2	1158.6	0.8309	0.4867	[illegible]	1700.0
1750.0	617.12	0.02450	0.20263	0.22713	642.5	513.1	1155.6	0.8363	0.4765	[illegible]	1750.0
1800.0	621.02	0.02472	0.19390	0.21861	648.5	503.8	[illegible]	0.84[illegible]	0.466[illegible]	[illegible]	1800.0
1850.0	624.83	0.02495	0.18558	0.21052	654.[illegible]	494.6	1149.0	0.8470	0.4561	[illegible]	1850.0
1900.0	628.56	0.02517	0.17761	0.20278	660.4	[illegible]	1145.6	0.85[illegible]	0.4459	[illegible]	1900.0
1950.0	[illegible]	0.02541	0.16999	0.19540	666.3	[illegible]	1142.0	0.8574	0.4358	[illegible]	1950.0
2000.0	635.80	0.02565	0.16266	0.18831	672.[illegible]	[illegible]	1138.[illegible]	0.8625	0.4256	[illegible]	2000.0
2100.0	[illegible]	0.02615	0.14885	0.17501	683.8	[illegible]	1130.5	0.87[illegible]	0.405[illegible]	[illegible]	2100.0
2200.0	649.45	0.02669	0.13603	0.162[illegible]	695.[illegible]	426.[illegible]	[illegible]	0.8828	0.3848	[illegible]	2200.0
2300.0	655.89	0.02727	0.12406	0.151[illegible]	[illegible]	406.0	[illegible]	0.8929	0.3640	[illegible]	2300.0
2400.0	662.11	0.02790	0.11287	0.14076	[illegible]	384.8	[illegible]	0.903[illegible]	0.3430	[illegible]	2400.0
2500.0	[illegible]	0.02859	0.10209	0.13068	731.[illegible]	[illegible]	1093.[illegible]	0.9139	0.3206	1.2345	2500.0
2600.0	673.91	0.02938	0.0917[illegible]	[illegible]	[illegible]	[illegible]	1082.0	[illegible]	[illegible]	[illegible]	2600.0
2700.0	679.53	0.03029	0.08165	[illegible]	[illegible]	[illegible]	1069.[illegible]	0.9356	[illegible]	[illegible]	2700.0
2800.0	684.96	[illegible]	[illegible]	0.10305	[illegible]	[illegible]	[illegible]	0.9468	[illegible]	[illegible]	2800.0
2900.0	[illegible]	[illegible]	0.06158	0.09420	[illegible]	[illegible]	[illegible]	0.9588	[illegible]	[illegible]	2900.0
3000.0	[illegible]	[illegible]	[illegible]	0.08500	801.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3000.0
3100.0	[illegible]	[illegible]	0.037[illegible]	0.07452	824.0	[illegible]	[illegible]	[illegible]	0.048[illegible]	[illegible]	3100.0
3200.0	705.08	[illegible]	[illegible]	0.05663	875.5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	3200.0
3208.2*	705.4[illegible]	0.05078	0.00000	0.05078	906.0	[illegible]	906.0	[illegible]	0.0000	[illegible]	3208.2*

*Critical pressure

Table 1. Saturated Steam: Temperature Table—*Continued*

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat Vapor s_g	Temp Fahr t
460.0	466.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460.0
464.0	485.56	0.01969	0.93588	0.95557	446.1	758.6	1204.7	0.6454	0.8213	1.4667	464.0
468.0	504.83	0.01976	0.89885	0.91862	450.7	754.0	1204.6	0.6502	0.8127	1.4629	468.0
472.0	524.67	0.01984	0.86345	0.88329	455.2	749.3	1204.5	0.6551	0.8042	1.4592	472.0
476.0	545.11	0.01992	0.82958	0.84950	459.9	744.5	1204.3	0.6599	0.7956	1.4555	476.0
480.0	566.15	0.02000	0.79716	0.81717	464.5	739.6	1204.1	0.6648	0.7871	1.4518	480.0
484.0	587.81	0.02009	0.76613	0.78622	469.1	734.7	1203.8	0.6696	0.7785	1.4481	484.0
488.0	610.10	0.02017	0.73641	0.75658	473.8	729.7	1203.5	0.6745	0.7700	1.4444	488.0
492.0	633.03	0.02026	0.70794	0.72820	478.5	724.6	1203.1	0.6793	0.7614	1.4407	492.0
496.0	656.61	0.02034	0.68065	0.70100	483.2	719.5	1202.7	0.6842	0.7528	1.4370	496.0
500.0	680.86	0.02043	0.65448	0.67492	487.9	714.3	1202.2	0.6890	0.7443	1.4333	500.0
504.0	705.78	0.02053	0.62938	0.64991	492.7	709.0	1201.7	0.6939	0.7357	1.4296	504.0
508.0	731.40	0.02062	0.60530	0.62592	497.5	703.7	1201.1	0.6987	0.7271	1.4258	508.0
512.0	757.72	0.02072	0.58218	0.60289	502.3	698.2	1200.5	0.7036	0.7185	1.4221	512.0
516.0	784.76	0.02081	0.55997	0.58079	507.1	692.7	1199.8	0.7085	0.7099	1.4183	516.0
520.0	812.53	0.02091	0.53864	0.55956	512.0	687.0	1199.0	0.7133	0.7013	1.4146	520.0
524.0	841.04	0.02102	0.51814	0.53916	516.9	681.3	1198.2	0.7182	0.6926	1.4108	524.0
528.0	870.31	0.02112	0.49843	0.51955	521.8	675.5	1197.3	0.7231	0.6839	1.4070	528.0
532.0	900.34	0.02123	0.47947	0.50070	526.8	669.6	1196.4	0.7280	0.6752	1.4032	532.0
536.0	931.17	0.02134	0.46123	0.48257	531.7	663.6	1195.4	0.7329	0.6665	1.3993	536.0
540.0	962.79	0.02146	0.44367	0.46513	536.8	657.5	1194.3	0.7378	0.6577	1.3954	540.0
544.0	995.22	0.02157	0.42677	0.44834	541.8	651.3	1193.1	0.7427	0.6489	1.3915	544.0
548.0	1028.49	0.02169	0.41048	0.43217	546.9	645.0	1191.9	0.7476	0.6400	1.3876	548.0
552.0	1062.59	0.02182	0.39479	0.41660	552.0	638.5	1190.6	0.7525	0.6311	1.3837	552.0
556.0	1097.55	0.02194	0.37966	0.40160	557.2	632.0	1189.2	0.7575	0.6222	1.3797	556.0
560.0	1133.38	0.02207	0.36507	0.38714	562.4	625.3	1187.7	0.7625	0.6132	1.3757	560.0
564.0	1170.10	0.02221	0.35099	0.37320	567.6	618.5	1186.1	0.7674	0.6041	1.3716	564.0
568.0	1207.72	0.02225	0.33741	0.35975	572.9	611.5	1184.5	0.7725	0.5950	1.3675	568.0
572.0	1246.26	0.02249	0.32429	0.34678	578.3	604.5	1182.7	0.7775	0.5859	1.3634	572.0
576.0	1285.74	0.02264	0.31162	0.33426	583.7	597.2	1180.9	0.7825	0.5766	1.3592	576.0
580.0	1326.17	0.02279	0.29937	0.32216	589.1	589.9	1179.0	0.7876	0.5673	1.3550	580.0
584.0	1367.7	0.02295	0.28753	0.31048	594.6	582.4	1176.9	0.7927	0.5580	1.3507	584.0
588.0	1410.0	0.02311	0.27608	0.29919	600.1	574.7	1174.8	0.7978	0.5485	1.3464	588.0
592.0	1453.3	0.02328	0.26499	0.28827	605.7	566.8	1172.6	0.8030	0.5390	1.3420	592.0
596.0	1497.8	0.02345	0.25425	0.27770	611.4	558.8	1170.2	0.8082	0.5293	1.3375	596.0
600.0	1543.2	0.02364	0.24384	0.26747	617.1	550.6	1167.7	0.8134	0.5196	1.3330	600.0
604.0	1589.7	0.02382	0.23374	0.25757	622.9	542.2	1165.1	0.8187	0.5097	1.3284	604.0
608.0	1637.3	0.02402	0.22394	0.24796	628.8	533.6	1162.4	0.8240	0.4997	1.3238	608.0
612.0	1686.1	0.02422	0.21442	0.23865	634.8	524.7	1159.5	0.8294	0.4896	1.3190	612.0
616.0	1735.9	0.02444	0.20516	0.22960	640.8	515.6	1156.4	0.8348	0.4794	1.3141	616.0
620.0	1786.9	0.02466	0.19615	0.22081	646.9	506.3	1153.2	0.8403	0.4689	1.3092	620.0
624.0	1839.0	0.02489	0.18737	0.21226	653.1	496.6	1149.8	0.8458	0.4583	1.3041	624.0
628.0	1892.4	0.02514	0.17880	0.20394	659.5	486.7	1146.1	0.8514	0.4474	1.2988	628.0
632.0	1947.0	0.02539	0.17044	0.19583	665.9	476.4	1142.2	0.8571	0.4364	1.2934	632.0
636.0	2002.8	0.02566	0.16226	0.18792	672.4	465.7	1138.1	0.8628	0.4251	1.2879	636.0
640.0	2059.9	0.02595	0.15427	0.18021	679.1	454.6	1133.7	0.8686	0.4134	1.2821	640.0
644.0	2118.3	0.02625	0.14644	0.17269	685.9	443.1	1129.0	0.8746	0.4015	1.2761	644.0
648.0	2178.1	0.02657	0.13876	0.16534	692.9	431.1	1124.0	0.8806	0.3893	1.2699	648.0
652.0	2239.2	0.02691	0.13124	0.15816	700.0	418.7	1118.7	0.8868	0.3767	1.2634	652.0
656.0	2301.7	0.02728	0.12387	0.15115	707.4	405.7	1113.1	0.8931	0.3637	1.2567	656.0
660.0	2365.7	0.02768	0.11663	0.14431	714.9	392.1	1107.0	0.8995	0.3502	1.2498	660.0
664.0	2431.1	0.02811	0.10947	0.13757	722.9	377.7	1100.6	0.9064	0.3361	1.2425	664.0
668.0	2498.1	0.02858	0.10229	0.13087	731.5	362.1	1093.5	0.9137	0.3210	1.2347	668.0
672.0	2566.6	0.02911	0.09514	0.12424	740.2	345.7	1085.9	0.9212	0.3054	1.2266	672.0
676.0	2636.8	0.02970	0.08799	0.11769	749.2	328.5	1077.6	0.9287	0.2892	1.2179	676.0
680.0	2708.6	0.03037	0.08080	0.11117	758.5	310.1	1068.5	0.9365	0.2720	1.2086	680.0
684.0	2782.1	0.03114	0.07349	0.10463	768.2	290.2	1058.4	0.9447	0.2537	1.1984	684.0
688.0	2857.4	0.03204	0.06595	0.09799	778.8	268.2	1047.0	0.9535	0.2337	1.1872	688.0
692.0	2934.5	0.03313	0.05797	0.09110	790.5	243.1	1033.6	0.9634	0.2110	1.1744	692.0
696.0	3013.4	0.03455	0.04916	0.08371	804.4	212.8	1017.2	0.9749	0.1841	1.1591	696.0
700.0	3094.3	0.03662	0.03857	0.07519	822.4	172.7	995.2	0.9901	0.1490	1.1390	700.0
702.0	3135.5	0.03824	0.03173	0.06997	835.0	144.7	979.7	1.0006	0.1246	1.1252	702.0
704.0	3177.2	0.04108	0.02192	0.06300	854.2	102.0	956.2	1.0169	0.0876	1.1046	704.0
705.0	3198.3	0.04427	0.01304	0.05730	873.0	61.4	934.4	1.0329	0.0527	1.0856	705.0
705.47*	3208.2	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	705.47*

