U. S. NUCLEAR REGULATORY COMMISSION

REGION III

Docket No. 50-331 License No. DPR-49

Licensee: Iowa Electric Light and Power Company
Cedar Rapids, IA

Facility Name: Duane Arnold

Examination At: Duane Arnold Energy Center, Cedar Rapids, IA

Examinations Conducted: March 27-29, 1984

Chief Examiner: J. I. McMillen for
William C. Cliff
Date: May 11, 1984

Examiner: J. I. McMillen for
Charles C. Henager
Date: May 11, 1984

Approved By: Joseph I. McMillen
Joseph I. McMillen
Section Chief
Date: May 11, 1984

Examination Summary

Examinations on March 27-29, 1984
Written and oral examinations were administered to four ROs and 2 SROs. A written examination was administered to one additional SRO candidate.
Results: Three ROs and three SROs passed these examinations; the other RO candidate failed.

DETAILS

1. Examiners

*William C. Cliff
Charles H. Henager

*Chief Examiner

2. Examination Review Meeting

At the conclusion of the written examinations, the examiners met with Charles Mick, Gary Van Middlesworth, Paul Roy, and Bob Schlesinger. As a result of this review, Questions 7.3.c, 7.4.a, and 8.1.c of the SRO examinations were deleted. Additional comments were supplied by your letter of April 5, 1984. Resolution of your comments is the subject of Paragraph 3.

3. Resolution of Comments

Question 1.1	Value of answer was changed to 0.75 and "formation and subsequent collapse of vapor bubbles along the pump impeller vanes" was also an acceptable answer.
Question 1.1.a	Utility proposed that "the difference between suction pressure and saturation pressure of the fluid being pumped" was also an acceptable answer. The examiner stated he would accept this answer.
Question 1.6	The examiner agreed that either D or C could be correct if an explanation were supplied.
Question 1.8.a	The examiner agreed that, "The fraction of all neutrons in the core that were born delayed" would also be an acceptable answer.
Question 1.8.b	The examiner agreed that the value of beta was not required for full credit.
Question 1.8.c.	The reviewers suggested that "at the end of core life the reactor has a quicker response" should also be an acceptable answer. Examiners did not accept this as an adequate answer without additional information.
Question 1.12.d	All the reviewers expressed concerns that the question was inappropriate for a nuclear plant. The examiner rejected the comment on the basis that the question tested fundamental knowledge of the effect of pressure changes on level measuring instruments.
Question 2.1.a	Three additional systems were considered to be also correct.

Question 2.2	Numbers on answer key were corrected. Typographic error.
Question 2.7.a	The answer was corrected to contain the proper values.
Question 2.7.c	It was agreed that refueling was an acceptable answer for the plant condition.
Question 2.9.a	Any answer that listed a pressure $\geq$ 0 was acceptable.
Question 2.9.c	Normal flow under given conditions would be 2 gpm. Answer key was changed.
Question 2.10.b	The examiner agreed that either True or False would be accepted since the question as written was misleading.
Question 2.10.d	The answer could be either True or False depending on circumtances. Answer key was corrected to accept either answer.
Question 3.3.b	The facility comment concerning no high flow indicator was rejected since there is an indicator on the back panel.
Question 3.4.b	Question contained a typographical error. RSCS should have been RMC. All candidates answered question properly. Therefore, question was not deleted.
Question 3.7	Question contained an error. GEMAC should have been Yarway. Therefore, credit was given for either True or False.
Question 3.8.b	Examiner agreed that APRM upscale was an acceptable answer.
Question 4.1.b	Reviewers stated that pressure, temperature and level could be acceptable answers. Examiners agreed they would accept pressure; temperature would be acceptable with proper explanation, but level was not acceptable.
Question 4.3	Reference contains a typographical error. It should have read, II.B.6 instead of 11.b.9.
Question 4.5	Examiner agreed that 1000 mr/quarter was also an acceptable answer.
Question 4.8	Examiner agreed that a, d, and f were the correct answers.
Question 4.11.b	Reviewers suggested that annunciator and logs were also correct answers. Examiners rejected as being vague and not showing adequate knowledge of the systems.
Question 5.5.c	One reviewer suggested that "never" might be a possible answer. Examiner rejected this comment.

Question 5.8	The value for temperature was changed to 0.5.
Question 6.1	It was agreed that full credit for the purpose of the system would be given if the candidate answered "to mitigate the postulated thrust load on Mark I Containment and discharge piping T quenchers".
Question 6.6.a	The answer key was changed to accept "mini purge" as a possible correct answer.
Question 6.6.b	Reviewers explained that "loop to loop" is the same as loop to vessel coolant" and that a 145° ΔT from top of vessel to bottom drain is also a possible answer. The answer key was corrected to accept these answers.
Question 6.12.b	The answer key was corrected to accept (66W + 54) as another possible answer.
Question 6.12.d	The answer was changed to "False" since rod block monitor downscale is also a Technical Specification limit.
Question 7.3.c	This question was deleted since the operation of the recirculation system in master manual above 50% of rated recirculation pump speed is no longer permitted.
Question 7.4.a	This question was deleted since the steam condensing mode is not used and is disabled.
Question 7.7.a	The answer key was corrected to read "Because they do not need 'AC' electrical power."
Question 7.8.a	"Computer printout" was included as an acceptable answer.
Question 7.9.b	The answer key was corrected to include "20%" if candidate also states that "this is the Technical Specification and house loads."
Question 8.1.c	This question was deleted since the STA does have a turnover check sheet but is not required by plant procedure.
Question 8.4.c	The answer key was corrected to include other persons as possible answers
Question 8.7.1	This answer contained a typographical error and should have read "less than". Key was corrected.
Question 8.7.3	The maximum pressure was changed to 1335.

4. Exit Meeting

At the conclusion of the site visit the examiners met with representatives of the plant staff to discuss the results of the examinations. Those individuals who clearly passed the oral examinations were identified in this meeting.

RECORD COPY

DUANE ARNOLD SRO EXAM - 3/27/84

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

Facility: Duane Arnold
Reactor Type: BWR-4
Date Administered: 3-27-84
Examiner: C. H. Henager
Candidate: _____

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheet. Points for each question are indicated in parenthesis after the question. The passing grade requires at least 70% in each category and a final grade of at least 80%. Examination papers will be picked up six (6) hours after the examination starts.

Category Value	% of Total	Candidate's Score	% of Cat. Value	Category
25	25.5			5. Theory of Nuclear Power Plant Operation, Fluids and Thermodynamics
25	25.5			6. Plant System Design, Control and Instrumentation
23.5 ~~25~~	24 ~~25~~			7. Procedures-Normal, Abnormal, Emergency, and Radiological Control
24.5 ~~25~~	25			8. Administrative Procedures, Conditions, and Limitations
98 ~~100~~				TOTALS

Final Grade _____ %

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

_____
Candidate's Signature

5.0 Theory of Nuclear Power Plant Operation, Fluids, and Thermodynamics

(25.0)

5.1 Besides local neutron flux, list five (5) other physical factors which help determine actual differential worth of a control rod (2.5)

5.2 For each of the events listed below, state which reactivity coefficient will respond first, why it responds first, and whether it adds positive or negative reactivity.

a) SRV opening at 100% power. (1.0)

b) Rod drop from 100% power. (1.0)

5.3 After operating several days at 100% power, the power is reduced quickly to 50%. Describe in general terms what will happen to power level over the next 24 hours if no further changes are made in rod positions or recirculation flow. (2.0)

5.4 Assume the reactor is operating at 100% power in 3-element control and one recirculation pump trips. Indicate how each listed parameter would initially respond (increase, decrease, remain the same) and briefly explain the reason for the response.

a) Reactor power (neutron flux) (1.0)

b) Reactor water level (1.0)

c) Feedwater flow. (1.0)

5.5 a) By what method is Samarium removed from the reactor poison inventory? (0.5)

b) When does Samarium reach its peak value? (0.5)

c) When would you expect the reactor to be Samarium-free? (0.5)

- Category 5 continued on next page -

DUANE ARNOLD SRO EXAM 3/27/84

5.6 Critical power is defined as: (0.5)

a) The value of the critical power ratio associated with the most critical assembly in the reactor core.

b) The bundle power which causes critical quality (boiling transition) to exist at some point in the bundle.

c) The power in a fuel rod which causes critical quality (boiling transition) to exist at some point on the rod.

d) The power at which the fuel assemblies go critical regardless of the quality of the coolant in the core.

5.7 True or False A BWR control rod will have a lower rod worth at high moderator temperatures than at low temperatures. (0.5)

5.8 Reactor coolant is at 420°F and 650 psig. Is the fluid saturated, subcooled, or superheated? If the fluid is not saturated, by how many degrees is it superheated/subcooled? Show all work if applicable. (1.0)

5.9 In terms of extracting energy from steam, which of the following statements best describes why the condenser is operated at a vacuum. (0.75)

a) Less energy is extracted from the steam but overall plant efficiency is increased.

b) As the vacuum is increased, the saturation temperature of the steam is decreased, allowing more energy to be extracted.

c) As the vacuum is increased, the saturation temperature of the steam is increased, allowing more energy to be extracted.

d) The amount of energy extracted from the steam is not dependent on condenser vacuum.

Category 5 continued next page

5.10 State four (4) factors in a reactor heat balance. For each one, tell whether it is a heat input or a heat output and give a brief description as to why. (2.0)

5.11 How long will it take to increase power from 75 watts to 750 KW on a 45 second period? Show all work. (2.0)

5.12 A centrifugal pump is forcing water through a given length of 2-inch diameter line. An operator revalves the system so that it pumps through the same length of 1-inch diameter line. What happens to the pump discharge head, pressure drop in the line, and the flow? (1.0)

a) Discharge head increases, pressure drop increases and flow increases.

b) Discharge head decreases, pressure drop decreases and flow decreases.

c) Discharge head increases, pressure drop increases and flow decreases.

d) Discharge head decreases, pressure drop decreases and flow increases.

5.13 A centrifugal pump operating at 1800 rpm is pumping 400 gpm of water at a discharge head of 20 psi using a power of 5 KW. If its speed is increased to 2700 rpm, which one of the following will happen? (1.0)

a) The flow rate will increase to 900 gpm.

b) The discharge head will increase to 30 psi.

c) The power requirements will increase to 11 KW.

d) The discharge head will increase to 45 psi.

5.14 Define enthalpy. (1.0)

Category 5 continued next page

5.15 The amount of Pu-239 and Pu-241 increase with core life. Pu-239 and Pu-241 yield more neutrons per fission than does U-235. Based upon these facts, why aren't fewer fissions per second required to produce 100% power? (1.5)

5.16 a) What is pump runout and why is it an undesirable condition? (0.75)

b) Explain what is meant by pump cavitation. State a method to reduce or eliminate cavitation. (1.0)

5.17 a) Explain what is meant by "shutdown margin ". (0.5)

b) What is the value of the shutdown margin that must always be maintained? (0.5)

- End of Category 5 -

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6.0 Plant Systems, Design, Control and Instrumentation (25.0)

6.1 What is the purpose of the newly installed LLS SRV System and how does it function to fulfill that purpose? (2.0)

6.2 Since all the condensate returning to the reactor vessel is continually cleaned by the condensate demineralizers, why is the RWCU system needed? (1.0)

6.3 Explain the problem and consequences of admitting steam to the turbine seals if the turbine rotor is not turning. (1.0)

6.4 What is the preferred alignment of control rod drive water pump suction when condensate pumps are running and what is the reason for this? (2.0)

6.5 With regard to the nuclear fuel:

a) List four (4) ways to verify the correct orientation of a fuel assembly within a control cell. (2.0)

b) Why are the fuel pellets chamfered? (1.0)

6.6 With regard to the Reactor Recirculation System:

a) What is the source of water to the recirculation pump seals to cool and keep the seals clean? (0.5)

b) If only one recirculation pump is running and the reactor coolant is at an elevated temperature, what are two important limitations on starting up the second pump? (1.0)

c) True or False Startup of a second recirculation pump draws more current than the first. Explain. (1.0)

Category 6 continued next page

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6.7 In the instrument and service system (I & SA System):

a) When air pressure drops below certain levels, interlocks function to try to maintain air pressure for vital instruments. What are these three interlocks? Include setpoints. (2.0)

b) True of False. Instrument air is oil-free because the air compressor cylinders have no oil lubrication. (0.5)

6.8 In a situation where the plant is at power and a LOCA occurs, what diesel stop signals are effective? Assume startup and backup power are not available. (1.5)

6.9 a) Describe the "one-out-of-two-twice" logic as used by RPS. A simple sketch may be used. (2.0)

b) Why is this method (logic) used? (1.0)

6.10 With regard to the HPCI system:

a) True or False. The HPCI system is capable of operation independent of auxiliary AC power, plant service air, or external cooling water system. (0.5)

b) What signals auto initiate the HPCI system? (Set points also required). (1.0)

c) What is the normal position of the minimum flow valve (MO-2318) when HPCI is in the standby mode? Why is it left in this position? (1.0)

d) What is its rated flow? (0.5)

Category 6 continued next page

6.11 Regarding the IRM system, which statement below best describes the system? (1.0)

a) The IRM: uses fission chamber detectors; is filled with argon at a lower pressure than the SRM's; uses a smaller amount of U-235 in the coating than the SRM's; uses the Campbell method to discriminate between neutrons and gamma.

b) The IRM: uses sensitive ionization chamber detectors; is filled with argon gas at a pressure lower than the SRM's; uses a lower voltage than the SRM's; uses a pulse-height discriminator to discriminate between neutrons and gamma.

c) The IRM: uses fission chamber detectors; is filled with argon gas at a lower pressure than the SRM's, uses a lower voltage than the SRM's; uses a pulse-height discriminator to discriminate between neutrons and gamma.

d) The IRM: uses sensitive ionization chamber detectors; is filled with argon at a lower pressure than the SRM's, uses a larger amount of U-235 in the coating than the SRM's; uses the Campbell method to discriminate between neutrons and gamma.

