U.S. NUCLEAR REGULATORY COMMISSION

REGION III

Report No. 50-254/OL-87-02

Docket Nos. 50-254; 50-265 Licenses No. DPR-29; DPR-30

Licensee: Commonwealth Edison Company
Post Office Box 767
Chicago, IL 60690

Facility Name: Quad Cities Nuclear Power Station

Examination Administered At: Quad Cities Nuclear Power Station

Examination Conducted: December 7-11, 1987

Examiners: G.M. Nejfelt — Date 1/25/88

D.E. Hills — Date 1/25/88

J.M. McGhee — Date 1/25/88

Approved By: T.M. Burdick, Chief
Operator Licensing Section — Date 1/25/88

Examination Summary

Examination Administered on December 7-11, 1987 (Report No. 50-254/OL-87-02): Written examinations were administered to six (6) Senior Reactor Operator (SRO) candidates and seven (7) SRO candidates were given oral examinations. Results: All candidates passed.

DETAILS

1. Examiners

G.M. Nejfelt, Chief Examiner
D.E. Hills
J.M. McGhee

2. Exit Meeting

At the conclusion of the site visit, the examiners met with facility representatives. The following personnel attended this exit meeting:

Facility Representatives

R.L. Bax, Station Manager
R. Robey, Services Superintendent
J. Neal, Training Supervisor
N.P. Digrindakis, Regulator Assurance Group Leader
C. Norton, Quality Assurance Engineer

NRC Representatives

G.M. Nejfelt, Operating Licensing Examiner
A.D. Morrongiello, Resident Inspector

The following items were discussed during the exit meeting:

a. No generic training weaknesses or strengths were observed during the operating examinations. (This comment was further substantiated upon review of examination results in NRC Regional Offices.)

b. Security and radiological accesses for examiners to the plant did not result in any undue delays.

c. Status of the suspension of NRC Requalification Examinations was discussed.

d. Active versus inactive license status in accordance with 10 CFR 55 as it applies to a Senior Reactor Operator Limited to Fuel Handling License was discussed.

3. Examination Review

Responses to licensee's comments, and other changes made to the December 7, 1987 examination are provided respectively in Attachment 1 and Attachment 2. Discrepancies identified during the oral portion of the examinations between training lesson plans and plant procedures are provided in Attachment 3.

ATTACHMENT 1

RESPONSE TO QUAD CITIES NUCLEAR POWER STATION COMMENTS
CONCERNING QUESTIONS AND ANSWERS OF THE NRC ADMINISTERED
SENIOR REACTOR OPERATOR LICENSE EXAMINATION
OF DECEMBER 7, 1987.

5.07

Facility Comment: The required answer does not include the pellet cracking and swelling that are the bases for LHGR [Linear Heat Generation Rate] limits. This would would be an appropriate response to the question and should also be accepted for full credit.

Reference - HTFF Chapter 9, Page 45, Paragraph 1.
- HTFF Chapter 9, Page 22, Paragraph 1.

NRC Resolution: Comment is accepted, as an alternate answer for the changes in pellet geometry. The answer key point is revised to read:

"a. Fuel pellets have a tendency to increase in density [0.5].

b. The change in density causes the pellet geometry to:

decrease in the pellet length
and a decrease in the pellet
diameter [0.75]

OR

crack [0.37] and swell [0.38]."

5.09.b

Facility Comment: Answer "b" only discusses axial flux shaping. Another acceptable answer should be "Radial flux shaping" or "flux shaping" alone which accounts for both axial and radial shaping.

Reference - Reactor Theory lesson plan Page 25.

NRC Resolution: Comment is partially accepted. The reference used does not substantiate that the gadolina rods are used for radial flux shaping. Furthermore, the reference stated that the "... deep rods locations set the desired radial power shape...."

However, since "flux shaping" infers both radial and axial directions, partial credit will be given for "flux shaping." The answer key point value is revised to read:

" b. Facilitate axial [0.25] flux shape or power shape control [0.25] (limits flux peaking problems and simultaneously simplifies control rod patterns)."

General Comment Concerning Section 6

Facility Comment: The use of general operating procedures and abnormal operating procedures for this section of the exam was felt to be an unusual practice. It required the examinee to memorize facts in these procedures when this information would be readily available during plant operation. This line of questioning also made the questions more integrated plant response questions instead of ones that dealt with the design, control or instrumentation of a plant system.

NRC Resolution: None of the facility comments pertaining to Section 6 questions substantiated that candidates were required to memorize any procedure. The references made in Section 6 questions to procedures were provided to aid candidates to associate questions concerning design intent, construction, operation, and interrelationships with normal nuclear power plant operation and reactor safety.

Reference - NUREG 1021, ES-402.A.2, Revision 4.

NOTE: The average grade for Section 6 was approximately 86 7/8.

6.01.a

Facility Comment: The required answer to this question could be considered incorrect. By adhering to the referenced procedure, the correct answer would be true but in reality an additional trip of the RCIC [Reactor Core Isolation Cooling] turbine is still active. This trip is the "local manual" trip. If this trip was considered by the examinee, the correct response would be false. Either answer should be acceptable.

Reference - RCIC Pages 13, 16.

Reference - Procedure Change Request to add this trip to the stated procedure.

NRC Resolution: Question 6.01, Part a, is deleted. The question total point value is reduced from 1.50 points to 1.00 point.

6.02.a
Facility Comment: This question should be deleted because it is misleading and confusing. The question infers that the fluid is flow of the shutdown cooling flow path when it really is referring to a small flow path to an auxiliary heat exchanger on the pump oil cooler. The question infers that increased RHR [Residual Heat Removal] service water is required as pressure is reduced in the shutdown cooling mode of RHR. In fact, RHR service water is always on during shutdown cooling and there is always flow to this heat exchanger. This flow can never be increased since it is always valved in. It is impossible to answer the question as stated.

NRC Resolution: Comment is not accepted. This question did not infer that the fluid flow is in the shutdown cooling flow path. Also, the "additional" cooling by RHR service water was the consequence of following the procedure for SHUTDOWN COOLING START-UP AND OPERATION, QOP 1000-5, Section F.2, Revision 13.

This question came directly from Quad Cities Lesson Plan, LIC-1000, RHR, Revision 2, page 8.

6.03.a
Facility Comment: Answer "a" should not require "mode switch in refuel" for full credit. This is not specified in Tech Specs [Technical Specifications].

Reference - Tech Spec Page 3.10/4.10-2.

NRC Resolution: Comment is accepted, because it is consistent with the exact wording used in Technical Specification (TS) 3.10.A.1.a. The answer key point value for Question 6.03, Part a, is reassigned as:

"With any control rod out [0.17] and fuel on any refueling hoist [0.17] and refueling platform near or over the vessel [0.16]."

NOTES:

(1). TS 3.10.A for both Unit 1 and Unit 2 requires that "The reactor mode switch shall be locked in the Refuel position during core alterations, and the refueling interlocks listed below [e.g., Refueling Platform Hoist Upward Travel Blocks] shall be operable...."

(2). QFP 100-1, MASTER REFUELING PROCEDURE, Section E.1.b(3), Revision 13, Page 4, specifically states that the mode switch is in "Refuel" for the Refueling Platform Hoist Upward Travel Blocks.

6.04.a

Facility Comment: Answer should allow for similar wording responses such as "oscillations" or "instabilities."

NRC Resolution: Comment is accepted. Also, other synonyms will be given full credit. Part "a" of the answer key is revised to read:

"a. Vibration or Oscillations or Instabilities [0.50]."

6.06

Facility Comment: The question is confusing in that it asks for a relation between Unit 2 being at power and the electrical lineup of a Unit 1 switchgear. Each is independent of each other. If Unit 2 is at power Unit One may or may not be, and it is Unit One's condition that determines the loading of transformer T-12. With Unit One at power T-12 carries buses 12 and 13. With Unit One shutdown, T-12 carries buses 11, 12, 13, and 14.

NRC Resolution: Comment is accepted. Because the question did not state, if Unit 1 was or was not at power, the answer key is revised to read:

"Any two of the following buses: 11, 12, 13, and/or 14. [0.50 point for each bus]."

Reference - QOP 6100-5, REMOVING RESERVE AUXILIARY TRANSFORMER 12(22) FROM SERVICE WITH UNIT 1(2) SHUTDOWN, Section C.3, Revision 3.

6.08

Facility Comment: Answer "a" is incorrect. The correct answer is HPCI [High Pressure Coolant Injection] WILL AUTO INJECT. There is no HPCI trip on low vacuum. The adverse affect would be gland steam and valve leak-off steam would cause the room to become airborne. Another adverse affect would be the room temperature rising to the isolation/trip setpoint. Either of these effects should be acceptable for full credit.

Reference - HPCI page 13.

Reference - HPCI page 31/32.

Answer "b" is correct, but for the wrong reason. The lack of high pressure oil will prevent the stop and control valves from opening. If the turbine could start, which it cannot, the emergency oil pump would provide adequate lubrication.

Reference - HPCI Page 8.

Reference - HPCI Page 9.

Reference - HPCI Pages 4 and 5, Section d and e.

Answer "c" - Another adverse affect that should be accepted for full credit would be reduced system flow to the reactor since a portion of the flow is diverted to the torus.

Answer "d" is incorrect. The correct answer is HPCI WILL NOT INJECT. The motor Gear Unit (MGU) will hold the turbine to 2000 RPM by running and staying on the Low Speed Stop (LSS). Insufficient discharge head will prevent injection to the reactor.

Reference - HPCI Page 12.

NRC Resolution: All comments are accepted. The answer key is revised to read:

"a. (1). WILL AUTO INJECT.
(2). Gland seal condenser will be unable to maintain a vacuum (because non-condensable gases would not be removed to maintain -10 inches of water).

b. (1). WILL NOT AUTO INJECT.
(2). The lack of high pressure oil will prevent the stop and control valves from opening.

c. (1). WILL NOT AUTO INJECT.
(2). It would be possible to drain the CCST into the torus
OR
It could be possible to reduce system flow to the reactor.

d. (1). WILL NOT AUTO INJECT.
(2). The desired system flow would be unable to be achieved (to accommodate varying reactor pressures. At operating pressure, the HPCI discharge head would be insufficient to inject, because the motor gear unit (MGU) would hold the turbine speed to 2,000 RPM by running and staying at the low speed stop (LSS)).

[0.50 point for each item]. (Correct alternate answers will be accepted)."

6.09
Facility Comment: The question implies a required action to be performed and misleads the examinee to produce actions for the question when by the referenced procedure NO ACTIONS ARE REQUIRED. This question should be deleted.

Reference - QOA 8650-1.

NRC Resolution: Comment is not accepted. The question asked for the "effect(s)" and not for any action to be performed.

6.11.a

Facility Comment: Answer "a" is incorrect. The correct answer is TRUE. The ACAD [Atmospheric Containment Atmosphere Dilution] System is placed into operation manually when predetermined plant conditions exist. It does not start automatically.

Reference - QOP 2500-1.

NRC Resolution: Comment is accepted. The question did not specifically refer to the ACAD Containment Atmosphere Monitoring (CAM) Subsystem that would be automatically initiated upon a Core Spray (CS) initiation signal, as stated in QOP 2400-1, Section F.2.a, Revision 7. The answer key is revised to read:

"a. True"

6.13

Facility Comment: Answer "a" infers that the APRM [Average Power Range Monitor] 15% scram is not valid when the mode switch is in "Shutdown." A better answer would be "... 15% when not in the RUN mode."

Answer "a" and "b" weight the response "high flux" heavily. Since APRMs are flux detectors, this can be assumed and should not be required in the answer for full credit.

NRC Resolution: Comments are accepted. Parts a and b for Question 6.13 is revised to read:

"a. APRM (fixed high flux) less than equal to 15% rated neutron flux [0.25] in REFUEL Mode or STARTUP HOT STANDBY Mode or °60 when not in RUN Mode. [0.25].'

b. APRM (variable high flux) less than equal to '0.58 W + 62' (FRP/MFLPD) [0.25] in RUN Mode [0.25] (maximum set point of 120% for core flow of greater than equal to 98E+6 lbm/hr)."

NOTE: The inference that the APRM 15% scram is not valid in the SHUTDOWN position of the mode selector switch is based on the exact wording used in QOP 700-4, Section E.2.a, Revision 5, which reads:

"APRM high flux _ 15% of rated neutron flux when in REFUEL or STARTUP HOT STANDBY Mode. (TS)."

6.14.a

Facility Comment: Answer "a" is incorrect. The correct answer is OPEN. The system lesson plan is incorrect in stating the valve is normally shut. The procedure for normal Core Spray Standby Operation has this valve open.

Reference - QOP 1400-1, Page 2.

NRC Resolution: Comment is accepted.

Part "a" of Question 6.14 is deleted, because of the conflict in position of the core spray minimum bypass flow valve (MO-1402-38A/B) between the System Lesson Plan, CORE SPRAY SYSTEM, LIC-1400, Revision 1, and procedure QOP 1400-1, Revision 4. The total point value for Question 6.14 is reduced from 1.50 points to 1.00 point.

6.15

Facility Comment: In answer "b", the time delay should not be required for full credit since it is not considered a part of the setpoint. At Quad Cities Station, the setpoint is considered simply 300% steam flow.

Reference - Tech Specs Page 3.2/4.2-8.

NRC Resolution: Comment is accepted. However, to be consistent with comment provided, QOP 1300-2, Section E.1, Revision 6, needs to be revised.

The answer key "b" is revised; and the question point values are redistributed to read:

"a. RCIC turbine area [0.15] high temperature [0.15]; and 200 +/- 5 degrees F [0.20].

b. RCIC Steam Line high flow [0.30]; and 300% of rated steam flow [0.20] (with a turbine delay of 3 seconds).

c. Reactor vessel low pressure [0.30]; and 50 +/- 2 psig [0.20]."

6.16

Facility Comment: The fact that the opposite gas treatment train is started requires the use of a cross connect line. This could be assumed and should not be required for full credit.

NRC Resolution: Comment is accepted. The answer is revised to read:

"Start the opposite train and draw air through the affected train [0.75] from the turbine building [0.50] (via the train cross connect)."

6.17

Facility Comment: At Quad Cities Station, the ECCS [Emergency Core Cooling System] fill system is also referred to as the "Jockey fill" or "keep fill" or "Maintenance fill" system. Any of these answers should also be considered correct.

NRC Resolution: Comment is accepted. The answer key is revised to read:

"... the ECCS Fill System (other acceptable names are: Jockey Fill, Keep Fill, or Maintenance Fill System)."

7.01

Facility Comment: This question should be deleted for the following reasons:

a. The stated panel and alarm are physically located in the HRSS building.
b. A Radiation Protection Technician (RCT) would respond to this alarm, not an operator.
c. Operators do not have access to this building since it is locked at all times.

NRC Resolution: Comment is accepted. The Question point value of 1.50 points was deleted.

7.03

Facility Comment: This question is both confusing and misleading because of the introductory statement describing a lighting strike. It is not clear if an actual toxic gas condition exists. Based on these considerations, any three immediate operator actions listed in the referenced procedure should be acceptable for full credit. Additionally, since step 6 of the referenced procedure, which is where the list answer originates, directs the operator to follow QOA-010-5 (Control Room Inaccessible). Any three immediate operator actions from this procedure [QOA 010-5] should be considered a correct response for full credit.

Reference - QOA 5750-13.

Reference - QOA 010-5.

NRC Resolution: Comment is partially accepted. The question clearly sought the actions to be taken, "... if occupation of the control room is no longer possible." Only those actions of QOA 010-5 that are specifically performed in the control room prior to its evacuation are added to the answer key. Question 7.03 Answer Key is revised to read:

"- Remove breathing air mask.
- Isolate air line manifold supply valve.
- Don an air pack.
- Evacuate control room (CR) to shutdown/cooldown the unit.
- Announce on the public address system that the CR is being evacuated.
- Manually scram the reactor, if possible.
- Leave Feedwater System in automatic on the low flow bypass valve, if possible.
- Notify the Chicago Load Dispatcher, if possible.

[Any 3 of 8 required with each worth 0.50 point]."

7.05

Facility Comment: Answer "a" is correct, but other similar intent responses should be accepted.

Answer "b-2" is correct but other similar intent wording, such as "adequate steam cooling" or "adequate core cooling" should be acceptable.

NRC Resolution: Comments are accepted. Similar wording is acceptable. No change to answer key is warranted.

7.07

Facility Comment: Another procedure could be used for the condition stated in the question. Any immediate actions required in "Reactivity Addition" procedure under the loss of feedwater heaters should be added to the list of acceptable responses.

Reference - QOA 400-1.

NRC Resolution: Comment is not accepted. The Question specially requested "... five (5) Immediate Operator Actions using QOA 3500-1, LOSS OF FEEDWATER HEATERS."

7.08

Facility Comment: This question asks for an answer for which there is no procedure or guideline and should be deleted from the exam. The question misleads the examinee to define an operable accumulator. Tech Specs, which is referenced in the question, states that if certain actions are taken, the accumulator need not be considered inoperable. This is very different than operable.

Reference - QOP 300-10.

NRC Resolution: Comment is not accepted. The answer key is taken directly from QOP 300-10, CRD SYSTEM ACCUMULATOR GAS DISCHARGING, Section E.2, Revision 4; and is based upon required Technical Specifications knowledge.

7.09

Facility Comment: The question implies that a reactor trip is required for varying conductivities in the stator cooling system. The answer key values of time are correct for the generator trip but not a reactor trip. It must be noted that the referenced procedure, QOA 5300-1, refers to a unit trip. In this context the unit is the main generator and not the reactor.

NRC Resolution: Comment is accepted. Full credit will be give if reference is either made to a unit or to a turbine trip with the appropriate time limitations.

7.10

Facility Comment: A description of the Iodine Spiking Phenomenon or stating that iodine will increase should be acceptable for full credit.

NRC Resolution: Comment is accepted. Also, other similar wording would be acceptable. No change to answer key is warranted.

7.11

Facility Comment: Answer "a" is incorrect. The correct answer is MORE THAN. Unit 1 MAPLHGR would change to 70% of its original value while Unit 2 will change 84%.

Answer "c" is incorrect. Regarding Rod Block Monitor (RBM) rod blocks, U-1 will be LESS THAN U-2 as stated in the answer. The question simply asks for "rod blocks" which could also mean APRM rod blocks. U-1 APRM rod blocks WILL BE THE SAME as U-2 APRM rod blocks. Both the SAME or LESS THAN responses should receive full credit.

Reference - QOA 202-4, Pages 1, 2, and 3.

NRC Resolution: The comment first part is accepted. The answer key is revised to read:

"a. MORE THAN. (Unit 1 factor is 0.70; and Unit 2 factor is 0.84)."

The comment second part is accepted, because it was not specified in the Question that only the APRM rod block set points were desired. The answer key is revised to read:

"c. SAME AS or LESS THAN. (Unit 1 and Unit 2 APRM set points are reduced by 3.5%; and Unit 1 RBM rod block set points are reduced by 3.5%, while the Unit 2 RBM rod block set points are reduced by 4.0%)."

7.12

Facility Comment: This question asks why condenser level is limited BELOW 35% level and references an operating procedure. The reference procedure infers but never states structural damage will occur at or above 35% as the answer key

states. Either the fact that circ [circulating water] pumps are running or structural damage may occur should be acceptable for full credit.

Reference - QOP 201-1, Page 3.

NRC Resolution: Comment is accepted. The answer key is revised to read:

"Structural damage may occur to the condenser (if level is exceeded and additional structural support is not installed) OR circulation water pumps are running. [1.00]"

NOTES:

(1). The Caution Statement of QOP 201-2, Section F.2.a, Revision 4, is quoted as:

> "Do not exceed 35% on the wide range monitor while circulating water pumps are running. Structural damage may occur to the condenser if this level is exceeded and additional structural support is not installed."

(2) It is unclear in the caution statement provided in NOTE (1) above, if the circulation pumps are needed to be running to cause structural damage above a main condenser level of 35%. Because of this ambiguity, credit is allowed for the alternate answer provided.

7.13
Facility Comment: The answer key is wrong in saying drive water does not cool.... Drive water DOES supply cooling header.

NRC Resolution: Comment is accepted. The answer key is revised to read:

"Electrical disarm is preferred because drive water cools [0.5] and it minimizes crud accumulation in the drive [0.5]."

7.15
Facility Comment: Answer "b" should allow for alternate, similar wording responses such as fouling or plugging.

NRC Resolution: Comment is accepted. Similar wording for response is acceptable. The answer key is revised to read:

"b. biofouling (other possible answers are 'fouling' and 'plugging')."

8.13

Facility Comment: In addition to the actions specified in the answer key, other similar actions are specified in QAP 300-27. These SCRE [Shift Control Room Engineer] actions should also be acceptable for credit.