*Critical temperature

Table 1. Saturated Steam: Temperature Table—*Continued*

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume* Sat. Liquid v_f	Specific Volume* Evap v_{fg}	Specific Volume* Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat. Vapor h_g	Entropy Sat. Liquid s_f	Entropy Evap s_{fg}	Entropy Sat. Vapor s_g	Temp Fahr t
180.0	7.5110	0.016510	50.21	50.22	148.00	990.2	1138.2	0.2631	1.5480	1.8111	180.0
182.0	7.850	0.016522	48.172	48.189	150.01	989.0	1139.0	0.2662	1.5413	1.8075	182.0
184.0	8.203	0.016534	46.232	46.249	152.01	987.8	1139.8	0.2694	1.5346	1.8040	184.0
186.0	8.568	0.016547	44.383	44.400	154.02	986.5	1140.5	0.2725	1.5279	1.8004	186.0
188.0	8.947	0.016559	42.621	42.638	156.03	985.3	1141.3	0.2756	1.5213	1.7969	188.0
190.0	9.340	0.016572	40.941	40.957	158.04	984.1	1142.1	0.2787	1.5148	1.7934	190.0
192.0	9.747	0.016585	39.337	39.354	160.05	982.8	1142.9	0.2818	1.5082	1.7900	192.0
194.0	10.168	0.016598	37.808	37.824	162.05	981.6	1143.7	0.2848	1.5017	1.7865	194.0
196.0	10.605	0.016611	36.348	36.364	164.06	980.4	1144.4	0.2879	1.4952	1.7831	196.0
198.0	11.058	0.016624	34.954	34.970	166.08	979.1	1145.2	0.2910	1.4888	1.7798	198.0
200.0	11.526	0.016637	33.622	33.639	168.09	977.9	1146.0	0.2940	1.4824	1.7764	200.0
204.0	12.512	0.016664	31.135	31.151	172.11	975.4	1147.5	0.3001	1.4697	1.7698	204.0
208.0	13.568	0.016691	28.862	28.878	176.14	972.8	1149.0	0.3061	1.4571	1.7632	208.0
212.0	14.696	0.016719	26.782	26.799	180.17	970.3	1150.5	0.3121	1.4447	1.7568	212.0
216.0	15.901	0.016747	24.878	24.894	184.20	967.8	1152.0	0.3181	1.4323	1.7505	216.0
220.0	17.186	0.016775	23.131	23.148	188.23	965.2	1153.4	0.3241	1.4201	1.7442	220.0
224.0	18.556	0.016805	21.529	21.545	192.27	962.6	1154.9	0.3300	1.4081	1.7380	224.0
228.0	20.015	0.016834	20.056	20.073	196.31	960.0	1156.3	0.3359	1.3961	1.7320	228.0
232.0	21.567	0.016864	18.701	18.718	200.35	957.4	1157.8	0.3417	1.3842	1.7260	232.0
236.0	23.216	0.016895	17.454	17.471	204.40	954.8	1159.2	0.3476	1.3725	1.7201	236.0
240.0	24.968	0.016926	16.304	16.321	208.45	952.1	1160.6	0.3533	1.3609	1.7142	240.0
244.0	26.826	0.016958	15.243	15.260	212.50	949.5	1162.0	0.3591	1.3494	1.7085	244.0
248.0	28.796	0.016990	14.264	14.281	216.56	946.8	1163.4	0.3649	1.3379	1.7028	248.0
252.0	30.883	0.017022	13.358	13.375	220.62	944.1	1164.7	0.3706	1.3266	1.6972	252.0
256.0	33.091	0.017055	12.520	12.538	224.69	941.4	1166.1	0.3763	1.3154	1.6917	256.0
260.0	35.427	0.017089	11.745	11.762	228.76	938.6	1167.4	0.3819	1.3043	1.6862	260.0
264.0	37.894	0.017123	11.025	11.042	232.83	935.9	1168.7	0.3876	1.2933	1.6808	264.0
268.0	40.500	0.017157	10.358	10.375	236.91	933.1	1170.0	0.3932	1.2823	1.6755	268.0
272.0	43.249	0.017193	9.738	9.755	240.99	930.3	1171.3	0.3987	1.2715	1.6702	272.0
276.0	46.147	0.017228	9.162	9.180	245.08	927.5	1172.5	0.4043	1.2607	1.6650	276.0
280.0	49.200	0.017264	8.627	8.644	249.17	924.6	1173.8	0.4098	1.2501	1.6599	280.0
284.0	52.414	0.01730	8.1280	8.1453	253.3	921.7	1175.0	0.4154	1.2395	1.6548	284.0
288.0	55.795	0.01734	7.6634	7.6807	257.4	918.8	1176.2	0.4208	1.2290	1.6498	288.0
292.0	59.350	0.01738	7.2301	7.2475	261.5	915.9	1177.4	0.4263	1.2186	1.6449	292.0
296.0	63.084	0.01741	6.8259	6.8433	265.6	913.0	1178.6	0.4317	1.2082	1.6400	296.0
300.0	67.005	0.01745	6.4483	6.4658	269.7	910.0	1179.7	0.4372	1.1979	1.6351	300.0
304.0	71.119	0.01749	6.0955	6.1130	273.8	907.0	1180.9	0.4426	1.1877	1.6303	304.0
308.0	75.433	0.01753	5.7655	5.7830	278.0	904.0	1182.0	0.4479	1.1776	1.6256	308.0
312.0	79.953	0.01757	5.4566	5.4742	282.1	901.0	1183.1	0.4533	1.1676	1.6209	312.0
316.0	84.688	0.01761	5.1673	5.1849	286.3	897.9	1184.1	0.4586	1.1576	1.6162	316.0
320.0	89.643	0.01766	4.8961	4.9138	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320.0
324.0	94.826	0.01770	4.6418	4.6595	294.6	891.6	1186.2	0.4692	1.1378	1.6071	324.0
328.0	100.245	0.01774	4.4030	4.4208	298.7	888.5	1187.2	0.4745	1.1280	1.6025	328.0
332.0	105.907	0.01779	4.1788	4.1966	302.9	885.3	1188.2	0.4798	1.1183	1.5981	332.0
336.0	111.820	0.01783	3.9681	3.9859	307.1	882.1	1189.1	0.4850	1.1086	1.5936	336.0
340.0	117.992	0.01787	3.7699	3.7878	311.3	878.8	1190.1	0.4902	1.0990	1.5892	340.0
344.0	124.430	0.01792	3.5834	3.6013	315.5	875.5	1191.0	0.4954	1.0894	1.5849	344.0
348.0	131.142	0.01797	3.4078	3.4258	319.7	872.2	1191.1	0.5006	1.0799	1.5806	348.0
352.0	138.138	0.01801	3.2423	3.2603	323.9	868.9	1192.7	0.5058	1.0705	1.5763	352.0
356.0	145.424	0.01806	3.0863	3.1044	328.1	865.5	1193.6	0.5110	1.0611	1.5721	356.0
360.0	153.010	0.01811	2.9392	2.9573	332.3	862.1	1194.4	0.5161	1.0517	1.5678	360.0
364.0	160.903	0.01816	2.8002	2.8184	336.5	858.6	1195.2	0.5212	1.0424	1.5637	364.0
368.0	169.113	0.01821	2.6691	2.6873	340.8	855.1	1195.9	0.5263	1.0332	1.5595	368.0
372.0	177.648	0.01826	2.5451	2.5633	345.0	851.6	1196.7	0.5314	1.0240	1.5554	372.0
376.0	186.517	0.01831	2.4279	2.4462	349.3	848.1	1197.4	0.5365	1.0148	1.5513	376.0
380.0	195.729	0.01836	2.3170	2.3353	353.6	844.5	1198.0	0.5416	1.0057	1.5473	380.0
384.0	205.294	0.01842	2.2120	2.2304	357.9	840.8	1198.7	0.5466	0.9966	1.5432	384.0
388.0	215.220	0.01847	2.1126	2.1311	362.2	837.2	1199.3	0.5516	0.9876	1.5392	388.0
392.0	225.516	0.01853	2.0184	2.0369	366.5	833.4	1199.9	0.5567	0.9786	1.5352	392.0
396.0	736.193	0.01858	1.9291	1.9477	370.8	829.7	1200.4	0.5617	0.9696	1.5313	396.0
400.0	247.259	0.01864	1.8444	1.8630	375.1	825.9	1201.0	0.5667	0.9607	1.5274	400.0
404.0	258.725	0.01870	1.7640	1.7827	379.4	822.0	1201.5	0.5717	0.9518	1.5234	404.0
408.0	270.600	0.01875	1.6877	1.7064	383.8	818.2	1201.9	0.5766	0.9429	1.5195	408.0
412.0	282.894	0.01881	1.6152	1.6340	388.1	814.2	1202.4	0.5816	0.9341	1.5157	412.0
416.0	295.617	0.01887	1.5463	1.5651	392.5	810.2	1202.8	0.5866	0.9253	1.5118	416.0
420.0	308.780	0.01894	1.4808	1.4997	396.9	806.2	1203.1	0.5915	0.9165	1.5080	420.0
424.0	322.391	0.01900	1.4184	1.4374	401.3	802.2	1203.5	0.5964	0.9077	1.5042	424.0
428.0	336.463	0.01906	1.3591	1.3782	405.7	798.0	1203.7	0.6014	0.8990	1.5004	428.0
432.0	351.00	0.01913	1.30266	1.32179	410.1	793.9	1204.0	0.6063	0.8903	1.4966	432.0
436.0	366.03	0.01919	1.24887	1.26806	414.6	789.7	1204.2	0.6112	0.8816	1.4928	436.0
440.0	381.54	0.01926	1.19761	1.21687	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440.0
444.0	397.56	0.01933	1.14874	1.16806	[illegible]	[illegible]	1204.6	0.6210	0.8643	1.4853	444.0
448.0	414.09	0.01940	1.10212	1.12152	428.0	[illegible]	1204.7	0.6259	0.8557	1.4815	448.0
452.0	431.14	0.01947	1.05764	1.07711	432.5	772.3	1204.8	0.6308	0.8471	1.4778	452.0
456.0	448.73	0.01954	1.01518	1.03472	437.0	767.8	1204.8	0.6356	0.8385	1.4741	456.0