6.12 With regard to the Rod Block Monitor (RBM):

a) At what power levels is it enforced? (0.5)

b) What is the high reference set point for the rod block trip unit during two recirculation loop operation? (0.5)

c) What parameters does the RBM use to generate rod blocks? (1.0)

d) True or False The high reference setpoint of the rod block trip unit is the only RBM setpoint required by Tech Specs as a Limiting Condition for Operation. (0.5)

- End of Category 6 -

DUANE ARNOLD SRO EXAM 3/27/84

7.0 Procedures - Normal, Abnormal, Emergency and Radiological Control (25.0)

7.1 Regarding normal fuel handling procedures:

a) How can you tell if a load shackle has been load tested? (0.25)

b) How many people are in a full complement of a fuel moving crew for fuel moves made within the reactor vessel or reactor vessel cavity? (0.25)

c) During fuel moving, where is the second Control Room Operator stationed and what is his function? (1.0)

d) True or False. During functional subcritical checks a licensed operator is required to confirm control rod movements on the refueling floor by direct line-of-sight observation. (0.5)

7.2 Relative to the Plant Emergency Instructions for Reactor Vessel Low Water Level (A.1):

a) List the six (6) of the eight (8) immediate actions (operator actions). List only key actions, not the detailed steps of each action. (2.0)

b) What additional source of water can be used if the normal sources are insufficient or not working? (0.5)

7.3 In the Integrated Plant Operating Instructions (IPOI) for reactor plant startup (Section II C Plant Startup):

a) What is the recommended stable period for approach to the power range? (0.5)

b) What is considered to be too fast a period? (0.5)

deleted

c) What is the stated reason for preferring the recirculation control to be in Master Manual mode for speeds above 50% of the rated recirculation pump speed? (1.0)

Category 7 continued next page

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7.4 Regarding Operating Instructions No. 50, Reactor Core Isolation Cooling System (RCIC):

deleted

a) True or False. The procedure advises that ~~when~~ RCIC is in the level control mode, ~~the rate~~ at which water is pumped into the ~~vessel is~~ controlled by the rate of change ~~of the water level~~. (0.5)

b) State the three (3) conditions that make it mandatory to initiate RCIC system operation. (1.5)

7.5 What are the three automatic actions that occur during Loss of Main Condenser Vacuum starting with vacuum at 19 in. Hg down to 0 inches Hg? (Include set points.) (1.5)

7.6 Regarding permissible radiation exposure limits:

a) What is the DAEC administrative exposure guide for whole body radiation in mrems per day for an individual. (1.0)

b) Are the permissible limits for exposure to the lens of the eyes more, less, or the same as whole body limits? (1.0)

c) A health physics representative monitors a work area and finds only 3 mrem/hr direct radiation. Will a RWP be required to perform work in this area? (0.5)

7.7 Regarding the Emergency Operating Instructions, Section 5, Loss of all AC power (Station Blackout) during power operation:

a) Why are HPCI and RCIC used in this case? (1.0)

b) How is the vessel pressure controlled? (0.5)

7.8 While operating at rated power, a single relief valve lifts:

a) List four (4) symptoms (besides the ADS Safety Valve Leaking Annunciator) that would indicate that it has failed to reseat. (1.0)

b) At what suppression pool temperatures is a scram a requirement? (0.5)

Category 7 continued next page

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7.9 During a normal shutdown:

a) Why should you avoid operation with two condensate pumps and one reactor feed pump? (1.0)

b) At what power level is the rod sequence control system (RSCS) required to be operable? (0.5)

c) What is the highest power level at which the turbine may be unloaded and shut down? (0.5)

d) Why should you avoid inserting all four (4) SRMs at once? (0.5)

e) The procedure cautions that problems may arise in proper feed water regulation if you fail to maintain sufficient bypass steam flow while lowering pressure to 500 psi. Explain how this might cause a scram in the IRM range. (1.0)

7.10 According to IPOI Vol. C-1.0, Section III, Reactor Scram, following a reactor scram:

a) What are the two conditions that require you to perform loss of shutdown margin IPOI C.II.D.2? (1.0)

b) State the indicated reason for placing the reactor mode switch in the shutdown position. (0.5)

c) How is water level maintained and at what level? (1.0)

d) What actions are to be taken to reduce reactor pressure if the MSIV's close? (1.0)

7.11 Concerning the Standby Liquid Control System (SBLC):

a) Name four conditions or combination of conditions that indicate a need to initiate SBLC. (2.0)

b) What sections of the SBLC system are heated? (0.5)

End of Category 7

DUANE ARNOLD SRO EXAM 3/27/84

8.0 Administrative Procedures, Conditions and Limitations (25.0)

8.1 Regarding the shift manning requirements and duties:

a) What are the manning requirements for the minimum shift crew when the reactor is in other than a cold shutdown mode and is not in the refuel mode at ≤ 140°F. List the six (6) positions/categories and the number of each as required by Administrative Control Procedure No. 1404.1, Shift Organization, Operation and Turnover. (3.0)

b) State the control room manning requirements when the reactor is operating. (1.0)

deleted

c) Which position on an operating crew does not have a shift turnover form? (0.5)

8.2 Under what conditions may operations personnel challenge a direction given by an operation shift supervisor? (2.0)

8.3 a) True or False. Anyone who recognizes a problem that should be corrected by the Maintenance Department can initiate a Maintenance Action Request (MAR). (0.5)

b) True or False. Instrumentation found out of tolerance during surveillance testing and reported on a deviation report does not require a MAR to perform corrective adjustment. (0.5)

8.4 With regard to revision of procedures and instructions:

a) Who by title, controls the Temporary Revision Log? (0.5)

b) Who by title, controls the Permanent Revision Log? (0.5)

c) List by title three (3) persons or groups of persons who are responsible and authorized to review and approve procedure and instruction revisions submitted to them? (1.5)

Category 8 continued next page

DUANE ARNOLD SRO EXAM 3/27/84

8.5 a) Describe the differences in using a hold card and a warning tag. (1.0)

b) Under what conditions should more than one set of tags be placed on a piece of equipment? (1.0)

c) Who is responsible for maintaining the Hold-Off Log Book, and where is it to be kept? (1.0)

8.6 a) Fill in the blanks in the following statement:

The purpose of the end-of-cycle recirculation pump trip (EOC-RPT) is to prevent adding (1)_____ reactivity from (2)_____ at a faster rate than the (3)_____ can add (4)_____ reactivity during a scram. (2.0)

b) What two events will cause the EOC-RPT to function? (2.0)

8.7 List four (4) of the six (6) safety limits for the Duane Arnold Plant. (4.0)

8.8 Which statement best describes the criticality design feature of the spent fuel storage racks?

A K_{eff} less than or equal to:

a) 0.95 when flooded with borated water.

b) 0.995 when flooded with borated water.

c) 0.95 when flooded with unborated water.

d) 0.995 when flooded with unborated water. (0.5)

8.9 a) According to Tech Specs, how many persons are required to be maintained as a fire brigade on site at all times? (0.5)

b) How many persons on the shift crew must be excluded? (0.5)

Category 8 continued next page

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8.10 a) During a plant alert or emergency, what are the first two (2) duties of the plant emergency coordinator (in general terms)? (1.0)

b) Who will normally fill the plant emergency coordinator position initially during off-shift hours? (0.5)

8.11 According to the procedure for Control of Jumpers, Lifted Leads and Test Box Devices:

a) Who must authorize each jumper or lifted lead? (0.5)

b) Where is the Jumper and Lifted Lead Log to be maintained? (0.5)

End of Category 8

End of Exam

EQUATIONS/DATA SHEET

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

$1 Ci = 3.7 \times 10^{10} Bq$

$\alpha_D = -1 \times 10^{-5} \frac{\Delta K/°F}{K}$

$\alpha_v = -1 \times 10^{-3} \frac{\Delta K/\% \text{ voids}}{K}$

$\alpha_M = -4.5 \times 10^{-4} \frac{\Delta K/\%°F}{K}$

$\alpha_p = -4.5 \times 10^{-4} \frac{\Delta K/\% \text{ power}}{K}$

$I(t) = I_o \, e^{-\lambda t}$

$T1/2 = \ln(2)/\lambda$

$Cp = (CP_{base}) \, (Ks) \, (K_A)$

$Q = MCp \, \Delta t$

$\Delta p = f \frac{L}{D} \frac{\rho V^2}{2 g_c}$

$f = 64/Re$

$\rho = \frac{k(eff) - 1}{K(eff)}$

$\frac{1}{M} = \frac{CR1}{CR2} = \frac{1-K(eff)2}{1-K(eff)1}$

$\dot{Q} = M \Delta h$

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

$M = 1/(1-k)$

$N(t) = No \, e^{-\lambda T}$

$\alpha_{rx} = (L_f + L_s) \frac{(\phi rod)^2}{(\phi avg)}$

$n = \nu/(1 + d)$

$P = \Sigma \, \phi \, \nu/(3.7 \times 10^{10})$

$\tau = (\beta - \rho)/\lambda\rho$

$\dot{\tau} = \bar{\ell}/\rho + (\beta - \rho)/\lambda\rho$

$\tau = \ell/(\rho - \beta)$

$v = v_f + x v_{fg}$

$H = x h_g + (1-x) \, h_f$

$S = x S_g + (1-x) \, S_f$

1 in. = 2.54 cm

1 gal. = 3.785 liters

1 kg = 2.205 lb

$N = \rho A_o / A$

17.58 watts = 1 BTU/min
1psi = 6.895 Pa
1psi = 2.036 " H_g (@ 0C)
1psi = 27.68 " H^2O (@ 4C)

$\bar{\beta} = .0071$

$\bar{\ell} = 2 \times 10^{-5}$ sec

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press. Lb per Sq In. p	Specific Volume Sat. Liquid v_f	Evap v_{fg}	Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat. Liquid s_f	Evap s_{fg}	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	527.5	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	392.9	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	1132.6	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	0.016474	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	992.6	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

*The states shown are metastable

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

Temp Fahr t	Abs Press. Lb per Sq In. p	Specific Volume Sat. Liquid v_f	Evap v_{fg}	Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat. Liquid s_f	Evap s_{fg}	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	236.193	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	423.5	781.1	1204.6	0.6210	0.8643	1.4853	444.0
448.0	414.09	0.01940	1.10212	1.12152	428.0	776.7	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—*Continued*

