ENCLOSURE 1

EXAMINATION REPORT - 50-83 OL-88-01

Facility Licensee: University of Florida
202 Nuclear Sciences Center
Gainesville, FL 32611

Facility Name: University of Florida Training Reactor

Facility Docket No.: 50-83

Written examinations and operating tests were administered at the University of Florida in Gainesville, Florida.

Chief Examiner: _____ 20 JUNE 1988
Jesse A. Arildsen — Date Signed

Approved by: _____ 5 JULY 1988
Kenneth E. Brockman, Section Chief — Date Signed
Operator Licensing Section 2

Summary:

Examinations on June 8-9, 1988.

Operating tests were administered to two candidates, two of whom passed; two candidates were administered written examinations, one candidate passed.

Based on the results described above, zero of one RO's passed and one of one SRO's passed.

REPORT DETAILS

1. Facility Employees Contacted:

   * W. G. Vernetson, Director of Nuclear Facilities, UFTR
     P. M. Whaley, Reactor Manager, UFTR

   *Attended Exit Meeting

2. Examiners:

   * J. A. Arildsen
     K. E. Brockman

   *Chief Examiner

3. Examination Review Meeting

   At the conclusion of the written examinations, the examiners provided Dr. Vernetson with a copy of the written examination and answer key for review. There were no facility comments.

4. Exit Meeting

   At the conclusion of the site visit the examiners met with representatives of the plant staff to discuss the results of the examination and forthcoming changes to procedures and other UFTR material.

   The cooperation given to the examiners and the effort to ensure an atmosphere in the control room conducive to oral examinations was noted and appreciated.

   The licensee did not identify as proprietary any of the material provided to or reviewed by the examiners.

MASTER

RO

Nuclear Regulatory Commission

Operator Licensing

Examination

This document is removed from
Official Use Only category on
date of examination.

U. S. NUCLEAR REGULATORY COMMISSION
REACTOR OPERATOR LICENSE EXAMINATION

FACILITY: UNIVERSITY OF FLORIDA

REACTOR TYPE: TEST

DATE ADMINISTERED: 88/06/08

EXAMINER: ARILDSEN, J.

CANDIDATE: _____

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. Examination papers will be picked up six (6) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	CANDIDATE'S SCORE	% OF CATEGORY VALUE		CATEGORY
15.00	15.04			A.	PRINCIPLES OF REACTOR OPERATION
15.00	15.04			B.	FEATURES OF FACILITY DESIGN
13.75	13.78			C.	GENERAL OPERATING CHARACTERISTICS
13.00	13.03			D.	INSTRUMENTS AND CONTROLS
14.75	14.79			E.	SAFETY AND EMERGENCY SYSTEMS
~~13.00~~	~~13.03~~			F.	STANDARD AND EMERGENCY OPERATING PROCEDURES
15.25	15.29			G.	RADIATION CONTROL AND SAFETY
~~99.75~~			%		Totals

Final Grade

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

_____
Candidate's Signature

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

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

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

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

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

6. Use only the paper provided for answers.

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

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

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

10. Skip at least three lines between each answer.

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

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 A.01 (1.00)

A reactor has been operating for an extended period of time at 50% reactor power. WHICH ONE of the following statements most accurately describes the concentration of samarium-149 if power were increased to and maintained at 75% reactor power?

a. The concentration of Sm-149 initially increases and then levels off to a new equilibrium level higher than the equilibrium level at 50% reactor power.

b. The concentration of Sm-149 initially increases but then decreases to an equilibrium level equal to the equilibrium level at 50% reactor power.

c. The concentration of Sm-149 initially decreases and then levels off to a new equilibrium level lower than the equilibrium level at 50% reactor power.

d. The concentration of Sm-149 initially decreases but then increases to an equilibrium level equal to the equilibrium level at 50% reactor power.

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

QUESTION A.02 (1.50)

a. DEFINE "thermal nonleakage factor". (0.5)

b. EXPLAIN HOW the thermal nonleakage factor can be greater than one. (1.0)

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

QUESTION A.03 (1.00)

Reactor power is 100 watts and increasing with a constant reactor period. FOUR (4) minutes later, reactor power is 2 KW. CALCULATE the reactor period during the last four minutes. SHOW ALL WORK!

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

QUESTION A.04 (2.00)

Reactor power is 2KW with rods in the following positions:

Safety Blade #1 - Position 1000
Safety Blade #2 - Position 1000
Safety Blade #3 - Position 1000
Regulating Blade - Position 400

CALCULATE the period one (1) minute after a scram. SHOW ALL WORK!
(ASSUME a Lambda of 0.0124 and a Beta Effective of 0.0065.)

NOTE: APPLICABLE GRAPHS ARE ATTACHED
SUR = Startup Rate = Decades / Minute

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

QUESTION A.03 (2.00)

For each of the following definitions, STATE the term that is defined.

a. The factor by which neutron population changes between generations (from fission).

b. The decay of an excited nucleus into a stable nucleus with the simultaneous ejection of electromagnetic energy.

c. The amount of time required for the neutron population to increase by a factor of "e" (2.718).

d. A gamma ray causes the ejection of an electron from a target atom; the gamma ray's energy is totally transmitted to the electron for ejection.

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

QUESTION A.06 (1.00)

Which one of the following describes the beta decay of a nuclide?

a. Atomic Mass # decreases by 1, number of protons remains constant

b. Atomic Mass # remains the same, number of protons increases by 1

c. Atomic Mass # remains the same, number of protons remains constant

d. Atomic Mass # decreases by 1, number of protons decreases by 1

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

QUESTION A.07 (1.00)

Which one of the following terms of the six factor formula is most affected by "Poisons".

a. Fast Fission Factor

b. Thermal Utilization Factor

c. Thermal Non-Leakage Probability

d. Reproduction Factor

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

QUESTION A.08 (1.00)

Which one of the following statements concerning the reactivity values of equilibrium (at power) xenon and peak (after shutdown) xenon is correct? Assume shutdown occurs from equilibrium conditions.

a. Equilibrium xenon is INDEPENDENT of power level; peak xenon is INDEPENDENT of power level.

b. Equilibrium xenon is INDEPENDENT of power level; peak xenon is DEPENDENT on power level.

c. Equilibrium xenon is DEPENDENT on power level; peak xenon is INDEPENDENT of power level.

d. Equilibrium xenon is DEPENDENT on power level; peak xenon is DEPENDENT on power level.