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume: Sat. Liquid v_f	Specific Volume: Evap v_{fg}	Specific Volume: Sat. Vapor v_g	Enthalpy: Sat. Liquid h_f	Enthalpy: Evap h_{fg}	Enthalpy: Sat. Vapor h_g	Entropy: Sat. Liquid s_f	Entropy: Evap s_{fg}	Entropy: Sat. Vapor s_g	Temp Fahr t
32.0*	0.08859	0.016022	3304.7	3304.7	-0.0179	1075.5	1075.5	0.0000	2.1873	2.1873	32.0*
34.0	0.09600	0.016021	3061.9	3061.9	1.996	1074.4	1076.4	0.0041	2.1762	2.1802	34.0
36.0	0.10395	0.016020	2839.0	2839.0	4.008	1073.2	1077.2	0.0081	2.1651	2.1732	36.0
38.0	0.11249	0.016019	2634.1	2634.2	6.018	1072.1	1078.1	0.0122	2.1541	2.1663	38.0
40.0	0.12163	0.016019	2445.8	2445.8	8.027	1071.0	1079.0	0.0162	2.1432	2.1594	40.0
42.0	0.13143	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	42.0
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	44.0
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	46.0
48.0	0.16514	0.016021	1830.0	1830.0	16.051	1066.4	1082.5	0.0321	2.1006	2.1327	48.0
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	50.0
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	52.0
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	56.0
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	58.0
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	60.0
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	62.0
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	64.0
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	66.0
68.0	0.33889	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	68.0
70.0	0.36292	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	70.0
72.0	0.38844	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	72.0
74.0	0.41550	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9708	2.0529	74.0
76.0	0.44420	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	76.0
78.0	0.47461	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	78.0
80.0	0.50683	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0359	80.0
82.0	0.54093	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	82.0
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	84.0
86.0	0.61518	0.016087	227.5	527.5	54.026	1045.0	1099.0	0.1043	1.9151	2.0193	86.0
88.0	0.65551	0.016093	496.8	496.8	56.022	1043.9	1099.9	0.1079	1.9060	2.0139	88.0
90.0	0.69813	0.016099	468.1	468.1	58.018	1042.7	1100.8	0.1115	1.8970	2.0086	90.0
92.0	0.74313	0.016105	441.3	441.3	60.014	1041.6	1101.6	0.1152	1.8881	2.0033	92.0
94.0	0.79062	0.016111	416.3	416.3	62.010	1040.5	1102.5	0.1188	1.8792	1.9980	94.0
96.0	0.84072	0.016117	392.8	392.9	64.006	1039.3	1103.3	0.1224	1.8704	1.9928	96.0
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	98.0
100.0	0.94924	0.016130	350.4	350.4	67.999	1037.1	1105.1	0.1295	1.8530	1.9825	100.0
102.0	1.00789	0.016137	331.1	331.1	69.995	1035.9	1105.9	0.1331	1.8444	1.9775	102.0
104.0	1.06965	0.016144	313.1	313.1	71.992	1034.8	1106.8	0.1366	1.8358	1.9725	104.0
106.0	1.1347	0.016151	296.16	296.18	73.99	1033.6	1107.6	0.1402	1.8273	1.9675	106.0
108.0	1.2030	0.016158	280.28	280.30	75.98	1032.5	1108.5	0.1437	1.8188	1.9626	108.0
110.0	1.2750	0.016165	265.37	265.39	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110.0
112.0	1.3505	0.016173	251.37	251.38	79.98	1030.2	1110.2	0.1507	1.8021	1.9528	112.0
114.0	1.4299	0.016180	238.21	238.22	81.97	1029.1	1111.0	0.1542	1.7938	1.9480	114.0
116.0	1.5133	0.016188	225.84	225.85	83.97	1027.9	1111.9	0.1577	1.7856	1.9433	116.0
118.0	1.6009	0.016196	214.20	214.21	85.97	1026.8	1112.7	0.1611	1.7774	1.9386	118.0
120.0	1.6927	0.016204	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120.0
122.0	1.7891	0.016213	192.94	192.95	89.96	1024.5	1114.4	0.1680	1.7613	1.9293	122.0
124.0	1.8901	0.016221	183.23	183.24	91.96	1023.3	1115.3	0.1715	1.7533	1.9247	124.0
126.0	1.9959	0.016229	174.08	174.09	93.96	1022.2	1116.1	0.1749	1.7453	1.9202	126.0
128.0	2.1068	0.016238	165.45	165.47	95.96	1021.0	1117.0	0.1783	1.7374	1.9157	128.0
130.0	2.2230	0.016247	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130.0
132.0	2.3445	0.016256	149.64	149.66	99.95	1018.7	1118.6	0.1851	1.7217	1.9068	132.0
134.0	2.4717	0.016265	142.40	142.41	101.95	1017.5	1119.5	0.1884	1.7140	1.9024	134.0
136.0	2.6047	0.016274	135.55	135.57	103.95	1016.4	1120.3	0.1918	1.7063	1.8980	136.0
138.0	2.7438	0.016284	129.09	129.11	105.95	1015.2	1121.1	0.1951	1.6986	1.8937	138.0
140.0	2.8892	0.016293	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140.0
142.0	3.0411	0.016303	117.21	117.22	109.95	1012.9	1122.8	0.2018	1.6534	1.8852	142.0
144.0	3.1997	0.016312	111.74	111.76	111.95	1011.7	1123.6	0.2051	1.6759	1.8810	144.0
146.0	3.3653	0.016322	106.58	106.59	113.95	1010.5	1124.5	0.2084	1.6684	1.8769	146.0
148.0	3.5381	0.016332	101.68	101.70	115.95	1009.3	1125.3	0.2117	1.6610	1.8727	148.0
150.0	3.7184	0.016343	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150.0
152.0	3.9065	0.016353	92.66	92.68	119.95	1007.0	1126.9	0.2183	1.6463	1.8646	152.0
154.0	4.1025	0.016363	88.50	88.52	121.95	1005.8	1127.7	0.2216	1.6390	1.8606	154.0
156.0	4.3068	0.016374	84.56	84.57	123.95	1004.6	1128.6	0.2248	1.6318	1.8566	156.0
158.0	4.5197	0.016384	80.82	80.83	125.96	1003.4	1129.4	0.2281	1.6245	1.8526	158.0
160.0	4.7414	0.016395	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160.0
162.0	4.9722	0.016406	73.90	73.92	129.96	1001.0	1131.0	0.2345	1.6103	1.8448	162.0
164.0	5.2124	0.016417	70.70	70.72	131.96	999.8	1131.8	0.2377	1.6032	1.8409	164.0
166.0	5.4623	0.016428	67.67	67.68	133.97	998.6	1132.5	0.2409	1.5961	1.8371	166.0
168.0	5.7223	0.016440	64.78	64.80	135.97	997.4	1133.4	0.2441	1.5892	1.8333	168.0
170.0	5.9926	0.016451	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2736	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5656	[illegible]	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8690	0.016486	54.59	54.61	143.99	992.5	1136.6	0.2568	1.5616	1.8184	176.0
178.0	7.1840	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