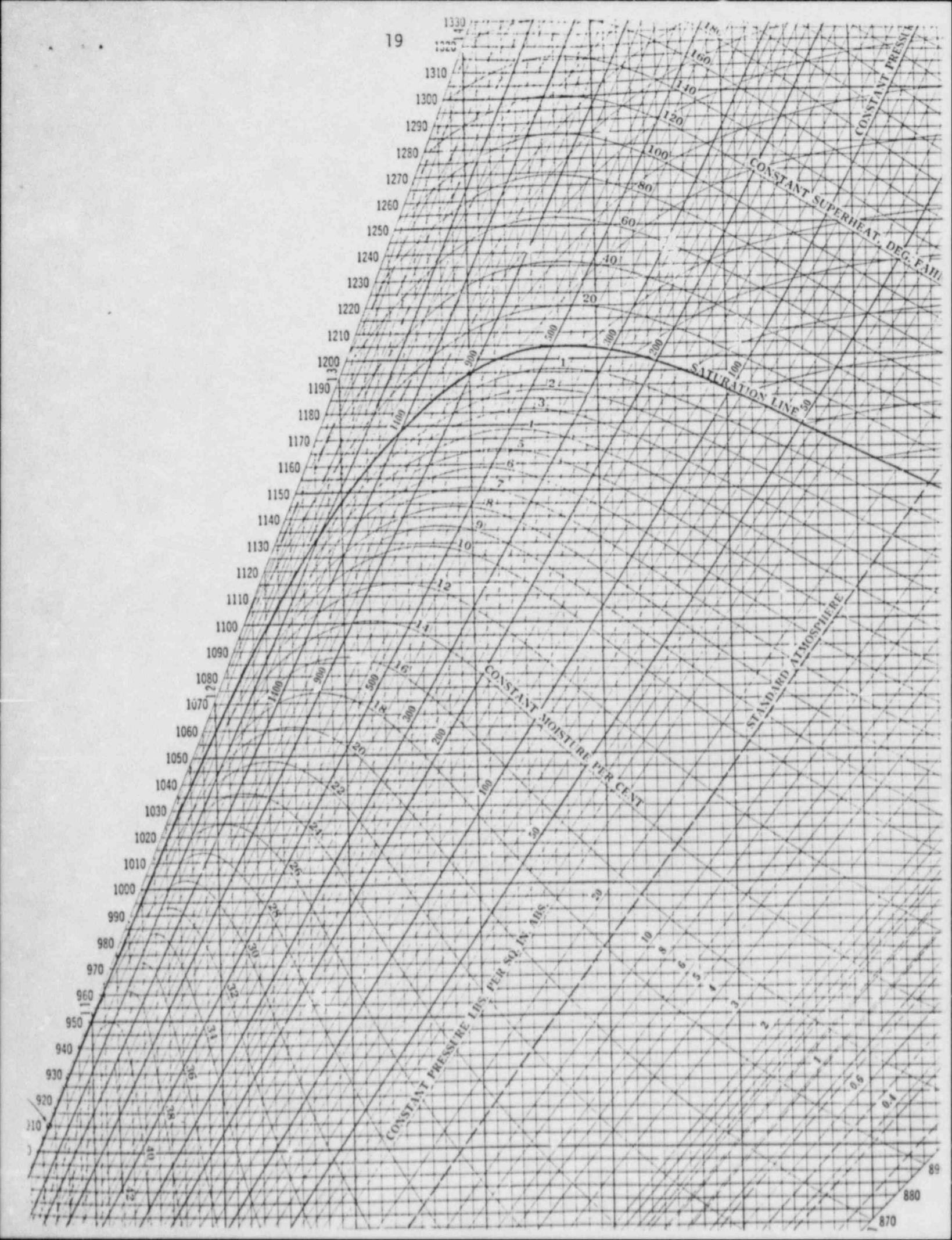
Temp Fahr t	Abs Press. Lb per Sq In. p	Specific Volume Sat. Liquid v_f	Evap v_{fg}	Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat. Liquid s_f	Evap s_{fg}	Sat. Vapor s_g	Temp Fahr t
460.0	466.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460.0
464.0	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	0.02235	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	1.3470	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
616.6	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	0.3341	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	740.7	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	0.07319	0.10453	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	0.02162	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 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	1.4547	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	1.3421	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	1.3274	1600.0
1650.0	609.05	0.02407	0.22143	0.24551	630.4	531.3	1161.6	0.8254	0.4971	1.3225	1650.0
1700.0	613.13	0.02428	0.21178	0.23607	636.5	522.2	1158.6	0.8309	0.4867	1.3176	1700.0
1750.0	617.12	0.02450	0.20263	0.22713	642.5	513.1	1155.6	0.8363	0.4765	1.3128	1750.0
1800.0	621.02	0.02472	0.19390	0.21861	648.5	503.8	1152.3	0.8417	0.4662	1.3079	1800.0
1850.0	624.83	0.02495	0.18558	0.21052	654.5	494.6	1149.0	0.8470	0.4561	1.3030	1850.0
1900.0	628.56	0.02517	0.17761	0.20278	660.4	485.2	1145.6	0.8522	0.4459	1.2981	1900.0
1950.0	632.22	0.02541	0.16999	0.19540	666.3	475.8	1142.0	0.8574	0.4358	1.2931	1950.0
2000.0	635.80	0.02565	0.16266	0.18831	672.1	466.2	1138.3	0.8625	0.4256	1.2881	2000.0
2100.0	642.76	0.02615	0.14885	0.17501	683.8	446.7	1130.5	0.8727	0.4053	1.2780	2100.0
2200.0	649.45	0.02669	0.13603	0.16272	695.5	426.7	1122.2	0.8828	0.3848	1.2676	2200.0
2300.0	655.89	0.02727	0.12406	0.15133	707.2	406.0	1113.2	0.8929	0.3640	1.2569	2300.0
2400.0	662.11	0.02790	0.11287	0.14076	719.0	384.8	1103.7	0.9031	0.3430	1.2460	2400.0
2500.0	668.11	0.02859	0.10209	0.13068	731.7	361.6	1093.3	0.9139	0.3206	1.2345	2500.0
2600.0	673.91	0.02938	0.09172	0.12110	744.5	337.6	1082.0	0.9247	0.2977	1.2225	2600.0
2700.0	679.53	0.03029	0.08165	0.11194	757.3	312.3	1069.7	0.9356	0.2741	1.2097	2700.0
2800.0	684.96	0.03134	0.07171	0.10305	770.7	285.1	1055.8	0.9468	0.2491	1.1958	2800.0
2900.0	690.22	0.03262	0.06158	0.09420	785.1	254.7	1039.8	0.9588	0.2215	1.1803	2900.0
3000.0	695.33	0.03428	0.05073	0.08500	801.8	218.4	1020.3	0.9728	0.1891	1.1619	3000.0
3100.0	700.28	0.03681	0.03771	0.07452	824.0	169.3	993.3	0.9914	0.1460	1.1373	3100.0
3200.0	705.08	0.04472	0.01191	0.05663	875.5	56.1	931.6	1.0351	0.0482	1.0832	3200.0
3208.2*	705.47	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	3208.2*

*Critical pressure


CONSTANT PRESSURE
CONSTANT SUPERHEAT, DEG. FAH
SATURATION LINE
CONSTANT MOISTURE PER CENT
STANDARD ATMOSPHERE
CONSTANT PRESSURE LBS. PER SQ. IN. ABS.

RECORD COPY

ANSWERS TO DUANE ARNOLD SRO EXAM 3/27/84

5.1 1. Location in core

2. Positioning of adjacent control rods

3. *Effects of Xenon poisoning

4. Installed poison concentration in the rod

5. Moderator temperature — 0.5 for each

6. *Core age — of 5 (2.5)

7. Void content

8. Type of poison used in the rod

9. Area of the rod

10. Variations in the thermal diffusion length

11. "Burnout" of the rod from age

Ref: DAEC Reactor Theory Part 31, Control Rod Worth.
* Not mentioned in the training material.

5.2 a) First effect of decrease in pressure is to cause increased voids, void coefficient would add negative reactivity. (1.0)

b) Rod drop inserts positive reactivity causing power to increase, fuel temperature increases before heat can affect moderator temperatures, and Doppler is first to react by adding negative reactivity. (1.0)

Ref: DAEC Reactor Theory, Part 26, Reactivity Coefficients and Defects

5.3 The power level will decrease for several hours because of xenon build up. After the peak xenon is reached and it starts decaying to the 50% equilibrium level, the power level will increase. (2.0)

Ref: DAEC Student Handout "Reactory Theory-Xenon", p.8 Fig 33.6

5.4 a) Decrease (0.5) due to increased void content in the core as recirc flow decreases. (0.5) (1.0)

b) Increase (0.34) due to increased voiding in the core (0.33) and recirc. pump no longer taking suction on the annulus (0.33). (1.0)

c) Decrease (0.34) due to steam flow decrease (0.33) and level increase (0.33). (1.0)

Ref: BWR Transient Analysis

5.5 a) By neutron absorption (Samarium burnout) (0.5)

b) About 12 days (0.25) after a reactor shutdown (0.25) (0.5)

c) In a new core before startup. (0.5)

Ref: DAEC Student Handout, "Reactor Theory", Chapter 32 and 33.

5.6 b (0.5)

Ref: DAEC Student Handout, "Heat Transfer", p. 12.3

5.7 False (0.5)

Ref: DAEC Student Handout, "Reactor Theory-Control Rod Worth", page 7.

5.8 420°F Sat. pressure = 308.78 psia

650 psig = 664.7 psia: Sat. temp. = 497.3°F

→ Fluid is subcooled (0.5) by 77.3°F ~~(1.0)~~ 0.5 (1.0)

Ref: Steam Tables

5.9 b) As vacuum is increased, the saturation temperature of the steam is decreased, allowing more energy to be extracted. (0.75)

Ref: DAEC Student Handout "Thermodynamics:, p. 17-22 and Steam Tables.

5.10 a) Feedwater flow - heat input (0.25) going into the vessel (or system) with positive enthalpy. (0.25)

b) Steam flow - heat output (0.25) due to steam removing energy from the core. (0.25)

c) Reactor core thermal energy - heat input (0.25), primary source of the thermal energy (0.25).

d) Recirc pump - heat input (0.25) due to energy added to the fluid in the core (or system) by the pumps. (0.25)

e) CRD flow - heat input (0.25) due to fluid flowing into the core (or system) (0.25) with a positive enthalpy. (See Ref. for additional inputs/outputs if named).

Grading 0.5 for each correct input/output (4 required) (2.0)

Ref: DAEC Student Handout, "Thermodynamics", Chapter 18 "Reactor Heat Balance".

5.11 414.5 sec or 6.9 min. (2.0)

$P = 750$ KW $\quad P_o = 75w \quad \tau = 45$ sec

$P = P_o e^{t/\tau}$, $\quad t = \tau \ln \frac{P}{P_o}$,

$t = (45 \text{ sec}) \ln \frac{750000}{75} = 45 \ln 10000$

$= 45\ (9.21) = 414.5 \text{ sec} = 6.9 \text{ min}$

Grading 1.0 for method (correct use of $P = P_o e^{t/\tau}$)
1.0 for correct answer

5.12 c (1.0)

Ref: Application of fluid flow fundamentals as in DAEC Student Handout, "Fluid Flow".

5.13 d) Discharge head is proportional to n^2, $\left(\frac{2700}{1800}\right)^2 = 2.25$; $2.25 \times 20 = 45$ (1.0)

Ref: DAEC Student Handout, "Fluid Flow", p. 4-6
Flow $\propto n$; Head $\propto n^2$, Power $\propto n^3$.

5.14 Enthalpy of a substance is defined as the sum of the internal energy (0.5) and the P-V energy (0.5) (P = pressure, V = volume). (1.0)

Ref: DAEC Student Handout, "Thermodynamics", Chapter 3, p. 3-4.

5.15 The average energy released per fission determines the fission rate required for a specific power level, not the number of neutrons. Since all fissions produce an average of approximately 200 MeV, the number of fissions per unit time required to produce 100% power is essentially the same at BOL and EOL. (1.5)

Ref: DAEC Student Handout - Reactor Theory Chapters 8-12.

5.16 a) Pump runout is the term used to describe a centrifugal pump when it is pumping at its maximum capacity (0.5). The increased flow causes the motor to draw more current and may damage the motor winding (0.25). or It may also cause cavitation (acceptable for 0.25) (0.75)

b) If the pressure drop in a pump is great enough, or if the temperature of the liquid is high enough, the liquid may boil in the pump. When this occurs, the pump is said to be cavitating. Damage occurs when the bubbles collapse (0.5). To prevent cavitation, the pump must have some minimum positive pressure at the pump suction (NPSH). This can be dealt with in two ways: (1) by increasing the suction pressure or (2) by cooling the fluid being pumped. (0.5 for either method or stating to increase NPSH) (1.0)

Ref: Student Handout "Fluid Flow", p. 4-4 & 4-5.

5.17 a) Shutdown margin is the amount of reactivity that the core is or can be made subcritical from its present condition with the most reactive control rod withdrawn from the core at any time during the core cycle. (0.5)

b) 0.38% $\Delta k/k$ (0.5)

- End of Category 5 -

ANSWERS TO DUANE ARNOLD SRO EXAM 3/27/84

6.0 Plant Systems, Design, Control and Instrumentation (25.0)

6.1 When a Safety/Relief valve reseats, the steam will condense and draw water into the discharge piping. If the valve is opened again, excessive pressure would be exerted. A vacuum relief valve is installed in the discharge piping from each valve and will open to prevent the formation of a vacuum. During small break LOCAs or abnormal pressure transients, there is not enough time for the vacuum breakers to clear the water leg before the Safety/Relief Valves (SRV) reopen. To mitigate the postulated thrust load concern of subsequent SRV actuations, Low-Low Set (LLS) relief logic (which is an automatic SRV control system for PSV 4401 and 4407) was added during the 1983 refueling outage. The LLS System will automatically control reactor pressure by opening and closing the LLS SRVs in response to reactor pressure as sensed by four independent pressure switches. (2.0)

Primary answer for "purpose" →

on Mark I containment and discharge piping, T-quenchers, e

(The above details are primarily for the benefit of the grader. Such detail is not required in the candidates answer. The basic reason and function will suffice.)

Ref: DAEC System Description A-6 Main Steam p. 13

6.2 It is needed to remove particulate matter, minerals and contaminants that would otherwise concentrate in the vessel because they do not carry over with the steam. (1.0)

Ref: DAEC System Description B-4, RWCU.

6.3 Uneven heating will result in a bowed rotor. (1.0)

Ref: System Operating Instructions OI-93 p. 1
(Main Turbine & Turbine Control System)

6.4 To the condensate reject line (1.0). The reason is to provide high quality deaerated, low conductivity water to control rod drives (1.0). (This will prevent cracking of CRD retainer tubes due to thermal cycles with exposure to aerated cooling water) (2.0)

Ref: DAEC System Operating Instructions OI-55/56 p. 1 (CRD System).

6.5 a) Correct orientation of a fuel assembly within a control cell can be verified in seven ways:

1) The channel fasterner (spring clip) should be at the center of the four-assembly cell. 2) The fuel channel spacer buttons should be located on the inside surfaces of the four bundle array. 3) The fuel orientation boss on the fuel assembly handle should point toward the center of the four bundle array. 4) The serial number of the assembly should be readable from the center of the cell. 5) Gadolinia rod location, as identified by extended upper end plugs, should be correct. 6) Fuel rod location by enrichment, as determined by upper tie plate hole sizes should be correct. 7) The cell should be symmetrical. (2.0)

Grading, 0.5 points each for any 4 of the above.

Ref: System Description A4. Nuclear Fuel and Control Rods, p. 62b-15.

b) To minimize the consequences of pellet-clad interaction (1.0)

Ref: Same as above, p. 62b-5.