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

QUESTION A.09 (1.00)

The ratio of Pu-239 and Pu-240 atoms to U-235 atoms changes over core life.

Which one of the following pairs of parameters is most affected by this change?

a). Moderator Temperature coefficient and Doppler Coefficient

b). Doppler Coefficient and Beta

c). Beta and Moderator Temperature Coefficient

d). Moderator Temperature Coefficient and Neutron Generation Time

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

QUESTION A.10 (1.00)

WHICH ONE of the following factors has the LEAST effect on the value of rod worth?

a. Number and location of adjacent control rods.

b. Temperature of the moderator.

c. Temperature of the fuel.

d. Core age.

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

QUESTION A.11 (2.50)

DEFINE EACH of the following terms:

a. Subcritical multiplication

b. Reflector

c. Xenon burnout

d. Decay heat

e. Differential rod worth

(***** END OF CATEGORY A *****)

QUESTION B.01 (2.00)

ANSWER EACH of the following questions TRUE or FALSE.

a. The Primary Reactor Cooling System does not contain any valves which could be left in the wrong position and restrict or shut off the primary flow without activation of the Reactor Protection System.

b. The Primary Coolant System is protected by a Graphite Rupture Disc set to burst at 7 PSI above the normal operating pressure.

c. The Primary Water Makeup System connects to the Coolant Storage Tank via the Purification System.

d. The Secondary Cooling System Sample Tank is normally kept isolated during Reactor operation.

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

QUESTION B.02 (2.50)

ANSWER EACH of the following questions concerning UFTR design features. (FILL IN THE BLANKS)

a. The Multiple Blade Withdrawal Interlock prevents exceeding a reactivity addition rate of _____ per second as specified in Technical Specifications.

b. The UFTR is designed to operate at a rated power of _____.

c. The core excess reactivity at cold critical, without xenon poisoning, shall not exceed _____.

d. The UFTR is heterogenous in design, using _____ percent enriched _____ _____ fuel elements.

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

QUESTION B.03 (1.00)

STATE what is used to separate and secure fuel assemblies to prevent lateral and vertical movement, assure proper flow, and a constant fuel to moderator ratio.

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

QUESTION B.04 (1.00)

STATE the purpose of the sixteen (16) vertical foil slots in the Reactor.

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

QUESTION 8.05 (2.00)

ANSWER EACH of the following questions concerning the Core Vent System.

a. STATE the purpose of the Vacuum Breaker Vent Lines. (1.0)

b. Where is the Effluent Gamma Detector located ? (0.5)

c. The Vent Damper is electrically interlocked so that it cannot be opened unless the dilution fan is energized. STATE the purpose of this interlock. (0.5)

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

QUESTION B.06 (1.00)

STATE two (2) purposes of the graphite blocks in the core.

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

QUESTION B.07 (2.00)

a. STATE the purpose of the Reactor Vent System.

b. LIST two (2) radioactive gases produced within the UFTR that are removed from the Reactor Cell by the Vent System.

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

QUESTION B.08 (1.50)

`i y tap water is used for makeup to the Primary System. E...LAIN HOW this water is purified to comply with Tech Spec requirements. Include in your answer a discussion of the physical processes by which the water is purified.

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

QUESTION B.09 (2.00)

STATE the PURPOSE of the following components of the Coolant Storage Tank AND HOW (by design) each one accomplishes this purpose.

a. Diffuser

b. Bucket Baffle

(***** END OF CATEGORY B *****)

QUESTION C.01 (2.00)

Reactivity in the core has been determined to be -0.1230 delta k/k. CALCULATE how much the Safety Blades must be withdrawn to increase the present count rate by 50%. SHOW ALL WORK!

NOTE: APPLICABLE CURVES ARE ATTACHED FOR REFERENCE
ASSUME ALL RODS WERE INITIALLY FULLY INSERTED
ASSUME ALL ROD WITHDRAWALS ARE PERFORMED IN SEQUENCE AND THAT THE FIRST ROD IS FULLY WITHDRAWN BEFORE THE NEXT ROD BEGINS ANY WITHDRAWAL

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

QUESTION C.02 (1.00)

WHICH ONE of the following is the reason for the -80 second period following a reactor scram?

a. The doppler effect adding positive reactivity due to the temperature decrease following a scram.

b. The ability of U-235 to fission with source neutrons.

c. The amount of negative reactivity added on a scram being greater than the Shutdown Margin.

d. The decay constant of the longest-lived group of delayed neutrons.

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

QUESTION C.03 (1.00)

Attached Figure # 219 shows a POWER HISTORY and four possible XENON traces (Reactivity vs. Time). SELECT the most accurate curve for displaying the expected XENON transient.

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

QUESTION C.04 (1.00)

WHICH ONE (1) of the following Control Blades has the LEAST amount of integral rod worth.

a. Safety Blade #1

b. Safety Blade #2

c. Safety Blade #3

d. Regulating Blade

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

QUESTION C.05 (1.00)

WHICH ONE (1) of the following is the expected maximum equilibrium Stack Monitor level usually indicated at 100 KWth power.

a.

b.

c. cps

d. 2000 cps

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

QUESTION C.06 (2.50)

FILL IN THE BLANKS with the normal operating values at 100 % Reactor power with the main secondary cooling system in operation (Except for part e).

a. Primary Coolant normal flow rate _____.

b. Reactor inlet temperature _____.

c. Reactor outlet temperature _____.

d. Temperature Coefficient of Reactivity _____.

e. Increase in above temperatures (b & c) using the backup secondary cooling system _____.

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

QUESTION C.07 (1.25)

It is desirable to operate a Reactor with a negative moderator coefficient. Hence, I conclude " The more negative the better ". STATE whether you agree or disagree with this statement and EXPLAIN your answer.