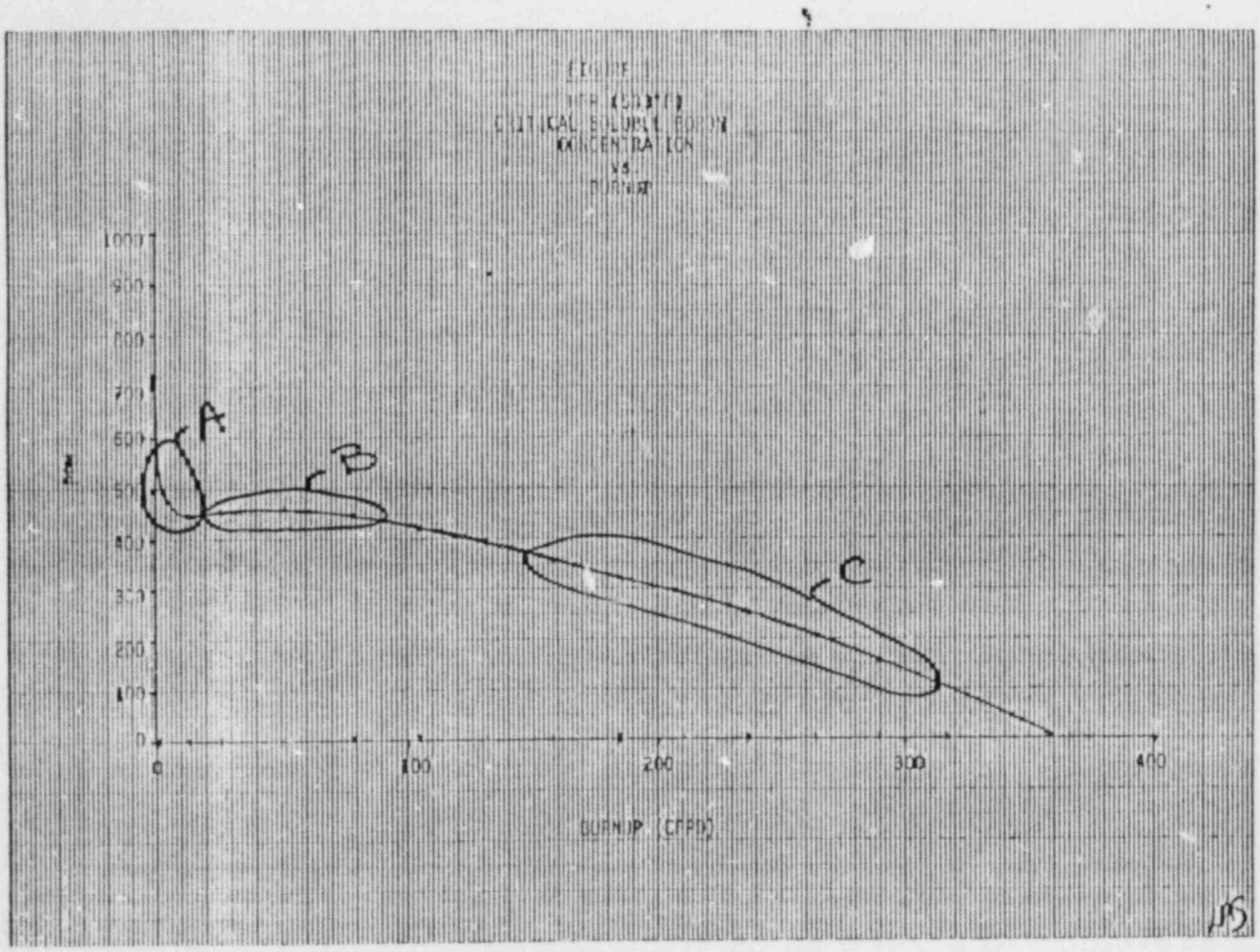

VS
1000
900
800
700
600
500
400
300
200
100
0
0
100
200
300
400
A
B
C

FIGURE 1.9

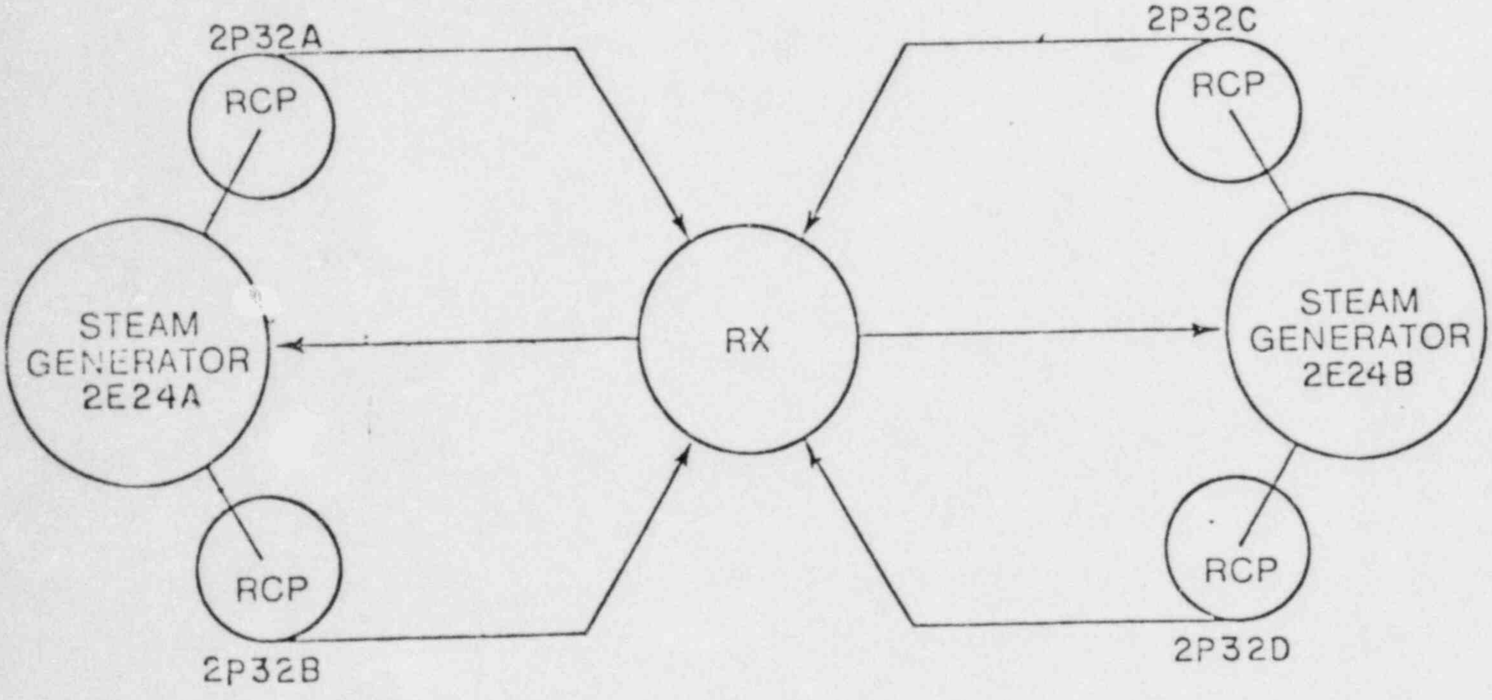
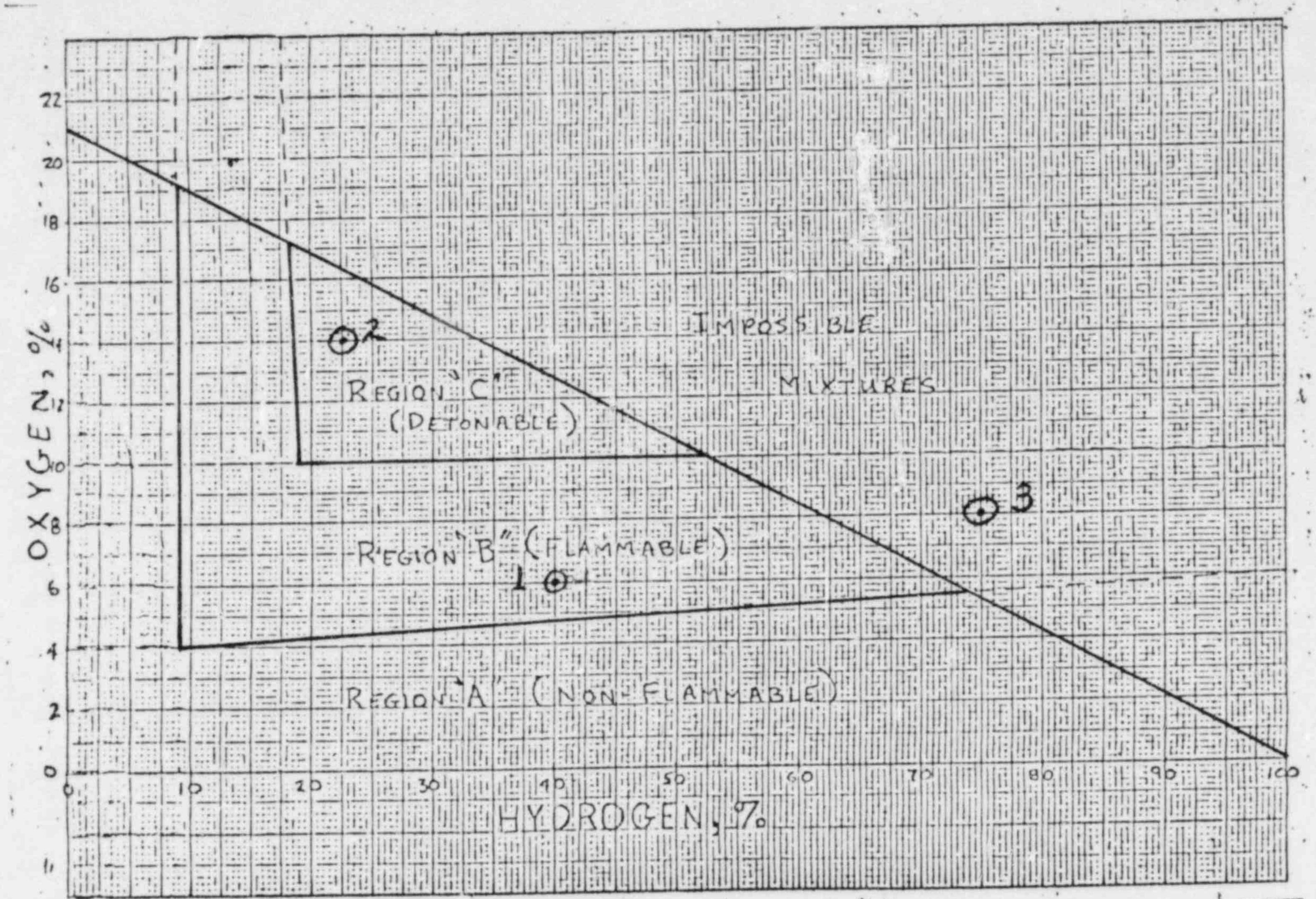