6.6 a) Control Rod Drive (CRD) Hydraulic System water. (0.5)
May also be called "mini-purge" (acceptable answer)

Ref: DAEC System Description, Chapter A-2, p. 4

any 2 at 0.5 each = 1.0

b) Operating pump must be < 50% flow, or speed locus must conform to chart in OI-64, (0.5) and ΔT between idle loop and vessel coolant temperature must be < 50°F. (0.5) (1.0)
Also, ΔT of < 145°F top of vessel to bottom drain (0.5)
ΔT of < 50°F Loop to Loop also accepta

Ref: DAEC OI-64, Reactor Recirulation System, p. 5,6

c) True. (0.5) Because of reverse flow in the idle loop. (0.5) (1.0)

Ref: Same as (a) above, p. 29

6.7 Vital Inst. air header isolation (0.33) 3 in. (0.33)

Service air header isolation (0.33) 82 psig (0.33)

Isolation of two (non-critical) instrument air headers (0.34) 80 psig (0.34) (2.0)

Ref: DAEC System Description, Chapter F-8, p. 5

b) True (0.5)

Ref: Same as (a) above, p. 2

6.8 1. Engine overspeed (0.5)

2. Generator lockout (0.5)

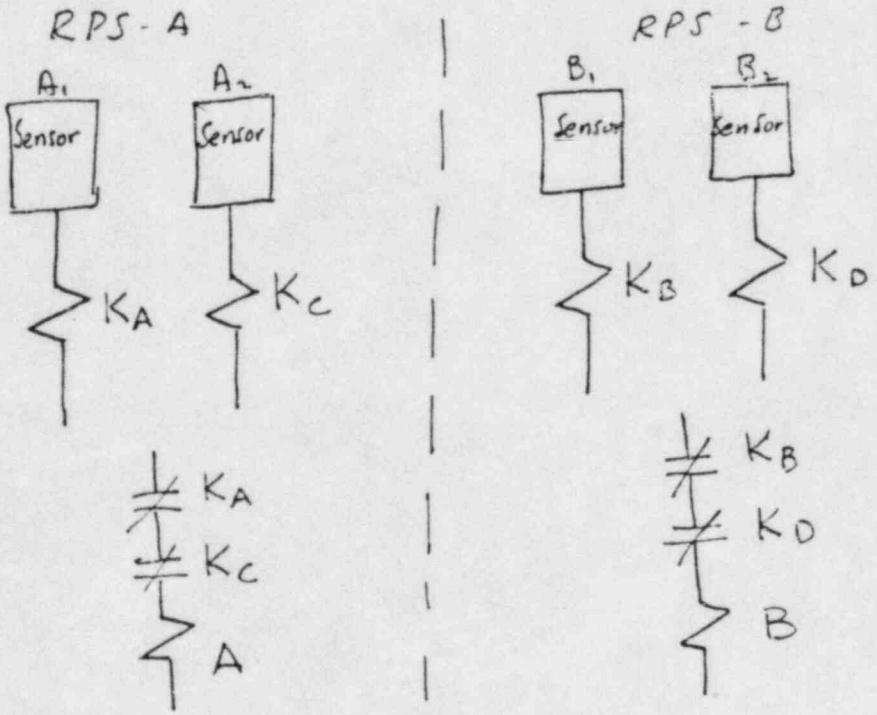
3. Manual Remote (0.5) (1.5)

Ref: DAEC System Description, Chapter G-2, p. 23

6.9 a) There are two sensors for each variable monitored by one RPS channel. There are two channels or Trip Systems, A & B.

If either of the two sensors in a trip system trips, it causes the affected trip system to de-energize - causing a half-scram. This is the "one-out-of-two" part.

Both RPS trip systems must be de-energized to cause a full scram, thus the condition must occur "twice".



Full credit for either explanation or sketch (2.0)

b) This logic is used to provide a high degree of reliability, or spurious trips are avoided and real trips are effective (1.0)

Ref: DAEC System Description, Chapter I & C - 7, p. 9.

6.10 a) True (0.5)

Ref: DAEC System Description, Chapter C-3, p. 1.

b) 1. High drywell pressure (0.25); 2 psig (0.25) (0.5)

2. Reactor low low level (0.25); level 2, 119.5" (0.25) (0.5)

Ref: Same as (a) above, p. 12, and Tech Specs, table 3.2-13, p. 3.2-8, 9.

c) Closed (0.5). Because if left open it would drain water from the CST into the suppression pool (0.5). (1.0)

Ref: Same as (a) above, p. 26.

d) 3000 gpm (0.5)

Ref: Same as (a) above, p. 8.

6.11 a. (1.0)

Ref: DAEC System Description, Chapter I & C - 1 and I & C - 2.

6.12 a) Above 30% power. (0.5)

Ref: DAEC System Description, Chapter I & C - 5, p. 2

Ref: Same as (a) above, p. 11 and Tech Specs, Table 3.2-C, p. 3.2-16.

(.66W + 54) is a backup rod block in case (.66W + 39) fails - is also a scram.

b) (0.66W + 39%) or (0.66W + 39) $\left(\frac{FRP}{MFLPD}\right)$ (acceptable answer) (0.5)

c) Rod selected (0.25). The LPRM outputs from LPRM strings adjacent to the selected rod (0.25), a reference APRM signal (0.25), and a flow-biased reference signal (0.25). (1.0)

Ref: Same as (a) above, p. 2.

d) ~~True.~~ False (Rod Block Monitor downscale is also a Tech Spec LCO) (0.5)

Ref: Same as (a) above, p. 11, and Tech Specs p. 3.2-16

- End of Category 6 -

ANSWERS TO DUANE ARNOLD SRO EXAM 3/27/84

7.0 Procedures - Normal, Abnormal, Emergency and Radiological Control (25.0)

7.1 a) They are painted yellow on one side. (0.25)

b) Three (0.25)

c) The second operator is stationed at IC-05 (~~0.5~~ 0.25) to observe nuclear instrumentation, (~~0.5~~) communicate w/refuel bridge (~~0.5~~ 0.25) and update fuel board area plan. (~~0.5~~ 0.25) (1.0)

d) False (0.5)

Ref: DAEC FRCHP #5 p. 4, 8, 9, 9.

7.2 a) 1. Verify automatic actions, manually initiate any automatic actions which failed to function.

2. Evaluate coincident alarms

3. Maintain Water Level with the feedwater and/or ECCS Systems.

4. Control Reactor pressure with the relief valves in accordance with Operating Instructions 62/80/83 Section C.5.1.

5. Initiate follow-up procedures for scram and plant shutdown.

6. Return to condenser operation as a heat sink when conditions permit.

7. Proceed with plant cooldown.

8. Initiate suppression pool water cooling.

Grading 0.33 to 0.34 points for each correct action, in any order. (?.0)

b) The CRD water via the CRD return line/spectacle flange. (0.5)

7.3 a) 60 - 100 seconds. (0.5)

b) 30 seconds or less. (0.5)

question 7.3c deleted.

~~c) Because it will limit pump speed to 100%.~~ ~~(1.0)~~

Ref: DAEC IPOI Vol. C 1.0, Section I, Part II C Plant Startup

question 7.4 7.4a deleted

~~a) False.~~ ~~(0.5)~~

b) It is mandatory that RCIC System operation be initiated when:

1. The reactor is shut down or generating power at a rate in excess of holding the reactor condition in hot standby, ~~(0.33)~~ 0.5 and

2. Feedwater is not available to the reactor vessel, ~~(0.33)~~ 0.5 and

3. The reactor vessel water level is low-low. This condition initiates the system automatically ~~(0.34)~~ 0.5 (1.5)

Ref: DAEC Operating Instructions No. 50, p. 1.

7.5 1. Turbine trip (0.25) at <19 in. Hg (0.25). (0.5)

2. MSIV closure (0.25) at <10 in. Hg (0.25). (0.5)

3. Turbine bypass valves close (0.25) at 7 in. Hg (0.25). (0.5)

Ref: DAEC Abnormal Operating Instructions, p. 0-2.

7.6 a) 150 mrem/day (1.0)

Ref: DAEC RPP 2.1, p. 1

b) They are the same (1.0)

Ref: DAEC RPP 2.1, p. 1

c) Yes $\geq$ 2.5 mrem/hr is a controlled radiation area requiring a RWP (0.5)

Ref: DAEC RPP 6.1 p. 3, and RPP 5.1, p. 1

7.7 a) Because they do not require AC electrical power. (1.0)

b) SRV's, or any combination of HPCI/RCIC/ADS that is necessary. (0.5)

Ref: Emergency operating instructions, Sect 5. Station Blackout.

7.8 a) 1. Reduction in station electrical output (~ 50MW(e))

2. Increased valve outlet temperature (recorders TR-4400 A,B,C, and D on panel 1C21)

3. Reduction in indicated steam flow

4. Oscillations in feedwater flow (minor)

5. Oscillations in vessel water level (minor)

6. Increasing torus temperature

7. White light de-energized on 1C21 (Tail pipe pressure switch 2/3 logic for each valve)

8. Noise in torus

Grading: 0.25 points for any 4 of the above or other reasonable answers includes: Computer printout Fluctuating Torus Level (1.0)

b) 110°F (0.5)

Ref: Plant Emergency Instructions IPOI Vol C-2.0, Section B, B.9, p. II.B.14 & 15

7.9 a) To avoid condensate pump vibration. (1.0)

b) 30% power (20% also acceptable if prefaced with note that 20% is the tech spec requirement) (0.5)

c) 30% power (which the bypass valves and house loads can handle) (0.5)

d) Inserting all four SRM's at once may cause an IRM scram due to noise from SRM drives. (0.5)

e) If there were large feed flow fluctuations adding a large amount of low temperature water could insert positive reactivity -- moderator temperature coefficient effect (1.0)

Ref: IPOI Vol C-1.0, Section V, shutdown.

7.10 a) 1. Two or more adjacent control rods not inserted past position 06, or (0.5)

2. Twenty-two or more of the total number of control rods not inserted past position 06 (0.5)

b) To prevent MSIV closure in the event main steam line pressure falls to 850 psig with switch in run. (0.5)

c) The reactor feedwater control system (0.5) At 175", provided operator sets controls to 175" (0.5) (1.0)
Level of 186" to 196" also accepted (partial credit)

d) Start HPCI and RCIC turbines pumping water CST to CST. (1.0)

Ref: IPOI Vol C-1.0, Section III, Reactor Scram

7.11 a) 1. Control rod system unable to maintain Rx subcritical and Rx level cannot be maintained above 119.5 inches.

2. Control rod system unable to maintain Rx subcritical and torus water temperature cannot be maintained below 110°F.

3. Increasing SRM, IRM, LPRM, or APRM levels.

4. Reactor subcritical, but will reach criticality within two (2) hours.

5. Reactor critical at a power level sufficient to increase reactor coolant temperature and/or steam flow at a rate in excess of that attributable to reactor decay heat alone.

6. A hazard involving reactor safety exists to personnel, to the environment, or to the plant, and, in the judgement of the senior operator on duty, this hazard requires a reactor shutdown when sufficient negative reactivity is unavailable from the control rods.

(0.5) for each of four correct answers. (2.0)

b) The storage tank (0.25) and the piping up to the pump suction (0.25). (0.5)

Ref: Operating Instructions No. 53, and IPOI C.II.D.2 (Plant Emergency Instructions) Loss of Shutdown Margin

End of Category 7

8.0 Administrative Procedures, Conditions and Limitations (25.0)

8.1 a)

Operating Shift Supervisor (SRO)	2	0.5 points
Nuclear Station Operating Engineer (RO)	1	for each
(First Asst) Assistant Nuclear Station Operating Engineer (RO)	1	correct
Second Assistant Nuclear Station Operating Engineer (RO) (Second Assistant)	1	answer
Nuclear Station Auxiliaries Engineer (Aux operator)	1	Abbreviated titles acceptable
Shift Technical Advisor	1	(3.0)

b) A senior licensed reactor operator should be in control room at all time. A licensed reactor operator should be in the control room at all times. (1.0)

Question 8.1c deleted ~~c) The Shift Technical Advisor.~~ ~~(0.5)~~

Ref: Admin. Control Procedure No. 1414.1

8.2 Operators shall challenge any direction given by a Operations Shift Supervisor or Upper Level Supervisor if, in his/her judgement, the direction is imprudent due to existing conditions or his/her understanding of the same, or if, in the fulfillment of that direction, the potential exists for violating technical and/or Environmental specifications, or an approved plant procedure. Final authority shall reside with the Operations Shift Supervisor or Upper Level Supervisor. (2.0)

Ref: Admin. Control Procedure No. 1404.1

8.3 a) True (0.5)

b) True (0.5)

Ref: Admin. Control Procedure No. 1408.1

8.4 a) The Operations Shift Supervisor (0.5)

b) The Support Services Supervisor (0.5)

c) 1. Operations Shift Supervisor (0.5)

2. Plant Management Staff (0.5)

3) Operations Committee (0.5)

also acceptable Plant Supt., alternate members of Operations Committee, all supervisors, all superintendents (last 2 are plant management staff) per AC 1406.3 p2 (1.5)

Ref: Admin. Control Procedure No. 1406.3
Revision of Procedures and Instructions.