Reference - QAP 300-27, Operating Department Procedure Revision Training.

NRC Resolution: Comment is accepted. Although the question specifically reference QAP 1100-5, TEMPORARY PROCEDURE AND TEMPORARY CHANGES TO PERMANENT PROCEDURES, it is not expected that a candidate memorizes a procedure. Therefore, the question modification is limited to those additional actions that would be taken by a SCRE involving the Operation Department. The answer key is revised to read:

"- The SCRE will consider initiating training of shift personnel.

- The SCRE will ensure that the Shift Engineer receives an authorized copy of the temporary procedure.

- If training is determined to be necessary, the SCRE will attach to a copy of the temporary procedure the appropriate list of names of personnel needing training.

- If training was necessary, the SCRE will ensure that the proper training is completed within one (1) week.

- If training was done, the SCRE will file list of names of personnel receiving training."

NOTE: Neither QAP 1100-5, Revision 17, nor QAP 300-27, Revision 1, references each other, although each procedure have separate administrative requirements for temporary procedures (e.g., QAP 300-27 requires the use of form QAP 300-T20; and QAP 1100-5 allows retention of a terminated temporary procedure, if the temporary procedure is stamped, "TERMINATED," while QAP 300-27 does not).

8.15

Facility Comment: This question should be deleted since it does not apply to operations at Quad Cities Station. It is a valid question for Maintenance or Contractor personnel. Fire watches applicable are generally the ones specified in Tech Specs.

NRC Resolution: Comment is not accepted. The licensee's knowledge of conducting normal business using the facility procedure, particularly, in the area of fire protection is expected.

8.17

Facility Comment: This question should be deleted. The question strongly implies that something must be checked prior to rod maintenance. At Quad Cities Station, and as stated in the reference procedures, shutdown margin [SDM] is verified simply by checking with a qualified Nuclear Engineer. The question leads the examinees to put down incorrect responses when something "physical" is asked for.

NRC Resolution: Comment is not accepted. A means to physically verify the SDM is provided in Unit 2 TS BASIS 3.3.A.1, Amendment No. 21; and it is correctly stated in the answer key. Secondly, the Question did not state that the SDM must be performed by procedure QOP 300-14, but rather how can the SDM be physically verified before using QOP 300-14.

8.22

Facility Comment: At Quad Cities Station, Gene Schabilion is the Station Industrial Hygiene Advisor. His name vice his title should be acceptable for full credit. It is also noted in the reference procedure that anyone, not only the SCRE, should contact the Hygienist if there is a question of safety. Regarding this concept, another appropriate response to the question may be "contact the man in charge of the work to get his men out of the space."

NRC Resolution: First part of comment, concerning the use of Station Industrial Hygiene Advisor's actually name, is acceptable for full credit. However, the second part of comment, concerning contacting "the man in charge of the work," is not acceptable, because the question specifically required the candidate to provide who the SCRE would contact to obtain a "definitive" answer for a worker health and safety concern.

The question answer key is revised to read:

"Station Industrial Hygiene Advisor or the actual name of the Station Industrial Hygiene Advisor provided by the facility. [0.50]"

ATTACHMENT 2

EXPANSION OR CLARIFICATION OF QUAD CITIES
NRC SENIOR REACTOR OPERATOR LICENSE EXAMINATION
OF DECEMBER 7, 1987.

Question No.	Answer Key Modification
5.02	Point values were redistributed. Answer key was revised to read: "a. LHGR - fuel pellet expansion [0.50]; and 1% plastic strain on cladding. [0.50] b. APLHGR - decay heat and stored heat following LOCA [0.50]; and clad temperature of 2200 degrees F. [0.50] c. CPR - loss of nucleate boiling (around cladding) [0.50]; and boiling transition. [0.50]"
6.09	Point values were redistributed; and an alternate answer for full credit was added. The answer key was revised to read: "Loss of high speed protective relaying or direct transfer trip capability for incoming power lines (0403 and 0404). (The Unit 2 generator trip scheme upon loss of these lines is necessary, because the Iowa-Illinois System cannot handle the output from both units). OR Loss to transmit/operate in Economic Generation Control (EGC). [1.00]"

ATTACHMENT 3

TRAINING DEPARTMENT MATERIAL DISCREPANCIES
NOTED DURING THE ADMINISTRATION
OF QUAD CITIES SRO ORAL OPERATOR LICENSING EXAMINATIONS
ON DECEMBER 8, 49, and 10, 1987

1. FIRE PROTECTION SYSTEM, LIC-4100, Revision 8: No plant procedures was located that electrically disconnected the diesel-driven fire pump discharge valve as stated in the lesson plan. Also, no reference was made in the lesson plan of the administrative controls that are used to prevent the inadvertent closure of this valve (e.g., the removal of the control handles in the control room; and the valve was chained and locked with a break away lock).

2. SERVICE WATER SYSTEM, LIC-3900, Revision 1; and CIRCULATION WATER SYSTEM, LIC-4400 Revision 2: The lesson plans stated that hypochlorite could be injected into the circulating water system either via a batch method or service water system. SERVICE WATER SYSTEM, QOP 3900-1, Revision 3, does to provide means for sodium hypochlorite injection as indicated in LIC-3900. Also, CIRCULATING WATER SYSTEM, QOP 44-2, Revision 7, Section F.1.h and F.2.c, require the operation of the circulating water hypochlorite system. However, QOP 4500-0, Revision 5, has deleted all operational hypochlorite procedures. No reference to the Chemistry Department procedures is stated in the QOPs.

3. STANDBY LIQUID CONTROL SYSTEM (SBLC), LIC-1100, Revision 1: Interlock associate with both SBLC pumps running has been removed.

4. "Site Specific Training Procedure," Revision 4, Page 6, stated that if a card reader red light occurs, the person should immediately contact security; and "Quad Cities Nuclear Power Station Training Department Booklet," 1985 Revision, Page 3, stated that the person should wait five (5) minutes before contacting security.

5. SERVICE WATER, LIC 3900, Revision 1, Page 12: Lesson Plan stated that the low fire protection pressure alarm is 65 psig. The actual alarm set point is 68 psig.

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

FACILITY:	QUAD_CITIES
REACTOR TYPE:	BWR-GE3
DATE ADMINSTERED:	87/12/07
EXAMINER:	NEJFELT, G.
CANDIDATE	

St Did Exam at 8:25 AM. Nt 5 extra minutes given to clarify several questions ([illegible], 5.07, 6.06, 7.09, & 8.14.b).

INSTRUCTIONS TO CANDIDATE:

Use separate paper for the answers. Write answers on one side only. Staple question sheet on top of the answer sheets. Points for each question are indicated in parentheses 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 CATEGORY VALUE		CATEGORY
25.50	~~24.91~~ 25.55			5.	THEORY OF NUCLEAR POWER PLANT OPERATION, FLUIDS, AND THERMODYNAMICS
~~26.10~~ 25.10	~~25.50~~ 25.15			6.	PLANT SYSTEMS DESIGN, CONTROL, AND INSTRUMENTATION
~~26.00~~ 24.50	~~25.40~~ 24.55			7.	PROCEDURES - NORMAL, ABNORMAL, EMERGENCY AND RADIOLOGICAL CONTROL
24.75	~~24.18~~ 24.75			8.	ADMINISTRATIVE PROCEDURES, CONDITIONS, AND LIMITATIONS
~~102.3~~ 99.85		Final Grade	%		Totals

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

Candidate's Signature

MASTER COPY

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

1. Cheating on the examination means an automatic denial of your application and could result in more severe penalties.

2. Restroom trips are to be limited and only one candidate at a time may leave. You must avoid all contacts with anyone outside the examination room to avoid even the appearance or possibility of cheating.

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

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

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

6. Use only the paper provided for answers.

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

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

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

10. Skip at least three lines between each answer.

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

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

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

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

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

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

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

18. When you complete your examination, you shall:

a. Assemble your examination as follows:

(1) Exam questions on top.

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

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

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

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

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

QUESTION 5.01 (1.00)

SELECT the one correct statement that describes the condition known as 'Condensate Depression:'

a. Can lead to condensate pump cavitation, if condensate depression is too great.

b. Decreases as hotwell level rises.

c. Reduces thermal cycle efficiency.

d. Increases as condensate temperature increases.

QUESTION 5.02 (3.00)

STATE the 'Cause of Failure;' AND the 'Limiting Condition' for each of the following core thermal limits:

a. LHGR

b. APLHGR

c. CPR

QUESTION 5.03 (1.00)

SELECT the one correct answer. For a reactor that is just critical, a given reactivity addition will:

a. cause a shorter period at BOL than at EOL.

b. cause a shorter period at EOL than at BOL.

c. cause a shorter period that is the same throughout core life.

d. have no effect on reactor period because the reactor is critical.

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

QUESTION 5.04 (1.00)

SELECT the one correct answer. As a subcritical reactor nears criticality, the length of time to reach equilibrium count rate after an insertion of equal positive reactivity:

a. IS THE SAME as the length of time required to reach equilibrium count rate after an equal insertion of negative reactivity.

b. INCREASES, primarily because of the increased population of delayed neutrons present in the core with no increase in prompt neutrons.

c. DECREASES, because the source neutrons are becoming less important in relation to the total neutron population.

d. INCREASES, because of a larger number of neutron life cycles required to reach equilibrium.

QUESTION 5.05 (1.00)

ANSWER each of the following items either TRUE or FALSE.

The percentage of power from decay heat from reactors that have respectively operated continuously at 100% power for 30 and 365 days is ~~ESSENTIALLY~~ THE SAME after a scram for the:

a. First hour

b. First week

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

QUESTION 5.06 (2.00)

SELECT the one correct choice in the parentheses for each of the following items:

a. The delayed neutron fraction, beta bar (INCREASES, DECREASES, or REMAINS CONSTANT) over core life, because...

b. the percentage of reactor power from...

(1). U-235 (INCREASES, DECREASES, or REMAINS CONSTANT)

(2). U-238 (INCREASES, DECREASES, or REMAINS CONSTANT)

(3). Pu-239 (INCREASES, DECREASES, or REMAINS CONSTANT)

QUESTION 5.07 (1.25)

DESCRIBE how fuel pellets deform under operating conditions. INCLUDE the change(s) that occur in the pellet density and geometry.

QUESTION 5.08 (1.50)

If a multiple feedwater heater or string loss occurs with the unit at 75% power, EXPLAIN what happens to reactor power. (INCLUDE the reactivity coefficient(s) involved; and EXPLAIN to the point where reactor power stabilizes for full credit). (No operator action).

QUESTION 5.09 (1.00)

LIST two (2) reasons for the use of gadol..a rods in the core fuel bundle.

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

QUESTION 5.10 (2.00)

A reactor startup is planned approximately 12 hours after a scram from a two month 100% power run. EXPLAIN the difference between the expected and the previous rod reactivity worths for each of the following:

(a). center control rods;

(b). peripheral control rods.

QUESTION 5.11 (1.00)

DESCRIBE two (2) removal mechanisms of Xe-135 from the reactor core.

QUESTION 5.12 (1.00)

SELECT the one following statement that correctly completes the statement: Departure from nucleate boiling is the point where...

a. the void fraction equals one.

b. the heat transfer mechanism changes from nucleate boiling to single phase.

c. radiative heat transfer becomes insignificant.

d. the heat transfer rate sustainable with nucleate boiling reaches its maximum.

QUESTION 5.13 (1.75)

DESCRIBE (i.e., significant or insignificant, increase or decrease, large or small, as appropriate) and EXPLAIN the effects of withdrawing a 'deep control rod' (Notch 00-18) in terms of:

a. change in core power. (0.75)

b. void effect (negative reactivity). (0.50)

c. axial power shape. (0.50)

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

QUESTION 5.14 (1.00)

EXPLAIN why the steady state MCPR value is increased for core flow less than rated core flow.

QUESTION 5.15 (2.00)

Core loading requires a shutdown margin (SDM) at least R + 0.25% delta K in the most reactive condition during the operating cycle. DEFINE the term 'R' in this SDM.

QUESTION 5.16 (1.50)

STATE the damage that would be caused to an induction motor (i.e., RHRS service water pump) by repeated starts and/or jogs, and EXPLAIN why repeated starts would cause this damage.

QUESTION 5.17 (1.00)

During a reactor startup, the first reactivity addition caused count rate to increase from 20 cps to 40 cps. The second reactivity addition caused count rate to increase from 40 cps to 80 cps. SELECT the correct following statement.

a. The first reactivity addition was larger.

b. The second reactivity addition was larger.

c. The first and second reactivity additions were equal.

d. There is not enough data given to determine relationship of reactivity values.

QUESTION 5.18 (1.50)

a. EXPLAIN the difference between driven flow and driving flow within the reactor vessel. (1.00 point)

b. STATE which one of these flows provides the greater contribution to the total core flow. (0.50 point)

(***** END OF CATEGORY 5 *****)

QUESTION 6.01 ~~(1.50)~~ 1.00

ANSWER each of the following items either TRUE or FALSE concerning QOA 1300-7, RCIC LOCAL MANUAL OPERATION:

~~a. The mechanical overspeed trip (5600 rpm) of the trip throttle valve is the only trip signal active for local manual operation.~~

b. When the local-remote selection switch for the RCIC Turbine Steam Supply Isolation Valve, MO-1301-16, is placed in the LOCAL position, all position indication in the control room for that valve is lost.

c. A local self-powered tachometer for Unit 1 RCIC turbine was installed for fire protection considerations.

QUESTION 6.02 (1.50)

STATE why each of the following conditions would be imposed during shutdown cooling operations:

a. During the normal shutdown cooling mode of operation, additional cooling by the RHR service water is required as reactor coolant pressure decreases.

b. RHR inlet temperature to its heat exchanger is used to determine reactor coolant temperature.

c. While using shutdown cooling, the MOVs to the suppression chamber (MO-1001-34 A/B and MO-10001-36 A/B) are not open.

QUESTION 6.03 (1.50)

LIST three (3) sets of conditions that would cause 'Refueling Platform Hoist Upward Travel Blocks.'

QUESTION 6.04 (1.00)

FILL in each of the following blanks with the correct one word answer. The purpose for placing a second main feedwater regulator into service when using QOP 600-3, during reactor power operation, is to reduce _____ at critical power limits. The critical power levels seem to be unpredictable but tend to occur above _____ % power.

(xxxxx CATEGORY 6 CONTINUED ON NEXT PAGE xxxxx)

QUESTION 6.05 (1.50)

EXPLAIN the potential consequence(s) of losing the Reactor Building Exhaust Fans. (INCLUDE equipment automatic trip set point(s) as applicable for full credit.)

QUESTION 6.06 (1.00)

LIST the two (2) buses that are fed by Transformer #12, when Unit 2 is at power. (Stated in Procedure QOA 6100-1 for loss of transformer during power operation.)

QUESTION 6.07 (0.75)

With a station blackout, STATE the three (3) expected automatic Group Isolations of QOA 6100-4, STATION BLACKOUT.

QUESTION 6.08 (4.00)

STATE, for each of the High Pressure Coolant Injection (HPCI) System component failures listed below, whether the HPCI System 'IS' or 'IS NOT' still capable of automatic injection. If it 'IS NOT' capable of automatic injection, EXPLAIN why. If it 'IS' capable of automatic injection, then DESCRIBE any adverse effect(s)/consequence(s) of automatic injection with this failure. CONSIDER each component failure as a separate case.

Assume that no ~~operation~~ operator action occurs, the component fails at the time of the automatic initiation signal, and reactor power is 100%.

a. The gland seal exhauster fails to operate. (1.00)

b. The turbine auxiliary lube oil pump fails to operate. (1.00)

c. The alternate minimum flow valve (2301-14) (e.g., valve 2301-3 is inoperable and left opened) fails to close, when system conditions require it to be close. (1.00)

d. The HPCI pump discharge flow element output signal to the HPCI flow controller is failed at its maximum output. (1.00)

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

QUESTION 6.09 (1.00)

STATE the effect(s) that losing the microwave radio system would have upon routine Unit 2 operations with Unit 1 on line.

QUESTION 6.10 (2.50)

ANSWER each of the following questions either TRUE or FALSE concerning the Rod Worth Minimizer (RWM) rod blocks:

a. After transferring from the A to B computer or back, the RWM is automatically initialized.

b. Whenever reactor power is below the low power set point, only INSERT rod blocks are active.

c. The RWM low power set point requires both rated steam flow and rated feedwater flow to be below 20% of their values.

d. If the RWM fails or is powered down with the mode switch in NORMAL, rod blocks will be applied only for reactor power levels less than 30%.

e. Any rod inserted one or more notches beyond its insert limit will cause an insert block to be issued for all rods without exception.

QUESTION 6.11 (2.00)

ANSWER each of the following questions either TRUE or FALSE concerning the Atmospheric Containment Atmosphere Dilution (ACAD)/Containment Atmosphere Monitoring (CAM) System:

a. The ACAD cannot be automatically initiated.

b. The Shift Engineer must receive authorization to place the ACAD/CAM mode switches (Panels 901-55/902-55 and 901-56/902-56) in OFF during a post-LOCA situation.

c. If CAMs are turned completely off (i.e., the heater boxes are allowed to cool), it will require 15 minutes to 1 hour to warm the unit up before it will be operable.

d. The hydrogen and oxygen monitor indications are not valid beyond their alarm points.

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

QUESTION 6.12 (1.00)

STATE why the physical location of the drywell radiation monitors result in the need to apply a correction factor to the readings obtained on the monitor to convert the readings to actual dose rate.

QUESTION 6.13 (2.10)

LIST the four (4) APRM reactor scrams; and INCLUDE the set points/conditions for each APRM reactor scram.

QUESTION 6.14 ~~(1.50)~~ 1.20

ANSWER each of the following questions concerning the Core Spray (CS) System either TRUE or FALSE:

~~a. The minimum bypass flow valve (MO-38 A/B) in each loop is normally open during standby operation, because there is no core spray flow.~~

a. ~~b.~~ The inboard injection valve (MO-25 A/B) is interlocked with the core spray testable check valve to prevent cycling the testable check valve when inboard injection valve is open.

b. ~~c.~~ Upon an automatic initiation of core spray, the CS systems logic will only inject CS flow into the recirculation loop that appears to have a break.

QUESTION 6.15 (1.50)

STATE the three (3) Reactor Core Isolation Cooling (RCIC) System automatic isolations (Group 5); and INCLUDE the set points.

QUESTION 6.16 (1.25)

If radioactive materials have accumulated on the Standby Gas Treatment System (SBGTS) Filters during operation, radioactive decay will cause internal heating of the filters. If heating is sufficient to require cooling, DESCRIBE the filter cooling flow path that can be used in accordance with QOP 1600-1, DRYWELL PRESSURE RELIEF THROUGH SBGTS.

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

QUESTION 6.17 (0.50)

STATE the auxiliary system that prevents water hammers from occuring in the Core Spray (CS) System.

(xxxxx END OF CATEGORY 6 xxxxx)

~~QUESTION 7.01 (1.50)~~ DELETED.

~~STATE three (3) Immediate Operator Actions for a 'HVAC EXHAUST FILTER TEMPERATURE HIGH' alarm using QOA 701-0, HRSS LSP ANNUNCIATOR PROCEDURES.~~

QUESTION 7.02 (1.50)

With the reactor critical, a control rod position indication does not change from position 16 when a control rod withdraw signal is applied. STATE three Immediate Operator Actions required by QOA 300-2, INABILITY TO DRIVE A CONTROL ROD: CONTROL ROD STUCK.

QUESTION 7.03 (1.50)

On July 29, 1987, a lightning strike on the 345 KV line caused a power fluctuation that resulted in a toxic gas analyzer system isolation of the control room.

Other than a manual reactor scram (and its corresponding immediate operator actions), LIST three (3) Immediate Operator Actions required by QOA 5750-13, TOXIC AIR OR SMOKE IN THE CONTROL ROOM, if occupation of the control room is no longer possible. (1.5 points)

QUESTION 7.04 (3.00)

a. QGA 500-7, LEVEL/POWER CONTROL, describes the method of lowering Reactor Pressure Vessel (RPV) water level to reduce the heat generation rate. EXPLAIN how lowering RPV water level assists in reducing the heat generation rate.

b. In order to lower RPV water level, QGA 500-7 prescribes terminating and preventing all injection into the RPV except from the boron injection system or the control rod drive system. EXPLAIN why injection is still allowed from these two sources.

c. QGA 500-7 further prescribes that RPV water level be lowered until any one of three conditions is met. One of these conditions is that RPV water level drops to -143 inches. EXPLAIN the significance of this -143 RPV inches water level.