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

QUESTION C.08 (2.00)

a. STATE the LFTR monthly energy generation limit. (0.5)

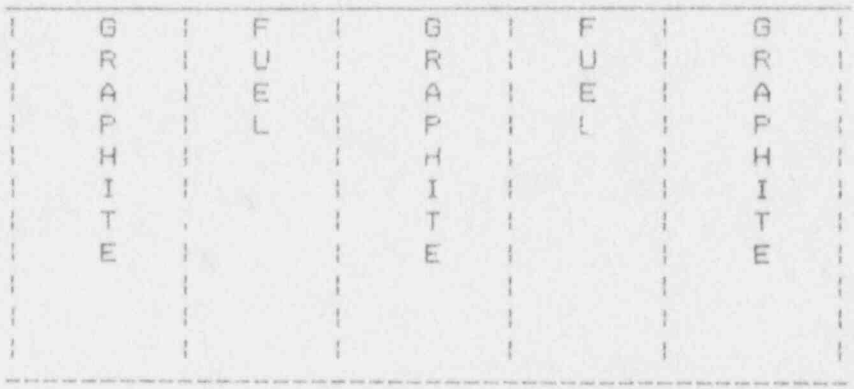
b. EXPLAIN the BASES for this limitation. (1.5)

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

QUESTION C.09 (2.00)

a. DRAW and LABEL, on the sketch below, the variation of thermal neutron flux through the core and the reflector.

b. SUPERIMPOSE on the sketch below the shape of the thermal neutron flux without a reflector present. (Disregard areas labeled graphite)



(***** END OF CATEGORY C *****)

QUESTION D.01 (2.00)

ANSWER EACH of the following questions TRUE or FALSE.

a. The console " Power ON " switch controls power to all parts of the control circuits and nuclear instrumentation channels.

b. Control Blade magnet power is controlled through the 3-position " OPERATE " key switch.

c. Depressing a Control Blade backlit ON switch will cause that Blade to return to the full in position.

d. A key operated switch on the back of the console controls the Secondary System City Water Valve.

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

QUESTION D.02 (2.50)

LIST five (5) conditions which will initiate a Full Trip of the Reactor and STATE the Nuclear Instrument Channel that is associated with each Trip. (#1,#2, both, or none)
(NOTE: INCLUDE SETPOINTS IN YOUR ANSWER)

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

QUESTION D.03 (1.00)

STATE the interlock that is associated with starting the Primary Coolant Pump.

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

QUESTION D.04 (1.00)

WHY is it not necessary to gamma-compensate the Safety Power Channels?

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

QUESTION D.05 (2.25)

a. DESCRIBE HOW the resistivity of the Primary Coolant is measured.
NOTE: INCLUDE IN YOUR ANSWER THE LOCATION OF ANY COMPONENTS USED.

b. EXPLAIN HOW flow is maintained through the Purification System when the Purification pump is secured.

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

QUESTION D.06 (2.00)

Answer the following questions concerning Radiation Detectors using the curve below.

a. LABEL EACH of the Regions (I-IV) on the curve .

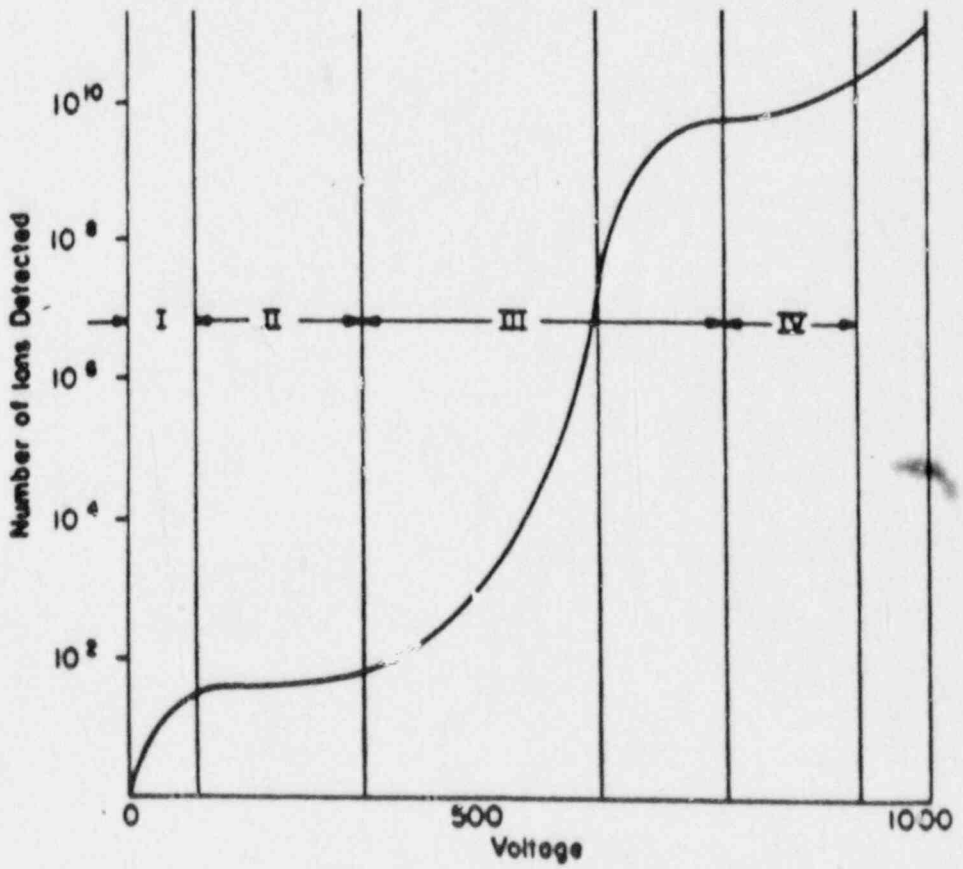
b. For each Detector(s) listed below, STATE the Region of the curve in which it operates.

1. B-10 (wide range ch) _____

2. NI ch 2 Safety channel _____

3. Reactor Vent Effluent Monitor _____

4. Portal Monitor (PCM-4A) _____



Number of Ions Detected versus Voltage for a Gas Filled Chamber

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

QUESTION D.07 (2.25)

a. DRAW a one line diagram of the Neutron Flux Control System and LABEL the inputs, outputs and components. (1.75)

b. State the fastest period obtainable in Auto Flux Control. (0.5)

(***** END OF CATEGORY D *****)

QUESTION E.01 (2.00 ~~2.50~~)

ANSWER EACH of the following questions TRUE or FALSE.

a. Nuclear Instrumentation and Control Blade Drive Instrumentation are an absolute necessity for shutting the UFTR down.

b. All reactivity Control Systems in the UFTR facility have Safety Related Functions (as considered in the FSAR).

c. Depressing the Manual Scram Trip Button will cause the Primary Coolant Dump Valve to open.

d. A Sonic Probe in the top of the Reactor Shield Tank will Trip the Reactor when the water level exceeds a preset value.