Category 8 continued next page

8.5 a) A hold card is attached to a switch, a device serving as a switch, or to a valve when it is required that the switch or valve be maintained in a specified position to safeguard human life. The hold card is not to be used when human life is not endangered. (0.5)

A Warning Tag shall be attached to a switch, a device serving as a switch or to a valve to safeguard equipment, service, or for other operational reasons. To be used when human life is not endangered if the component or device is operated. (0.5)

b) When there are multiple clearances e.g. more than one group working on a system or component (0.5) and it is impractical or unsafe to issue one clearance (0.5). (1.0)

c) The Operation Shift Supervisor maintains the Hold-Off Log Book. (0.5)

It is kept in the Control Room. (0.5)

Ref: Admin. Procedure 1404.5 Hold-off-Procedure.

8.6 a) (1) positive (0.5), (2) collapse of voids (or pressure increase, or turbine trip) (0.5), (3) control rods (0.5), (4) negative (0.5) (2.0)

b) Fast closure of the turbine control valves, ≥ 30% power. (1.0)
Closure of the turbine stop valves, ≥ 30% power. (1.0)

Ref: DAEC System Description, Chapter A-2 p. 16, 42
Table 1

8.7 1. Thermal power shall not exceed 25% of rated thermal power with vessel pressure less than 785 psig or core flow ~~greater~~ less than 10% of rated.

2. MCPR shall not be less than 1.07 with vessel pressure greater than 785 psig and core flow greater than 10% of rated.

3. Maximum system pressure in the vessel steam dome of ~~1325~~ 1335 psig.

4. Vessel water level must be not less than 12 inches above the top of the normal active fuel zone. (344.5 inches above vessel zero)

5. Each required scram must be initiated by its primary source signal.

6. Maximum pressure in vessel dome of 135 psig when RHR is in shutdown cooling mode

Grading, 1.0 point each for any four of the above. (4.0)

Ref: Tech Specs Sections 1.1 and 1.2

8.8 c $K_{eff} \leq 0.95$ when flooded with unborated water (0.5)

Ref: Tech Specs, Section 5.5, p. 5.5-1

8.9 a) 5 (0.5)

b) 2 (0.5)

Ref: Tech Specs, Section 6.2, page 6.2-2

8.10 a) 1. Review plant status and event classification (0.5)

2. Verify notifications are being made (0.5)

Ref: Emergency Plan Implementing Procedures 7.1 Emergency Coordinator Duties

b) The Operations Shift Supervisor (0.5)

Ref: EPIP 1.1, p. 1

8.11 a) The Operations Shift Supervisor (0.5)

b) In the control room (0.5)

Ref: Admin. Control Procedure 1410.6, Jumper and Lifted Lead Control, p. 3, 4.

End of Category 8

MASTER

3-27-84 Master Workup Copy

U. S. NUCLEAR REGULATORY COMMISSION

REACTOR OPERATOR LICENSE EXAMINATION

Facility: DUANE ARNOLD

Reactor Type: BWR-4

Date Administered: 3-27-84

Examiner: I. S. Levy

Candidate: _____

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheet. Points for each question are indicated in parenthesis after the question. The passing grade requires at least 70% in each category and a final grade of at least 80%. Examination papers will be picked up six (6) hours after the examination starts.

Category Value	% of Total	Candidate's Score	% of Cat. Value	Category
24.5 ~~25~~	25			1. Principles of Nuclear Power Plant Operation, Thermodynamics, Heat Transfer and Fluid Flow
25	25			2. Plant Design Including Safety and Emergency Systems
25	25			3. Instruments and Controls
25	25			4. Procedures: Normal, Abnormal, Emergency, and Radiological Control
100				TOTALS

Final Grade _____%

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

_____
Candidate's Signature

1.0 Principles of Nuclear Power Plant Operation, Thermodynamics, Heat Transfer, and Fluid Flow (25.0) 24.5

1.1 With regard to fluid flow through a pump: 0.75

a. Define cavitation. (1.25)

b. Briefly, what does Net Positive Suction Head (NPSH) measure? (Do not give an equation.) (0.75)

c. During normal operation, what interlocks ensure an adequate NPSH for the recirculation pumps? (0.75)

1.2 Assume Duane Arnold is operating at 100% power when a manual scram is initiated. Initially, do the items below increase, decrease, or stay the same? Give a short explanation to justify your answer. (Assume no operator actions taken.)

a. Core flow (0.75)

b. Flow through control rod drive pumps (0.75)

- Category 1 continued on next page -

1.3 To ensure fuel rod integrity at power, certain parameters are monitored (directly or indirectly). For each of the four "fuel integrity items" (a-d) listed below, pick the one "parameter" from the list (1-8) below which most closely corresponds to it. (A number for each letter is sufficient in your answer.)

Fuel Integrity Items

a. The maximum of this parameter is specified to limit plastic strain and deformation of cladding to less than 1%. (0.5)

b. Specified to maintain adequate margin to the onset of transition boiling. (0.5)

c. The parameter specifically limited to assure that a peak fuel cladding temperature of 2200°F will not be exceeded. (0.5)

d. Individual bundle power divided by core average bundle power. (0.5)

Parameters

1. LHGR
2. Radial Peaking Factor
3. Critical Quality
4. Axial Peaking Factor
5. DNB
6. Boiling Length
7. MCPR
8. APLHGR

1.4 With respect to reactor coolant quality:

a. Why are the technical specification limits on chloride more restrictive for startup than for power operation? (1.5)

b. What control room indicator(s) does the operator have that chloride concentration is within limits? (0.5)

- Category 1 continued on next page -

1.5 The following statements are concerned with subcritical multiplication. Choose the one underlined word that will make the sentence correct.

a. As K_{eff} approaches unity, a larger/smaller change in neutron level occurs for a given change in K_{eff}. (0.5)

b. As K_{eff} approaches unity, a shorter/longer period of time is required to reach the equilibrium neutron level for a given change in K_{eff}. (0.5)

1.6 Which one of the following conditions will result in an increase in control rod worth? Why does it? (1.5)

a. an decrease in void fraction

(b.) an increase in moderator temperature } either answer could be correct

(c.) an increase in control rod density

d. an increase in fuel temperature

1.7 With regard to the effects of equilibrium Xenon (the reactor has been operated at a constant power for many hours):

a. If reactor power is then doubled, will the new equilibrium Xenon concentration be exactly twice as great? Explain. (1.5)

b. If the reactor is shut down, initially by 1% $\Delta K/K$, will the initial effect of Xenon be to increase or decrease the shutdown margin? (0.5)

1.8 With regard to Delayed Neutrons:

a. Define Beta (0.75)

b. Explain how and why the value of Beta changes from beginning of core life to end of core life. (0.75)

c. Explain the effect on reactor control of the change in Beta with core life. (0.75)

- Category 1 continued on next page -

1.9 Concerning reactivity coefficients, fill in the blank with the one correct response: more negative, less negative, the same.

a. The void reactivity coefficient becomes _____ with an increase in fuel temperature (0.5)

b. The doppler reactivity coefficient becomes _____ over core life. Why is this? (1.25)

1.10 What affect (increase, decrease, remain the same) will a change from 85°F to 65°F in the main condenser circulating water inlet temperature have on the following plant parameters: (Assume a stable power level, and condenser pressure greater than designed optimum.) (2.0)

a. Condenser Vacuum

b. Main Generator Output

c. Condensate Pump NPSH

d. Turbine Efficiency

1.11 Given:
Rx pressure at time T = 690 psia
Rx pressure at time T + 1 hr = 230 psia

a. What is the Rx cool down rate for this hour? Show all calculations. (0.75)

b. Is this rate acceptable at your plant? (0.5)

1.12 Answer TRUE or FALSE for each of the following:

a. Heat transfer always takes place from high temperatures to low temperatures. (0.5)

b. Somewhere within a jetpump, water is actually flowing from an area of lower pressure to an area of higher pressure. (0.5)

c. As water flows around a bend in a pipe, the velocity of the water is uniform throughout the diameter of the pipe. (0.5)

d. The pressure in a static fluid (e.g., reference leg of level indicator) always decreases with increasing elevation of the measurement. (0.5)

- Catetory 1 continued on next page -

1.13 Give four (4) inputs or outputs for a reactor heat balance, stating whether it is an input or output and a brief description as to why it is. (3.0)

- End Category 1 -

2.0 Plant Design Including Safety and Emergency Systems (25.0)

2.1 a. List four (4) of five (5) auxiliary systems which must be in operation for proper starting and extended operation of the diesel generator. (2.0)

b. During a ECCS initiation, what three (3) diesel trips are still in effect? (1.5)

2.2 With regard to the Standby Gas Treatment System (SGTS):

a. List the four (4) conditions that will cause automatic initiation. (Set points also required). (2.0)

b. What are the three (3) normal operating modes for an SGTS train? (1.5)

2.3 What automatic action(s) occurs at each of the following pressures:

a. 1120 psig? (0.5)

b. 1110 psig? (0.5)

c. 1020 psig? (0.5)

d. 900 psig? (0.5)

2.4 With regard to vital loads supplied by the Service and Instrumental Air system, which one(s) can only be isolated by manual operated valves? (2.0)

a. HPCI
b. ~~SCRAM~~ CRD Scram
c. Offgas System
d. SGTS
e. Fire Protection System
f. RHR

2.5 a. List the sources of water available to the suction of the RCIC pump; specify when each is used. (1.5)

b. Explain the purpose for and the operation of the RCIC system barometric condenser. (2.0)

- Category 2 continued on next page -

2.6 Concerning the Standby Liquid Control system:

a. The SBLC pumps are heat traced? (TRUE or FALSE) (0.5)

b. What is the purpose behind the two (2) SBLC storage tank heaters? (1.0)

2.7 Answer the following questions concerning the Core Spray System (CSS):

a. What signals (include setpoints) will cause the CS pump to start? (1.5)

b. What is the minimum flow bypass valve setpoint (open/close)? (0.5)

c. What is [redacted] used as a source for CSS pump suction when performing core spray injection tests? Under what plant conditions would these tests be performed? (1.25)

2.8 With regard to the Reactor Building Closed Cooling Water System (RBCCW):

a. How is temperature regulated as heat load on the system increases? (1.0)

b. Where is temperature measured? (0.75)

2.9 Concerning the CRD Hydraulic System, give the appropriate values for the following:

a. Accumulator pressure that would meet scram times at 1000 psig reactor pressure and discharge volume at atmospheric pressure. (0.5)

b. Drive water pressure at 400 psig reactor pressure. (0.5)

c. Normal CRD withdrawal flow rate during 100% power operation. (0.5)

d. Flow through stabilizing valves during normal operation (ro rod motion). (0.5)

- Category 2 continued on next page -

2.10 State whether each of the following statements about the AC Electrical Systems is TRUE or FALSE:

a. The power supply for 1A1 and 1A2 during normal operation is the S/U transformer. (0.5)

b. Startup transformer supplies 1A3,4 only when main generator is feeding 161 KV grid. (0.5)

c. The reactor recirculation M-G set is powered from the 1A3 and 1A4 switchgear. (0.5)

d. When normal power returns following an automatic transfer of the uninterruptable AC control power to an alternative source, the transfer will occur automatically. (0.5)

- End Category 2 -

3.0 Instruments and Controls ~~(0.25)~~ (25.0)

3.1 With regard to the Rod Worth Minimizer System (RWM):

a. Under what two (2) conditions will the Select Error indicator light amber? (1.0)

b. Under what three (3) conditions will the Withdraw Error display window be blank? (1.5)

c. TRUE or FALSE: A rod block is applied upon the second insertion error. (0.5)

3.2 For the events listed, match the action, or actions, that will occur in the Recirculation System. Assume that the pumps are running in high speed. (An action may be used more than once) (2.5)

Events:
1. Suction or discharge block valves <90% open
2. Vessel hi presssure (ATWS)
3. Turbine stop valve closure ≤90% open when ≥30% Rx power
4. LPCI loop selection logic initiation
5. Generator lockout relay tripped

Actions:
a. Trip of drive motor (MG Set Drive Motor)
b. Trip of recirculation pump MOTOR

3.3 With regard to the Automatic Depressurization System (ADS):

a. List (including setpoints) the automatic activation sequence for ADS. (3.0)

b. How is high flow through a relief valve sensed and indicated? (1.0)

- Category 3 continued on next page -

3.4 In reference to the Source Range Monitors (SRM):

a. What two (2) types of radiation are separated by the pulse height discriminator (PHD)? Which one causes output from the PHD? (1.0)

b. Indicate (by yes or no) whether the following trip circuits in the SRM electrical circuitry will generate a signal for use in the ~~RSCS~~ rod block circuitry: (3.0)

1. Downscale
2. Retract Permit
3. Upscale High
4. Upscale High High (shorting links installed)
5. Inop.
6. Reactor period.