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

QUESTION 7.05 (3.00)

a. QGA 500-2, EMERGENCY REACTOR PRESSURE VESSEL (RPV) DEPRESSURIZATION, requires verification that the suppression pool level is above 5.0 feet prior to opening all the Automatic Depressurization System (ADS) valves.

EXPLAIN why this limit on suppression pool level is imposed for Emergency RPV Depressurization using the ADS valves. (1.00 point)

b. QGA 500-2 further prescribes that if fewer than 3 ADS valves are open and RPV pressure is at least 50 psig above suppression chamber pressure then rapidly depressurize the RPV using one or more of several systems (e.g., main turbine bypass valves, main steam line drains, HPCI turbine, RCIC turbine, RPV head vent , steam jet air ejectors, RWCU).

(1). EXPLAIN why RPV pressure is required to be at least 50 psig above suppression chamber pressure prior to performing this step. (INCLUDE the significance of this 50 psig value). (1.00 point)

(2). EXPLAIN why three (3) ADS values are the minimum number required for Emergency Depressurization. (1.00 point)

QUESTION 7.06 (1.50)

The unit is operating at 100% power, when a complete loss of essential services occurs. LIST five (5) control room indications, which would be disabled due to the loss of essential service power.

QUESTION 7.07 (2.50)

While the unit is operating at 75% power in EGC, an 'A' feedwater heater high level occurs. STATE five (5) Immediate Operator Actions using QOA 3500-1, LOSS OF FEEDWATER HEATERS.

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

QUESTION 7.08 (1.00)

STATE the two (2) conditions required before an inoperable Control Rod Drive (CRD) Accumulator is reclassified as operable in accordance with QOP 300-10, CRD SYSTEM ACCUMULATOR GAS DISCHARGING, and Technical Specifications.

QUESTION 7.09 (1.50)

Using the Immediate Operator Actions for LOSS OF STATOR COOLING, QOA 5300-1, STATE the maximum time that the unit can remain critical for each of the following stator cooling water conductivity values:

a. 0.2 umho/cm

b. 2.0 umho/cm

c. 20.0 umho/cm

QUESTION 7.10 (1.00)

EXPLAIN why an Off-Gas System chimney monitor alarm may be likely to occur following a rapid power reduction.

QUESTION 7.11 (1.00)

In single loop operation, SELECT for each parameter listed below, if the Unit 1 value is changed (MORE THAN, SAME AS, or LESS THAN) the Unit 2 change in value:

a. maximum average planar linear heat generation rate (MAPLHGR) limit multiplication correction factor.

b. minimum critical power ratio (MCPR) safety limit.

c. Rod Block Set Points.

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

QUESTION 7.12 (1.00)

STATE why the main condenser level is limited below 35% level when implementing QOP 201-1, DRAINING THE REACTOR VESSEL AND RECIRCULATION LOOPS.

QUESTION 7.13 (1.00)

If a control rod is required to be taken out of service, EXPLAIN why it is preferable to electrically disarm the drive in accordance with QOP 300-7, CRD SYSTEM, DRIVE DISARMAMENT, rather than valving out the drive in accordance with QOP 300-8, CRD SYSTEM, HYDRAULIC CONTROL MODULE ISULATION.

QUESTION 7.14 (1.50)

STATE the three (3) restrictions imposed by Technical Specifications and QOP 1100-1, STANDBY OPERATION OF STANDBY LIQUID CONTROL SYSTEM (SLCS), which allow the SLCS to be inoperable with fuel in the reactor vessel.

QUESTION 7.15 (1.50)

FILL in each of the following blanks with a single word answer concerning QOP 1000-5, SHUTDOWN COOLING STARTUP AND OPERATION:

a. If both recirculation pumps are off, temperature stratification may occur due to lack of upward core flow. This may result in reactor ----------.

b. In the event of inadequate heat transfer across the RHR heat exchanger or inadequate RHR service water flow, consideration should be given to ---------- of the heat exchanger as the possible cause.

c. The differential temperature between the reactor vessel flange and ---------- is to be maintained less than 140 degrees F.

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

QUESTION 7.16 (2.00)

Reactor Pressure Vessel (RPV) water level cannot be determined. The RPV is therefore flooded in accordance with QGA 500-6, REACTOR PRESSURE VESSEL FLOODING. Injection into the RPV is controlled in accordance with the procedure to maintain at least three Automatic Depressurization System (ADS) valves open and RPV pressure at least 77 psig above suppression chamber pressure, but as low as practical. Forty minutes later with five ADS valves open (reactor pressure has remained above suppression chamber pressure for this entire time) RPV water level instrumentation is available; temperature near the RPV cold water level instrument leg vertical runs is below 212 degrees F; and suppression chamber pressure is below 55 psig. Under these conditions, QGA 500-6 then prescribes that all injection into the RPV be terminated and RPV water level be reduced. QGA 500-6 also prescribes a maximum core uncovery time limit after commencing termination of injection into the RPV after which flooding is to be resumed, if RPV water level indication is not restored.

EXPLAIN why QGA 500-6 requires this RPV:

a. water level reduction. (1.0 point)

b. flooding to be resumed, if water level indication is not restored within the Maximum Core Uncovery Time Limit. (1.0 point)

(***** END OF CATEGORY 7 *****)

QUESTION 8.01 (1.00)

SELECT the one correct answer. If an entry condition for an Emergency Operating Procedure (QGA) occurs, for a QGA procedure that has been completed, then the completed QGA procedure:

a. is immediately performed again.

b. is perfomed again, after completing the QGAs that have been started.

c. is not required to be performed again.

d. can be performed again, but it is entirely at the discretion of the Shift Engineer.

QUESTION 8.02 (1.00)

SELECT the one correct answer. QAP 500-9, PREVENTATIVE MAINTENANCE, requires the Operations Department to:

a. lubricate motors and equipment which have a circulating oil system or a reservoir.

b. lubricate motors and equipment without a circulating oil system or a reservoir.

c. lubricate all motors and equipment.

d. lubricate neither motors nor equipment.

QUESTION 8.03 (1.00)

Technical Specifications (TSs) require the reactor to be shutdown, if it is determined that a jet pump is inoperable. STATE two (2) reasons, which are taken into consideration by the design base accident (DBA) for loss of coolant accident (LOCA), for this requirement.

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

QUESTION 8.04 (1.00)

A spurious unplanned control room ventilation system isolation requires: (SELECT the one correct answer from the following.)

a. A one (1) hour telephone notification to the NRC Operations Center.

b. A four (4) hour telephone notification to the NRC Operations Center.

c. No NRC telephone notification.

d. Only a telephone call to the NRC Resident Inspector.

QUESTION 8.05 (1.50)

STATE the Technical Specification Basis for requiring a Condenser Low Vacuum Scram (1.00); and how this scram can be bypassed. (0.50)

QUESTION 8.06 (1.00)

FILL in each blank with the correct value. Unit 1 Technical Specification Basis states that a leak as small as _____ gpm is possible to be detected by the Main Steam Line Tunnel High Temperature Alarm. The alarm set point for this high temperature alarm is _____ degrees F.

QUESTION 8.07 (1.50)

INDICATE whether each of the following statement concerning Unit 2 secondary containment is either TRUE or FALSE.

a. Each train of the Standby Gas Treatment (SBGT) System is required to have the capability to maintain at least a 1/2 inch of water vacuum within the secondary containment.

b. The SBGT charcoal filter should be tested, if it was exposed to paint fumes.

c. An efficiency of 94.9% is adequate for the SBGT filter to retain particulates that may be released to the reactor building following an accident.

(xxxxx CATEGORY 8 CONTINUED ON NEXT PAGE xxxxx)

QUESTION 8.08 (1.00)

STATE the primary disadvantage, as provided in the Technical Specification Basis, of lowering the reactor vessel low water level scram set point.

QUESTION 8.09 (1.00)

Other than personnel safety considerations, STATE the Shift Engineer's principal purpose for reviewing an area, in which, radiography is to be performed.

QUESTION 8.10 (1.50)

In accordance with the Generating Station Emergency Plan (GSEP), LIST three (3) conditions that would prevent the evacuation of nonessential personnel, after assembly/accounting of personnel within the Protected Area has been completed.

QUESTION 8.11 (1.00)

STATE two (2) conditions required by QAP 300-2, CONDUCT OF SHIFT OPERATIONS, to use the PULL-TO-LOCK switch position for testing.

QUESTION 8.12 (1.00)

SELECT the correct answer. An orderly unit shutdown will be initiated immediately with reduction of coolant temperature to less than 212 degrees F, as rapidly as other plant constraints permit, when Chemistry issues an ACTION LEVEL:

a. One.
b. Two.
c. Three.
d. Four.

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

QUESTION 8.13 (1.00)

If a temporary procedure review by the SCRE involves the Operation Department (i.e., operation of a RHR pump), STATE two (2) SCRE actions that are required to be performed in addition to the review, in accordance with QAP 1100-5, TEMPORARY PROCEDURES AND TEMPORARY CHANGES TO PERMANENT PROCEDURES.

QUESTION 8.14 (2.00)

ANSWER each of the following questions either TRUE or FALSE concerning QAP 1120-6, ENTERING A LOCKED HIGH RADIATION AREA WITHOUT A TIMEKEEPER:

a. Entry into a high radiation area is absolutely prohibited without the use of a safety man in lieu of a timekeeper.

b. Transfer of the 'R-key' between individuals is only routinely allowed between security guards.

c. The safety man is required to immediately notify the control room, when an individual enters and leaves a high radiation area.

d. An individual will only be allowed one 'R-key' at a given time.

QUESTION 8.15 (0.50)

FILL in the blank with the correct value. QAP 1170-14, FIRE WATCH RESPONSIBILITIES, states that persons performing fire watch duties for other than cutting and welding jobs shall make a round of the assigned area at least once every _____ unless otherwise defined in Technical Specifications.

QUESTION 8.16 (1.00)

STATE the two (2) restrictions imposed upon the Shift Engineer during absences from the control room/Shift Engineer's Office by QAP 300-1, OPERATIONS DEPARTMENT ORGANIZATION.

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

QUESTION 8.17 (1.25)

EXPLAIN how an adequate shutdown margin (SDM) can be physically verified before performing maintenance on a control rod drive using QOP 300-14, CONTROL ROD OR CRD MAINTENANCE.

QUESTION 8.18 (1.50)

EXPLAIN the Technical Specification Basis for requiring the Rod Worth Minimizer (RWM) to be operable for less than 20% power.

QUESTION 8.19 (1.00)

SELECT the one correct answer. When performing QAP 300, EQUIPMENT OUT-OF-SERVICE, the individual items should be normally taken out in the following specific order:

a. electrical feed, main isolation points, control switch.

b. main isolation points, control switch, electrical feed.

c. control switch, electrical feed, main isolation points.

d. main isolation points, electrical feed, control switch.

QUESTION 8.20 (1.00)

FILL in each blank with the correct value or one word answer. QAP 300-19, REVIEW OF ACTIVE OUT-OF-SERVICES, requires:

'Monthly, at least [a.] _____ percent of those out of services older than [b.] _____ days and not in a high radiation area shall be physically reviewed.'

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

QUESTION 8.21 (1.50)

LIST by title, the position that would assume each of the following on-site fire protection position title, in accordance with QAP 1170-17, FIRE PROTECTION PROGRAM:

a. Fire Commissioner.

b. Fire Chief.

c. Assistant Fire Chief.

QUESTION 8.22 (0.50)

QAP 1150-6, ACCESS TO CONFINED SPACES, defines what constitutes a confined space and the requirements of working in such an area. If the SCRE has any concern, which may affect worker health and safety, STATE by title, the person that the SCRE would contact to obtain a definitive answer to his concern.

(***** END OF CATEGORY 8 *****)
(********** END OF EXAMINATION **********)

ANSWER 5.01 (1.00)

c. [1.00 point]

REFERENCE

HTFF Text, Chp. 7, Heat Transfer, Rev. 1, pg. 7-45.
293007K109 ..(KA's)

ANSWER 5.02 (3.00)

a. LHGR - fuel pellet expansion [0.50]; and 1% ~~[0.10]~~ plastic strain ~~[0.30]~~ on cladding ~~[0.10].~~ [0.50]

b. APLHGR - decay heat ~~[0.25]~~ and stored heat following LOCA [~~0.25~~]; and clad temperature ~~[0.40]~~ of 2200 degrees F [0.~~1~~0].

c. CPR - loss of nucleate boiling ~~[0.40]~~ (around cladding) [0.~~10~~]; and boiling transition [0.50].

REFERENCE

HTFF Text, Chp 9, BWR THERMAL LIMITS, Rev. 1, Fig. 9-5, pg. 9-15.
Quad Cities, N-NOLR-FA84; SRO REQUAL, Question No. 5.05.
293009K112 293009K111 293009K108 293009K107 ..(KA's)

ANSWER 5.03 (1.00)

b. [1.00 point]

REFERENCE

GE Student Text, LIC-THEO, REACTOR THEORY, Rev. 2, Figure 46
Quad Cities, N-NOLR-FA84; SRO REQUAL, Question No. 5.11.
292008K108 ..(KA's)

ANSWER 5.04 (1.00)

d. [1.00 point]

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

REFERENCE

GE Student Text, LIC-THEO, REACTOR THEORY, Rev. 2, Figure 46.
Quad Cities, N-NOLR-SRO-D-85; SRO REQUAL, Quest. No. 5.03.
292008K105 ..(KA's)

ANSWER 5.05 (1.00)

a. True
b. False
[0.50 point for each)

REFERENCE

Reactor Theory, LIC-THEO, REACTOR THEORY, Rev. 2, Figure 7 at top of page.
292008K130 ..(KA's)

ANSWER 5.06 (2.00)

a. Decreases

b. (1). Decreases
(2). Remains Constant
(3). Increases

[0.50 point each]

REFERENCE

Reactor Theory, Lic-Theo, Rev. 2, pg. 13 and Figure 29
292003K103 ..(KA's)

ANSWER 5.07 (1.25)

Fuel pellets have a tendency to increase in density [0.5]. This causes a decrease ~~[0.25],~~ in the pellet length [0.25] and a decrease ~~[0.25],~~ in the pellet diameter ~~[0.25]~~. 0.75

The change in density causes the pellet to crack [0.37] and swell [0.38].

REFERENCE

HTFF Text, Chp. 9, BWR THERMAL LIMITS, pg. ~~9-46~~. 9-22, 9-44, and 9-45.
293009K131 ..(KA's)

(xxxxx CATEGORY 5 CONTINUED ON NEXT PAGE xxxxx)

ANSWER 5.08 (1.50)

Reactor power increases [0.50], due to the reduction in feedwater temperature [0.30]. Positive reactivity is inserted by the moderator temperature coefficient [0.30]. Natural feedback to limit power increase is provided by the void coefficient [0.20] and the fuel temperature coefficient (doppler) [0.20].

REFERENCE

QOA 3500-1, LOSS OF FEEDWATER HEATERS, Rev. 4, pg. 2.
Quad Cities Lesson Plan, LIC-THEO, REACTOR THEORY, Rev. 2, pgs. 15-18.
259001K312 ..(KA's)

ANSWER 5.09 (1.00)

a. Allow more fuel to be loaded (without increasing the number of control rods) [0.50].

[0.25] flux shape ~~c2~~ [0.25]

b. Facilitate axial power shape control (limits flux peaking problems and simultaneously simplifies control rod patterns). ~~[0.50]~~

REFERENCE

Quad Cities Lesson Plan, LIC-THEO, REACTOR THEORY, Rev. 2, pg. 25.
292007K101 ..(KA's)

ANSWER 5.10 (2.00)

a. The center control rods will be worth less [0.50] because the xenon concentration will be highest in regions of the core where neutron flux was highest during the previous operational phase [0.50].

b. The peripheral control rods will be worth more [0.50] because the thermal flux will be pushed to the core edge by the xenon building in the core center [0.50].

REFERENCE

GE Reactor Theory, LIC-THEO, Rev. 2, pg. 24.
292006K108 292006K107 ..(KA's)

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

ANSWER 5.11 (1.00)

a. Burnout (Xe-135 absorption of a thermal neutron to become Xe-136 with a small thermal neutron cross section). [0.50]

b. Decay (Xe-135 half-life to Cs-135 is 9.2 hours). [0.50]

REFERENCE

GE Reactor Theory, LIC-THEO, Rev. 2, pg. 23.
292006K104 ..(KA's)

ANSWER 5.12 (1.00)

d. [1.00 point]

REFERENCE

HTFF Text, Chp. 8, BWR THERMAL HYDRAULICS, Rev. 1, pg. 8-12.
293008K108 ..(KA's)

ANSWER 5.13 (1.75)

a. Core power is significantly [0.25] increased [0.25], because of its large rod worth [0.25].

b. Void effect is small [0.25], because the increase voids affect only a small length of fuel [0.25].

c. Only a small effect in axial power shape [0.25] because most of the bundle is controlled [0.25].

REFERENCE

GE Reactor Theory, LIC-THEO, Rev. 2, pg. 21.
292005K112 ..(KA's)

(*****CATEGORY 5 CONTINUED ON NEXT PAGE *****)

ANSWER 5.14 (1.00)

This ensures that the MCPR will be maintained greater than that required (Unit 1 TS 1.1.A) [0.50] even in the event that the motor-generator set speed controller causes the scoop tube positioner for the fluid coupler to move to the maximum speed position [0.50]. (Alternate word is acceptable for full credit).

REFERENCE

Unit 1 TS BASIS 3.5.K, Amendment No. 66, pg. 3.5/4.5-22.
293009K123 ..(KA's)

ANSWER 5.15 (2.00)

The value of R is the difference [0.50] between the calculated core reactivities [0.50] at the beginning of the operating cycle [0.50] and any time later in the cycle [0.30] where it would be greater than at the beginning [0.20].

REFERENCE

Unit 2 TS BASIS 3.3.A.1, Amendment No. 2, pg. 3.3/4.3-7
292002K110 ..(KA's)

ANSWER 5.16 (1.50)

a. Life of the winding insulation would be (greatly) reduced. [0.50]

b. The heat produced [0.50] by each acceleration or jog is much more than that produced (and dissipated) by the motor under full load [0.50].

REFERENCE

QOP 1000-4, RHRS SERVICE WATER SYSTEM STARTUP AND OPERATION, Section F.5.b, Rev. 9, pg. 2.
291005K106 ..(KA's)

ANSWER 5.17 (1.00)

a. [1.00 point]

(***** CATEGORY 5 CONTINUED ON NEXT PAGE *****)

REFERENCE

Quad Cities Lesson Plan, LIC-THEO, REACTOR THEORY, Rev. 2, pgs. 9 & 11.
292008K103 ..(KA's)

ANSWER 5.18 (1.50)

a. Driving flow is provided to the jet pumps from the recirculation pumps [0.50], while driven flow comes from the vessel downcomer region (e.g., dryer and separator drains plus feed flow). [0.50]

b. Driven flow. [0.50]

REFERENCE

Quad Cities Lesson Plan, RECIRCULATION, LIC-0202-1, Rev. 1, pgs. RECIR-2 & RECIR-3.
290002K102 293006K102 ..(KA's)

(***** END OF CATEGORY 5 *****)

ANSWER 6.01 ~~(1.50)~~

~~a. True.~~
~~b.~~ True.
~~c.~~ True.
[0.50 point each]

REFERENCE

QOA 1300-7, RCIC LOCAL MANUAL OPERATION, Rev. 5, pg. 3
P&ID, Diagram of RCIC Piping, M-50, Rev. AB
217000K406 ..(KA's)

ANSWER 6.02 (1.50)

a. ... because, the line could flash to steam (a temperature of 281 degrees F could be approached, which is the saturation temperature for 50 psig). [0.50]

b. ... to obtain temperature reading with no reactor recirculation pump operating. [0.50]

c. ... to prevent draining water from reactor vessel. [0.50]

REFERENCE

QOP 1000-5, SHUTDOWN COOLING STARTUP AND OPERATION, Rev. 13, pgs. 1 and 7.
Quad Cities Lesson Plan, LIC-1000, RHR, Rev.2, pg. 8.
IE Rpt No. 50-265/87019 (DRP), pg. 7.
205000K102 205000K101 205000K114 205000K115 ..(KA's)

ANSWER 6.03 (1.50)

a. ~~Mode switch in refuel [0.20]~~ With any control rod out [~~0.10~~] and fuel on any refueling hoist [~~0.10~~] and refueling platform near or over the vessel [~~0.10~~].

b. Hoist overload. [0.50]

c. High position limitations. [0.50]

(xxxxx CATEGORY 6 CONTINUED ON NEXT PAGE xxxxx)

REFERENCE

QFP 100-1, MASTER REFUELING PROCEDURE, Section E.1.b(3), Rev. 13, pg. 4.
234000K402 ..(KA's)

ANSWER 6.04 (1.00)
or Oscillations or Instabilities

a. Vibrations; [0.50]

b. 40 +/- 5%. [0.50]

REFERENCE

QOP 600-3, PLACING THE SECOND MAIN FEEDWATER REGULATOR IN SERVICE,
Section A, Rev. 5, pg. 1
259001K307 ..(KA's)

ANSWER 6.05 (1.50)

- Loss of these fans may result in a positive pressure inside the reactor building [0.50]. Excessive building pressure would eventually cause one (of the six) reactor building blow off panels (refuel floor level) to be released [0.50].