2P32A
RCP
2P32C
RCP
STEAM
GENERATOR
2E24A
RX
STEAM
GENERATOR
2E24B
RCP
2P32B
RCP
2P32D

Figure 2.7



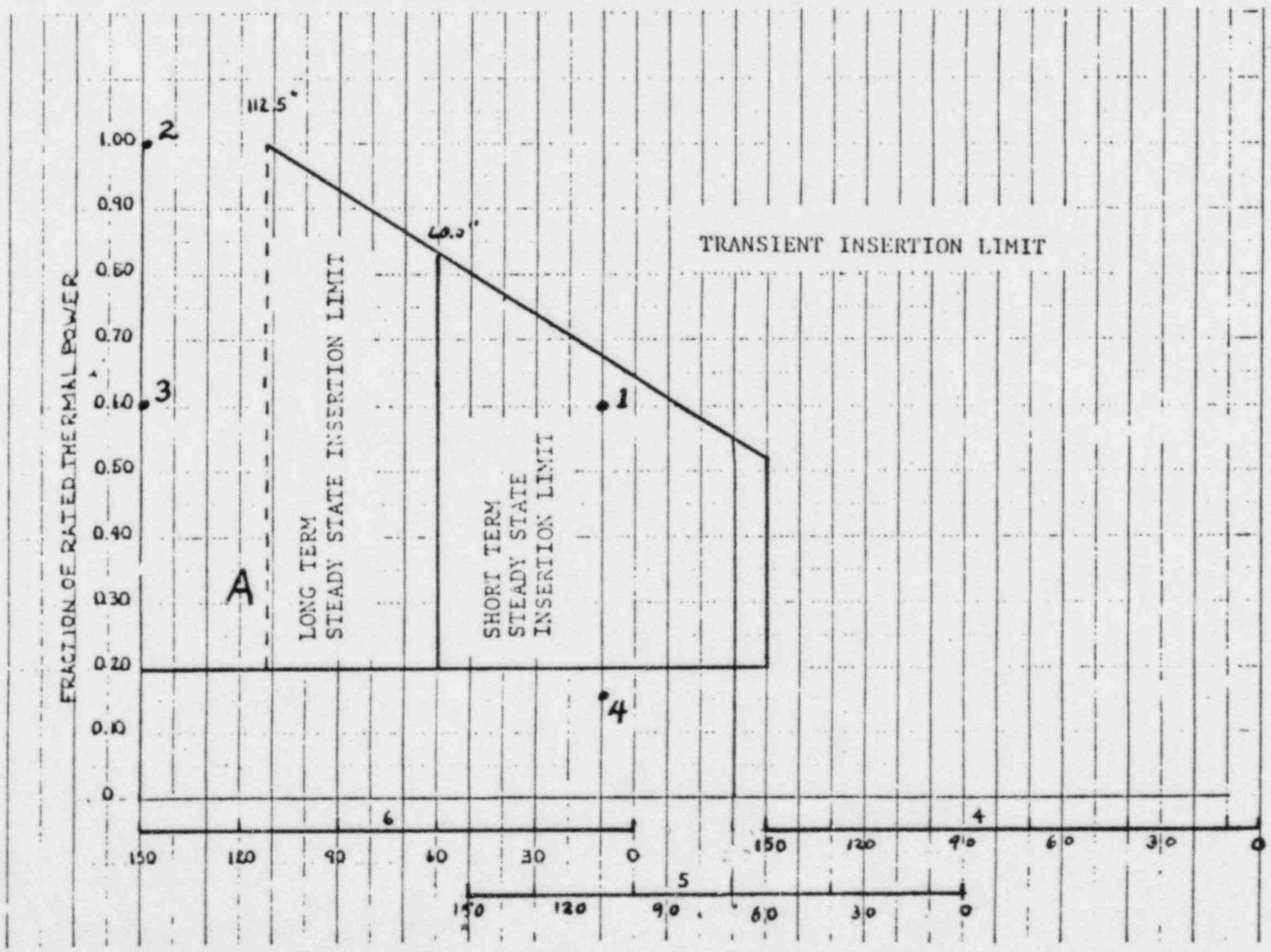
IMPOSSIBLE
MIXTURES
REGION "C"
(DETONABLE)
REGION "B" (FLAMMABLE)
REGION "A" (NON-FLAMMABLE)
OXYGEN, %
HYDROGEN, %
1
2
3
0
2
4
6
8
10
12
14
16
18
20
22
10
20
30
40
50
60
70
80
90
100

Figure 4.1

Table 4.9.1

Core Burnup	300 EFPD
PLCEA ht	150 in.
Boron concentration	430 ppm
Tave	566
Pzr Level	52%
VCT level	40%
BAST concentration	12,000 ppm

(For ease of calculations only assume Xe free and 100% eq Sm)



CEA WITHDRAWAL - INCHES

FIGURE 4.9.1

CEA Insertion Limits vs THERMAL POWER

	PLANT MANUAL SECTION: REACTOR COOLANT SYSTEM OPERATING	PROCEDURE/WORK PLAN TITLE: REACTIVITY BALANCE CALCULATION	NO: 2102.15
	ARKANSAS NUCLEAR ONE	PAGE 52 of 96	
		REVISION 11 DATE 11/16/83	
		CHANGE DATE	

ANO-2 Cycle 4
Figure A-1

CORE EXCESS REACTIVITY VERSUS BURNUP

HFP, No Xe, ARO, Eq. Sm

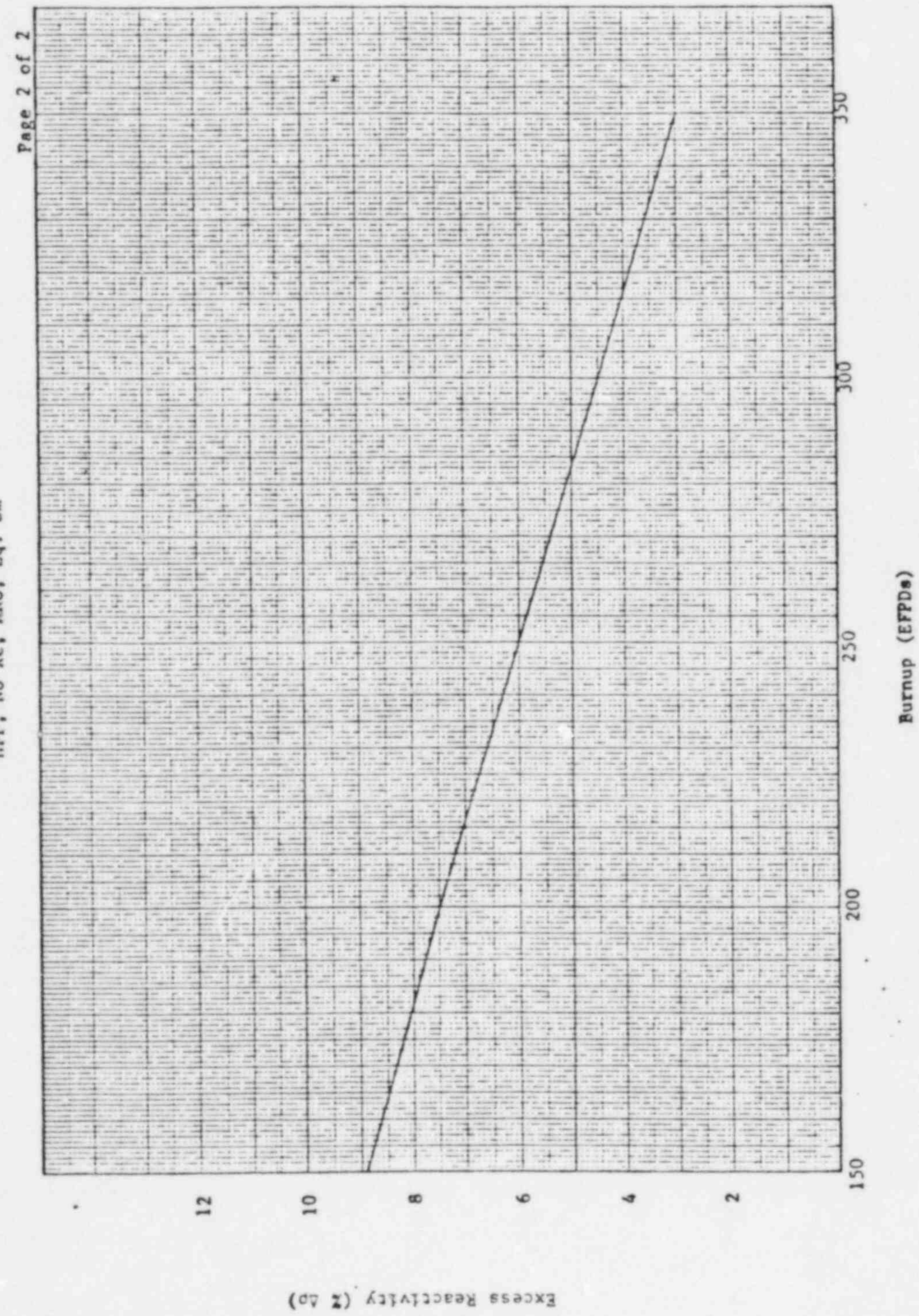


Figure 4.9.2

PLANT MANUAL SECTION: REACTOR COOLANT SYSTEM OPERATING	PROCEDURE/WORK PLAN TITLE: REACTIVITY BALANCE CALCULATION	NO: 2103.15