~~e. If the Core overheats, the negative void and temperature coefficients will cause the Core to shut down even without Control Blade insertion.~~ DELETED

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

QUESTION E.02 (2.50)

LIST five (5) conditions/interlocks that will function to prevent Control Blade withdrawal.

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

QUESTION E.03 (1.50)

LIST ALL of the conditions that should result in both MANUAL and AUTOMATIC actuation of the Evacuation Alarm.

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

QUESTION E.04 (3.00)

LIST twelve (12) conditions which will initiate a Reactor Trip without dump of primary water (Blade-Drop Trips).
NOTE: INCLUDE SETPOINTS WHERE APPLICABLE

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

QUESTION E.03 (2.75)

LIST the sequence of automatic protective actions that occur when two (2) Area Radiation Monitors detect a HIGH LEVEL of Radiation during Reactor operation. Next to each event STATE WHY that protective action occurred.

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

QUESTION E.06 (1.50)

EXPLAIN WHY the Reactor Protection System is Fail Safe and requires no auxilliary power to ensure shutdown. INCLUDE in your answer a complete description of how the Reactor Trips on Loss of Offsite Power.

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

QUESTION E.07 (1.00)

DESCRIBE the Power Supply to the Area Radiation Monitors.

(***** END OF CATEGORY E *****)

QUESTION F.01 (3.00)

Match the evolution / function in Column A to the ONE responsible person(s) in Column B (Answers in Column B may be used more than once.)

Column A		Column B
1. _____	designates personnnel for the performance of maintenance	A. Licensed Reactor Operator
2. _____	circuit breaker operation	B. Reactor Manager
3. _____	indicates specific codes, standards, and regulations to be used or referenced in the various phases of a modification	C. Radiation Control Officer
~~4. _____~~	~~required to sign only certain Level I RWP's and all Level II RWP's~~ DELETED	D. Reactor Safety Review Subcommittee
5. _____	completion of a TRIP EVENT DATA ANALYSIS AND EVALUATION	
6. _____	grants written authorization of major maintenance items	

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

QUESTION F.02 (1.00)

ANSWER EACH of the following concerning reporting and recording events. (FILL IN THE BLANKS)

a. The NRC Operations Center shall be notified by telephone within _____ minutes after discovery of any accidental criticalty.

b. The initial telephone notification (stated above) shall be followed within a period of _____ days by a written report.

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

QUESTION F.03 (1.50)

ANSWER EACH of the following questions concerning UFTR fuel handling. (FILL IN THE BLANKS).

a. If a fuel plate or element is dropped from a height of about _____ or more, fuel handling operations must be secured and the _____ or his designated alterate must be notified.

b. Shield tank water should be sampled and analyzed for _____ and radioactive contamination before and after work with irradiated fuel.

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

QUESTION F.04 (1.00)

Who's approval (if any) is required prior to the performance of any maintenance to CORRECT a significant primary coolant leak.

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

QUESTION F.05 (1.00)

The immediate actions in the event of a Radiological Emergency per SOP-B.1 are independently specified for WORKING and NON-WORKING HOURS. In this regard, what is the definition of WORKING HOURS?

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

QUESTION F.06 (2.00)

STATE the three (3) actions (in order) that are required if the Reactor is operating at 100 KWth and stack counts indicate SIGNIFICANTLY above the maximum equilibrium level.

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

QUESTION F.07 (1.50)

LIST the three (3) actions that are required if radiation level indications of about 1.5 mr/hr are indicated by the Area Radiation Monitors while at 5 KWth power.

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

QUESTION F.08 (2.00)

STATE the standard class of UFTR Facility Emergency Situation (Class Ø,I,or II) that would be applicable for EACH of the following events:

a. Hurricane

b. Personnel injury complicated by the injured person having low level radiological contamination.

c. Small fire in the Control Room.

d. Severe fuel damage during fuel handling.

(***** END OF CATEGORY F *****)

QUESTION G.01 (1.00)

If you are in an 80 mRad/hr neutron radiation field (neutron energy 20 Mev), what is the dose in mREM that you would receive after 45 minutes?

a. 60 mREM

b. 120 mREM

c. 180 mREM

d. 600 mREM

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

QUESTION G.02 (.50)

ANSWER whether the following statement is TRUE or FALSE.
Shortly after power operations, a few drops of primary coolant could contaminate a swipe to 450 cpm beta-gamma activity. Adjusting for detector efficiency, this indicates approximately ten times the permissible UFTR limit.

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

QUESTION G.03 (.50)

ANSWER whether the following statement is TRUE or FALSE.
Samples, NOT LEAVING the UFTR building complex, that were irradiated via the pneumatic rapid sample transfer (RABBIT) system are required to have processed a completed UFTR form SOP-D.4B, Sample Record Index.

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

QUESTION G.04 (1.00)

STATE the unshielded sample radiation levels (two) beyond which the Radiation Control Officer or his designated alternate must authorize transfer.

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

QUESTION G.05 (2.50)

a. LIST the two (2) conditions specified by UFTR Technical Specifications in which the reactor vent system is required to be operated.

b. LIST the three (3) failure(s) or indication(s) that UFTR Technical Specification 3.4.3 requires for the reactor vent system to be immediately secured.

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

QUESTION G.06 (2.00)

a. STATE the maximum permissible concentration (MPC) of the gaseous effluent discharge of Argon-41 as specified in UFTR SOP-E.6 and UFTR Technical Specifications.

b. STATE whether the associated sample of the core ventilation flow is taken PRIOR TO or AFTER dilution by the diluting fan.

c. What factor is used to account for atmospheric dilution of Argon-41 in the determination of stack effluent concentrations as per UFTR Technical Specifications?

d. STATE the minimum time required after a reactor startup to allow for the Argon-41 emission level indicated by the stack monitor to stabilize.

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

QUESTION G.07 (2.00)

LIST the four (4) actions which must be taken in the event that radiation levels following shielding alterations are found to be significantly in excess of anticipated radiation levels.

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

QUESTION G.08 (1.00)

STATE the criterion (dpm/cm^2 above background) used to permit the return to normal use of a potentially contaminated area that had been isolated.

(***** CATEGORY G CONTINUED ON NF PAGE *****)

QUESTION G.09 (1.00)

A point source of gamma radiation gives an exposure rate of 90 mR/hr at ONE meter, CALCULATE the exposure rate at THREE meters.