- The reactor building supply fans [0.25] automatically trip at a building pressure of + 1.0 +/- 0.2 inches [0.25].

REFERENCE

QOA 5750-5, LOSS OF REACTOR BUILDING EXHAUST FANS, Sect. E, Rev. 7, pg. 2
288000K305 ..(KA's)

ANSWER 6.06 (1.00)

~~Buses 12 [0.5] and 13 [0.5].~~ Any two of the following buses: 11, 12, 13, and/or H.D. [0.50 point for each bus].

REFERENCE

QOA 6100-1, Loss of Transformer 12(22) During Power Operation, Rev. 2,
Section B, pg. 1.
262001K103 ..(KA's)

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

ANSWER 6.07 (0.75)

a. Group I
b. Group II
c. Group III
[0.25 point for each item]

REFERENCE

QOA 6100-4, STATION BLACKOUT, Rev. 2, Section B.6, pg. 1.
223002K601 ..(KA's)

ANSWER 6.08 (4.00)

a. (1). WILL ~~NOT~~ AUTO INJECT.
(2). Gland seal condensor will be unable to maintain a vacuum (because non-condensable gases would not be removed to maintain -10 inches of water).

b. (1). WILL NOT AUTO INJECT. The loss of high pressure oil will prevent the stop and control valves from opening
(2). ~~Unable to meet system lubriction requirement (during startup and low speed operation below 2,000 rpm).~~

c. (1). WILL AUTO INJECT.
(2). It would be possible to drain the CCST into the torus.

d. (1). WILL NOT AUTO INJECT. It would be possible to reduce system flow to the point.
(2). The desired system flow would be unable to be achieved (to accomodate varying reactor pressures). At operating pressure, the HPCI discharge head would be insufficient to lift the main gear unit (MGU) would hold the turbine to 2000 RPM by running; staying of low speed stop (LSS!).
[0.50 point for each item] (Correct alternate answers will be accepted).

REFERENCE

Quad Cities Lesson Plan, LIC-2300-1, HPCI SYSTEM, Rev. 0, pgs. HPCI-9, HPCI-12, HPCI-13, HPCI-17, and HPCI-31.
Quad Cities SRO Requal Exam, Question 6.09, date unknown.
206000A214 206000K417 206000K413 206000K401 ..(KA's)

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

ANSWER 6.09 (1.00)

Loss of high speed protective relaying ~~[0.40] and~~ OR direct transfer trip [0.~~40~~80] capability for incoming power lines (0403 and 0404). [0.20] (The Unit 2 generator trip scheme upon loss of these lines is necessary, because the Iowa-Illinois System cannot handle the output from both units).

OR
Loss to transmit/operate in EGC. [1.00]

REFERENCE

QOA 8650-1, LOSS OF POWER TO MICROWAVE RADIO BUILDING, Section E.1, Rev. 1, pg. 2
262001K404 ..(KA's)

ANSWER 6.10 (2.50)

a. False (operator needs to press SYSTEM INITIALIZE button).

b. False (INSERT and WITHDRAWAL rod blocks are active).

c. False (either steam flow or feedwater flow).

d. False (at any power).

e. False (except for rods withdrawn errors or rods in the current sequence step).
[0.50 pt for each item]

REFERENCE

QOP 207-1, NEW ROD WORTH MINIMIZER OPERATION, Section E, Rev. 3, pgs. 1-2
201006K402 201006K401 201006K409 ..(KA's)

ANSWER 6.11 (2.00)

a. ~~False (auto start upon CS initiation signal)~~ True.

b. False (Shift Engineer can authorize this)

c. False (2-6 hours)

d. True

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

REFERENCE

QOP 2400-1, ACAD/CAM SYSTEM, Sections E and F.2.a, Rev. 7, pgs 2-3
223001K404 ..(KA's)

ANSWER 6.12 (1.00)

Drywell radiation monitors are not physically inside the drywell [0.75]; and are located inside sleeves OR shielded by the material around the detector [0.25].

REFERENCE

QOP 2400-1, ACAD/CAM SYSTEM, Section E.3, Rev. 7, pg. 2.
272000K119 ..(KA's)

ANSWER 6.13 (2.10)

a. APRM (fixed) high flux ~~[0.30]~~ less than equal to 15% rated neutron flux ~~[0.10]~~ in REFUEL or STARTUP HOT STANDBY Mode ~~[0.10]~~, OK when not in Run Mode. [0.25]

b. APRM (variable) high flux ~~[0.30]~~ less than equal to '0.58 W + 62' (FRP/MFLPD) ~~[0.20]~~ in Run Mode ~~[0.10]~~ (maximum set point of 120% for core flow of greater than equal to 98E+6 lbm/hr)

c. APRM INOPERABLE [0.30] due to:
(1). Less than 50% of assigned LPRM's in OPERATE. [0.10]
(2). APRM module unplugged. [0.10]
(3). APRM mode switch not in OPERATE. [0.10]

d. APRM downscale [0.30] with an associated IRM Hi Hi or INOP [0.10] in Run Mode [0.10].

REFERENCE

QOP 700-4, APRM SYSTEM OPERATION, Section E.2, Rev. 5, pg. 2.
215005K402 ..(KA's)

ANSWER 6.14 (~~1.50~~ 1.00)

~~a. False. (This is a normally closed valve).~~

a. ~~b.~~ True.
b. ~~c.~~ False. (Both CS pumps will inject into both loops).
[0.50 point for each]

(***** CATEGORY 6 CONTINUED ON NEXT PAGE *****)

REFERENCE

QOA 1400-1, CS SYSTEM AUTOMATIC INITIATION, Sec. B.1, Rev. 8, pg. 1.
Quad Cities Lesson Plan, CS SYSTEM, LIC-1400, Rev.1, pgs. CS-5 and CS-6.
Quad Cities SRO Requal Exam, Question No. 6.08.d, Licensee's ref. pg. 1951G.
209001K408 209001K407 209001K405 ..(KA's)

ANSWER 6.15 (1.50)

a. RCIC turbine area [0.15] high temperature [0.15]
200 +/- 5 degrees F [0.20].

b. RCIC Steam Line high flow [0.30]
300% of rated steam flow [~~0.10~~ 0.20] (with a turbine delay ~~[0.10]~~ of
3 ~~+/- 1~~ 0 seconds) ~~[0.10]~~.

c. Reactor vessel low pressure [0.30]
50 +/- 2 psig [0.10]

REFERENCE

QOP 1300-2, RCIC System Manual Startup, Section E.1, Rev. 6, pg. 1
259002K116 217000K107 ..(KA's)

ANSWER 6.16 (1.25)

Start the opposite train and draw air through the affected train [0.75]
from the turbine building ~~[0.25]~~ 0.5 (via the train cross connect) ~~[0.25]~~.

REFERENCE

QOP 1600-1, DRYWELL PRESSURE RELIEF THROUGH SBGTS, Sec. D.2, Rev. 5, pg. 1.
261000K402 261000G001 ..(KA's)

ANSWER 6.17 (0.50)

... the ECCS Fill System. [0.50]
(Other acceptable names are: Jockey Fill, Keep Fill, or Maintenance Fill System).

REFERENCE

Lesson Plan No. LIC-1400, CS SYSTEM, Sec. B.13.a, Rev. 1, pg. CS-8.
209001K402 ..(KA's)

(***** END OF CATEGORY 6 *****)

Deleted.

ANSWER 7.01 (1.50)

- Turn off filter exhaust fans 1 and 2.
- Turn on bypass exhaust fan.
- Determine if there is a fire in HVAC charcoal bed by looking for signs of excessive heat.
- If there is indication of a fire, notify Shift Engineer.
- Contact Chemistry Supervisor.

[3 of 5 required at 0.50 pts each]

REFERENCE

QOA 701-B, Revision 1, Item B-5, pg. 2
294001K116 ..(KA's)

ANSWER 7.02 (1.50)

- Attempt to operate the drive in both positions (to determine the exact position).
- Verify normal drive water flow fluctuation.
- Increase drive water pressure and attempt to move the rod.
- If control rod does not move, consult TS (TS 3.3.A.2.a and TS 4.3.A.2).

[3 of 4 required at 0.50 pts each]

REFERENCE

QOA 300-2, Inability to Drive A Control Rod: Control Rod Stuck, Rev. 4
201001G014 ..(KA's)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

- Announce in the public address system that CR is being evacuated.
- Manually scram reactor, if possible.
- Leave Feedwater System in Automatic on low flow bypass, if possible.
- Notify the Energy Load Dispatcher, if possible.

ANSWER 7.03 (1.50)

- Remove breathing air mask.
- Isolate air line manifold supply valve.
- Don an air pack.
- Evacuate CR to shutdown/cooldown the unit.

[3 of 4 required with each worth 0.50 point each]

REFERENCE

QOA 5750-13, TOXIC AIR OR SMOKE IN THE CONTROL ROOM, Rev. 5, pgs. 1-2
IE Rpt No. 50-254/87019 (DRP) dtd 10-15-87, pg. 10
LER 87014, Rev. 0
294001K113 294001K111 ..(KA's)

QOA 010-5, PLANT OPERATION WITH THE CONTROL ROOM INACCESSIBLE, Rev. 4.

ANSWER 7.04 (3.00)

a. As RPV water level is lowered, the driving head for natural circulation is decreased [0.5]. The resultant reduction in core flow causes an increase in void fraction to add negative reactivity to the core [0.5].

b. To continue attempts to achieve reactor shutdown [1.0].

c. Flow stagnation water level;
OR
lowest water level in the downcomer region, which can support natural circulation flow through the steam seperators with no control rod insertion from a 100% power control rod pattern and no boron injection;
OR
top of the active fuel [1.0].
(Any of these answers is acceptable for full credit).

REFERENCE

QGA 500-7, LEVEL/POWER CONTROL, Rev. 1, pg.3.
Emergency Operating Procedures (QGAs) Lesson Plan, pg. 125.
GE Emergency Operating Procedure Fundamentals, pg. C7-2.
295037K303 295037K209 295037K102 293008K134 293008K121
..(KA's)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

ANSWER 7.05 (3.00)

a. to ensure that steam will not be discharged directly into the air space of the suppression chamber. [1.00]

b. (1). At least 50 psig is needed to keep the relief valves open. (Emergency depressurization can be considered complete below this value). [1.00]

(2). This is the minimum number required to attain the depressurization rate needed to maintain peak cladding temperature less than 1500 degrees F. [1.00]

REFERENCE

QGA 500-2, EMERGENCY REACTOR PRESSURE VESSEL (RPV) DEPRESSURIZATION, Rev. 1, pg. 3.
GE Emergency Operating Procedure Fundamentals, pg. C2-1.
Emergency Operating Procedures (QGAs) Lesson Plan, pg. 97.
218000G007 295030K301 295030K208 295025A204 218000K302
..(KA's)

ANSWER 7.06 (1.50)

- HPCI flow controller (2340-1)
- Off-gas panel (901-54 (902-54))
- process radiation monitor panel (901-10 (902-10))
- RPIS, rod select, RWM
- feedwater level control system
- process computer
- control room panels 90X-3, 5, 6, and 7
- process radiation recorder (panel 912-4)
- PCI relay panel (901-17 (902-17))
- SRM, IRM, APRM recorders
- RCIC flow controller and testable check valve
- YARWAY narrow range level instrumentation
- main steam relief and safety valve acoustic position monitors

(Alternate correct answers will be acceptable).
[Any 5 worth 0.30 point each]

REFERENCE

QOA 6800-3, 120/240 VAC ESSENTIAL SERVICE BUS FAILURE, Rev. 8, pgs. 3 & 4.
Quad Cities SRO Repl Exam, Question No. 7.01.b, Ref. No. N-NOLR-SRO-C-85.
262002K305 262002K303 262002K302 262002K301 ..(KA's)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

ANSWER 7.07 (2.50)

- Reduce loads as necessary.
- Trip EGC and return to MANUAL flow control.
- Reduce recirculation flow at least 20% speed.
- Place RWM mode switch in the BYPASS position. (QOP 207-2 is not required to be completed.)
- Insert control rods starting at the present location in sequence and work backwards.
- Any rods inserted should be continuously inserted all the way to position 00.
- Check flow control line (FCL) and continue control rod insertion until the reactor is under the 100% FCL.
- Monitor reactor power and water level.
- Verify 'A' heater string isolates and bypass opens.
- If reactor power is low enough to permit operation in two heater strings (Note: it will be) prevent heat bypass opening by putting bypass valve control switch to PULL-TO-STOP. As soon as 'A' heater level is reduced, return switch to normal. Notify Shift Engineer if switch position is off normal.

[5 of 10 required at 0.50 pt each]

REFERENCE

QOA 3500-1, LOSS OF FEEDWATER HEATERS, Rev. 4, pg. 2
Feedwater Heater LIC-3200-2, Rev. 1, pg. 24
P&ID M-61, Diagram of Extraction Steam Piping, Rev. H
259001G014 ..(KA's)

ANSWER 7.08 (1.00)

a. Control rod with an inoperable accumulator is inserted 'full in.' (0.5)

b. Its directional control valves are electrically disarmed. (0.5)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

REFERENCE

QOP 300-10, CRD SYSTEM ACCUMULATOR GAS DISCHARGING, Section E.2, Rev. 4, pg. 1
Technical Specification 3.3.D
201001G001 ..(KA's)

ANSWER 7.09 (1.50)

a. 60 +/- 6 minutes
b. 3 +/- 0.5 minutes
c. immediately TRIP unit
[0.5 pts each]

REFERENCE

QOA 5300-1, LOSS OF STATOR COOLING, Section C, Revision 4, pg. 1
245000K605 245000K303 ..(KA's)

ANSWER 7.10 (1.00)

The release rate of radioactive iodine increases due to the iodine spiking phenomenon.

REFERENCE

QOA 5400-1, Off-Gas Explosion - Recombiner and Filters Bypassed, Section E, Rev. 6, pg. 3
271000K102 ..(KA's)

ANSWER 7.11 (1.00)

a. ~~LESS~~ MORE THAN. (Unit 1 factor is 0.70; and Unit 2 factor is 0.84).
b. MORE THAN. (Unit 1 change is 0.03 compared to 0.01 for Unit 2).
c SAME AS. (Unit 1 and Unit 2 set points all are reduced by 3.5%).
LESS THAN

REFERENCE

Unit 1 TS License Condition, Item K, Am. 73 (6/30/81), pg. 6.
Unit 2 TS 3.6.H.3., Amendment No. 95, pg. 3.6/4.6-5a.
202001G001 ..(KA's)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

ANSWER 7.12 (1.00)

Structural damage may occur to the condenser (if level is exceeded and additional structural support is not installed). ~~(1.0)~~ Circulating water pumps are OR running [1.0].

REFERENCE

QOP 201-1, Draining The Reactor Vessel and Recirculation Loops, Section F.2.a, Rev. 4, pg. ~~2~~ 3
245000G001 ..(KA's)

ANSWER 7.13 (1.00)

Electrical disarm is preferred because drive water does ~~not~~ S cool [0.5] and it minimizes crud accumulation in the drive [0.5].

REFERENCE

QOP 300-7, CRD System, Drive Disarmament, Rev. 1
QOP 300-8, CRD System, Hydraulic Control Module Isolation, Rev. 7
Unit 2 TS Basis 3.3.A.2, Amendment No. 21, pg. 3.3/4.3-7
201003G001 201003G006 ..(KA's)

ANSWER 7.14 (1.50)

a. Reactor is in Cold Shutdown Condition.

b. All control rods are fully inserted.

c. Core loading is limited (to that which can be made subcritical in the most reactive condition during the operating cycle with the strongest operable control rod in its full out position and all other operable rods fully inserted). (Alternate wording is acceptable).

[0.50 pt each]

REFERENCE

QOP 1100-1, Standby Operation of SLCS, Section E.1, Rev. 6, pg. 1
Units 1 and 2 TS 3.4.A
211000G005 211000G001 ..(KA's)

(***** CATEGORY 7 CONTINUED ON NEXT PAGE *****)

ANSWER 7.15 (1.50)

a. re-pressurization
b. biofouling (other possible answers are "fouling" and "plugging")
c. shell

(0.5 pts each)

REFERENCE

QOP 1000-5, Shutdown Cooling Startup and Operation, Sections D.6, D.8, and E.2, Rev. 13, pg. 2-3
205000K114 205000K115 205000K101 ..(KA's)

ANSWER 7.16 (2.00)

a. RPV water level must be reduced to verify proper level instrument response. [1.0]

b. To ensure adequate core cooling. [1.0] (Correct definitions of Maximum Core Uncovery Time Limit will also be given full credit).

REFERENCE

QGA 500-6, REACTOR PRESSURE VESSEL FLOODING, pg. 15.
GE Emergency Operating Procedure Fundamentals, pg. C6-6.
Emergency Operating Procedure (QGAs) Lesson Plan, pg. 119.
295031K201 295031K101 295024K305 216000K501 216000K324
..(KA's)

(***** END OF CATEGORY 7 *****)

ANSWER 8.01 (1.00)

a. [1.00]

REFERENCE

QGA-00, QGA MANUAL PREFACE, Rev. 3, pgs. 1-3
295031K305 295026G005 295026A202 ..(KA's)

ANSWER 8.02 (1.00)

a. [1.00]

REFERENCE

QAP 500-9, PREVENTATIVE MAINTENANCE, Sec. C.4.a, Rev. 2, pg. 2.
294001K117 294001K106 ..(KA's)

ANSWER 8.03 (1.00)

- the blowdown area would increase. [0.50]
- eliminate the capability of reflooding the core. [0.50]

REFERENCE

Unit 1 TS BASIS 3.6.G, no Amendment No. listed, pg. 3.6/4.6-23.
Unit 2 TS BASIS 3.6.G, Amendment No. 95, pg. 3.6/4.6-13.
Quad Cities SRO Repl Exam, Question 8.10.a, date unknown.
202001G006 ..(KA's)

ANSWER 8.04 (1.00)

b. [1.00]

REFERENCE

IE Rpt No. 50-254/87019 (DRP) dtd 10-15-87 for closing violation 254/87008-01, pg. 3
10 CFR 50.72
290003G003 ..(KA's)

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

ANSWER 8.05 (1.50)

- Acts as a backup to the main stop valve closure scram [0.50] such that the pressure and neutron flux transient is less severe [0.50].

- When not in the 'RUN' mode. [0.50]

REFERENCE

Quad Cities Lesson Plan, REACTOR PROTECTION SYSTEM, LIC-0500-1, Rev. 1, pg. 30.
Unit 2 TS BASIS, Amendment No. 86, pg. 3.1/4.1-3.
Quad Cities, SRO SRO Requal Exam, N-NOLR-SRO-B-85, Question No. 8.05, Items a & c.
212000G006 212000K412 212000K111 ..(KA's)

ANSWER 8.06 (1.00)

7.5 +/- 2.5 gpm [0.50]
200 +/- 10 degrees F [0.50]

REFERENCE

Unit 1 TS BASIS, no Amendment No. listed, pg. 3.2/4.2-8.
239001K114 ..(KA's)

ANSWER 8.07 (1.50)

a. False (1/4 inch)
b. True
c. False (99% efficiency)
[0.50 point each]

REFERENCE

Unit 2 TS BASIS 4.7.C, Amendment No. 34, pg. 3.7/4.7-17.
290001K104 290001G006 ..(KA's)

ANSWER 8.08 (1.00)

Lowering the reactor vessel low water level scram would increase the capability requirement of each of the ECCS components. [1.00]

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

REFERENCE

Unit 1 TS BASIS, no Amendment No. listed, pg. 1.1/2.1-14.
259002G006 ..(KA's)

ANSWER 8.09 (1.00)

... to anticipate actuation of any Engineered Safety Feature. [1.00]

REFERENCE

QAP 900-5, IN-PLANT RADIOGRAPHY--REQUIRED NOTIFICATIONS AND ACTIONS, Rev. 2, Section C.1.b.
50-265 LER 86018, Rev. 0
294001K103 ..(KA's)

ANSWER 8.10 (1.50)

- Severe weather conditions threaten safe transport.
- A significant radiological hazard would be encountered.
- There is a security threat occurring which would have an adverse impact on the personnel while leaving the site.
- A condition similar to these in magnitude which, in the opinion of the Station Director, CCC Director, or Manager of Emergency Operations, would adversely affect the site personnel.