ANO-2 Cycle 4
Figure A-2

BORON REACTIVITY WORTH VERSUS BORON CONCENTRATION
BOC 4, T avg = 580°F

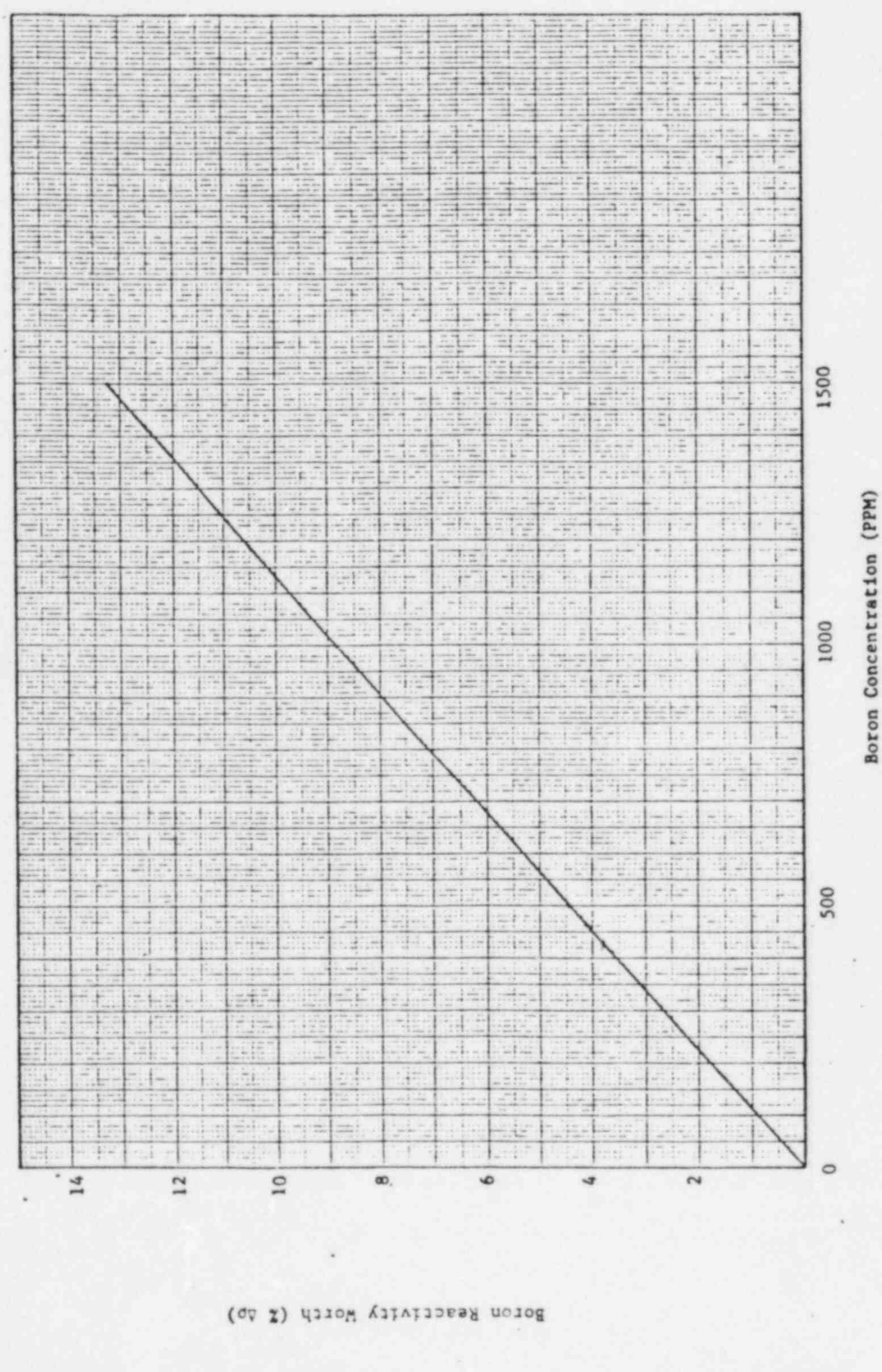


Figure 4.9.3

PLANT MANUAL SECTION:	PROCEDURE/WORK PLAN TITLE:	NO:
REACTOR COOLANT SYSTEM OPERATING	REACTIVITY BALANCE CALCULATION	2103.15