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

QUESTION G.10 (1.00)

a. STATE the maximum reactor power level at which the opening of the vertical ports for sample irradiation shall be considered a routine operation.

b. Would such a routine operation require an RWP?

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

QUESTION G.11 (1.50)

STATE the normal working dose rates (in mREM/wk for whole body, extremities, and skin) which require preparation of a radiation work permit (RWP) and compliance with the provisions of UFTR SOP-D.2 prior to commencement of work or operations which have the potential of exceeding those rates.

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

QUESTION G.12 (1.25)

STATE the specific definitions of a "RADIATION AREA" and of a "HIGH RADIATION AREA."

(***** END OF CATEGORY G *****)
(********** END OF EXAMINATION **********)

ANSWER A.01 (1.00)

d

REFERENCE

Westinghouse Design Technical Manual, Chapter 2

ANSWER A.02 (1.50)

a. The fraction of thermal neutrons that escape leakage while thermal. (0.5)

b. If a reactor had a reflector, fast neutrons which escaped from the core can be thermalized and then reflected back into the core (0.5). The net result can be that more thermal neutrons enter the core than leak from it. (0.5)

REFERENCE

General Electric, Reactor Theory, App. G

ANSWER A.03 (1.00)

P = Po*exp (t/T) (0.4)

T = t/ln(P/Po) (0.4)

T = 240/ln(2000/100) = 80 sec (0.2)

REFERENCE

General Electric, Reactor Theory, Chap. 3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER A.04 (2.00)

Neg. reactivity added by all rods dropping (from IRW curve) =
-0.3138 (SB 1) - 0.0132 (SB 2) - 0.0222 (SB 3) -0.0056 (RB)
= -0.0548 (0.8)

$\tau = (b_{eff} - \rho) / (\lambda * \rho + d\rho/dt)$

~~SUR = 26.06 * (lambda * p + dp/dt) / (b eff - p)~~ (0.8)

$\tau = (.0065 - [-.0548]) / (.0124 * [-.0548] + 0)$

~~SUR = 26.06 * (0.0124*[-0.0548] + 0) / (0.0065 - [-0.0548])~~ (0.2)

$\tau = -90$ sec (± 2 sec)

~~SUR = -0.29 DPM (+- 0.02 DPM)~~ (0.2)

NOTE: APPLICABLE GRAPHS ARE ATTACHED

~~If SUR is not a term taught at the facility, the question will be graded on the individual's knowledge of the concept. If SUR understood, grading will be per the answer key.~~

REFERENCE

Westinghouse Design Technology Manual, Chap. 2
UFTR: FSAR

ANSWER A.05 (2.00)

a. K-effective (0.5 each)

b. Gamma Decay

c. Period (Fermi Age)

d. Photoelectric Effect

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p.56,89
General Electric, Reactor Theory, Chapters 1, 3

ANSWER A.06 (1.00)

(b)

REFERENCE
NUS, Vol 2, pp 7.3-2

ANSWERS -- UNIVERSITY OF FLORIDA -86/06/08-ARILDSEN, J.

ANSWER A.07 (1.00)

(b)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p. 158

ANSWER A.08 (1.00)

(d)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, pp.161-162

ANSWER A.09 (1.00)

b

REFERENCE
CR Training Ltr TRA 85-0013
DPC, Fundamentals of Nuclear Reactor Engineering, p. 38, 39, 146

ANSWER A.10 (1.00)

c

REFERENCE

General Electric, Reactor Theory, Chap. 5

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER A.11 (2.50)

a. Steady state neutron level higher than source alone due to the multiplication of fissionable fuel.

b. Material at core edges which reduces neutron leakage by scattering neutrons back into the core.

c. Removal of Xe-135 from the core by absorption of a neutron to Xe-136.

d. Heat produced by the decay of radioactive nuclides.

e. Reactivity change per unit of rod motion.

REFERENCE

General Electric, Reactor Theory, App. G

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ANSWER B.01 (2.00)

a. TRUE
b. FALSE
c. FALSE
d. TRUE

REFERENCE
UFTR: FSAR CH 5

ANSWER B.02 (2.50)

a. .06% ^k/k
b. 100 KWth
c. 2.3% ^k/k
d. 93% , uranium aluminum or uranium 235 (0.5 each blank)

REFERENCE
UFTR: FSAR CH 4.1 , TECH SPEC 3.0

ANSWER B.03 (1.00)

Fuel Bundle Aluminum Wedging Pins ~~(0.5)~~ (1.00) (are inserted into the center of the fuel boxes) ~~(0.5)~~.

REFERENCE
UFTR: SOP C2,7.4.1.2

ANSWER B.04 (1.00)

Foils are installed in the slots for irradiation (0.5) and are used for flux mapping (0.5).

REFERENCE
UFTR: FSAR CH 4.1.4

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ANSWER B.05 (2.00)

a. Allows an air return path to the top of the fuel boxes (0.5) to allow rapid dumping of the water from the boxes (0.5).

b. Located at the base of the stacks before dilution occurs (0.5).

c. Prevents the discharge of undiluted air effluent (0.5).

REFERENCE
UFTR: CH 9.4.2

ANSWER B.06 (1.00)

Functions as both a Moderator (.5) and a Reflector (.5).

REFERENCE
UFTR: Emergency Plan Ch. 1.3

ANSWER B.07 (2.00)

a. Prevents diffusion of radioactive gases or particulate matter into the Reactor Room during Reactor operation. (1.0)

b. Ar-41
N-16 (0.5 each)

REFERENCE
UFTR: FSAR CH. 9

ANSWER B.08 (1.50)

Tap water is passed through 2 demineralizers in series (0.5) that are filled with nuclear grade resin (amberlite) (0.5). As the water passes through, it undergoes mechanical filtration (.25) and ionic impurities are exchanged with H+ and 0H- Resin ions (through the process of adsorption) (.25).

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ANSWER B.09 (2.00)

a. The Diffuser eliminates the formation of vortices inside the storage tank (as a result of the pump's suction) (0.5), by forcing the water to diffuse through the input line to the Primary Coolant Pump (0.5).

b. The Baffle eliminates air being trapped in the coolant (0.5), by suppressing the splashing of water comming into the CST (0.25) and changing its direction of flow (0.25).