[0.50 point each for any 3 items]

REFERENCE

GSEP, Section 6.4.3.1, Rev. 6, pg. 6-35
294001A116 ..(KA's)

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

QUESTION	VALUE	REFERENCE
5.01	1.00	ZZZ0000001
5.02	3.00	ZZZ0000002
5.03	1.00	ZZZ0000003
5.04	1.00	ZZZ0000004
5.05	1.00	ZZZ0000005
5.06	2.00	ZZZ0000006
5.07	1.25	ZZZ0000007
5.08	1.50	ZZZ0000008
5.09	1.00	ZZZ0000009
5.10	2.00	ZZZ0000010
5.11	1.00	ZZZ0000011
5.12	1.00	ZZZ0000012
5.13	1.75	ZZZ0000013
5.14	1.00	ZZZ0000014
5.15	2.00	ZZZ0000015
5.16	1.50	ZZZ0000016
5.17	1.00	ZZZ0000017
5.18	1.50	ZZZ0000018
	25.50	
6.01	1.50	ZZZ0000019
6.02	1.50	ZZZ0000020
6.03	1.50	ZZZ0000021
6.04	1.00	ZZZ0000022
6.05	1.50	ZZZ0000023
6.06	1.00	ZZZ0000024
6.07	0.75	ZZZ0000025
6.08	4.00	ZZZ0000026
6.09	1.00	ZZZ0000027
6.10	2.50	ZZZ0000028
6.11	2.00	ZZZ0000029
6.12	1.00	ZZZ0000030
6.13	2.10	ZZZ0000031
6.14	1.50	ZZZ0000032
6.15	1.50	ZZZ0000033
6.16	1.25	ZZZ0000034
6.17	0.50	ZZZ0000035
	26.10	
7.01	1.50	ZZZ0000036
7.02	1.50	ZZZ0000037
7.03	1.50	ZZZ0000038
7.04	3.00	ZZZ0000039
7.05	3.00	ZZZ0000040
7.06	1.50	ZZZ0000041
7.07	2.50	ZZZ0000042
7.08	1.00	ZZZ0000043
7.09	1.50	ZZZ0000044
7.10	1.00	ZZZ0000045
7.11	1.00	ZZZ0000046
7.12	1.00	ZZZ0000047
7.13	1.00	ZZZ0000048
7.14	1.50	ZZZ0000049

QUESTION	VALUE	REFERENCE
7.15	1.50	ZZZ0000050
7.16	2.00	ZZZ0000051
	26.00	
8.01	1.00	ZZZ0000052
8.02	1.00	ZZZ0000053
8.03	1.00	ZZZ0000054
8.04	1.00	ZZZ0000055
8.05	1.50	ZZZ0000056
8.06	1.00	ZZZ0000057
8.07	1.50	ZZZ0000058
8.08	1.00	ZZZ0000059
8.09	1.00	ZZZ0000060
8.10	1.50	ZZZ0000061
8.11	1.00	ZZZ0000062
8.12	1.00	ZZZ0000063
8.13	1.00	ZZZ0000064
8.14	2.00	ZZZ0000065
8.15	0.50	ZZZ0000066
8.16	1.00	ZZZ0000067
8.17	1.25	ZZZ0000068
8.18	1.50	ZZZ0000069
8.19	1.00	ZZZ0000070
8.20	1.00	ZZZ0000071
8.21	1.50	ZZZ0000072
8.22	0.50	ZZZ0000073
	24.75	
	102.3	

QUESTION	VALUE	REFERENCE
5.01	1.00	ZZZ0000001
5.02	3.00	ZZZ0000002
5.03	1.00	ZZZ0000003
5.04	1.00	ZZZ0000004
5.05	1.00	ZZZ0000005
5.06	2.00	ZZZ0000006
5.07	1.25	ZZZ0000007
5.08	1.50	ZZZ0000008
5.09	1.00	ZZZ0000009
5.10	2.00	ZZZ0000010
5.11	1.00	ZZZ0000011
5.12	1.00	ZZZ0000012
5.13	1.75	ZZZ0000013
5.14	1.00	ZZZ0000014
5.15	2.00	ZZZ0000015
5.16	1.50	ZZZ0000016
5.17	1.00	ZZZ0000017
5.18	1.50	ZZZ0000018
	25.50	
6.01	1.50	ZZZ0000019
6.02	1.50	ZZZ0000020
6.03	1.50	ZZZ0000021
6.04	1.00	ZZZ0000022
6.05	1.50	ZZZ0000023
6.06	1.00	ZZZ0000024
6.07	0.75	ZZZ0000025
6.08	4.00	ZZZ0000026
6.09	1.00	ZZZ0000027
6.10	2.50	ZZZ0000028
6.11	2.00	ZZZ0000029
6.12	1.00	ZZZ0000030
6.13	2.10	ZZZ0000031
6.14	1.50	ZZZ0000032
6.15	1.50	ZZZ0000033
6.16	1.25	ZZZ0000034
6.17	0.50	ZZZ0000035
	26.10	
7.01	1.50	ZZZ0000036
7.02	1.50	ZZZ0000037
7.03	1.50	ZZZ0000038
7.04	3.00	ZZZ0000039
7.05	3.00	ZZZ0000040
7.06	1.50	ZZZ0000041
7.07	2.50	ZZZ0000042
7.08	1.00	ZZZ0000043
7.09	1.50	ZZZ0000044
7.10	1.00	ZZZ0000045
7.11	1.00	ZZZ0000046
7.12	1.00	ZZZ0000047
7.13	1.00	ZZZ0000048
7.14	1.50	ZZZ0000049

QUESTION	VALUE	REFERENCE
7.15	1.50	ZZZ0000050
7.16	2.00	ZZZ0000051
	26.00	
8.01	1.00	ZZZ0000052
8.02	1.00	ZZZ0000053
8.03	1.00	ZZZ0000054
8.04	1.00	ZZZ0000055
8.05	1.50	ZZZ0000056
8.06	1.00	ZZZ0000057
8.07	1.50	ZZZ0000058
8.08	1.00	ZZZ0000059
8.09	1.00	ZZZ0000060
8.10	1.50	ZZZ0000061
8.11	1.00	ZZZ0000062
8.12	1.00	ZZZ0000063
8.13	1.00	ZZZ0000064
8.14	2.00	ZZZ0000065
8.15	0.50	ZZZ0000066
8.16	1.00	ZZZ0000067
8.17	1.25	ZZZ0000068
8.18	1.50	ZZZ0000069
8.19	1.00	ZZZ0000070
8.20	1.00	ZZZ0000071
8.21	1.50	ZZZ0000072
8.22	0.50	ZZZ0000073
	24.75	
	102.3	

ANSWER 8.11 (1.00)

- It is impractical to modify the equipment or procedure to allow testing in a normal alignment.
- The test is per a regular procedure.
- An operator is available to return the switch immediately when the test is completed or if interrupted.

[0.50 point each for any 2 items]

REFERENCE

QAP 300-2, CONDUCT OF SHIFT OPERATIONS, Sec. C.8.b(3), Rev. 19, pg. 5.
294001K106 ..(KA's)

ANSWER 8.12 (1.00)

c. [1.00 point]

REFERENCE

QAP 300-22, WATER CHEMISTRY CONTROL, Sec. C, Rev. 4.
294001A114 294001A116 ..(KA's)

ANSWER 8.13 (1.00)

- The SCRE ^will consider initiating training of shift personnel. [0.50]
- The SCRE will ^ensure the Shift Engineer receives an authorized copy of the temporary procedure. [0.50]

REFERENCE QAP 300-27, Revision 1, Operations DEPARTMENT Procedure REVISION TRAINING

QAP 1100-5, TEMPORARY PROCEDURES AND TEMPORARY CHANGES TO PERMANENT PROCEDURES, Sec. C.6, Rev. 17, pg. 2.
294001K106 ..(KA's)

- If training is determined to be necessary, the SCRE will attach a copy of the temporary procedure & the appropriate list of names of personnel needing training.
- If training was necessary, the SCRE will ensure that the proper training is completed within one (1) week.
- If training was done, the SCRE will file list of names of personnel receiving training.

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

ANSWER 8.14 (2.00)

a. False.
b. False.
c. False.
d. True.
[0.50 point each]

REFERENCE

QAP 1120-6, ENTERING A LOCKED HIGH RADIATION AREA WITHOUT A TIMEKEEPER, Sec. C, Rev. 9, pgs. 2 & 3.
94001K103 ..(KA's)

ANSWER 8.15 (0.50)

20 (or less) minutes. [0.50]

REFERENCE

QAP 1170-14, FIRE WATCH RESPONSIBILITIES, Sec. C.4, Rev. 1, pg. 1.
294001K116 ..(KA's)

ANSWER 8.16 (1.00)

a. be within 10 minutes of the control room. [0.50]
b. be able to be reached immediately. [0.50]

REFERENCE

QAP 300-1, OPERATIONS DEPARTMENT ORGANIZATION, Sec. C.3.b, Rev. 15, pg. 2.
294001A103 ..(KA's)

ANSWER 8.17 (1.25)

This margin is demonstrated by full withdrawal of the strongest rod [0.50] and partial withdrawal of an adjacent rod [0.50] to exceed a calculated margin (R + 0.25% delta K) [0.25].

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

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REFERENCE

QOP 300-14, CONTROL ROD OR CRD MAINTENANCE, Sections C.6 & F.1, Rev. 7.
Unit 2 TS BASIS, 3.3.A.1, Amendment No. 21, pg. 3.3/4.3-7.
201001G006 ..(KA's)

ANSWER 8.18 (1.50)

To assure that the maximum in sequence individual control rod or control rod segments which are withdrawn [0.50] could not be worth enough to cause the rod drop accident design limit (280 cal/gm) to be exceeded [0.50], if the rods were to drop out of the core in a manner defined for the rod drop accident [0.50]. Alternate wording is acceptable.

REFERENCE

Unit 1 TS BASIS 3.3.B.3, pg. 3.3/4.3-11, No Amendment No. listed.
215004G006 ..(KA's)

ANSWER 8.19 (1.00)

c. [1.00]

REFERENCE

QAP 300-14, EQUIPMENT CUT-OF-SERVICE, Sec. C.13, Rev. 14, pg. 3.
294001K102 294000K101 ..(KA's)

ANSWER 8.20 (1.00)

a. 30 +/- 5 %
b. 30 +/- 5 days
[0.50 point for each item]

REFERENCE

QAP 300-19, REVIEW OF ACTIVE OUT-OF-SERVICES, Sec. C.2, Rev. 7, pg. 1.
294001K102 ..(KA's)

(***** CATEGORY 8 CONTINUED ON NEXT PAGE *****)

ANSWER 8.21 (1.50)

a. Station Manager
b. Shift Foreman.
c. Radwaste Foreman.
[0.50 point each]

REFERENCE

QAP 1180-17, FIRE PROTECTION PROGRAM, Sections C.b(1), C.b(5), & C.b(6), Rev. 1, pgs. 2 & 4.
294001K116 ..(KA's)

ANSWER 8.22 (0.50)

Station Industrial Hygiene Advisor. [0.50]
or the actual name of the Station Industrial Hygiene Advisor provided by the facility

REFERENCE

QAP 1150-6, ACCESS TO CONFINED SPACES, Sec. C.2.a, Rev. 4, pg. 1.
294001K114 ..(KA's)

(***** END OF CATEGORY 8 *****)
(********** END OF EXAMINATION **********)

DATA SHEET

REACTOR THEORY EQUATIONS:

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

$$P = \frac{\Sigma \phi_{th} V}{3.12 \times 10^{10} \text{ fissions/sec}}$$

$$P_{th} = \frac{1}{1 + (B^2 L_{th}^2)} = e^{-(B^2 L_{th}^2)}$$

$$P_f = e^{-(B^2 L_f^2)}$$

$$p = e^{-[N][I_{eff}]/\S\Sigma_s}$$

$$C_1 (1-K_{eff1}) = C_2 (1-K_{eff2})$$

$$m = \frac{1}{1-K} = \frac{C_{final}}{C_{initial}}$$

$$\alpha_T = \frac{1}{f}\frac{\Delta f}{\Delta t} + \frac{1}{p}\frac{\Delta p}{\Delta t} - B^2 \left(\frac{\Delta L_f^2}{\Delta t} + \frac{\Delta L_{th}^2}{\Delta t}\right)$$

$$K_{eff} = \epsilon P_f p P_{th} f \eta$$

$$P = P_0 10^{SUR(t)}$$

$$SUR = 26.06/\tau$$

$$\rho = \frac{l^*}{\tau} + \frac{\bar{\beta}_{eff}}{1 + \tau}$$

$$\rho = \frac{K - 1}{K}$$

$$\Delta\rho = \ln \frac{K_{final}}{K_{initial}}$$

$$\tau = \frac{\bar{\beta}_{eff} - \rho}{\lambda\rho}$$

$$\tau = \frac{l^*}{\rho}$$

$$P_1 = P_0 \frac{\bar{\beta}_{eff} - \rho_0}{\bar{\beta}_{eff} - \rho_1}$$

DATA SHEET

THERMODYNAMICS AND FLUID MECHANICS FORMULAS:

$$\dot{Q} = \dot{m}\,\Delta h$$

$$\dot{Q} = U A (\Delta T_m)$$

$$\dot{Q} = \dot{m} c_p (\Delta T)$$

$$\eta = \frac{\dot{Q}_{in} - \dot{Q}_{out}}{\dot{Q}_{in}}$$

$$\eta_p = \frac{W_{actual}}{W_{supplied}}$$

$$\dot{m} = \rho A V$$

$$\dot{m} = KA \sqrt{\Delta P_x \rho}$$

$$\Delta T_m = \frac{\Delta T\ (in) - \Delta T\ (out)}{\ln\left(\frac{\Delta T\ (in)}{\Delta T\ (out)}\right)}$$

$$T_{cl} - T_{ps} = \frac{Gr^2}{4k}$$

$$\dot{Q} = \frac{A\,\Delta T_{total}}{\frac{\Delta x_a}{K_a} + \frac{\Delta x_b}{K_b} + \ldots + \frac{\Delta x_n}{K_n}}$$

$$\dot{Q} = \frac{2\pi L \Delta T}{\frac{1}{K} + \frac{\ln R_2/R_1}{K_2} + \frac{\ln R_3/R_2}{K_3}}$$

$$\dot{Q} = \alpha \delta A R^4$$

$$\eta = \frac{(h_{in} - h_{out})_{real}}{(h_{in} - h_{out})_{ideal}}$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\rho_1 A_1 V_1 = \rho_2 A_2 V_2$$

$$\dot{m}_{nc} = KA_Q \sqrt[3]{\dot{Q}} = KA\,\Delta T \sqrt{\Delta T} = KA\,\Delta p \sqrt{\Delta P}$$

$$G = \frac{\Sigma_f \delta_{th}}{8.8 \times 10^9}$$

$$\dot{Q} = \frac{kA\Delta T}{\Delta x}$$

DATA SHEET

CENTRIFUGAL PUMP LAWS:

$$\frac{N_1}{N_2} = \frac{\dot{m}_1}{\dot{m}_2} \qquad \frac{(N_1)^2}{(N_2)^2} = \frac{H_1}{H_2} \qquad \frac{(N_1)^3}{(N_2)^3} = \frac{P_1}{P_2}$$

RADIATION AND CHEMISTRY FORMULAS:

$R/hr = 6CE/d^2$ $\qquad I_x = I_0 e^{-mx}$ $\qquad C_1V_1 = C_2V_2$

$G = \frac{\text{Dilution Rate}}{\text{Volume}}$ $\qquad I = I_0 \frac{(i)}{10}^n$ $\qquad C = C_0 e^{-Gt}$

$A = A_0 e^{-\lambda t}$ $\qquad A = \lambda N$

CONVERSIONS:

1 gm/cm^3 = 62.4 lbm/ft^3 — Density of water (20 C) = 62.4 lbm/ft^3

1 gal = 8.345 lbm

1 ft^3 = 7.48 gal — Avogadro's Number = 6.023×10^{23}

1 gal = 3.78 liters — Heat of Vapor (H_2O) = 970 Btu/lbm

1 lbm = 454 grams — Heat of Fusion (ICE) = 144 Btu/lbm

e = 2.72 — 1 AMU = 1.66×10^{-24} grams

π = 3.14159 — Mass of Neutron = 1.008665 AMU

1 KW = 738 ft-lbf/sec — Mass of Proton = 1.007277 AMU

1 KW = 3413 Btu/hr — Mass of Electron = 0.000549 AMU

1 HP = 550 ft-lbf/sec — One atmosphere = 14.7 psia = 29.92 in. Hg

1 HP = .746 KW — °F = 9/5 °C + 32

1 HP = 2545 Btu/hr — °C = 5/9 (°F - 32)

1 Btu = 778 ft-lbf — °R = °F + 460

1 MEV = 1.54×10^{-16} Btu — °K = °C + 273

h = 6.13×10^{-21} M-sec

1 W = 3.12×10^{10} fissions/sec

g_c = 32.2 lbm-ft/lbf-sec^2 — c^2 = 931 MEV/AMU

1 inch = 2.54 cm — C = 3×10^8 m/sec

σ = 0.1714×10^{-8} Btu/hr ft^2 R^4

DATA SHEET

AVERAGE THERMAL CONDUCTIVITY (K)

Material	K
Cork	0.025
Fiber Insulating Board	0.028
Maple or Oak Wood	0.096
Building Brick	0.4
Window Glass	0.45
Concrete	0.79
1% Carbon Steel	25.00
1% Chrome Steel	35.00
Aluminum	118.00
Copper	223.00
Silver	235.00
Water (20 psia, 200 degrees F)	0.392
Steam (1000 psia, 550 degrees F)	0.046
Uranium Dioxide	1.15
Helium	0.135
Zircaloy	10.0

MISCELLANEOUS INFORMATION:

$E = mc^2$

$KE = 1/2\ mv^2$

$PE = mgh$

$V_f = V_0 + at$

Geometric Object	Area	Volume
Triangle	$A = 1/2\ bh$	////////////////////
Square	$A = S^2$	////////////////////
Rectangle	$A = L \times W$	////////////////////
Circle	$A = \pi r^2$	////////////////////
Rectangular Solid	$A = 2(L \times W + L \times H + W \times H)$	$V = L \times W \times H$
Right Circular Cylinder	$A = (2\ \pi r^2)h + 2(\pi r^2)$	$V = \pi r^2 h$
Sphere	$A = 4\ \pi r^2$	$V = 4/3\ (\pi r^2)$
Cube	////////////////////////////////	$V = S^3$

DATA SHEET

MISCELLANEOUS INFORMATION (continued):

Material	Half-Life	Gamma Energy MEV per Disintegration		10 CFR 20 Appendix B Table I Col I Air uc/ml	Table I Col II Water uc/ml	Table II Col I Air uc/ml	Table II Col II Water uc/ml
Ar-41	1.84 h	1.3	Sub	2×10^{-6}	-----	4×10^{-8}	------
Co-60	5.27 y	2.5	S	3×10^{-7}	1×10^{-3}	1×10^{-8}	5×10^{-5}
I-131	8.04 d	0.36	S	9×10^{-9}	6×10^{-5}	1×10^{-10}	3×10^{-7}
Kr-85	10.72 y	0.04	Sub	1×10^{-5}	-----	3×10^{-7}	------
Ni-65	2.52 h	0.59	S	9×10^{-7}	4×10^{-3}	3×10^{-8}	1×10^{-4}
Pu-239	2.41×10^{4} y	0.008	S	2×10^{-12}	1×10^{-4}	6×10^{-14}	5×10^{-6}
Sr-90	29 y	-----	S	1×10^{-9}	1×10^{-5}	3×10^{-11}	3×10^{-7}
Xe-135	9.09 h	0.25	Sub	4×10^{-6}	-----	1×10^{-7}	------
Any single radionuclide with $T_{1/2}$ > 2 hr which does not decay by alpha or spontaneous fission				3×10^{-9}	9×10^{-5}	1×10^{-10}	3×10^{-6}

Neutron Energy (MEV)	Neutrons per cm^2 equivalent to 1 rem	Average flux to deliver 100 mrem in 40 hours
thermal	970×10^{6}	670
0.02	400×10^{6}	280 (neutrons)
0.5	43×10^{6}	30 ----------
10	24×10^{6}	17 cm^2 x sec

Linear Absorption Coefficients μ (cm^{-1})				
Energy (MEV)	Water	Concrete	Iron	Lead
0.5	0.090	0.21	0.63	1.7
1.0	0.067	0.15	0.44	0.77
1.5	0.057	0.13	0.40	0.57
2.0	0.048	0.11	0.33	0.51
2.5	0.042	0.097	0.31	0.49
3.0	0.038	0.088	0.30	0.47