3.5 With regard to the Reactor Manual Control System (RMCS):

a. What action(s) is required to test the rod drift alarm circuity and what indicates the test is satisfactory? (1.5)

b. Under what conditions, and in what manner will the Refuel Mode Select Permissive be indicated? (1.5)

c. Can an overtravel alarm be received if the control rod is connected to its drive unit (yes or no)? (0.5)

3.6 Duane Arnold is at 100% power with the Feedwater Control System in 3-element level control when the output from one steam flow transmitter is lost. Assuming no operator action, what will be the system response regarding the following:

a. Initial indicated steam flow (%) (0.5)

b. The initial feed-flow to steam-flow relationships (0.5)

c. Final feed flow response (increased, decreased, no change) (0.5)

d. Final vessel level (higher, lower, no change) (0.5)

e. Final steam flow and feed flow (%) (0.5)

- Category 3 continued on next page -

3.7 Concerning vessel instrumentation, state whether the following are TRUE or FALSE:

a. The Fuel Zone Range GEMAC is calibrated cold. (0.5)

b. Level 2 (119.5") will initiate all of the following PCIS Group isolations: 2, 3, 4, and 5. (0.5)

c. The two reference leg design of the Yarway Level Indicator allows for uniform indication even under extreme pressure transients. (0.5)

d. Jet pumps 1, 5, 9, and 13 were individually flow calibrated prior to installation. (0.5)

e. If pressure were to rise to 1080 psig and open the SRV set at this pressure, the two LLS valves would open? (0.5)

3.8 With regard to the Power Range Monitoring System:

a. Which trip circuit is adjusted to ensure the maximum LHGR is not exceeded? (0.5)

b. Which trips are input to RPS? (1.0)

3.9 Which type of detector (scintillation, ion chamber, fission chamber or Geiger Mueller) is used in the following process radiation measurements?

a. Main steam line (0.5)
b. Off-gas post-treatment (0.5)
c. Reactor building main exhaust (0.5)

- End Category 3 -

4.0 Procedures - Normal, Abnormal, Emergency, and Radiological Control (25.0)

4.1 With regard to Integrated Plant Operating Procedures for Shutdown:

a. What action should the operator take to maintain the cooldown when reactor pressure reaches 150 psig. (1.0)

b. With what plant parameter is the operator to be concerned when placing the RHR system in the Shutdown Cooling Mode? Briefly explain. (2.0)

4.2 With regard to the Operating Instructions for the Control Rod Drive System:

a. When the operator drains the accumulator, how does he know the accumulator is fully drained? (1.0)

b. What is the purpose of the on/off control valve (CV 1497)? (1.0)

4.3 Relative to the Emergency Operating Procedure for Reactor Vessel Low Water Level (II.B.9): (170")

a. If the Low Level trip point were reached, what four (4) automatic actions would you expect to see? (2.0)

b. If feedwater is inoperable, what system(s) is the operator to use to maintain level? (0.5)

4.4 While operating at rated power, a single relief valve opens and fails to reseat:

a. What is the only automatic action that will occur and what is its effect? (1.0)

b. In the Emergency Operating Procedure for Relief Valve Fails to Reseat (II.B.9), a torus water temperature is given that requires action. What is this temperature and what operator action(s) must be taken? (2.0)

- Category 4 continued on next page -

4.5 According to DAEC Radiation Protection Procedures:

a. What are the administrative whole body dose limits? (0.75)

b. Based upon 10CFR20, what is the maximum allowable whole body exposure for a 30 year old person? (0.5)

c. What is the definition of a radiation area? (1.0)

4.6 Assuming Duane Arnold was at 100% power when feedwater temperature started dropping:

a. What would be your major concern? (1.0)

b. What two (2) indication(s) would you have to confirm your concern? (1.0)

c. What would your first operator action likely be? (1.0)

4.7 With regard to the reactor coolant system pressure safety limit, what component(s)/system(s) are required to function to prevent vessel pressure from exceeding the safety limit? (1.5)

4.8 When the reactor is in cold shutdown, which of the following scrams need not be operable? (There may be more than one correct answer.) (2.0)

a. Main steam line high radiation scram.

b. IRM high flux scram

c. Scram discharge volume high level scram

d. Low reactor water level scram

e. APRM 15% flux scram

f. Drywell high pressure scram

g. Manual scram

- Category 4 continued on next page -

4.9 With regard to Administrative Control Procedures:

a. When is a Hold Card used? (1.0)

b. TRUE or FALSE: More than one person may hold clearances on one piece of equipment. (0.5)

c. What are the four (4) plant status entries the Operating Engineer (RO) is to make when he assumes the watch? (0.75)

d. TRUE or FALSE: When the reactor is in other than cold shutdown or refuel, two Operations Shift Supervisors are required on shift. (0.5)

4.10 On a Loss of +24 VDC Distribution Panel 1D50 or 1D60, list four (4) of the 5 automatic actions that would occur. (1.0)

4.11 With regard to coolant leaks into primary containment:

a. What two kinds of leakages into primary containment would constitute an LCO? (GIVE RATES, GPM) (1.0)

b. What two (2) ways would you check for these leaks? (1.0)

- End of Exam -

EQUATIONS/DATA SHEET

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

$1 Ci = 3.7 \times 10^{10} Bq$

$\alpha_D = -1 \times 10^{-5} \frac{\Delta K/°F}{K}$

$\alpha_v = -1 \times 10^{-3} \frac{\Delta K/\% \text{ voids}}{K}$

$\alpha_M = -4.5 \times 10^{-4} \frac{\Delta K/\%°F}{K}$

$\alpha_p = -4.5 \times 10^{-4} \frac{\Delta K/\% \text{ power}}{K}$

$I(t) = I_0 e^{-\lambda t}$

$T1/2 = \ln(2)/\lambda$

$Cp = (CP_{base})\ (Ks)\ (K_A)$

$Q = MCp\ \Delta t$

$\Delta\rho = f \frac{L}{D} \frac{\rho V^2}{2g_c}$

$f = 64/Re$

$\rho = \frac{k(eff) - 1}{K(eff)}$

$\frac{1}{M} = \frac{CR1}{CR2} = \frac{1-K(eff)2}{1-K(eff)1}$

$\dot{Q} = M\Delta h$

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

$M = 1/(1-k)$

$N(t) = No\ e^{-\lambda T}$

$\alpha_{r\alpha} = (L_f + L_s) \frac{(\phi rod)^2}{(\phi avg)}$

$n = \nu/(1 + d)$

$P = \Sigma\ \phi\ \nu/(3.7 \times 10^{10})$

$\tau = (\beta - \rho)/\lambda\rho$

$\dot{\tau} = \bar{\ell}/\rho + (\beta - \rho)/\lambda\rho$

$\tau = \ell/(\rho - \beta)$

$v = v_f + x v_{fg}$

$H = xh_g + (1-x)\ h_f$

$S = xS_g + (1-x)\ S_f$

1 in. = 2.54 cm

1 gal. = 3.785 liters

1 kg = 2.205 lb

$N = \rho A_0/A$

17.58 watts = 1 BTU/min
1psi = 6.895 Pa
1psi = 2.036 " H_g (@ 0C)
1psi = 27.68 " H^2O (@ 4C)

$\bar{\beta} = .0071$

$\bar{\ell} = 2 \times 10^{-5}$ sec

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press. Lb per Sq in p	Specific Volume Sat Liquid v_f	Evap v_{fg}	Sat Vapor v_g	Enthalpy Sat. Liquid h_f	Evap h_{fg}	Sat. Vapor h_g	Entropy Sat Liquid s_f	Evap s_{fg}	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	0.016025	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016026	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	1056.5	F088.6	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	0.1005	1.9242	2.0248	84.0
86.0	0.61518	0.016087	527.5	527.5	54.025	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	392.9	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	1.6834	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	0.016373	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	5.2123	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	1132.6	0.2409	1.5961	1.8371	166.0
168.0	5.7223	0.016440	64.79	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	6.5655	0.016474	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	992.6	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

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	228.75	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	0.3875	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	1.6549	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	7.2201	7.2375	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	1.1674	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	0.01765	4.8961	4.9138	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320.0
324.0	94.825	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	3.4256	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	2.6693	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	236.193	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	1.4809	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	793.8	1204.0	0.6063	0.8903	1.4966	432.0
436.0	366.03	0.01919	1.24887	1.25806	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	1.14873	1.16806	423.5	781.1	1204.6	0.6210	0.8643	1.4853	444.0
448.0	414.09	0.01940	1.10212	1.12152	428.0	776.7	1204.7	0.6259	0.8557	1.4815	448.0
452.0	431.14	0.01947	1.05768	1.07715	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—*Continued*