REFERENCE
UFTR: FSAR CH 5.1.1

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ANSWER C.01 (2.00)

Subscript 1 refers to values when all rods are inserted. Subscript 2 refers to values when Rod A is withdrawn.

Keff1 = 1/(1-p1)
= 1/(1+0.1230)
= 0.89 (0.4)

CR1/CR2 = (1-Keff2)/(1-Keff1) =>
Keff2 = 1-[CR1/CR2 * (1-Keff1)]
= 1-[2/3 * (1-0.89)]
= 0.927 (0.6)

p2 = (Keff2-1)/Keff2
= (0.927-1)/0.927
= -0.0790 (0.4)

Required reactivity addition needed = p2 - p1 = +0.0440 (0.2)

From IRW curve, SB 1 must be withdrawn to position ~~100% (+-0%) withdrawn~~ 560 (0.2)
SB 2 must be ~~100% (+-0%) withdrawn~~ 560 (0.2)
SB 3 must be ~~54% (+-2%) withdrawn~~ 560 (0.2)
RB must be " " 380 (120) (0.)

REFERENCE

General Electric, Reactor Theory, Chap. 3
UFTR: FSAR

ANSWER C.02 (1.00)

(d)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p. 106
VEGP, Training Text, Vol. 9, p. 21-47
Westinghouse Reactor Physics, pp. 1-3.17 & 19

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER C.03 (1.00)

(c)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p.163
General Electric, Reactor Theory, Chapter 6
EIH: GPNT,Vol VII, Chapter 10.1-83-86
BSEP: L/P 02-2/3-A, pp 172 - 176; 02-OG-A, pp 57 - 60

ANSWER C.04 (1.00)

d (1.0)

REFERENCE
UFTR: FSAR CH 4.6

ANSWER C.05 (1.00)

d (1.0)

REFERENCE
UFTR: SOP 4.3 , 4.6.1

ANSWER C.06 (2.50)

a. 40 (+or-1) gpm
b. 86 (+or-2) deg F or 105(+-5) deg F
c. 103 (+or-2) deg F or 120(+-5) deg F
d. -0.3 X 10 exp -4 delta k/k per deg F
e. approx 40 deg F (0.5 each)

REFERENCE
UFTR: FSAR CH 4.1.2

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ANSWER C.07 (1.25)

DISAGREE (0.5)
More excess reactivity must be added to get to power (.25)- a higher loaded core is more hazardous (.25). Also, cold water accidents are more severe (.25).

REFERENCE
UFTR: SRO TEST 5/30/84

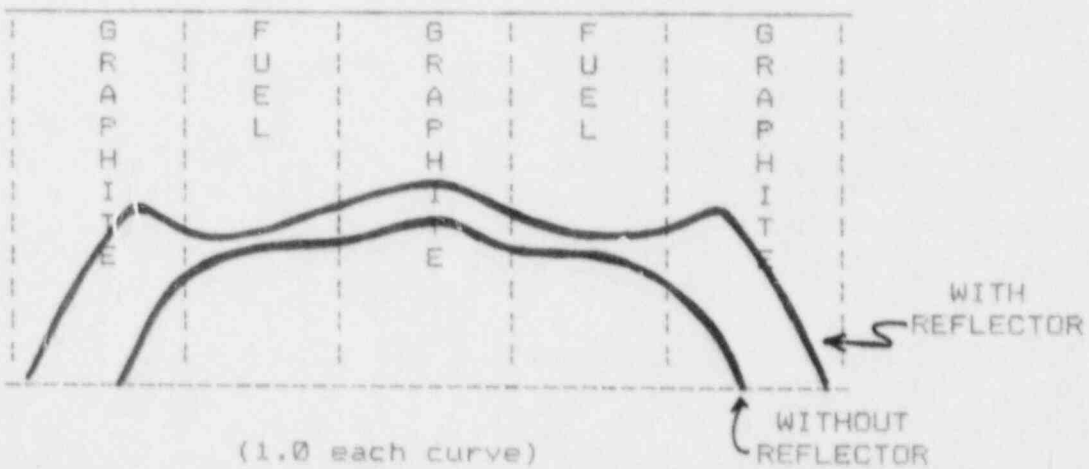
ANSWER C.08 (2.00)

a. 23535 KWHR / month or 235 FPH / month (0.5)

b. The principal routine emmission from the UFTR facility is AR-41 (0.5). The concentration of AR-41 from the stack after dilution is approximately 3.1 X MPC as recommended by the Florida Division of Health (0.5). Reactor operations are limited to limit the Argon-41 discharges to MPC when averaged over a month (0.5).

REFERENCE
UFTR: FSAR CH 11

ANSWER C.09 (2.00)



(1.0 each curve)

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REFERENCE
UFTR: SRO TEST 5/30/84

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER D.01 (2.00)

a. FALSE
b. TRUE
c. TRUE
d. FALSE

REFERENCE
UFTR: FSAR CH 7

ANSWER D.02 (2.50)

1) fast period <= 3 sec	(.25)	ch #1	(.25)
2) high power >= 125 %	(.25)	both	(.25)
3) reduction of HV to neutron chambers of >= 10 %	(.25)	both	(.25)
4) turning off the console magnet power switch	(.25)	none	(.25)
5) AC power failure	(.25)	none	(.25)

REFERENCE
UFTR: FSAR CH 7

ANSWER D.03 (1.00)

The Purification Pump shuts off when the Primary Coolant Pump is running. (1.0) -OR- The Primary Coolant Pump will not start unless the dump valve is closed. (1.0)

REFERENCE
UFTR: FSAR 9.2.4

ANSWER D.04 (1.00)

This channel operates at power levels at which the gamma radiation is negligible compared to the neutron level. Therefore, it is not necessary to use a gamma compensated detector. (1.0)

REFERENCE
UFTR: FSAR CH 9

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER D.05 (2.25)

a. An in line (wall mounted) resistivity bridge (0.5) receives two ~~a~~ signals from ~~a~~ conductivity cells (0.5) located upstream ~~of~~ and downstream of the demineralizer in the Purification System (.25).

b. The Primary Coolant Pump gerneates sufficient driving head to Maintain a flow through the Purification Loop when it is in operation (1.0).