Table 1. Saturated Steam: Temperature Table

Temp Fahr t	Abs Press Lb per Sq In p	Specific Volume Sat Liquid v_f	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat Vapor s_g	Temp Fahr t
32.0*	0.08859	0.016022	3304.7	3304.7	−0.0179	1075.5	1075.5	0.0000	2.1873	2.1873	32.0*
34.0	0.09600	0.016021	3061.9	3061.9	1.996	1074.4	1076.4	0.0041	2.1762	2.1802	34.0
36.0	0.10395	0.016020	2839.0	2839.0	4.008	1073.2	1077.2	0.0081	2.1651	2.1732	36.0
38.0	0.11249	0.016019	2634.1	2634.2	6.018	1072.1	1078.1	0.0122	2.1541	2.1663	38.0
40.0	0.12163	0.016019	2445.8	2445.8	8.027	1071.0	1079.0	0.0162	2.1432	2.1594	40.0
42.0	0.13143	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	42.0
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	44.0
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	46.0
48.0	0.16514	0.016021	1830.0	1830.0	16.051	1066.4	1082.5	0.0321	2.1006	2.1327	48.0
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	50.0
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	52.0
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	56.0
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	58.0
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	60.0
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	62.0
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	64.0
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	66.0
68.0	0.33889	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	68.0
70.0	0.36292	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	70.0
72.0	0.38844	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	72.0
74.0	0.41550	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9708	2.0529	74.0
76.0	0.44420	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	76.0
78.0	0.47461	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	78.0
80.0	0.50683	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0359	80.0
82.0	0.54093	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	82.0
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	84.0
86.0	0.61518	0.016087	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	392.8	392.9	64.006	1039.3	1103.3	0.1224	1.8704	1.9928	96.0
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	98.0
100.0	0.94924	0.016130	350.4	350.4	67.999	1037.1	1105.1	0.1295	1.8530	1.9825	100.0
102.0	1.00789	0.016137	331.1	331.1	69.995	1035.9	1105.9	0.1331	1.8444	1.9775	102.0
104.0	1.06965	0.016144	313.1	313.1	71.992	1034.8	1106.8	0.1366	1.8358	1.9725	104.0
106.0	1.1347	0.016151	296.16	296.18	73.99	1033.6	1107.6	0.1402	1.8273	1.9675	106.0
108.0	1.2030	0.016158	280.23	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	2.1066	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	0.015265	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	2.8890	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	0.016374	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	62.06	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2734	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5650	0.016474	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8676	0.016486	54.59	54.61	143.99	992.6	1136.6	0.2568	1.5616	1.8184	176.0
178.0	7.1815	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

*Use data above for metastable

Table 1. Saturated Steam: Tempereture 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
202.0	12.512	0.016664	31.135	31.151	172.11	975.4	1147.5	0.3001	1.4697	1.7698	202.0
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	0.017192	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	1185.3	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	1.3781	405.7	798.0	1203.7	0.6014	0.8990	1.5004	428.0
432.0	351.00	0.01913	1.30066	1.32179	410.1	793.9	1204.0	0.6063	0.8903	1.4966	432.0
436.0	366.03	0.01919	1.24881	1.26800	414.6	789.7	1204.2	0.6112	0.8816	1.4928	436.0
440.0	381.56	0.01926	1.19961	1.21687	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440.0
444.0	397.56	0.01933	1.15284	1.16816	423.5	781.1	1204.6	0.6210	0.8643	1.4853	444.0
448.0	414.06	0.01940	1.10832	1.12152	428.0	776.7	1204.7	0.6259	0.8557	1.4815	448.0
452.0	431.14	0.01947	1.06596	1.07711	432.5	772.3	1204.8	0.6308	0.8471	1.4778	452.0
456.0	448.73	0.01954	1.01558	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	Specific Volume Evap v_{fg}	Specific Volume Sat Vapor v_g	Enthalpy Sat Liquid h_f	Enthalpy Evap h_{fg}	Enthalpy Sat Vapor h_g	Entropy Sat Liquid s_f	Entropy Evap s_{fg}	Entropy Sat Vapor s_g	Temp Fahr t
460.0	466.87	0.01961	0.97463	0.99424	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460.0
464.0	485.56	0.01969	0.93588	0.95557	446.1	758.6	1204.7	0.6454	0.8213	1.4667	464.0
468.0	504.83	0.01976	0.89885	0.91862	450.7	754.0	1204.6	0.6502	0.8127	1.4629	468.0
472.0	524.67	0.01984	0.86345	0.88329	455.2	749.3	1204.5	0.6551	0.8042	1.4592	472.0
476.0	545.11	0.01992	0.82958	0.84950	459.9	744.5	1204.3	0.6599	0.7956	1.4555	476.0
480.0	566.15	0.02000	0.79716	0.81717	464.5	739.6	1204.1	0.6648	0.7871	1.4518	480.0
484.0	587.81	0.02009	0.76613	0.78622	469.1	734.7	1203.8	0.6696	0.7785	1.4481	484.0
488.0	610.10	0.02017	0.73641	0.75658	473.8	729.7	1203.5	0.6745	0.7700	1.4444	488.0
492.0	633.03	0.02026	0.70794	0.72820	478.5	724.6	1203.1	0.6793	0.7614	1.4407	492.0
496.0	656.61	0.02034	0.68065	0.70100	483.2	719.5	1202.7	0.6842	0.7528	1.4370	496.0
500.0	680.86	0.02043	0.65448	0.67492	487.9	714.3	1202.2	0.6890	0.7443	1.4333	500.0
504.0	705.78	0.02053	0.62938	0.64991	492.7	709.0	1201.7	0.6939	0.7357	1.4296	504.0
508.0	731.40	0.02062	0.60530	0.62592	497.5	703.7	1201.1	0.6987	0.7271	1.4258	508.0
512.0	757.72	0.02072	0.58218	0.60289	502.3	698.2	1200.5	0.7036	0.7185	1.4221	512.0
516.0	784.76	0.02081	0.55997	0.58079	507.1	692.7	1199.8	0.7085	0.7099	1.4183	516.0
520.0	812.53	0.02091	0.53864	0.55956	512.0	687.0	1199.0	0.7133	0.7013	1.4146	520.0
524.0	841.04	0.02102	0.51814	0.53916	516.9	681.3	1198.2	0.7182	0.6926	1.4108	524.0
528.0	870.31	0.02112	0.49843	0.51955	521.8	675.5	1197.3	0.7231	0.6839	1.4070	528.0
532.0	900.34	0.02123	0.47947	0.50070	526.8	669.6	1196.4	0.7280	0.6752	1.4032	532.0
536.0	931.17	0.02134	0.46123	0.48257	531.7	663.6	1195.4	0.7329	0.6665	1.3993	536.0
540.0	962.79	0.02146	0.44367	0.46513	536.8	657.5	1194.3	0.7378	0.6577	1.3954	540.0
544.0	995.22	0.02157	0.42677	0.44834	541.8	651.3	1193.1	0.7427	0.6489	1.3915	544.0
548.0	1028.49	0.02169	0.41048	0.43217	546.9	645.0	1191.9	0.7476	0.6400	1.3876	548.0
552.0	1062.59	0.02182	0.39479	0.41660	552.0	638.5	1190.6	0.7525	0.6311	1.3837	552.0
556.0	1097.55	0.02194	0.37966	0.40160	557.2	632.0	1189.2	0.7575	0.6222	1.3797	556.0
560.0	1133.38	0.02207	0.36507	0.38714	562.4	625.3	1187.7	0.7625	0.6132	1.3757	560.0
564.0	1170.10	0.02221	0.35099	0.37320	567.6	618.5	1186.1	0.7674	0.6041	1.3716	564.0
568.0	1207.72	0.02235	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	1.3420	592.0
596.0	1497.8	0.02345	0.25425	0.27770	611.4	558.8	1170.2	0.8082	0.5293	1.3375	596.0
600.0	1543.2	0.02364	0.24384	0.26747	617.1	550.6	1167.7	0.8134	0.5196	1.3330	600.0
604.0	1589.7	0.02382	0.23374	0.25757	622.9	542.2	1165.1	0.8187	0.5097	1.3284	604.0
608.0	1637.3	0.02402	0.22394	0.24796	628.8	533.6	1162.4	0.8240	0.4997	1.3238	608.0
612.0	1686.1	0.02422	0.21442	0.23865	634.8	524.7	1159.5	0.8294	0.4896	1.3190	612.0
616.6	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	0.3361	1.2425	664.0
668.0	2498.1	0.02858	0.10229	0.13087	731.5	362.1	1093.5	0.9137	0.3210	1.2347	668.0
672.0	2566.6	0.02911	0.09514	0.12424	740.2	345.7	1085.9	0.9212	0.3054	1.2266	672.0
676.0	2636.8	0.02970	0.08799	0.11769	749.2	328.5	1077.6	0.9287	0.2892	1.2179	676.0
680.0	2708.6	0.03037	0.08080	0.11117	758.5	310.1	1068.5	0.9365	0.2720	1.2086	680.0
684.0	2782.1	0.03114	0.07349	0.10463	768.2	290.2	1058.4	0.9447	0.2537	1.1984	684.0
688.0	2857.4	0.03204	0.06595	0.09799	778.8	268.2	1047.0	0.9535	0.2337	1.1872	688.0
692.0	2934.5	0.03313	0.05797	0.09110	790.5	243.1	1033.6	0.9634	0.2110	1.1744	692.0
696.0	3013.4	0.03455	0.04916	0.08371	804.4	212.8	1017.2	0.9749	0.1841	1.1591	696.0
700.0	3094.3	0.03662	0.03857	0.07519	822.4	172.7	995.2	0.9901	0.1490	1.1390	700.0
702.0	3135.5	0.03824	0.03173	0.06997	835.0	144.7	979.7	1.0006	0.1246	1.1252	702.0
704.0	3177.2	0.04108	0.02192	0.06300	854.2	102.0	956.2	1.0169	0.0876	1.1046	704.0
705.0	3198.3	0.04427	0.01304	0.05730	873.0	61.4	934.4	1.0329	0.0527	1.0856	705.0
705.47*	3208.2	0.05078	0.00000	0.05078	906.0	0.0	906.0	1.0612	0.0000	1.0612	705.47*

*Critical temperature

Table 3. Superheated Steam

Abs Press Lb/Sq In (Sat. Temp)		Sat Water	Sat Steam	Temperature – Degrees Fahrenheit 200	250	300	350	400	450	500	600	700	800	900	1000	1100	1200
1 (101.74)	Sh			98.26	148.26	198.26	248.26	298.26	348.26	398.26	498.26	598.26	698.26	798.26	898.26	998.26	1098.26
	v	0.01614	333.6	392.5	422.4	452.3	482.1	511.9	541.7	571.5	631.1	690.7	750.3	809.8	869.4	929.0	988.6
	h	69.73	1105.8	1150.1	1172.9	1195.7	1218.7	1241.8	1265.1	1288.6	1336.1	1384.5	1433.7	1483.8	1534.9	1586.8	1639.7
	s	0.1326	1.9781	1.0509	1.5841	2.1152	2.1445	2.1722	2.1985	2.2237	2.2708	2.3144	2.3551	2.3934	2.4296	2.4640	2.4969
5 (162.24)	Sh			37.76	87.76	137.76	187.76	237.76	287.76	337.76	437.76	537.76	637.76	737.76	837.76	937.76	1037.76
	v	0.01641	73.53	78.14	84.21	90.24	96.25	102.24	108.23	114.21	126.15	138.08	150.01	161.94	173.86	185.78	197.70
	h	130.20	1131.1	1148.6	1171.7	1194.8	1218.0	1241.3	1264.7	1288.2	1335.9	1384.3	1433.6	1483.7	1534.7	1586.7	1639.6
	s	0.2349	1.8443	1.8716	1.9054	1.9369	1.9664	1.9943	2.0208	2.0460	2.0932	2.1369	2.1776	2.2159	2.2521	2.2865	2.3194
10 (193.21)	Sh			6.79	56.79	106.79	156.79	206.79	256.79	306.79	406.79	506.79	606.79	706.79	806.79	906.79	1006.79
	v	0.01659	38.42	38.84	41.93	44.98	48.02	51.03	54.04	57.04	63.03	69.00	74.98	80.94	86.91	92.87	98.84
	h	161.26	1143.3	1146.6	1170.2	1193.7	1217.1	1240.6	1264.1	1287.8	1335.5	1384.0	1433.4	1483.5	1534.6	1586.6	1639.5
	s	0.2836	1.7879	1.7928	1.8273	1.8593	1.8892	1.9173	1.9439	1.9692	2.0166	2.0603	2.1011	2.1394	2.1757	2.2101	2.2430
14.696 (212.00)	Sh				38.00	88.00	138.00	188.00	238.00	288.00	388.00	488.00	588.00	688.00	788.00	888.00	988.00
	v	0.017	26.799		28.42	30.52	32.60	34.67	36.72	38.77	42.86	46.93	51.00	55.06	59.13	63.19	67.25
	h	180.17	1150.5		1168.8	1192.6	1216.3	1239.9	1263.6	1287.4	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4
	s	3121	1.7568		1.7833	1.8158	1.8463	1.8743	1.9010	1.9265	1.9739	2.0177	2.0585	2.0969	2.1332	2.1676	2.2005
15 (213.03)	Sh				36.97	86.97	136.97	186.97	236.97	286.97	386.97	486.97	586.97	686.97	786.97	886.97	986.97
	v	0.01673	26.290		27.837	29.899	31.939	33.963	35.977	37.985	41.986	45.978	49.964	53.946	57.926	61.905	65.882
	h	181.21	1150.9		1168.7	1192.5	1216.2	1239.9	1263.6	1287.3	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4
	s	0.3137	1.7552		1.7809	1.8134	1.8437	1.8720	1.8988	1.9242	1.9717	2.0155	2.0563	2.0946	2.1309	2.1653	2.1982
20 (227.96)	Sh				22.04	72.04	122.04	172.04	222.04	272.04	372.04	472.04	572.04	672.04	772.04	872.04	972.04
	v	0.01683	20.087		20.788	22.356	23.900	25.428	26.946	28.457	31.466	34.465	37.458	40.447	43.435	46.420	49.405
	h	196.27	1156.3		1167.1	1191.4	1215.4	1239.2	1263.0	1286.9	1334.9	1383.5	1432.9	1483.2	1534.3	1586.3	1639.3
	s	0.3358	1.7320		1.7475	1.7805	1.8111	1.8397	1.8666	1.8921	1.9397	1.9836	2.0244	2.0628	2.0991	2.1336	2.1665
25 (240.07)	Sh				9.93	59.93	109.93	159.93	209.93	259.93	359.93	459.93	559.93	659.93	759.93	859.93	959.93
	v	0.01693	16.301		16.558	17.829	19.076	20.307	21.527	22.740	25.153	27.557	29.954	32.348	34.740	37.130	39.518
	h	208.52	1160.6		1165.6	1190.2	1214.5	1238.5	1262.5	1286.4	1334.6	1383.3	1432.7	1483.0	1534.1	1586.2	1639.2
	s	0.3535	1.7141		1.7212	1.7547	1.7856	1.8145	1.8415	1.8672	1.9149	1.9588	1.9997	2.0381	2.0744	2.1089	2.1418
30 (250.34)	Sh					49.66	99.66	149.66	199.66	249.66	349.66	449.66	549.66	649.66	749.66	849.66	949.66
	v	0.01701	13.744			14.810	15.859	16.892	17.914	18.929	20.945	22.951	24.952	26.949	28.943	30.936	32.927
	h	218.93	1164.1			1189.0	1213.6	1237.8	1261.9	1286.0	1334.2	1383.0	1432.5	1482.8	1534.0	1586.1	1639.0
	s	0.3682	1.6995			1.7334	1.7647	1.7937	1.8210	1.8467	1.8946	1.9386	1.9795	2.0179	2.0543	2.0888	2.1217
35 (259.29)	Sh					40.71	90.71	140.71	190.71	240.71	340.71	440.71	540.71	640.71	740.71	840.71	940.71
	v	0.01708	11.896			12.654	13.562	14.453	15.334	16.207	17.939	19.662	21.379	23.092	24.803	26.512	28.220
	h	228.03	1167.1			1187.8	1212.7	1237.1	1261.3	1285.5	1333.9	1382.8	1432.3	1482.7	1533.9	1586.0	1638.9
	s	0.3809	1.6872			1.7157	1.7468	1.7761	1.8035	1.8294	1.8774	1.9214	1.9624	2.0009	2.0372	2.0717	2.1046
40 (267.25)	Sh					32.75	82.75	132.75	182.75	232.75	332.75	432.75	532.75	632.75	732.75	832.75	932.75
	v	0.01715	10.497			11.036	11.838	12.624	13.398	14.165	15.685	17.195	18.699	20.199	21.697	23.194	24.689
	h	236.14	1169.8			1186.6	1211.7	1236.4	1260.8	1285.0	1333.6	1382.5	1432.1	1482.5	1533.7	1585.8	1638.8
	s	0.3921	1.6765			1.6992	1.7312	1.7608	1.7883	1.8143	1.8624	1.9065	1.9476	1.9860	2.0224	2.0569	2.0899
45 (274.44)	Sh					25.56	75.56	125.56	175.56	225.56	325.56	425.56	525.56	625.56	725.56	825.56	925.56
	v	0.01721	9.399			9.777	10.497	11.201	11.892	12.577	13.932	15.276	16.614	17.950	19.282	20.613	21.943
	h	243.49	1172.3			1185.4	1210.4	1235.7	1260.2	1284.6	1333.3	1382.3	1431.9	1482.3	1533.6	1585.7	1638.7
	s	0.4021	1.6671			1.6849	1.7173	1.7471	1.7748	1.8010	1.8492	1.8934	1.9345	1.9730	2.0093	2.0439	2.0768
50 (281.02)	Sh					18.98	68.98	118.98	168.98	218.98	318.98	418.98	518.98	618.98	718.98	818.98	918.98
	v	0.01727	8.514			8.769	9.424	10.062	10.688	11.306	12.529	13.741	14.947	16.150	17.350	18.549	19.746
	h	250.21	1174.1			1184.1	1209.9	1234.9	1259.6	1284.1	1332.9	1382.0	1431.7	1482.2	1533.4	1585.5	1638.6
	s	0.4112	1.6586			1.6720	1.7048	1.7349	1.7628	1.7890	1.8374	1.8816	1.9227	1.9613	1.9977	2.032.	2.0652
55 (287.07)	Sh					12.93	62.93	112.93	162.93	212.93	312.93	412.93	512.93	612.93	712.93	812.93	912.93
	v	0.01733	7.787			7.945	8.546	9.130	9.702	10.267	11.381	12.485	13.583	14.677	15.769	16.859	17.948
	h	256.43	1176.0			1182.9	1208.9	1234.2	1259.1	1283.8	1332.6	1381.8	1431.5	1482.0	1533.3	1585.5	1638.5
	s	0.4196	1.6510			1.6601	1.6933	1.7237	1.7518	1.7781	1.8266	1.8710	1.9121	1.9507	1.987	2.022	2.055
60 (292.71)	Sh					7.29	57.29	107.29	157.29	207.29	307.29	407.29	507.29	607.29	707.29	807.29	907.29
	v	0.01738	7.174			7.257	7.874	8.454	8.881	9.400	10.475	11.438	12.446	13.450	14.452	15.452	16.450
	h	262.21	1177.6			1181.6	1208.0	1233.5	1258.5	1283.2	1332.3	1381.5	1431.3	1481.8	1533.2	1585.3	1638.4
	s	0.4273	1.6440			1.6492	1.6829	1.7134	1.7417	1.7681	1.8168	1.8612	1.9024	1.9410	1.9774	2.0120	2.0450
65 (297.98)	Sh					2.02	52.02	102.02	152.02	202.02	302.02	402.02	502.02	602.02	702.02	802.02	902.02
	v	0.01743	6.653			6.675	7.295	7.897	8.186	8.867	9.615	10.552	11.484	12.412	13.337	14.261	15.183
	h	267.63	1179.1			1180.2	1207.0	1232.7	1257.9	1282.7	1331.9	1381.3	1431.1	1481.6	1533.0	1585.2	1638.3
	s	0.4344	1.6375			1.6390	1.6731	1.7040	1.7324	1.7590	1.8077	1.8522	1.8935	1.9321	1.9685	2.0031	2.0361
70 (303.93)	Sh						47.07	97.07	147.0.	197.07	297.07	397.07	497.07	597.07	697.07	797.07	897.07
	v	0.01748	6.205				6.664	7.133	7.590	8.039	8.922	9.793	10.656	11.522	12.380	13.240	14.097
	h	272.74	1180.6				1206.0	1232.0	1257.3	1282.2	1331.6	1381.0	1430.9	1481.5	1532.9	1585.1	1638.2
	s	0.4411	1.6316				1.6640	1.6951	1.7237	1.7504	1.7993	1.8439	1.8852	1.9238	1.9603	1.9949	2.0279
75 (307.61)	Sh						42.39	92.39	142.39	192.39	292.39	392.39	492.39	592.39	692.39	792.39	892.39
	v	0.01753	5.814				6.204	6.645	7.074	7.494	8.330	9.135	9.945	10.750	11.553	12.355	13.155
	h	277.56	1181.9				1205.0	1231.2	1256.7	1281.7	1331.3	1380.7	1430.7	1481.3	1532.7	1585.0	1638.1
	s	0.4474	1.6260				1.6564	1.6868	1.7156	1.7424	1.7915	1.8361	1.8774	1.9161	1.9526	1.9872	2.0202