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CHANGE		DATE	

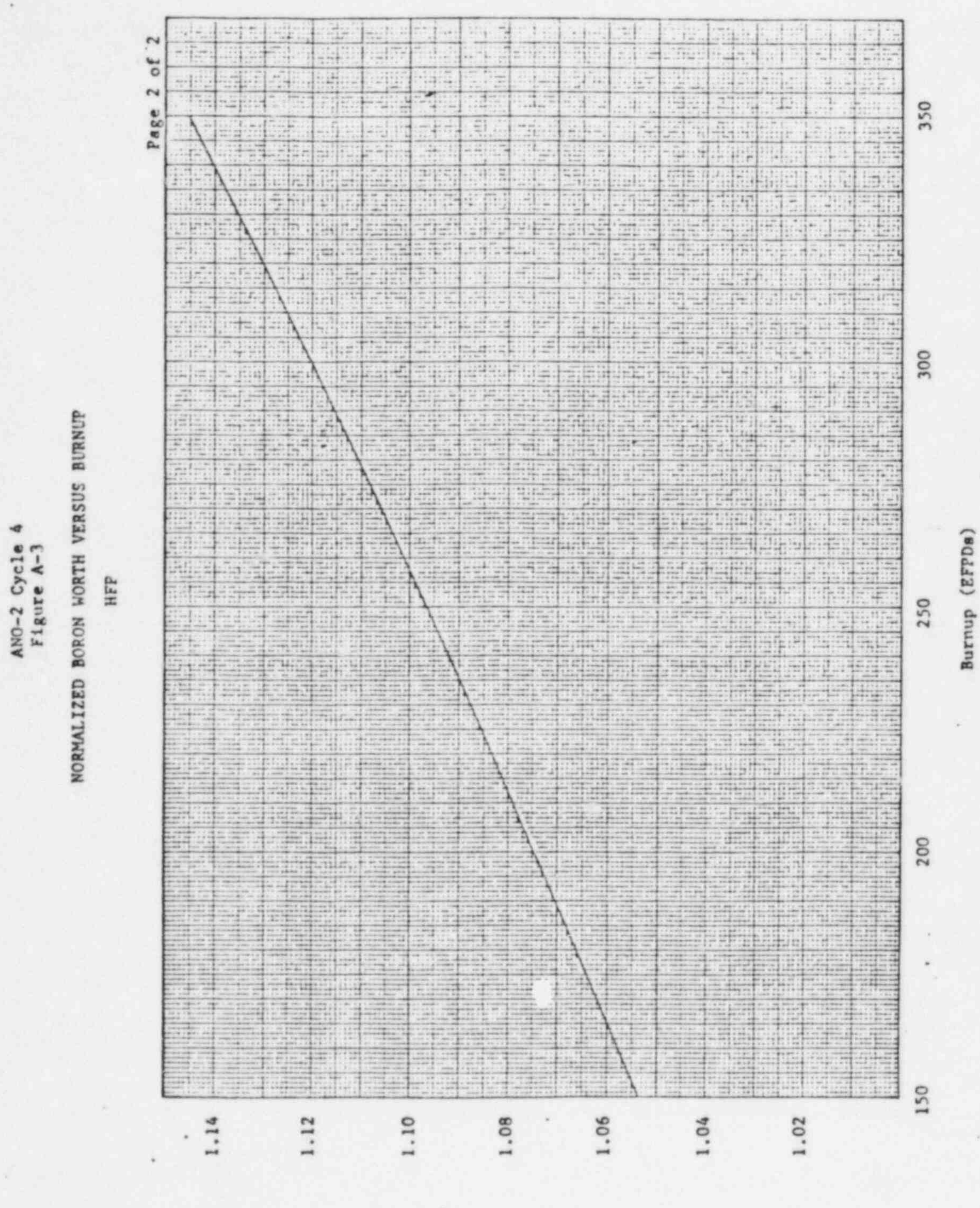

Figure 4.4.4

ANO-2 Cycle 4
Figure A-4.B

NORMALIZED BORON WORTH VERSUS MODERATOR TEMPERATURE
EOC

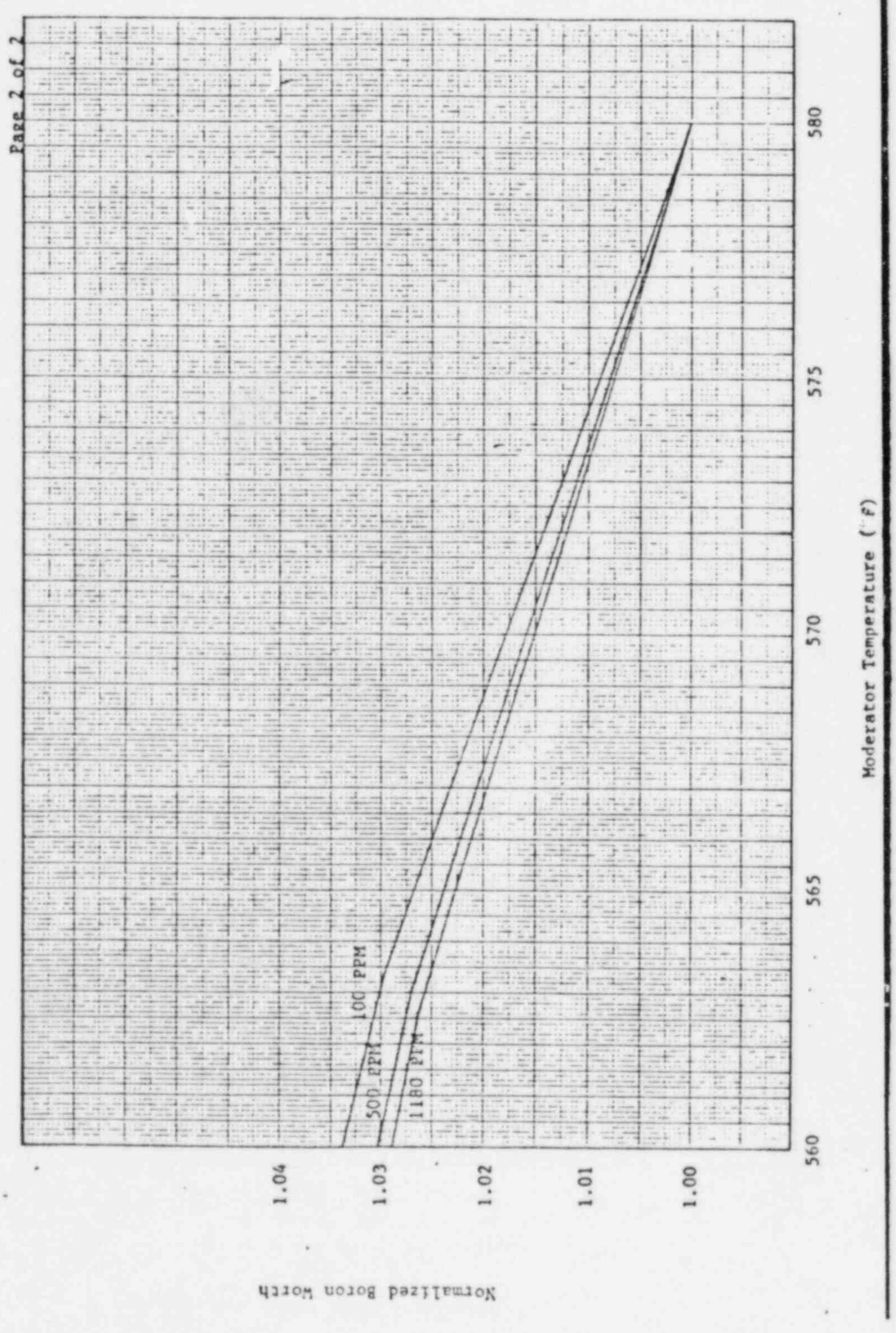

Figure 4.9.5

ANO-2 Cycle 4
Figure A-5.C

ITC VERSUS T AVERAGE

EOC

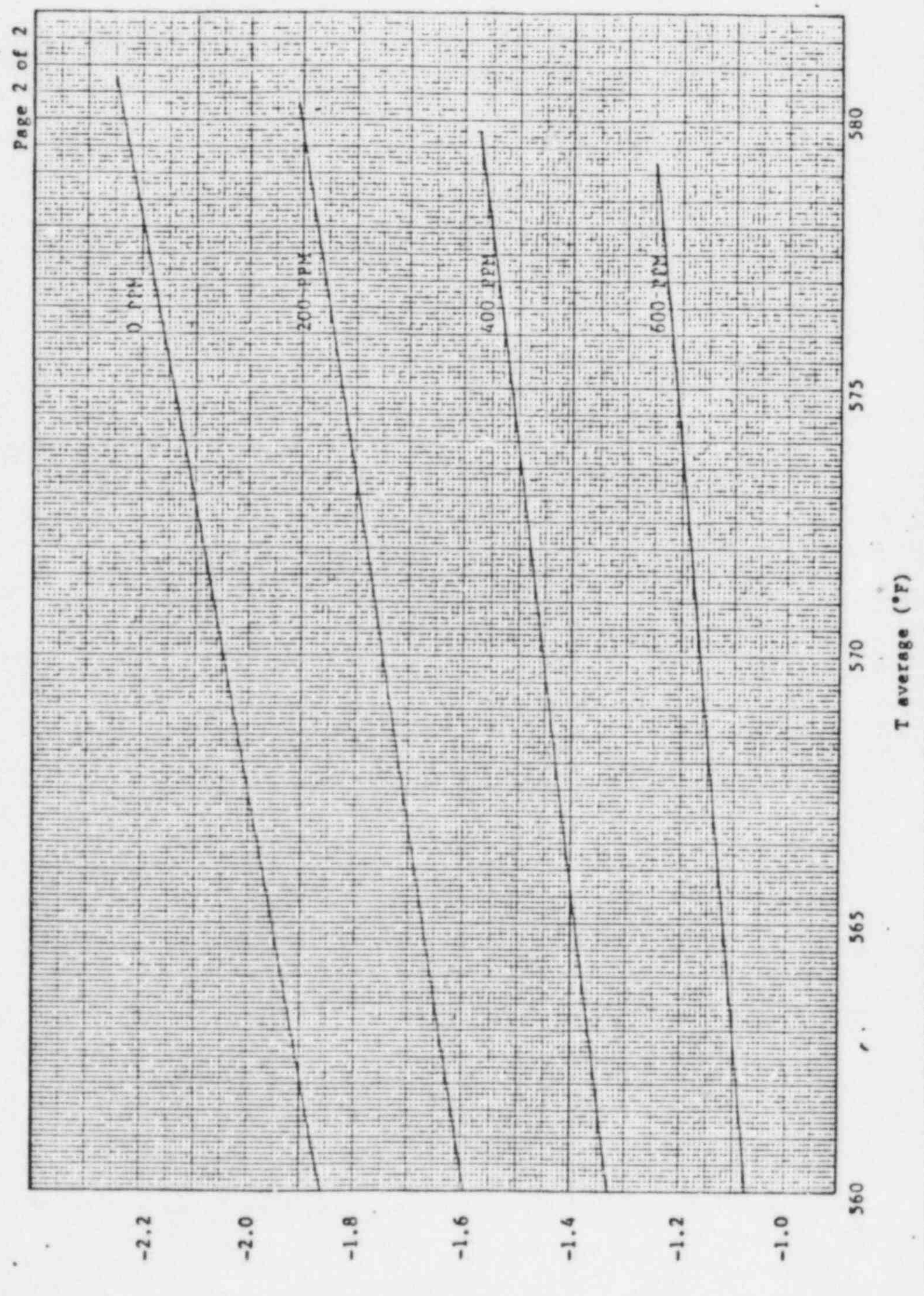

Figure 4.9.6

ANO-2 Cycle 4
Figure A-6

REGULATING CEA WORTH VERSUS WITHDRAWAL
HFP

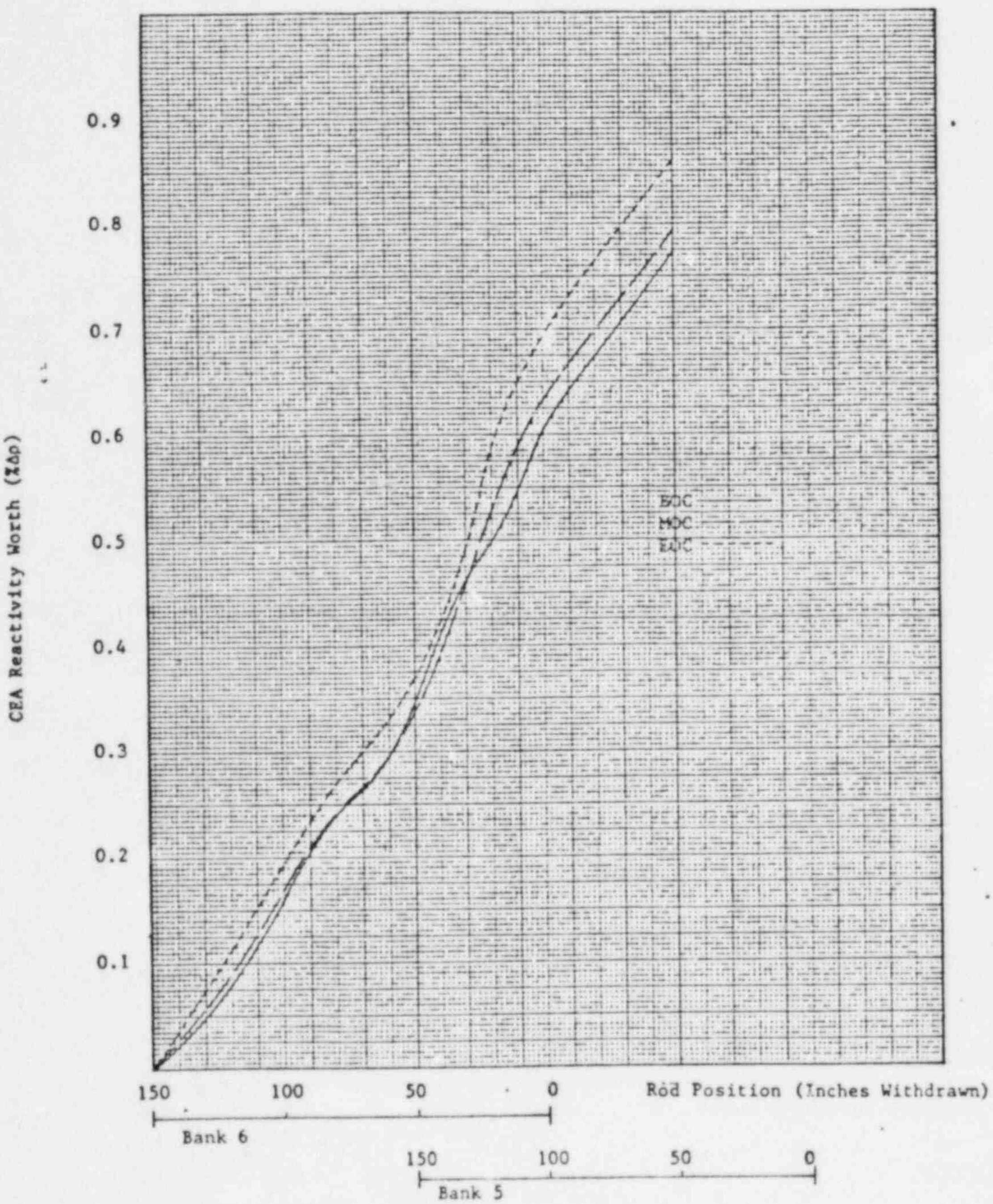

Figure 4.9.7

ANO-2 Cycle 4
Figure A-8

CEA Temperature Correction Factor Versus Mod. Temperature
Referenced to 580°F

Page 2 of 2

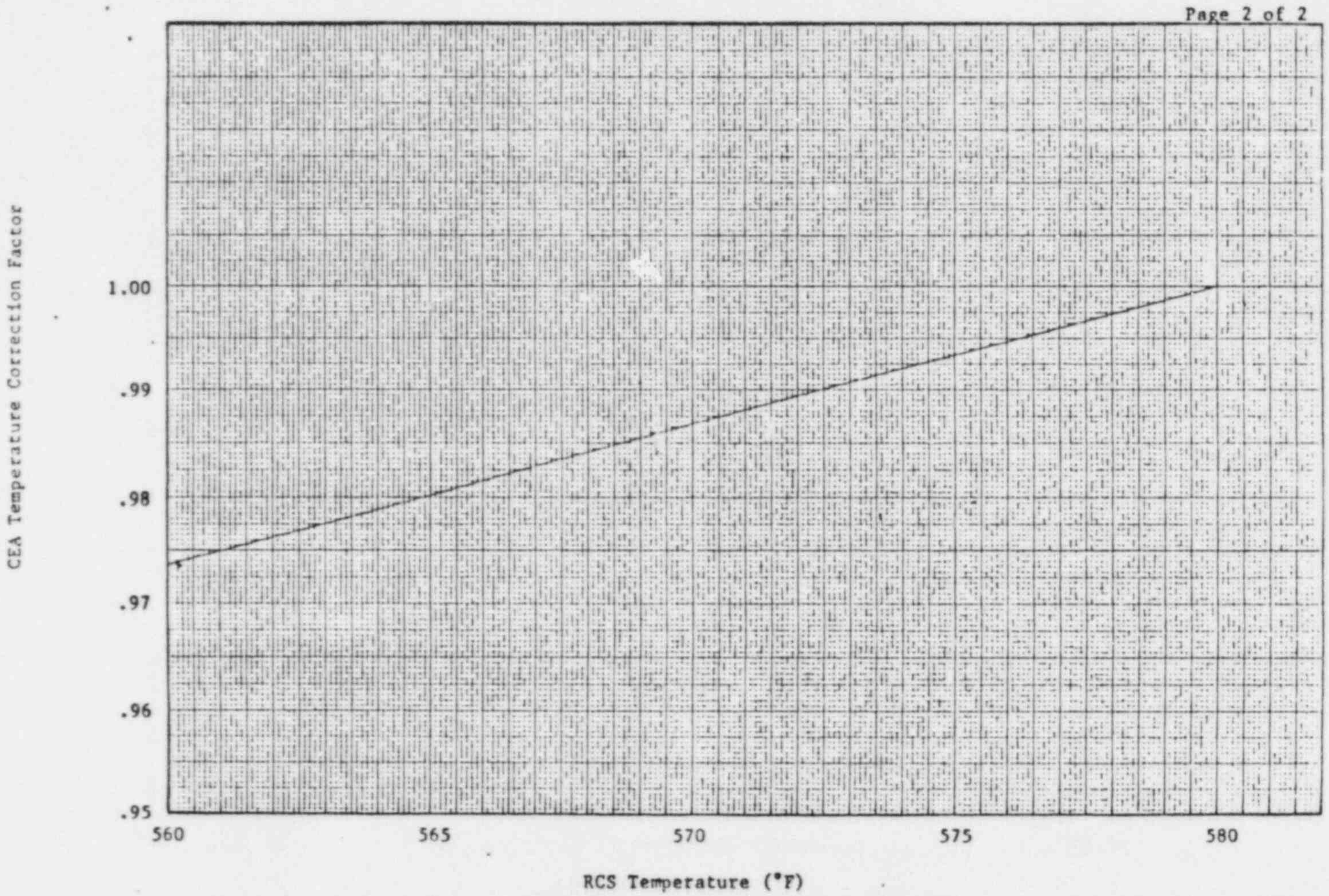

Figure 4.9.8

PLANT MANUAL SECTION: REACTOR COOLANT SYSTEM OPERATING	PROCEDURE/WORK PLAN TITLE: REACTIVITY BALANCE CALCULATION
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ANO-2 Cycle 4
Figure A-9

DOPPLER DEFECT VERSUS POWER LEVEL

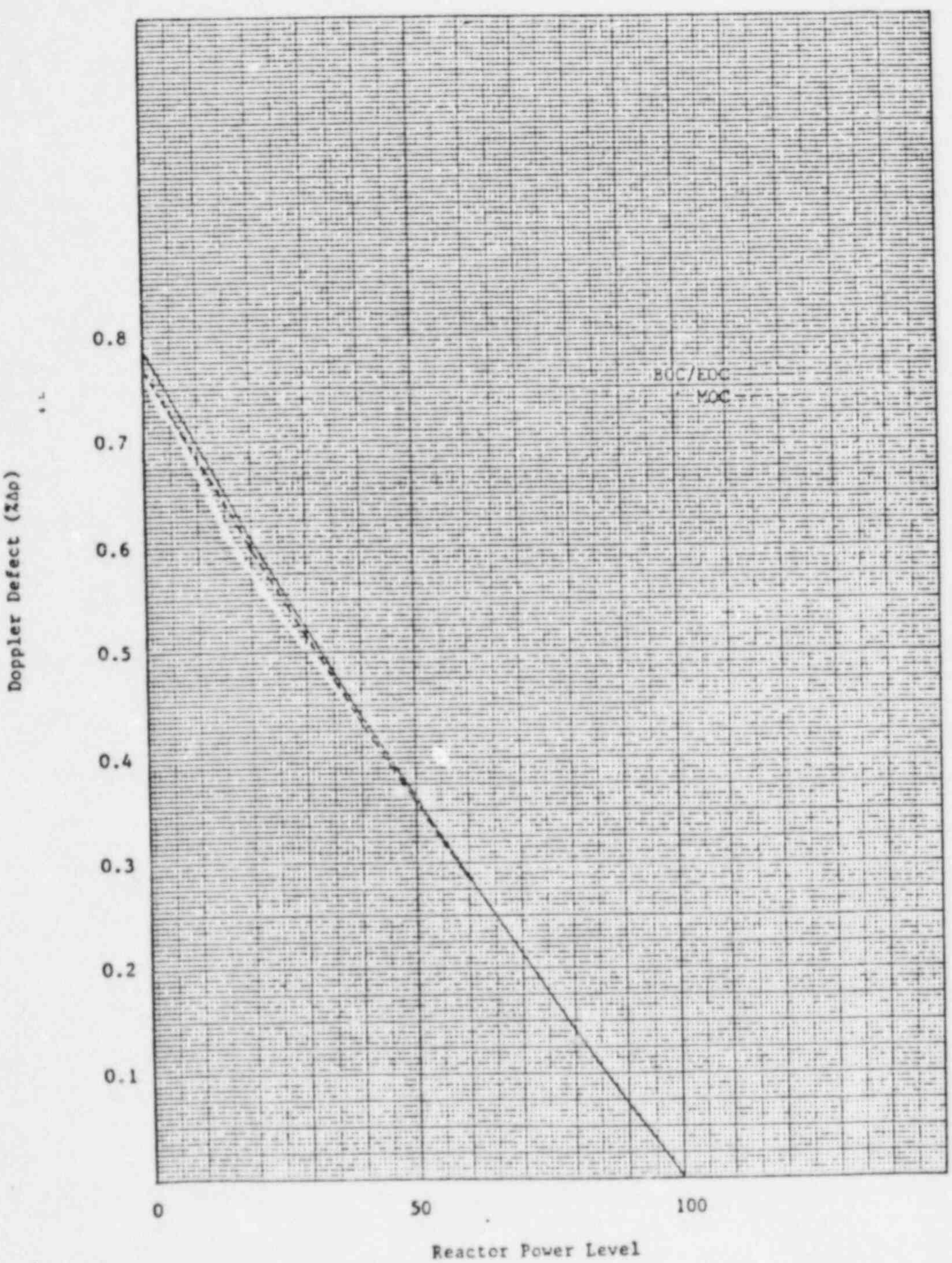

Figure 4.9.9

ARKANSAS POWER & LIGHT COMPANY
Arkansas Nuclear One

TITLE: WORK SHEET A-1 FORM NO. 2103.15A
REV. # 11 PC #

Page 1 of 2

Work Sheet A-1 Reactivity Balance During Critical Operations to Analyze for Reactivity Anomolies

Reference Conditions: 100%FP, 583°F, 2250 psia, no Xenon, no Boron, HFP equilibrium Samarium

Data Needed for Calculation:

Cycle Burnup ______ EFPD ; RCS Boron Conc. ______ ppm

*RCS T_{avg} ______ °F ; Heat Balance Power Level ______ %FP

*NOTE: Use average of CPC Channel A PID 160 & PID 162 for T_{avg} (or an equivalent indication) From: SEL |___|, Other ______

CEA Grp. 1 ______ in wd., CEA Grp. 2 ______ in wd., CEA Grp. 3 ______ in wd

CEA Grp. 4 ______ in wd., CEA Grp. 5 ______ in wd., CEA Grp. 6 ______ in wd

PLCEA Grp ______ in.wd.

1. From Attachment A-1: ρ(Fuel) = ______ % Δk/k

2. From Attachment A-2: ρ(Boron) = ______ % Δk/k

   From Attachment A-3: Boron Worth Burnup Correction = ______

   From Attachment A-4: Boron Worth Temp. Correction = ______

   ρ(Boron)* = ρ(Boron) x Burnup Correction x Temperature Correction