REFERENCE
UFTR: FSAR 5.1.4 , 9.2.4

ANSWER D.06 (2.00)

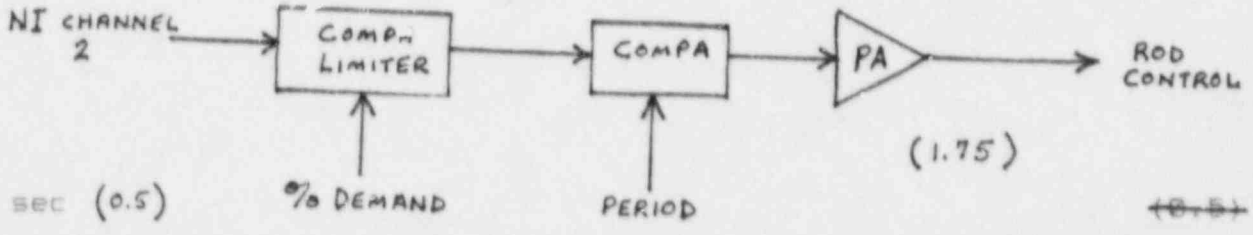
a.
I RECOMBINATION
II IONIZATION CHAMBER
III PROPORTIONAL
IV G-M

b. 1. PROPORTIONAL
2. ION CHAMBER
3. G-M
4. G-M

REFERENCE
NUCLEAR POWER SYSTEMS CH 7

ANSWER D.07 (2.25)

a.



(1.75)

b. 30 sec (0.5) ~~(0.5)~~

REFERENCE
UFTR: FSAR CH 9

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER E.01 (2.50)

a. FALSE
b. TRUE
c. FALSE
d. FALSE
e. TRUE

REFERENCE
UFTR: FSAR CH 7, CH 15

ANSWER E.02 (2.50)

1. source counts < 2cps
2. reactor period ~~≤~~ 10 seconds
3. attempt to raise any two or more Blades simultaneously.
4. Safety Channels 1 and 2 and Wide Range Drawer Calibrate (or Safety 1 Trip Test) switches not in OPERATE.
5. Power is raised in AUTO control at a period faster than 30 sec.

(0.5 each)

REFERENCE
UFTR: FSAR CH 7

ANSWER E.03 (1.50)

1) 2 Area Radiation Monitors Alarm in coincidence (at >= 25 mr/hr) ~~(.25)~~ (0.5)
~~Automatic (.25)~~
2) Air Particulate Monitor with valid alarm condition ~~(.25)~~ (0.5)
~~Manual (.25)~~
3) Reactor operator detects a potentially hazardous radiological condition (and preventive actions are required to protect personnel). ~~(.25)~~ (0.5)
~~Manual (.25)~~

REFERENCE
UFTR: TECH SPEC 3.6.1

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ANSWER E.04 (3.00)

1) Loss of power to the Reactor Vent Blower System. (.25)
2) " " Primary Cooling Pump (.25)
3) " " Vent Diluting System (.25)
4) " " Secondary System Well Pump (.15)
when above 1 KW and using this system for cooling. (0.1)
5) Less than 60 gpm Secondary System Flow when using Well Water for cooling (.15) and above 1 KW power (0.1).
6) Less than 8 gpm Secondary System Flow when using city water for cooling (.15) and above 1 KW power (0.1).
7) Drop in Water Level of the Shield Tank (about 4 in.). (.25)
8) Reduction of Primary Coolant Flow <= 30 gpm (.25)
9) Loss of Primary coolant Flow (return line < 10gpm) (.25)
10) Reduction of Primary Coolant Level (.25)
11) High Temp Primary Coolant return 155 deg F (.25)
12) Manual Reactor Trip Button depressed. (.25)

REFERENCE
UFTR: FSAR CH 7.3.2

ANSWER E.05 (2.75)

Evacuation Alarm Actuates	(0.5)	due to 2 RAD Monitors alarming	(.25)
Reactor Cell AC trips	(0.5)	due to actuation of the	(.25)
Reactor Vent Sys trips (diluting fan, vent fan and damper close)	(0.5)	Evacuation Alarm	
Reactor Trips (blade trip)	(0.5)	due to loss of power to Diluting Fan, Vent Fan	(.25)

REFERENCE
UFTR: FSAR CH 7.6 ,9.4.2

ANSWER E.06 (1.50)

The loss of Offsite Power drops out the Scram Relays (.25) and deenergizes the Magnetic Clutches (.25) to Trip the Reactor by dropping the Control Rods under gravity completely into the core (.5). It is Fail Safe since a loss of power will result in a Reactor Trip (.5).

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REFERENCE
UFTR: FSAR CH 8.2

ANSWER E.07 (1.00)

24VDC power supply (0.5) backed up with a floating battery pack (0.5).

REFERENCE
UFTR: FSAR CH 8.4

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ANSWER F.01 ~~(3.00)~~ (2.50)

1. B
2. A
3. B
4. ~~C~~ DELETED
5. A
6. B (0.5 each)

REFERENCE
UFTR: SOP-0.2, 7.2.2 and 7.2.2.3
SOP-0.2, APPENDIX I
Form 0.2A
SOP-0.3, 3.3.4.1
SOP-0.6, 7.1.2.11

ANSWER F.02 (1.00)

a. 60
b. 30 (0.5 each)

REFERENCE
UFTR: SOP F.8 , 7.1 AND 7.3.1

ANSWER F.03 (1.50)

a. 1 ft.
Reactor Manager

b. conductivity (0.5 each)

REFERENCE
UFTR: SOP-C.4, 4.10 and 4.13

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ANSWER F.04 (1.00)

The Reactor Manager or his authorized representative (1.0)

REFERENCE
UFTR: SOP-D.3, 4.3.1

ANSWER F.05 (1.00)

Any time that authorized personnel are in the Reactor Cell. (1.0)

REFERENCE
UFTR: SOP-B.1, 7.1.1

ANSWER F.06 (2.00)

1) Shutdown the Reactor
2) Notify the SRO on call
3) Determine the cause

(Emergency Plan actions accepted)
(0.5 each and 0.5 for ~~#3~~ #1 being listed ~~last~~ first)

REFERENCE
UFTR: SOP - A.3 , 4.6.3

ANSWER F.07 (1.50)

1) Determine the cause
2) implement appropriate corrective action.
3) Notify the SRO on call.