Sh = superheat, F
v = specific volume, cu ft per lb
h = enthalpy, Btu per lb
s = entropy, Btu per R per lb

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	69.72	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	1.30647	1.32564	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	0.90781	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	0.45069	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	0.40041	0.42224	550.1	640.9	1191.0	0.7507	0.6344	1.3851	1050.0
1100.0	556.28	0.02195	0.37863	0.40058	557.5	631.5	1189.1	0.7578	0.6216	1.3794	1100.0
1150.0	561.82	0.02214	0.35859	0.38073	564.8	622.2	1187.0	0.7647	0.6091	1.3738	1150.0
1200.0	567.19	0.02232	0.34013	0.36245	571.9	613.0	1184.8	0.7714	0.5969	1.3683	1200.0
1250.0	572.38	0.02250	0.32306	0.34556	578.8	603.8	1182.6	0.7780	0.5850	1.3630	1250.0
1300.0	577.42	0.02269	0.30722	0.32991	585.6	594.6	1180.2	0.7843	0.5733	1.3577	1300.0
1350.0	582.32	0.02288	0.29250	0.31537	592.3	585.4	1177.8	0.7906	0.5620	1.3525	1350.0
1400.0	587.07	0.02307	0.27871	0.30178	598.8	576.5	1175.3	0.7966	0.5507	1.3474	1400.0
1450.0	591.70	0.02327	0.26584	0.28911	605.3	567.4	1172.8	0.8026	0.5397	1.3423	1450.0
1500.0	596.20	0.02346	0.25372	0.27719	611.7	558.4	1170.1	0.8085	0.5288	1.3373	1500.0
1550.0	600.59	0.02366	0.24235	0.26601	618.0	549.4	1167.4	0.8142	0.5182	1.3324	1550.0
1600.0	604.87	0.02387	0.23159	0.25545	624.2	540.3	1164.5	0.8199	0.5076	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	1.2933	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	0.2973	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	0.06156	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	0.9738	0.1891	1.1616	3000.0
3100.0	700.28	0.03693	0.03791	0.07485	824.0	169.0	993.0	0.9914	0.1469	1.1370	3100.0
3200.0	705.08	0.04417	0.01152	0.05663	875.5	56.1	931.8	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

Table 3. Superheated Steam – *Continued*

Abs Press Lb/Sq In (Sat. Temp)		Sat. Water	Sat. Steam	Temperature – Degrees Fahrenheit 350	400	450	500	550	600	700	800	900	1000	1100	1200	1300	1400
	Sh			37.96	87.96	137.96	187.96	237.96	287.96	387.96	487.96	587.96	687.96	787.96	887.96	987.96	1087.96
80	v	0.01757	5.471	5.802	6.218	6.622	7.018	7.408	7.794	8.560	9.319	10.075	10.829	11.581	12.331	13.081	13.829
(312.04)	h	282.15	1183.1	1264.0	1230.5	1256.1	1281.3	1306.2	1330.9	1380.5	1430.5	1481.1	1532.6	1584.9	1638.0	1692.0	1746.8
	s	0.4534	1.6208	1.6473	1.6790	1.7080	1.7349	1.7602	1.7842	1.8289	1.8702	1.9089	1.9454	1.9800	2.0131	2.0446	2.0750
	Sh			33.74	83.74	133.74	183.74	233.74	283.74	383.74	483.74	583.74	683.74	783.74	883.74	983.74	1083.74
85	v	0.01762	5.167	5.445	5.840	6.223	6.597	6.966	7.330	8.052	8.768	9.480	10.190	10.898	11.604	12.310	13.014
(316.26)	h	286.52	1184.2	1203.0	1229.7	1255.5	1280.8	1305.8	1330.6	1380.2	1430.3	1481.0	1532.4	1584.7	1637.9	1691.9	1746.8
	s	0.4590	1.6159	1.6396	1.6716	1.7008	1.7279	1.7532	1.7772	1.8220	1.8634	1.9021	1.9386	1.9733	2.0063	2.0379	2.0682
	Sh			29.72	79.72	129.72	179.72	229.72	279.72	379.72	479.72	579.72	679.72	779.72	879.72	979.72	1079.72
90	v	0.01766	4.895	5.128	5.505	5.869	6.223	6.572	6.917	7.600	8.277	8.950	9.621	10.290	10.958	11.625	12.290
(320.28)	h	290.69	1185.3	1202.0	1228.9	1254.9	1280.3	1305.4	1330.2	1380.0	1430.1	1480.8	1532.3	1584.6	1637.8	1691.8	1746.7
	s	0.4643	1.6113	1.6323	1.6646	1.6940	1.7212	1.7467	1.7707	1.8156	1.8570	1.8957	1.9323	1.9669	2.0000	2.0316	2.0619
	Sh			25.87	75.87	125.87	175.87	225.87	275.87	375.87	475.87	575.87	675.87	775.87	875.87	975.87	1075.87
95	v	0.01770	4.651	4.845	5.205	5.551	5.889	6.221	6.548	7.196	7.838	8.477	9.113	9.747	10.380	11.012	11.643
(324.13)	h	294.70	1186.2	1200.9	1228.1	1254.3	1279.8	1305.0	1329.9	1379.7	1429.9	1480.6	1532.1	1584.5	1637.7	1691.7	1746.6
	s	0.4694	1.6069	1.6253	1.6580	1.6876	1.7149	1.7404	1.7645	1.8094	1.8509	1.8897	1.9263	1.9609	1.9940	2.0256	2.0559
	Sh			22.18	72.18	122.18	172.18	222.18	272.18	372.18	472.18	572.18	672.18	772.18	872.18	972.18	1072.18
100	v	0.01774	4.431	4.590	4.935	5.266	5.589	5.904	6.216	6.833	7.443	8.050	8.655	9.258	9.860	10.460	11.060
(327.82)	h	298.34	1187.2	1199.9	1227.4	1253.7	1279.3	1304.6	1329.6	1379.5	1429.7	1480.4	1532.0	1584.4	1637.6	1691.6	1746.5
	s	0.4703	1.6027	1.6187	1.6516	1.6814	1.7088	1.7344	1.7586	1.8036	1.8451	1.8839	1.9205	1.9552	1.9883	2.0199	2.0502
	Sh			18.63	68.63	118.63	168.63	218.63	268.63	368.63	468.63	568.63	668.63	768.63	868.63	968.63	1068.63
105	v	0.01777	4.231	4.359	4.690	5.007	5.315	5.617	5.915	6.504	7.086	7.665	8.241	8.816	9.389	9.961	10.532
(331.37)	h	302.24	1188.0	1198.8	1226.6	1253.1	1278.8	1304.2	1329.2	1379.2	1429.4	1480.3	1531.8	1584.2	1637.5	1691.5	1746.4
	s	0.4790	1.5988	1.6122	1.6455	1.6755	1.7031	1.7288	1.7530	1.7981	1.8396	1.8785	1.9151	1.9498	1.9828	2.0145	2.0448
	Sh			15.21	65.21	115.21	165.21	215.21	265.21	365.21	465.21	565.21	665.21	765.21	865.21	965.21	1065.21
110	v	0.01782	4.048	4.149	4.468	4.772	5.068	5.357	5.642	6.205	6.761	7.314	7.865	8.413	8.961	9.507	10.053
(334.79)	h	305.80	1188.9	1197.7	1225.8	1252.5	1278.3	1303.8	1378.9	1379.0	1429.2	1480.1	1531.7	1584.1	1637.4	1691.4	1746.4
	s	0.4834	1.5950	1.6061	1.6396	1.6698	1.6975	1.7233	1.7476	1.7929	1.8344	1.8732	1.9096	1.9446	1.9777	2.0093	2.0397
	Sh			11.92	61.92	111.92	161.92	211.92	261.92	361.92	461.92	561.92	661.92	761.92	861.92	961.92	1061.92
115	v	0.01785	3.881	3.957	4.265	4.558	4.841	5.119	5.392	5.932	6.465	6.994	7.521	8.046	8.570	9.093	9.615
(338.08)	h	309.25	1189.6	1196.7	1225.0	1251.8	1277.9	1303.3	1328.6	1378.7	1429.0	1479.9	1531.6	1584.0	1637.2	1691.4	1746.3
	s	0.4877	1.5913	1.6001	1.6340	1.6644	1.6922	1.7181	1.7425	1.7877	1.8294	1.8682	1.9049	1.9396	1.9727	2.0044	2.0347
	Sh			8.73	58.73	108.73	158.73	208.73	258.73	358.73	458.73	558.73	658.73	758.73	858.73	958.73	1058.73
120	v	0.01789	3.7275	3.7815	4.0781	4.3610	4.6341	4.9009	5.1637	5.6813	6.1978	6.7006	7.2060	7.7096	8.2119	8.7130	9.2134
(341.27)	h	312.58	1190.4	1195.6	1224.1	1251.2	1277.4	1302.9	1328.2	1378.5	1428.8	1479.8	1531.4	1583.9	1637.1	1691.3	1746.2
	s	0.4919	1.5879	1.5943	1.6286	1.6592	1.6872	1.7132	1.7376	1.7829	1.8246	1.8635	1.9001	1.9349	1.9680	1.9996	2.0300
	Sh			2.67	52.67	102.67	152.67	202.67	252.67	352.67	452.67	552.67	652.67	752.67	852.67	952.67	1052.67
130	v	0.01796	3.4544	3.4699	3.7489	4.0129	4.2672	4.5151	4.7589	5.2364	5.7118	6.1814	6.6486	7.1140	7.5781	8.0413	8.5033
(347.33)	h	318.95	1191.7	1193.4	1222.5	1249.9	1276.4	1302.1	1327.5	1377.9	1428.4	1479.4	1531.1	1583.6	1636.9	1691.1	1746.1
	s	0.4998	1.5813	1.5833	1.6187	1.6493	1.6775	1.7037	1.7283	1.7737	1.8155	1.8545	1.8911	1.9259	1.9591	1.9907	2.0211
	Sh				46.96	96.96	146.96	196.96	246.96	346.96	446.96	546.96	646.96	746.96	846.96	946.96	1046.96
140	v	0.01803	3.2190		3.4663	3.7143	3.9536	4.1844	4.4119	4.8588	5.2995	5.7364	6.1709	6.6036	7.0349	7.4652	7.8946
(353.04)	h	324.96	1193.0		1220.8	1248.7	1275.3	1301.3	1326.8	1377.4	1428.0	1479.1	1530.8	1583.4	1636.7	1690.9	1745.9
	s	0.5071	1.5752		1.6085	1.6400	1.6686	1.6949	1.7196	1.7652	1.8071	1.8461	1.8828	1.9176	1.9508	1.9825	2.0129
	Sh				41.57	91.57	141.57	191.57	241.57	341.57	441.57	541.57	641.57	741.57	841.57	941.57	1041.57
150	v	0.01809	3.0139		3.2208	3.4555	3.6799	3.8978	4.1112	4.5298	4.9421	5.3507	5.7568	6.1612	6.5642	6.9661	7.3671
(358.43)	h	330.65	1194.1		1219.1	1247.4	1274.3	1300.3	1326.1	1376.9	1427.6	1478.7	1530.5	1583.1	1636.5	1690.7	1745.7
	s	0.5141	1.5695		1.5993	1.6313	1.6607	1.6867	1.7115	1.7573	1.7992	1.8383	1.8751	1.9099	1.9431	1.9748	2.0052
	Sh				36.45	86.45	136.45	186.45	236.45	336.45	436.45	536.45	636.45	736.45	836.45	936.45	1036.45
160	v	0.01815	2.8336		3.0060	3.2288	3.4413	3.6469	3.8480	4.2470	4.6295	5.0132	5.3945	5.7741	6.1522	6.5293	6.9055
(363.55)	h	336.07	1195.1		1217.4	1246.0	1273.3	1299.6	1325.4	1376.4	1427.2	1478.4	1530.3	1582.9	1636.3	1690.5	1745.6
	s	0.5206	1.5641		1.5906	1.6231	1.6522	1.6790	1.7039	1.7499	1.7919	1.8310	1.8678	1.9027	1.9359	1.9676	1.9980
	Sh				31.58	81.58	131.58	181.58	231.58	331.58	431.58	531.58	631.58	731.58	831.58	931.58	1031.58
170	v	0.01821	2.6738		2.8161	3.0285	3.2306	3.4255	3.6158	3.9879	4.3536	4.7155	5.0749	5.4325	5.7889	6.1440	6.4983
(368.42)	h	341.24	1196.0		1215.6	1244.7	1272.2	1298.8	1324.7	1375.8	1426.8	1478.0	1530.0	1582.6	1636.1	1690.4	1745.4
	s	0.5269	1.5591		1.5823	1.6157	1.6447	1.6717	1.6968	1.7428	1.7850	1.8243	1.8610	1.8959	1.9291	1.9608	1.9913
	Sh				26.92	76.92	126.92	176.92	226.92	326.92	426.92	526.92	626.92	726.92	826.92	926.92	1026.92
180	v	0.01827	2.5312		2.6674	2.8609	3.0433	3.2186	3.3890	3.7221	4.0482	4.3698	4.6890	5.0065	5.3227	5.6378	5.9520
(373.08)	h	346.19	1196.9		1212.8	1241.4	1271.2	1297.9	1324.0	1375.3	1426.3	1477.7	1529.7	1582.4	1635.9	1690.2	1745.3
	s	0.5328	1.5543		1.5743	1.6078	1.6379	1.6651	1.6900	1.7367	1.7784	1.8176	1.8545	1.8894	1.9227	1.9545	1.9849
	Sh				22.47	72.47	122.47	172.47	222.47	322.47	422.47	522.47	622.47	722.47	822.47	922.47	1022.47
190	v	0.01833	2.4030		2.4961	2.6915	2.8756	3.0525	3.2245	3.5601	3.8889	4.2140	4.5365	4.8572	5.1766	5.4949	5.8124
(377.53)	h	350.94	1197.6		1210.0	1242.0	1270.1	1296.7	1323.3	1374.8	1425.9	1477.4	1529.4	1582.1	1635.7	1690.0	1745.1
	s	0.5384	1.5498		1.5667	1.6009	1.6307	1.6581	1.6835	1.7299	1.7722	1.8115	1.8486	1.8834	1.9166	1.9484	1.9789
	Sh				18.20	68.20	118.20	168.20	218.20	318.20	418.20	518.20	618.20	718.20	818.20	918.20	1018.20
200	v	0.01839	2.2627		2.3599	2.5461	2.7207	2.8869	3.0468	3.3563	3.6591	3.9574	4.2527	4.5459	4.8378	5.1287	5.4189
(381.79)	h	355.51	1198.3		1208.1	1240.8	1269.4	1296.2	1322.9	1374.5	1425.8	1477.4	1529.4	1582.1	1635.7	1690.0	1745.2
	s	0.5436	1.5454		1.5593	1.5938	1.6241	1.6518	1.6772	1.7239	1.7663	1.8057	1.8426	1.8776	1.9109	1.9427	1.9732

Sh = superheat, F
v = specific volume, cu ft per lb
h = enthalpy, Btu per lb
s = entropy, Btu per R per lb