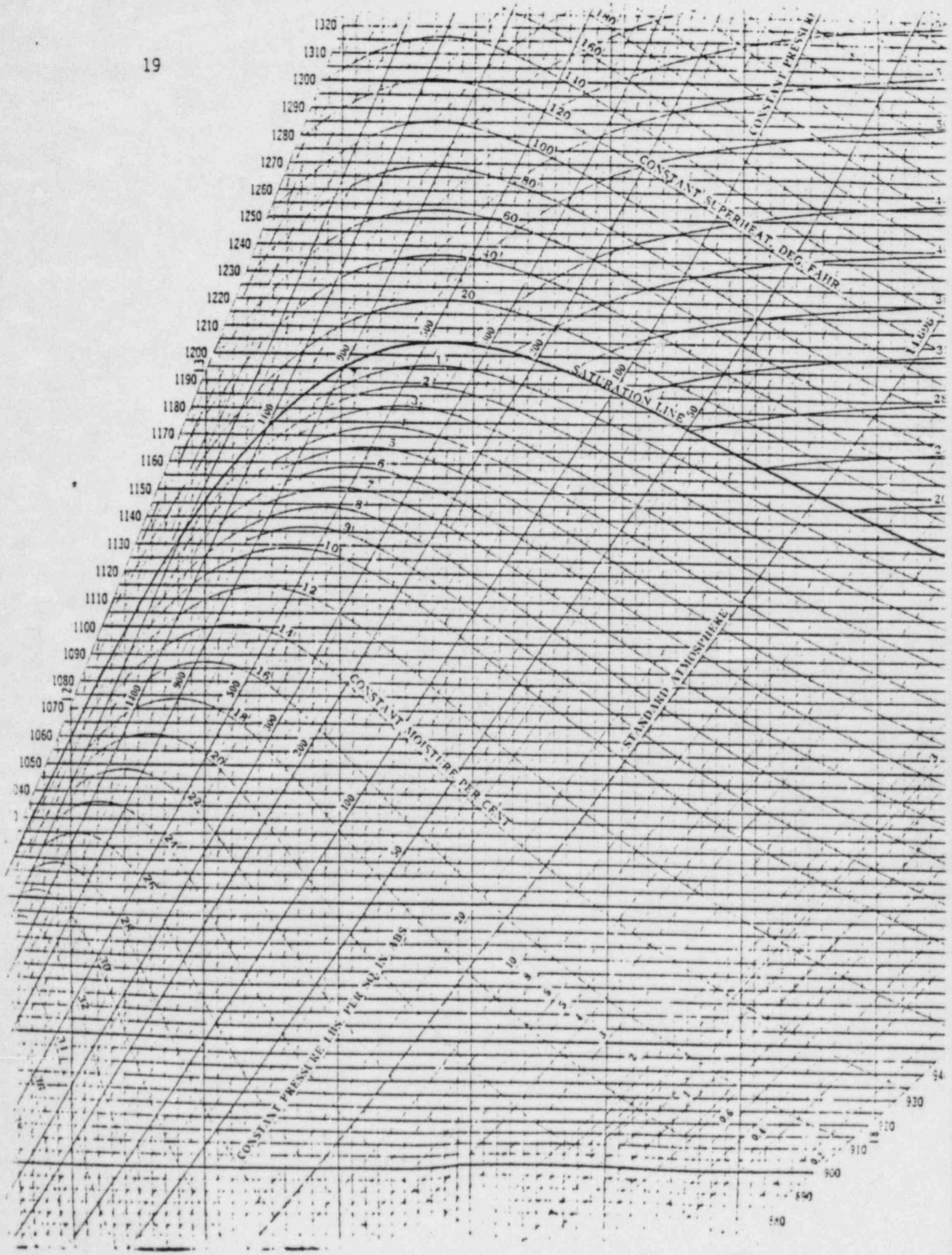
Temp °F t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Evap v_{fg}	Sat Vapor v_g	Enthalpy Sat Liquid h_f	Evap h_{fg}	Sat Vapor h_g	Entropy Sat Liquid s_f	Evap s_{fg}	Sat Vapor s_g	Temp °F t
460.0	466.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6405	0.5599	1.1704	460.0
464.0	485.56	0.01969	0.93588	0.95557	446.1	758.6	1204.7	0.6454	0.5213	1.1667	464.0
468.0	504.93	0.01976	0.89885	0.91862	450.7	754.0	1204.6	0.6502	0.5127	1.1629	468.0
472.0	524.67	0.01984	0.86345	0.88329	455.2	749.3	1204.5	0.6551	0.5042	1.1592	472.0
476.0	545.11	0.01992	0.82958	0.84950	459.9	744.5	1204.3	0.6599	0.4956	1.1555	476.0
480.0	566.15	0.02000	0.79716	0.81717	464.5	739.6	1204.1	0.6648	0.4871	1.1518	480.0
484.0	587.81	0.02009	0.76613	0.78622	469.1	734.7	1203.8	0.6696	0.4785	1.1481	484.0
488.0	610.10	0.02017	0.73641	0.75658	473.8	729.7	1203.5	0.6745	0.4700	1.1444	488.0
492.0	633.03	0.02026	0.70794	0.72820	478.5	724.6	1203.1	0.6793	0.4614	1.1407	492.0
496.0	656.61	0.02034	0.68065	0.70100	483.2	719.5	1202.7	0.6842	0.4528	1.1370	496.0
500.0	680.86	0.02043	0.65448	0.67492	487.9	714.3	1202.2	0.6890	0.4443	1.1333	500.0
504.0	705.78	0.02053	0.62938	0.64991	492.7	709.0	1201.7	0.6939	0.4357	1.1296	504.0
508.0	731.40	0.02062	0.60530	0.62592	497.5	703.7	1201.1	0.6987	0.4271	1.1258	508.0
512.0	757.72	0.02072	0.58218	0.60289	502.3	698.2	1200.5	0.7036	0.4185	1.1221	512.0
516.0	784.76	0.02081	0.55997	0.58079	507.1	692.7	1199.8	0.7085	0.4099	1.1183	516.0
520.0	812.53	0.02091	0.53864	0.55956	512.0	687.0	1199.0	0.7133	0.4013	1.1146	520.0
524.0	841.04	0.02102	0.51814	0.53916	516.9	681.3	1198.2	0.7182	0.3926	1.1108	524.0
528.0	870.31	0.02112	0.49843	0.51955	521.8	675.5	1197.3	0.7231	0.3839	1.1070	528.0
532.0	900.34	0.02123	0.47947	0.50070	526.8	669.6	1196.4	0.7280	0.3752	1.1032	532.0
536.0	931.17	0.02134	0.46123	0.48257	531.7	663.6	1195.4	0.7329	0.3665	1.0993	536.0
540.0	962.79	0.02146	0.44367	0.46513	536.8	657.5	1194.3	0.7378	0.3577	1.0954	540.0
544.0	995.22	0.02157	0.42677	0.44834	541.9	651.3	1193.2	0.7427	0.3489	1.0915	544.0
548.0	1028.49	0.02169	0.41048	0.43217	546.9	645.0	1191.9	0.7476	0.3400	1.0876	548.0
552.0	1062.59	0.02182	0.39479	0.41660	552.0	638.5	1190.6	0.7525	0.3311	1.0837	552.0
556.0	1097.55	0.02194	0.37966	0.40160	557.2	632.0	1189.2	0.7575	0.3222	1.0797	556.0
560.0	1133.39	0.02207	0.36507	0.38714	562.4	625.3	1187.7	0.7625	0.3132	1.0757	560.0
564.0	1170.10	0.02221	0.35099	0.37320	567.6	618.5	1186.1	0.7674	0.3041	1.0715	564.0
568.0	1207.72	0.02235	0.33741	0.35975	572.9	611.5	1184.5	0.7725	0.2950	1.0675	568.0
572.0	1246.26	0.02249	0.32429	0.34678	578.3	604.5	1182.7	0.7775	0.2859	1.0634	572.0
576.0	1285.74	0.02264	0.31162	0.33426	583.7	597.2	1180.9	0.7825	0.2766	1.0592	576.0
580.0	1326.17	0.02279	0.29937	0.32216	589.1	589.9	1179.0	0.7876	0.2673	1.0550	580.0
584.0	1367.7	0.02295	0.28753	0.31048	594.6	582.4	1176.9	0.7927	0.2580	1.0507	584.0
588.0	1410.0	0.02311	0.27608	0.29919	600.1	574.7	1174.8	0.7978	0.2485	1.0464	588.0
592.0	1453.3	0.02329	0.26499	0.28827	605.7	566.8	1172.6	0.8030	0.2390	1.0420	592.0
596.0	1497.8	0.02345	0.25425	0.27770	611.4	558.8	1170.2	0.8082	0.2293	1.0375	596.0
600.0	1543.2	0.02364	0.24384	0.26747	617.1	550.6	1167.7	0.8134	0.2196	1.0330	600.0
604.0	1589.7	0.02382	0.23374	0.25757	622.9	542.2	1165.1	0.8187	0.2097	1.0284	604.0
608.0	1637.3	0.02402	0.22394	0.24796	628.8	533.6	1162.4	0.8240	0.1997	1.0238	608.0
612.0	1686.1	0.02422	0.21442	0.23865	634.8	524.7	1159.5	0.8294	0.1896	1.0190	612.0
616.0	1735.9	0.02444	0.20516	0.22960	640.8	515.6	1156.4	0.8348	0.1794	1.0141	616.0
620.0	1786.9	0.02466	0.19615	0.22081	646.9	506.3	1153.2	0.8403	0.1689	1.0092	620.0
624.0	1839.0	0.02489	0.18737	0.21225	653.1	496.6	1149.8	0.8458	0.1583	1.0041	624.0
628.0	1892.4	0.02514	0.17880	0.20394	659.5	486.7	1146.1	0.8514	0.1474	1.0988	628.0
632.0	1947.0	0.02539	0.17044	0.19583	665.9	476.4	1142.2	0.8571	0.1364	1.0934	632.0
636.0	2002.8	0.02566	0.16226	0.18792	672.4	465.7	1138.1	0.8628	0.1251	1.0879	636.0
640.0	2059.9	0.02595	0.15427	0.18021	679.1	454.6	1133.7	0.8686	0.1134	1.0821	640.0
644.0	2118.3	0.02625	0.14644	0.17269	685.9	443.1	1129.0	0.8746	0.1015	1.0761	644.0
648.0	2178.1	0.02657	0.13876	0.16534	692.9	431.1	1123.9	0.8806	0.0893	1.0699	648.0
652.0	2239.2	0.02691	0.13124	0.15816	700.0	418.7	1118.7	0.8868	0.0767	1.0634	652.0
656.0	2301.7	0.02728	0.12387	0.15115	707.4	405.7	1113.1	0.8931	0.0637	1.0567	656.0
660.0	2365.7	0.02768	0.11663	0.14431	714.9	392.1	1107.0	0.8995	0.0502	1.0498	660.0
664.0	2431.1	0.02811	0.10947	0.13757	722.9	377.7	1100.6	0.9064	0.0361	1.0425	664.0
668.0	2498.1	0.02858	0.10229	0.13087	731.5	362.1	1093.5	0.9137	0.0210	1.0347	668.0
672.0	2566.6	0.02911	0.09514	0.12424	740.2	345.7	1085.9	0.9212	0.0054	1.0266	672.0
676.0	2636.8	0.02970	0.08799	0.11769	749.2	328.5	1077.6	0.9287	0.0892	1.0179	676.0
680.0	2708.6	0.03037	0.08080	0.11117	758.5	310.1	1068.5	0.9365	0.0720	1.0086	680.0
684.0	2782.1	0.03114	0.07349	0.10463	768.2	290.2	1058.4	0.9447	0.0537	0.9984	684.0
688.0	2857.4	0.03204	0.06595	0.09799	778.8	268.2	1047.0	0.9535	0.0337	0.9872	688.0
692.0	2934.5	0.03313	0.05797	0.09110	790.5	243.1	1033.6	0.9634	0.0110	0.9744	692.0
696.0	3013.4	0.03455	0.04916	0.08371	804.4	212.8	1017.2	0.9749	0.1841	0.1591	696.0
700.0	3094.3	0.03662	0.03857	0.07519	822.4	172.7	995.2	0.9901	0.1490	0.1390	700.0
702.0	3135.5	0.03824	0.03173	0.06997	835.0	144.7	979.7	1.0006	0.1236	0.1242	702.0
704.0	3177.2	0.04108	0.02192	0.06300	854.2	102.0	956.2	1.0169	0.0876	0.1046	704.0
705.0	3198.3	0.04427	0.01304	0.05730	871.0	61.4	934.4	1.0329	0.0527	0.0856	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 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	312.5	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	1.4547	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	0.8025	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	1.3274	1600.0
1650.0	609.05	0.02407	0.22143	0.24551	630.4	531.3	1161.6	0.8254	0.4971	1.3225	1650.0
1700.0	613.13	0.02428	0.21178	0.23607	636.5	522.2	1158.6	0.8309	0.4867	1.3176	1700.0
1750.0	617.12	0.02450	0.20263	0.22713	642.5	513.1	1155.6	0.8363	0.4765	1.3128	1750.0
1800.0	621.02	0.02472	0.19390	0.21861	648.5	503.8	1152.3	0.8417	0.4662	1.3079	1800.0
1850.0	624.83	0.02495	0.18558	0.21052	654.5	494.6	1149.0	0.8470	0.4561	1.3030	1850.0
1900.0	628.56	0.02517	0.17761	0.20278	660.4	485.2	1145.6	0.8522	0.4459	1.2981	1900.0
1950.0	632.22	0.02541	0.16999	0.19540	666.3	475.8	1142.0	0.8574	0.4358	1.2931	1950.0
2000.0	635.80	0.02565	0.16266	0.18831	672.1	466.2	1138.3	0.8625	0.4256	1.2881	2000.0
2100.0	642.76	0.02615	0.14885	0.17501	683.8	446.7	1130.5	0.8727	0.4053	1.2780	2100.0
2200.0	649.45	0.02669	0.13603	0.16272	695.5	426.7	1122.2	0.8828	0.3848	1.2676	2200.0
2300.0	655.89	0.02727	0.12406	0.15133	707.2	406.0	1113.2	0.8929	0.3640	1.2569	2300.0
2400.0	662.11	0.02790	0.11287	0.14076	719.0	384.8	1103.7	0.9031	0.3430	1.2460	2400.0
2500.0	668.11	0.02859	0.10209	0.13068	731.7	361.6	1093.3	0.9139	0.3206	1.2345	2500.0
2600.0	673.91	0.02938	0.09172	0.12110	744.5	337.6	1082.0	0.9247	0.2977	1.2225	2600.0
2700.0	679.53	0.03029	0.08165	0.11194	757.3	312.3	1069.7	0.9356	0.2741	1.2097	2700.0
2800.0	684.96	0.03134	0.07171	0.10305	770.7	285.1	1055.8	0.9468	0.2491	1.1958	2800.0
2900.0	690.22	0.03262	0.06158	0.09420	785.1	254.7	1039.8	0.9588	0.2215	1.1803	2900.0
3000.0	695.33	0.03428	0.05073	0.08500	801.8	218.4	1020.3	0.9728	0.1891	1.1619	3000.0
3100.0	700.28	0.03681	0.03771	0.07452	824.0	169.3	993.3	0.9914	0.1460	1.1373	3100.0
3200.0	705.08	0.04472	0.01191	0.05663	875.5	56.1	931.6	1.0351	0.0482	1.0832	3200.0
3208.2*	705.47	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	3208.2*

*Critical pressure


CONSTANT PRESSURE
CONSTANT SUPERHEAT, DEG. FAHR.
SATURATION LINE
STANDARD ATMOSPHERE
CONSTANT MOISTURE PER CENT
CONSTANT PRESSURE LBS PER SQ. IN. ABS

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MASTER

ANSWERS TO DUANE ARNOLD RO EXAM - 3/27/84

1.0 Principle of Nuclear Power Plant Operation, Thermodynamics, Heat Transfer and Fluid Flow (25.0)

1.1 a. Cavitation is a phenomenon of vapor pocket formation and sudden collapse ~~(0.5)~~ 3.75. The vapor forms when a fluid's static pressure falls below its saturation pressure. The collapse occurs when the vapor pockets are carried downstream to a region of higher pressure ~~(0.5).~~ (1.25)

Ref: DAEC Thermo/HT/Fluid Flow, pg. 4-4.

b. It measures how close the (suction side of the) system (subcooled) fluid is to saturation conditions (i.e., how many psi or ft of water the fluid is subcooled; that is, the permissible head drop before the vapor pressure of the fluid is reached). (0.75)

Ref: DAEC Thermo/HT/Fluid Flow, pg. 4-4.

c. Recirculation system flow control places an upper limit (<20%) on speed control set point signal until feedwater flow is greater than 20% of rated and recirculation pump discharge valve is fully open. (0.75)

Ref: DAEC System Descrip., Section A-2, pg 36.

1.2 (What happens @ 0.25 points each; why @ 0.50 each.)

a. Increases. Voids collapse on power decrease; therefore, less 2 phase flow and less flow resistance. (0.75)

Ref: DAEC Thermo/HT/Fluid Flow, pg. 3-7.

b. Increases. Charging head decreases (recharging of scram accumulators) (0.75)

Ref: DAEC, System Description, A-1, pg. 18.

1.3 a. 1 (0.5)

b. 7 (0.5)

c. 8 (0.5)

d. 2 (0.5)

Ref: DAEC Thermo/HT/Fluid Flow, pgs. 15-7; 13-1; 16-4; 15-6, respectively.

1.4 a. chloride, in combination with oxygen and stress, causes stress-corrosion cracking (0.5). When the reactor is not steaming at significant power, such as at startup, oxygen level will be higher (0.5). Therefore, to ensure the combination of chloride and oxygen will always be well below stress-corrosion failure limits, the chloride limit is made more restrictive (0.5). (1.5)

Ref: DAEC Tech. Specs., pg. 3.3-20, 21

b. coolant conductivity (0.5)

Ref: DAEC Tech Specs., pg. 3.3-21

1.5 a. larger (0.5)

b. longer (0.5)

Ref: DAEC Reactor Theory, Chap. 21, pg. 6

1.6 "b" (0.5). Will cause increase because thermal diffusion length increases (0.5); this increases leakage of thermal neutrons from fuel bundles and into control rod regions (0.5). (1.5)

Ref: DAEC Reactor Theory, Chap. 31, pg. 7.

1.7 a. No (0.5); the production rate is directly proportional to power level, but removal rate is proportional to Xenon concentration and it contains a power dependent term, thermal neutron flux. Since flux is directly proportional to power level the burnout term becomes more significant. This results in an equilibrium Xenon value which is higher than the original equilibrium value, but not twice as high (1.0). (1.5)

Ref: DAEC Reactor Theory, Chap. 33, pg. 6-7.

b. increase (0.5)

Ref: DAEC Reactor Theory, Chap. 33, pg. 8.