   ρ(Boron)* = ______ %Δk/k x ______ x ______

   $\boxed{\rho(\text{Boron})^* = \_\_\_\_\_\_ \ \%\ \Delta k/k}$

3. If T_{avg} = 580°F ± 2°F, neglect temperature correction, ρ(Temp) = 0, otherwise, from Attachment A-5:

$$\alpha temp(Tavg) = \_\_\_\_\_\_ \times 10^{-4} \frac{\Delta k}{k°F}$$

$$\alpha temp(580°F) = \_\_\_\_\_\_ \times 10^{-4} \frac{\Delta k}{k°F}$$

$$\rho(Temp) = \frac{\alpha temp(Tavg) + \alpha temp(580°F)}{2} \times (Tavg - 580°F) \times 100\%$$

$$= \frac{\_\_\_\_ + \_\_\_\_}{2} \times 10^{-4} \frac{\Delta k}{k°F} \times \_\_\_\_ °F \times 100\%$$

$\boxed{\rho(\text{Temp}) = \_\_\_\_\_\_ \%\Delta k/k}$

4. From Attachment A-6 (Interpolate between parametric burnup curves):

   a) For present controlling CEA group position ρ(CEAs) = ______ %Δk/k

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b) From Attachment A-7:
Additional worth due to PLCEAs = ______________ %Δk/k

c) Sum of 4a and 4b: ρ(CEAs) + ρ(PLCEAs) = ______________ % Δk/k

d) From Attachment A-8:
Temperature Correction Factor (TCF) = __________________

e) ρ(CEAs net) = [ρ(CEAs) + ρ(PLCEAs)] x TCF

| ρ(CEAs net) = ______________ % Δk/k |

5. From Attachment A-9 (Interpolate between parametric Burnup Curves)

| ρ(Power) = ______________ %Δk/k |

6. From: SAXON2 |___|, Other ______________________ (Indicate Method)

| ρ(Xenon) = ______________ % Δk/k |

7. If samarium is at HFP equilibrium, neglect additional samarium worth, ρ(Samarium) = 0

Otherwise, From: SAM2 |___|, Other ______________ (Indicate Method)

| ρ(Samarium) = ______________ % Δk/k |

8. Sum the following:

ρ(Net) = ρ(Fuel) - ρ(Boron)* ± ρ(Temp) - ρ(CEAs net) + ρ(Power) - ρ(Xenon) - [± ρ(Samarium)]

| ρ(Net) = ______________ %Δk/k |

If ρ(Net) exceeds ± 0.5%Δk/k refer to Section 4.0, Limits and Precautions.

Performed By ______________________________

Date ______________________ Time ______________

Reviewed By ______________________________
Nuclear Engineer or Nuclear Support Supervisor