Table 3. Superheated Steam – *Continued*

Abs Press Lb/Sq In (Sat Temp)		Sat Water	Sat Steam	Temperature – Degrees Fahrenheit 400	450	500	550	600	700	800	900	1000	1100	1200	1300	1400	1500
	Sh			14.09	64.09	114.09	164.09	214.09	314.09	414.09	514.09	614.09	714.09	814.09	914.09	1014.09	1114.09
210	v	0.01844	2.1822	2.2364	2.4181	2.5880	2.7504	2.9078	3.2137	3.5128	3.8080	4.1007	4.3915	4.6811	4.9695	5.2571	5.5440
(385.91)	h	359.91	1195.0	1208.2	1239.2	1268.0	1295.3	1321.9	1373.7	1425.1	1476.7	1528.8	1581.6	1635.2	1689.6	1744.8	1800.8
	s	0.5490	1.5413	1.5522	1.5872	1.6180	1.6458	1.6715	1.7182	1.7607	1.8001	1.8371	1.8721	1.9054	1.9372	1.9677	1.9970
	Sh			10.12	60.12	110.12	160.12	210.12	310.12	410.12	510.12	610.12	710.12	810.12	910.12	1010.12	1110.12
220	v	0.01850	2.0863	2.1240	2.2999	2.4638	2.6199	2.7710	3.0642	3.3504	3.6327	3.9125	4.1905	4.4671	4.7426	5.0173	5.2913
(389.88)	h	364.17	1199.6	1206.3	1237.8	1266.9	1294.5	1321.2	1373.2	1424.7	1476.3	1528.5	1581.4	1635.0	1689.4	1744.7	1800.6
	s	0.5540	1.5374	1.5453	1.5808	1.6120	1.6400	1.6658	1.7128	1.7553	1.7948	1.8318	1.8668	1.9002	1.9320	1.9625	1.9919
	Sh			6.30	56.30	106.30	156.30	206.30	306.30	406.30	506.30	606.30	706.30	806.30	906.30	1006.30	1106.30
230	v	0.01855	1.9885	2.0212	2.1919	2.3503	2.5008	2.6461	2.9276	3.2070	3.4726	3.7406	4.0069	4.2717	4.5355	4.7984	5.0606
(393.70)	h	368.28	1200.1	1204.4	1236.3	1265.7	1293.6	1320.4	1372.7	1424.2	1476.0	1528.2	1581.1	1634.8	1689.3	1744.5	1800.5
	s	0.5588	1.5336	1.5385	1.5747	1.6062	1.6344	1.6604	1.7075	1.7502	1.7897	1.8268	1.8618	1.8952	1.9270	1.9576	1.9869
	Sh			2.61	52.61	102.61	152.61	202.61	302.61	402.61	502.61	602.61	702.61	802.61	902.61	1002.61	1102.61
240	v	0.01860	1.9177	1.9268	2.0928	2.2465	2.3915	2.5316	2.8024	3.0661	3.3259	3.5831	3.8385	4.0926	4.3456	4.5977	4.8492
(397.39)	h	372.27	1200.6	1202.4	1234.9	1264.6	1292.7	1319.7	1372.1	1423.8	1475.6	1527.9	1580.9	1634.6	1689.1	1744.3	1800.4
	s	0.5634	1.5299	1.5320	1.5687	1.6006	1.6291	1.6552	1.7025	1.7452	1.7848	1.8219	1.8570	1.8904	1.9223	1.9528	1.9822
	Sh				49.03	99.03	149.03	199.03	299.03	399.03	499.03	599.03	699.03	799.03	899.03	999.03	1099.03
250	v	0.01865	1.8432		2.0016	2.1504	2.2909	2.4262	2.6872	2.9410	3.1909	3.4382	3.6837	3.9278	4.1709	4.4131	4.6546
(400.97)	h	376.14	1201.1		1233.4	1263.5	1291.8	1319.0	1371.6	1423.4	1475.3	1527.6	1580.6	1634.4	1688.9	1744.2	1800.2
	s	0.5679	1.5264		1.5629	1.5951	1.6239	1.6502	1.6976	1.7405	1.7801	1.8173	1.8524	1.8858	1.9177	1.9482	1.9776
	Sh				45.56	95.56	145.56	195.56	295.56	395.56	495.56	595.56	695.56	795.56	895.56	995.56	1095.56
260	v	0.01870	1.7742		1.9173	2.0619	2.1981	2.3289	2.5808	2.8256	3.0663	3.3044	3.5408	3.7758	4.0097	4.2427	4.4750
(404.44)	h	379.90	1201.5		1231.9	1262.4	1290.9	1318.2	1371.1	1423.0	1474.9	1527.3	1580.4	1634.2	1688.7	1744.0	1800.1
	s	0.5722	1.5230		1.5573	1.5899	1.6189	1.6453	1.6930	1.7359	1.7756	1.8128	1.8480	1.8814	1.9133	1.9439	1.9732
	Sh				42.20	92.20	142.20	192.20	292.20	392.20	492.20	592.20	692.20	792.20	892.20	992.20	1092.20
270	v	0.01875	1.7101		1.8491	1.9799	2.1121	2.2388	2.4824	2.7186	2.9509	3.1806	3.4084	3.6349	3.8603	4.0849	4.3087
(407.80)	h	383.56	1201.9		1230.4	1261.2	1290.0	1317.5	1370.5	1422.6	1474.6	1527.1	1580.1	1634.0	1688.5	1743.9	1800.0
	s	0.5764	1.5197		1.5518	1.5848	1.6140	1.6406	1.6885	1.7315	1.7713	1.8085	1.8437	1.8771	1.9090	1.9396	1.9690
	Sh				38.93	88.93	138.93	188.93	288.93	388.93	488.93	588.93	688.93	788.93	888.93	988.93	1088.93
280	v	0.01880	1.6505		1.7665	1.9037	2.0322	2.1551	2.3909	2.6194	2.8437	3.0655	3.2855	3.5042	3.7217	3.9384	4.1543
(411.07)	h	387.12	1202.3		1228.8	1260.0	1289.1	1316.8	1370.0	1422.1	1474.2	1526.8	1579.9	1633.8	1688.4	1743.7	1799.8
	s	0.5805	1.5166		1.5464	1.5798	1.6093	1.6361	1.6841	1.7273	1.7671	1.8043	1.8395	1.8730	1.9050	1.9356	1.9649
	Sh				35.75	85.75	135.75	185.75	285.75	385.75	485.75	585.75	685.75	785.75	885.75	985.75	1085.75
290	v	0.01885	1.5948		1.6988	1.8327	1.9578	2.0772	2.3058	2.5269	2.7440	2.9585	3.1711	3.3824	3.5926	3.8019	4.0106
(414.25)	h	390.60	1202.6		1227.3	1258.9	1288.1	1316.0	1369.5	1421.7	1473.9	1526.5	1579.6	1633.5	1688.2	1743.6	1799.7
	s	0.5844	1.5135		1.5412	1.5750	1.6048	1.6317	1.6799	1.7232	1.7630	1.8003	1.8356	1.8690	1.9010	1.9316	1.9610
	Sh				32.65	82.65	132.65	182.65	282.65	382.65	482.65	582.65	682.65	782.65	882.65	982.65	1082.65
300	v	0.01889	1.5427		1.6356	1.7665	1.8883	2.0044	2.2263	2.4407	2.6509	2.8585	3.0643	3.2688	3.4721	3.6746	3.8764
(417.35)	h	393.99	1202.9		1225.7	1257.7	1287.2	1315.2	1368.9	1421.3	1473.6	1526.2	1579.4	1633.3	1688.0	1743.4	1799.6
	s	0.5882	1.5105		1.5361	1.5703	1.6003	1.6274	1.6758	1.7192	1.7591	1.7964	1.8317	1.8652	1.8972	1.9278	1.9572
	Sh				29.64	79.64	129.64	179.64	279.64	379.64	479.64	579.64	679.64	779.64	879.64	979.64	1079.64
310	v	0.01896	1.4939		1.5763	1.7044	1.8233	1.9363	2.1520	2.3600	2.5638	2.7650	2.9644	3.1625	3.3594	3.5555	3.7509
(420.36)	h	397.30	1203.2		1224.1	1256.5	1286.3	1314.5	1368.4	1420.9	1473.2	1525.9	1579.2	1633.1	1687.8	1743.3	1799.4
	s	0.5920	1.5076		1.5311	1.5657	1.5960	1.6233	1.6719	1.7153	1.7553	1.7927	1.8280	1.8615	1.8935	1.9241	1.9536
	Sh				26.69	76.69	126.69	176.65	276.69	376.69	476.69	576.69	676.69	776.69	876.69	976.69	1076.69
320	v	0.01899	1.4480		1.5207	1.6462	1.7623	1.8725	2.0803	2.2843	2.4821	2.6774	2.8708	3.0628	3.2538	3.4438	3.6332
(423.31)	h	400.53	1203.4		1222.5	1255.2	1285.3	1313.7	1367.8	1420.5	1472.9	1525.6	1578.9	1632.9	1687.6	1743.1	1799.3
	s	0.5956	1.5048		1.5261	1.5612	1.5918	1.6192	1.6680	1.7116	1.7516	1.7890	1.8243	1.8579	1.8899	1.9206	1.9500
	Sh				23.82	73.82	123.82	173.82	273.82	373.82	473.82	573.82	673.82	773.82	873.82	973.82	1073.82
330	v	0.01903	1.4048		1.4684	1.5915	1.7050	1.8125	2.0168	2.2132	2.4054	2.5950	2.7828	2.9692	3.1545	3.3389	3.5227
(426.18)	h	403.70	1203.6		1220.9	1254.0	1284.4	1313.0	1367.3	1420.0	1472.5	1525.3	1578.7	1632.7	1687.5	1742.9	1799.2
	s	0.5991	1.5021		1.5213	1.5568	1.5876	1.6153	1.6643	1.7079	1.7480	1.7855	1.8208	1.8544	1.8864	1.9171	1.9465
	Sh				21.01	71.01	121.01	171.01	271.01	371.01	471.01	571.01	671.01	771.01	871.01	971.01	1071.01
340	v	0.01908	1.3640		1.4191	1.5399	1.6511	1.7561	1.9552	2.1463	2.3333	2.5175	2.7000	2.8811	3.0611	3.2402	3.4186
(428.99)	h	406.80	1203.8		1219.2	1252.8	1283.4	1312.2	1366.7	1419.6	1472.2	1525.0	1578.4	1632.5	1687.3	1742.8	1799.0
	s	0.6026	1.4994		1.5165	1.5525	1.5836	1.6114	1.6606	1.7044	1.7445	1.7820	1.8174	1.8510	1.8831	1.9138	1.9432
	Sh				18.27	68.27	118.27	168.27	268.27	368.27	468.27	568.27	668.27	768.27	868.27	968.27	1068.27
350	v	0.01912	1.3255		1.3725	1.4913	1.6002	1.7028	1.8970	2.0832	2.2652	2.4445	2.6219	2.7980	2.9730	3.1471	3.3205
(431.73)	h	409.83	1204.0		1217.5	1251.5	1282.4	1311.4	1366.2	1419.2	1471.8	1524.7	1578.2	1632.3	1687.1	1742.6	1798.9
	s	0.6059	1.4968		1.5119	1.5483	1.5797	1.6077	1.6571	1.7009	1.7411	1.7787	1.8141	1.8477	1.8798	1.9105	1.9400
	Sh				15.59	65.59	115.59	165.59	265.59	365.59	465.59	565.59	665.59	765.59	865.59	965.59	1065.59
360	v	0.01917	1.2891		1.3285	1.4454	1.5521	1.6525	1.8421	2.0237	2.2009	2.3755	2.5482	2.7196	2.8898	3.0592	3.2279
(434.41)	h	412.93	1204.1		1215.8	1250.3	1281.5	1310.6	1365.6	1418.7	1471.5	1524.4	1577.9	1632.1	1686.9	1742.5	1798.8
	s	0.6092	1.4943		1.5073	1.5441	1.5758	1.6040	1.6537	1.6976	1.7379	1.7754	1.8109	1.8445	1.8766	1.9073	1.9368
	Sh				10.39	60.39	110.39	160.39	260.39	360.39	460.39	560.39	660.39	760.39	860.39	960.39	1060.39
380	v	0.01925	1.2218		1.2472	1.3606	1.4635	1.5598	1.7410	1.9139	2.0825	2.2484	2.4124	2.5750	2.7366	2.8973	3.0572
(439.61)	h	416.59	1204.4		1212.4	1247.7	1279.5	1309.0	1364.5	1417.9	1470.8	1523.8	1577.4	1631.6	1686.5	1742.2	1798.5
	s	0.6151	1.4894		1.4982	1.5380	1.5683	1.5965	1.6470	1.6911	1.7315	1.7690	1.8047	1.8384	1.8705	1.9012	1.9307

Sh = superheat, F
v = specific volume, cu ft per lb
h = enthalpy, Btu per lb
s = entropy, Btu per R per lb

Table 3. Superheated Steam – *Continued*

Abs Press Lb/Sq In (Sat. Temp)		Sat Water	Sat Steam	Temperature – Degrees Fahrenheit 450	500	550	600	650	700	800	900	1000	1100	1200	1300	1400	1500
	Sh			5.40	55.40	105.40	155.40	205.40	255.40	355.40	455.40	555.40	655.40	755.40	855.40	955.40	1055.40
400	v	0.01934	1.1610	1.1738	1.2841	1.3836	1.4763	1.5646	1.6499	1.8151	1.9759	2.1339	2.2901	2.4450	2.5987	2.7515	2.9037
(444.60)	h	424.17	1204.6	1208.8	1245.1	1277.5	1307.4	1335.9	1363.4	1417.0	1470.1	1523.3	1576.9	1631.2	1686.2	1741.9	1798.2
	s	0.6217	1.4847	1.4894	1.5282	1.5611	1.5901	1.6163	1.6406	1.6850	1.7255	1.7632	1.7988	1.8325	1.8647	1.8955	1.9250
	Sh			60	50.60	100.60	150.60	200.60	250.60	350.60	450.60	550.60	650.60	750.60	850.60	950.60	1050.60
420	v	0.01942	1.1057	1.1071	1.2148	1.3113	1.4007	1.4856	1.5676	1.7258	1.8795	2.0304	2.1795	2.3273	2.4739	2.6196	2.7647
(449.40)	h	429.56	1204.7	1205.2	1242.4	1275.4	1305.8	1334.5	1362.3	1416.2	1469.4	1522.7	1576.4	1630.8	1685.8	1741.6	1798.0
	s	0.6276	1.4802	1.4808	1.5206	1.5542	1.5835	1.6100	1.6345	1.6791	1.7197	1.7575	1.7932	1.8269	1.8591	1.8899	1.9195
	Sh				45.97	95.97	145.97	195.97	245.97	345.97	445.97	545.97	645.97	745.97	845.97	945.97	1045.97
440	v	0.01960	1.0554		1.1517	1.2454	1.3319	1.4138	1.4926	1.6445	1.7918	1.9363	2.0790	2.2203	2.3605	2.4998	2.6384
(454.03)	h	434.77	1204.8		1239.7	1273.4	1304.2	1333.2	136.1	1415.3	1468.7	1522.1	1575.9	1630.4	1685.5	1741.2	1797.7
	s	0.6332	1.4759		1.5132	1.5474	1.5772	1.6040	1.6286	1.6734	1.7142	1.7521	1.7878	1.8216	1.8538	1.8847	1.9143
	Sh				41.50	91.50	141.50	191.50	241.50	341.50	441.50	541.50	641.50	741.50	841.50	941.50	1041.50
460	v	0.01959	1.0092		1.0939	1.1852	1.2691	1.3482	1.4242	1.5703	1.7117	1.8504	1.9872	2.1226	2.2569	2.3903	2.5230
(458.50)	h	439.83	1204.8		1236.9	1271.3	1302.5	1331.8	1360.0	1414.4	1468.0	1521.5	1575.4	1629.9	1685.1	1740.9	1797.4
	s	0.6387	1.4718		1.5060	1.5409	1.5711	1.5982	1.6230	1.6680	1.7089	1.7469	1.7826	1.8165	1.8488	1.8797	1.9093
	Sh				37.18	87.18	137.18	187.18	237.18	337.18	437.18	537.18	637.18	737.18	837.18	937.18	1037.18
480	v	0.01967	0.9668		1.0409	1.1300	1.2115	1.2881	1.3615	1.5023	1.6384	1.7716	1.9030	2.0330	2.1619	2.2900	2.4173
(462.82)	h	444.75	1204.8		1234.1	1269.1	1300.8	1330.5	1358.8	1413.6	1467.3	1520.9	1574.9	1629.5	1684.7	1740.6	1797.2
	s	0.6439	1.4677		1.4990	1.5346	1.5652	1.5925	1.6176	1.6628	1.7038	1.7419	1.7777	1.8116	1.8439	1.8748	1.9045
	Sh				32.99	82.99	132.99	182.99	232.99	332.99	432.99	532.99	632.99	732.99	832.99	932.99	1032.99
500	v	0.01975	0.9276		0.9919	1.0791	1.1584	1.2327	1.3037	1.4397	1.5708	1.6992	1.8256	1.9507	2.0746	2.1977	2.3200
(467.01)	h	449.52	1204.7		1231.2	1267.0	1299.1	1329.1	1357.7	1412.7	1466.6	1520.3	1574.4	1629.1	1684.4	1740.3	1796.9
	s	0.6490	1.4639		1.4921	1.5284	1.5595	1.5871	1.6123	1.6578	1.6990	1.7371	1.7730	1.8069	1.8393	1.8702	1.8998
	Sh				28.93	78.93	128.93	178.93	228.93	328.93	428.93	528.93	628.93	728.93	828.93	928.93	1028.93
520	v	0.01982	0.8914		0.9466	1.0321	1.1094	1.1816	1.2504	1.3819	1.5085	1.6323	1.7542	1.8746	1.9940	2.1125	2.2302
(471.07)	h	454.18	1204.5		1228.3	1264.8	1297.4	1327.7	1356.5	1411.8	1465.9	1519.7	1573.9	1628.7	1684.0	1740.0	1796.7
	s	0.6540	1.4601		1.4853	1.5223	1.5539	1.5818	1.6072	1.6530	1.6943	1.7325	1.7684	1.8024	1.8348	1.8657	1.8954
	Sh				24.99	74.99	124.99	174.99	224.99	324.99	424.99	524.99	624.99	724.99	824.99	924.99	1024.99
540	v	0.01990	0.8577		0.9045	0.9884	1.0640	1.1342	1.2010	1.3284	1.4508	1.5704	1.6880	1.8047	1.9193	2.0336	2.1471
(475.01)	h	458.71	1204.4		1225.3	1262.5	1295.7	1326.3	1355.3	1410.9	1465.1	1519.1	1573.4	1628.2	1683.6	1739.7	1796.4
	s	0.6587	1.4565		1.4786	1.5164	1.5485	1.5767	1.6023	1.6483	1.6897	1.7280	1.7640	1.7981	1.8305	1.8615	1.8911
	Sh				21.16	71.16	121.16	171.16	221.16	321.16	421.16	521.16	621.16	721.16	821.16	921.16	1021.16
560	v	0.01998	0.8264		0.8653	0.9479	1.0217	1.0902	1.1562	1.2787	1.3972	1.5129	1.6266	1.7388	1.8500	1.9603	2.0699
(478.84)	h	463.14	1204.2		1222.2	1260.3	1293.9	1324.9	1354.2	1410.0	1464.4	1518.6	1572.9	1627.8	1683.3	1739.4	1796.1
	s	0.6634	1.4529		1.4720	1.5106	1.5431	1.5717	1.5975	1.6438	1.6853	1.7237	1.7598	1.7939	1.8263	1.8573	1.8870
	Sh				17.43	67.43	117.43	167.43	217.43	317.43	417.43	517.43	617.43	717.43	817.43	917.43	1017.43
580	v	0.02006	0.7971		0.8287	0.9100	0.9824	1.0492	1.1125	1.2374	1.3473	1.4593	1.5693	1.6780	1.7855	1.8921	1.9980
(482.57)	h	467.47	1203.9		1219.1	1258.0	1292.1	1323.4	1353.0	1409.2	1463.7	1518.0	1572.4	1627.4	1682.9	1739.1	1795.9
	s	0.6679	1.4495		1.4654	1.5049	1.5380	1.5668	1.5929	1.6394	1.6811	1.7196	1.7556	1.7898	1.8223	1.8533	1.8831
	Sh				13.80	63.80	113.80	163.80	213.80	313.80	413.80	513.80	613.80	713.80	813.80	913.80	1013.80
600	v	0.02013	0.7697		0.7944	0.8746	0.9456	1.0109	1.0726	1.1892	1.3008	1.4093	1.5160	1.6211	1.7252	1.8284	1.9309
(486.20)	h	471.70	1203.7		1215.9	1255.6	1290.3	1322.0	1351.8	1408.3	1463.0	1517.4	1571.9	1627.0	1682.6	1738.8	1795.6
	s	0.6723	1.4461		1.4590	1.4993	1.5329	1.5621	1.5884	1.6351	1.6769	1.7155	1.7517	1.7859	1.8184	1.8494	1.8792
	Sh				5.11	55.11	105.11	155.11	205.11	305.11	405.11	505.11	605.11	705.11	805.11	905.11	1005.11
650	v	0.02032	0.7084		0.7173	0.7954	0.8634	0.9254	0.9835	1.0929	1.1969	1.2979	1.3969	1.4944	1.5909	1.6864	1.7813
(494.89)	h	481.89	1202.8		1207.6	1249.6	1285.7	1318.3	1348.7	1406.0	1461.2	1515.9	1570.7	1625.9	1681.6	1738.0	1794.9
	s	1.6828	1.4381		1.4430	1.4858	1.5207	1.5507	1.5775	1.6249	1.6671	1.7059	1.7422	1.7765	1.8092	1.8403	1.8701
	Sh					46.92	96.92	146.92	196.92	296.92	396.92	496.92	596.92	u96.92	796.92	896.92	996.92
700	v	0.02050	0.6556			0.7271	0.7928	0.8520	0.9072	1.0102	1.1078	1.2023	1.2948	1.3856	1.4757	1.5647	1.6530
(503.08)	h	491.60	1201.8			1243.4	1281.0	1314.6	1345.6	1403.7	1459.4	1514.4	1569.4	1624.8	1680.7	1737.2	1794.3
	s	0.6928	1.4304			1.4726	1.5090	1.5399	1.5673	1.6154	1.6580	1.6970	1.7335	1.7679	1.8006	1.8318	1.8617
	Sh					39.16	89.16	139.16	189.16	289.16	389.16	489.16	589.16	689.16	789.16	889.16	989.16
750	v	0.02069	0.6095			0.6676	0.7313	0.7883	0.8409	0.9386	1.0306	1.1195	1.2063	1.2916	1.3759	1.4592	1.5419
(510.84)	h	500.89	1200.7			1236.9	1276.1	1310.7	1342.5	1401.5	1457.6	1512.9	1568.2	1623.8	1679.8	1736.4	1793.6
	s	0.7022	1.4232			1.4598	1.4977	1.5296	1.5577	1.6065	1.6494	1.6886	1.7252	1.7598	1.7926	1.8239	1.8538
	Sh					31.79	81.79	131.79	181.79	281.79	381.79	481.79	581.79	681.79	781.79	881.79	981.79
800	v	0.02087	0.5690			0.6161	0.6774	0.7323	0.7829	0.8759	0.9631	1.0470	1.1289	1.2093	1.2885	1.3669	1.4446
(518.21)	h	509.81	1199.4			1230.1	1271.1	1306.8	1339.3	1399.1	1455.8	1511.4	1566.9	1622.7	1678.9	1735.7	1792.9
	s	0.7111	1.4163			1.4472	1.4869	1.5198	1.5484	1.5980	1.6413	1.6807	1.7175	1.7522	1.7851	1.8164	1.8464
	Sh					24.76	74.76	124.76	174.76	274.76	374.76	474.76	574.76	674.76	774.76	874.76	974.76
850	v	0.02105	0.5330			0.5683	0.6296	0.6829	0.7315	0.8205	0.9034	0.9830	1.0606	1.1366	1.2115	1.2855	1.3588
(525.24)	h	518.40	1198.0			1223.0	1265.9	1302.8	1336.0	1396.8	1454.0	1510.0	1565.7	1621.6	1678.0	1734.9	1792.3
	s	0.7167	1.4096			1.4347	1.4763	1.5102	1.5396	1.5899	1.6336	1.6733	1.7102	1.7450	1.7780	1.8094	1.8395
	Sh					18.05	68.05	118.05	168.05	268.05	368.05	468.05	568.05	668.05	768.05	868.05	968.05
900	v	0.02123	0.5009			0.5263	0.5869	0.6388	0.6858	0.7713	0.8504	0.9262	0.9998	1.0720	1.1430	1.2131	1.2825
(531.95)	h	526.70	1196.4			1215.5	1260.6	1298.6	1332.7	1394.4	1452.2	1508.5	1564.4	1620.6	1677.1	1734.1	1791.6
	s	0.7219	1.4032			1.4223	1.4659	1.5010	1.5311	1.5822	1.6263	1.6662	1.7033	1.7382	1.7713	1.8028	1.8329

Sh = superheat, F
v = specific volume, cu ft per lb
h = enthalpy, Btu per lb
s = entropy, Btu per R per lb