1.8 a. Beta is delayed neutron fraction or the fraction of the fast neutron population which comes from delayed neutron processors. (0.75)

Ref: DAEC Reactor Theory, Chap. 23a, pg. 5.

b. Beta will decrease from 0.007 at BOL to 0.0055 at EOL due to buildup of Pu-239 and depletion of U-235. (0.75)

Ref: DAEC Reactor Theory, Chap. 23b, pg. 4-6.

c. As beta decreases with core age, reactor period decreases; and, therefore, for the same reactivity addition rate, a shorter period and less easy control is obtained at EOL. (0.75)

Ref: DAEC Reactor Theory, Chap. 24, pg. 9.

1.9 a. more negative (0.5)

b. more negative (0.5). Pu240, which is a significant resonant absorber, builds up causing a decrease in the resonant escape probability (0.75) (1.25)

Ref: DAEC, Reactor Theory, pg. 26-15, 30-7, respectively.

1.10 a. Increase (0.5)

b. Increase (0.5)

c. Increase (0.5)

d. Increase (0.5)

Ref: General Thermodynamics

1.11 a. (Because the reactor operates at saturated conditions the temperature for time T and T + 1 hr can be found using the steam tables.)

1. Saturation temperature for 690 psia is approximately 502°F.
Saturation temperature for 230 psia is approximately 394°F. (0.375)

2. Cool down rate = (502°F - 394°F)/1 hr.
Cool down rate = 108°F/1 hr. (0.375)

b. No. The cool down rate limit DAEC is 100°F per hour. (0.5)

Ref: Steam Tables and DAEC Tech. Specs.

1.12 a. True (0.5)

b. True (0.5)

c. False (0.5)

d. True (0.5)

Ref: General fluid Dynamics Text

1.13 (any 4)

a. Feedwater flow - heat input (0.25) going into the vessel (or system) with positive enthalpy (0.5) (0.75)

b. Steam flow - heat output (0.25) due to steam removing energy from the core (0.25). (0.75)

c. Recirc pump - heat input (0.25) due to energy added to the fluid in the core (or system) by the pumps (0.5) (0.75)

d. CRD flow - heat input (0.25) due to fluid flowing into the core (or system) (0.5) with a positive enthalpy. (0.75)

e. Rx core thermal energy - heat input (0.25) due to being primary source of heat input (0.5). (0.75)

Ref: DAEC Student Handout, "Thermodynamics", Chapter 18 "Reactor Heat Balance".

See Ref: if other inputs/outputs are named.

- End Category 1 -

2.5 (source, 0.25; use, 0.25 each)

a. 1. CST (normal) (0.5)

2. Suppression pool (backup) auto transfer on low CST level. (0.5)

3. RHR Heat exchangers (Hot Standby Mode Only). (0.5)

b. Purpose: Maintains vacuum on seals to prevent steam leakage to RCIC room (0.5)

Condenses steam from seals, turbine governor valve and trip-throttle valve steam leakage (0.5)

Operation: Steam is condensed by water spray provided by the lube oil cooler water returning to the condenser line. Condensate is removed from the barometric condenser whenever the condenser water level gets high to RCIC pump suction or corner room equipment drain sump. Non-condensibles are exhausted to the ~~SJBS~~. SGTS. (1.0)

Ref: DAEC, System Description, B-2, pg. 21-22 and pg. 5, respectively.

2.6 a. FALSE (0.5)

b. One maintains constant temp. during standby (0.5); the other for tank filling operations (0.5) (1.0)

Ref: DAEC, System Description, C-4, pg. 4 and pg. 3, respectively.

2.7 a. low Rx vessel level (0.5), ~~@~~46.5" (0.25); high drywell pressure (0.5), ~~@~~2 psig (0.25). (1.5)

b. 300 gpm (0.5)

c. CST (0.5); when the plant is shutdown and depressurized (0.75) (1.25)

Ref: DAEC, System Description, C-2, pg. 8, 10 and 5, respectively.

2.8 a. By manual positioned throttle valves on outlet side of each Hx (1.0)

b. Shell side outlet of the RBCCW Hx (0.75) (0.75)

Ref: DAEC, System Description, F-5, pg. 6 and 4, respectively.

2.0 Plant Design Including Safety and Emergency Systems (25.0)

2.1 a. (any 4, 0.5 each) (2.0)
1. Fuel Oil System
2. Air Starting System
3. Circulating Water System
4. Lube Oil System
5. Intake, Scavenging and Exhaust

b. 1. Overspeed (0.5)
2. Gen. lockout (0.5)
3. Manual remote (0.5)

Ref: DAEC, System Description, G-2, pg. 4, 8 and 23, respectively.

2.2 a. (4 conditions at 0.25 each; 4 set points at 0.25 each) (2.0)

(1) Lo Reactor Water Level - ~~+12"~~ new number needed = 170"
(2) Hi dry well pressures - ~~2~~ psig.
(3) Hi Radiation - Reactor building vent. - ~~9 MR/hr~~ 11 mR/hr
(4) Hi Radiation Refuel floor vent. - ~~11 MR/hr~~ 9 mR/hr

b. (3 modes at 0.5 each) (1.5)

(1) Reset mode
(2) Operating mode
(3) Standby mode

Ref: DAEC, System Description, E-12, pg. 7-8.

2.3 a. Recirculation pump ATWS trip (0.5)

b. Two (2) relief values open (0.5)

c. Low LLS valve open signal (0.5)

d. LPCI loop select, low LLS valve close signal (0.5)

Ref: DAEC, System Description, A-5, pg. 7

2.4 b, c, e (0.67 each) (2.0)

Ref: DAEC, System Description, F-8, pg. 9.

2.9 a. 0 psig (i.e., not needed) (0.5)

b. Rx + 260 =660 psig (+240-260) OK (0.5)

c. ~~60 gpm~~ 2gpm (0.5)

d. 6 gpm (0.5)

Ref: DAEC, System Description, A-1, pg. 18, 15, 29, 15, respectively.

2.10 a. False (0.5)

b. ~~True~~ False Accepted w c c (0.5)

c. False (0.5)

d. False (0.5)

Ref: DAEC, System Description, G-1, pg. 2, 3; and G-4, pg. 1, respectively

- End Category 2 -

3.0 Instruments and Controls (0.25)

3.1 a. Whenever a selected control rod is not in the currently latched group (0.5) or is not an error rod responsible for an existing rod block (0.5) 1.0 (~~0.5~~)

b. When no withdraw error (0.5), RWM manually bypassed (0.5) and lower level above the LPAP (0.5) (1.5)

c. False (0.5)

Ref: DAEC, System Description, I&C-10, pg. 3,5;
Oper. Inst. 78-3,, pg. 10

3.2 (0.5) each (2.5)
1. A
2. A
3. B
4. A
5. A

Ref: DAEC, System Description, A-2, Table 1.

3.3 (0.~~25~~ 0.5 each for event; ~~0.25~~ 0.5 for setpoint)

a. 1. Hi drywell pressure - 2 psig (~~0.5~~)(0.6)
2. Lo Rx level - 46.5" (~~0.5~~)(0.6)
3. Confirmatory Lo Rx level - 170" (~~0.5~~)(0.6)
4. Either RHR pump discharge pressure - 125 psig or CS pump discharge pressure - 145 psig (~~0.5~~)(0.6)
5. Time delay - 120 secs (~~0.5~~)(0.6)

} 10.0 / 7.2

b. Pressure switches in relief valve tailpipe sense discharge pressure to determine if flow is present (0.5). If pressure switches sense high flow, a white lite on back panel 1C21 goes out to indicate alarm condition (0.50) (1.0)

Ref: DAEC, System Description, A-7, pg. 7, 8.

3.4 a. Neutron and gamma radiation (0.5); neutrons cause output (0.5) (1.0)

b. (0.5) each (3.0)
1. Yes
2. Yes
3. Yes
4. No
5. Yes
6. No

Ref: DAEC, System Description, I&C-1, pg. 9 and 11 thru 12, respectively.

3.5 a. Rod Drift Alarm switch is held in test position and a rod is moved from an even notched position (0.75); Red Rod Drift light goes on (0.75) and annunciator alarm. (1.5)

b. Mode switch in refuel (and) all rods in (and) no rod selected (0.75); white lite (Refuel Mode Select Permissive) (0.75) (1.5)

c. No. (0.5)

Ref: DAEC, System Description, I&C-8, pg. 8 and 10, 10, 8, respectively.

3.6 a. 75% (0.5)

b. Feed flow 100%; steam flow 75% (0.5)

c. Decreased (0.5)

d Lower (0.5)

e. Both 100% (0.5)

Ref: DAEC, System Description, D-16, pg. 1-2;
NRC I&E BWR Systems Manual, 3.1

3.7 (0.5) each (2.5)

a. True

b. False

c. False

d. True

e. True

Ref: DAEC, System Description, A-5, pg. 14-15, 6, 32, 20, and 7, respectively.

3.8 a. LPRM upscale (0.5)

b. APRM thermal power (0.33), inop. (0.33), downscale (0.33) (1.0)

Ref: DAEC, System Description, I&C-3, 4, pg. 1, 15, 19, respectively.

3.9 a. Ion chamber (0.5)

b. Scintillation (0.5)

c. Scintillation (0.5)

Ref: DAEC, System Description, I&C-12, pg. 7, 12, 29 respectively.

- End Category 3 -

4.0 Procedures - Normal, Abnormal, Emergency and Radiological Control (25.0)

4.1 a. Open the turbine bypass valves by using the bypass opening jack (1.0)

Ref: DAEC IPOI, Shutdown, pg. 6, ¶ 2.6.

b. Pressure (0.5); RHR shutdown cooling should not be placed in service at Rx pressure >135 psig (0.5); RHR shutdown cooling piping is designed for 135 psig maximum (1.0) (2.0)

Ref: DAEC IPOI, Shutdown, pg. 3, ¶ 9 and pg. 6, ¶ 27.

4.2 a. When the gas pressure as shown on pressure indicator PI 1F47 remains constant (1.0)

b. To prevent drainage of the condensate line in the event both condensate pumps trip or are shut down. (1.0)

Ref: DAEC, OI-55/56, pg. 6 and 1, respectively.

4.3 a. All of the following at 0.5 each (2.0)
1) Reactor scram
2) Group 2, 3, 4, and 5 valves close
3) SBGTS is initiated
4) Reactor building vent system shutdown and isolation

b. RCIC (0.5)

Ref: DAEC EOP, II.B.9, pg. 9 and 10, respectively.

4.4 a. The EHC system will reduce turbine load (0.5) to maintain steam pressure constant (0.5) (1.0)

b.
- Torus water temperature of 110°F (0.5)
- Scram the reactor (0.5), decrease reactor pressure to less than 145 psig (0.5) by using four relief valves (0.3). Close the relief valves before reaching 100 psig (0.2) (1.5)

Ref: DAEC EOP, II.B.9, pg. 14.

4.5 a. 150 mrem/day, 5000mrem/year, 3000 mrem/week, 1000mR/quarter (0.75)

b. 5(N-18) = 5(30-18) - 5 x 12 - 60 rem (0.5)

c. Any area accessible to personnel in which there exists or is likely to exist radiation such that a major portion or portions of the body could receive an exposure rate in excess of 2.5 mrem/hr (1.0)

Ref: DAEC Radiation Protection Manual, 2.1 pg. 1, 2.1, pg. 2 and 6.1 pg. 1, respectively.

4.6 a. Increasing reactor power which would lead to a (flow-biased) scram (1.0)

b. Indications:
- Decreased Final Feedwater Temperature (Panel 1C06, TR 1587) (0.5)
- Increasing APRM levels on Panel 1C05 (Manual Control only) (0.5)

c. Reduce reactor power quickly by reducing recirculation flow and inserting control rods (1.0)

Ref: DAEC, Plant Abnormal Op. Instructions, Q.5, pg. q-14, 15, 14, respectively.

4.7 ~~a. 1335 psig measured by the vessel steam space pressure indicator assures not exceeding 1375 psig at the lowest elevation of the reactor coolant system (0.75); ASME code only permits pressure transient up to 10% over the design pressure (i.e., 1250 x 110% = 1375 psig) (0.75).~~ ~~(1.5)~~

~~Ref: DAEC Tech. Spec., pg. 1.2-3~~

~~b.~~ (0.5 each): Relief valves, safety valves and RPS (1.5)

Ref: DAEC Tech. Spec., pg. 1.2-1 and 2.

a, d, f (0.67 each

4.8 ~~b, c, e, g, (0.5 each)~~ (2.0)

Ref: DAEC Tech. Spec. pg. 3.1-6

4.9 a. When it is required that a switch or valve be maintained in a specified position to safeguard human life (1.0)

Ref: DAEC, Admin. Control Proc., 1404.5, pg. 1

b. True (0.5)

Ref: DAEC, Admin. Control. Proc., 1404.5, pg. 5

c. (0.19 each) (0.75)
1) Plant mode
2) Power level (MW_T and MW_E)
3) Electrical 4160 VK lineup
4) Major components OOS including LCOs

Ref: DAEC, Admin. Control. Proc., 1404.5, pg. 4

d. True (0.5)

Ref: DAEC, Admin. Control. Proc., 1404.1, pg. 2

4.10 a. (any 4, 0.25 each) (1.0)
1) Rod withdrawal block
2) RPS A(B) half-scram
3) SGTS A(B) starts
4) Reactor building inboard (outboard) vent system isolates
5) Group III Isolation

Ref: DAEC, PAOI, pg. C-40

4.11 a. Unidentified (0.5); total (0.5) (1.0)

b. Check the sump (0.5) and air sampling system (0.5) (1.0)

- End of Exam -