(0.5 each)

REFERENCE
UFTR: SOP - A.3 , 4.5.2

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ANSWER F.08 (2.00)

a. Class I
b. Class 0
c. Class I
d. Class ~~II~~ I - or - Class II (0.5 each)

REFERENCE
UFTR: EMERGENCY PLAN 4.1,4.2,4.3

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ANSWER G.01 (1.00)

~~b~~ d QF=10 (80)(45/60)(10)=600 (1.0)

REFERENCE
10 CFR 20.4

ANSWER G.02 (.50)

TRUE (0.5)

REFERENCE
UFTR: SOP-D.3, 4.3

ANSWER G.03 (.50)

FALSE (0.5)

REFERENCE
UFTR: SOP-D.4, 7.7

ANSWER G.04 (1.00)

1.5 R/hr at one foot 1.0 ~~(0.5)~~
or
(200 mR/hr at the surface of the transfer container) ~~(0.5)~~

REFERENCE
UFTR: SOP-D.4, 7.3

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ANSWER G.05 (2.50)

a. 1. During reactor operations
2. Stack monitor indicates greater than 10 cps

b. 1. Failure in the monitoring system
2. Failure of the absolute filter
3. Unanticipated high stack count rate (0.5 each)

REFERENCE
UFTR: Tech. Spec. 3.4.3

ANSWER G.06 (2.00)

a. 4.0 E-8 microC/ml

b. PRIOR TO

c. 200

d. 4 hours (0.5 each)

REFERENCE
UFTR: SOP-E.6
UFTR: Tech. Spec. 3.4.2

ANSWER G.07 (2.00)

1. Shutdown the reactor immediately

2. Promptly replace the shielding

3. Notify the Reactor Manager or his designated representative

4. Evaluate the situation and determine the cause of the higher radiation levels

(0.5 each)

REFERENCE
UFTR: SOP-E.2, 7.1.3

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ANSWER G.08 (1.00)

20 dpm/cm^2 (1.0)

REFERENCE
Emergency Plan for the UFTR, 7.1.2.3

ANSWER G.09 (1.00)

10 mR/hr (1.0)

REFERENCE
UFTR: FSAR 12.10

ANSWER G.10 (1.00)

a. 1 KW

b. No (0.5 each)

REFERENCE
UFTR: SOP-E.2, 7.2

ANSWER G.11 (1.50)

75 mREM/wk whole body
500 mREM/wk extremities
400 mREM/wk skin (0.5 each)

REFERENCE
UFTR: SOP-D.1, 4.4

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ANSWER G.12 (1.25)

"RADIATION AREA" - Any area accessible to personnel (0.25) in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 mREM (0.25) or in any 5 consecutive days a dose in excess of 100 mREM (0.25).

"HIGH RADIATION AREA" - Any area accessible to personnel (0.25) in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 mREM (0.25).

REFERENCE
UFTR: SOP-D.1, 3.2.3 and 3.2.4

QUESTION	VALUE	REFERENCE
A.01	1.00	GTH0000846
A.02	1.50	GTH0000848
A.03	1.00	GTH0000849
A.04	2.00	GTH0000850
A.05	2.00	GTH0000853
A.06	1.00	GTH0000854
A.07	1.00	GTH0000857
A.08	1.00	GTH0000858
A.09	1.00	GTH0000860
A.10	1.00	GTH0000862
A.11	2.50	GTH0000863
	15.00	
B.01	2.00	GTH0000790
B.02	2.50	GTH0000794
B.03	1.00	GTH0000796
B.04	1.00	GTH0000788
B.05	2.00	GTH0000789
B.06	1.00	GTH0000792
B.07	2.00	GTH0000793
B.08	1.50	GTH0000787
B.09	2.00	GTH0000791
	15.00	
C.01	2.00	GTH0000851
C.02	1.00	GTH0000852
C.03	1.00	GTH0000855
C.04	1.00	GTH0000796
C.05	1.00	GTH0000880
C.06	2.50	GTH0000798
C.07	1.25	GTH0000795
C.08	2.00	GTH0000799
C.09	2.00	GTH0000797
	13.75	
D.01	2.00	GTH0000804
D.02	2.50	GTH0000802
D.03	1.00	GTH0000805
D.04	1.00	GTH0000800
D.05	2.25	GTH0000806
D.06	2.00	GTH0000803
D.07	2.25	GTH0000801
	13.00	
E.01	2.50	GTH0000808
E.02	2.50	GTH0000807

QUESTION	VALUE	REFERENCE
E.03	1.50	GTH0000810
E.04	3.00	GTH0000811
E.05	2.75	GTH0000813
E.06	1.50	GTH0000809
E.07	1.00	GTH0000812
	14.75	
F.01	3.00	GTH0000870
F.02	1.00	GTH0000878
F.03	1.50	GTH0000881
F.04	1.00	GTH0000820
F.05	1.00	GTH0000830
F.06	2.00	GTH0000873
F.07	1.50	GTH0000874
F.08	2.00	GTH0000882
	13.00	
G.01	1.00	GTH0000814
G.02	.50	GTH0000815
G.03	.50	GTH0000824
G.04	1.00	GTH0000817
G.05	2.50	GTH0000818
G.06	2.00	GTH0000819
G.07	2.00	GTH0000821
G.08	1.00	GTH0000822
G.09	1.00	GTH0000823
G.10	1.00	GTH0000827
G.11	1.50	GTH0000828
G.12	1.25	GTH0000829
	15.25	
	79.75	

MASTER
RO

SRO / RO

UNIVERSITY OF FLORIDA TEST REACTOR

LICENSE EXAMINATION

88/06/08

HANDOUTS

EQUATION SHEET ------ 1 PAGE
STEAM TABLES -------- 7 PAGES
FIGURE #219
FIGURE 4-26
FIGURE 4-27
FIGURE 4-28
FIGURE 4-29

$f = ma$

$w = mg$

$E = mc^2$

$KE = 1/2\ mv^2$

$PE = mgh$

$V_f = V_o + at$

$W = v\ \Delta P$

$\Delta E = 931\ \Delta m$

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

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

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

$Pwr = W_f \Delta h$

$P = P_o 10^{sur(t)}$

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

$SUR = 26.06/T$

$SUR = 26\rho/\ell^* + (\beta - \rho)T$

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

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

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

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

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

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

$\Sigma = \sigma N$

$v = s/t$

$s = V_o t + 1/2\ at^2$

$a = (V_f - V_o)/t$

$w = \theta/t$

$A = \frac{\pi D^2}{4}$

$\dot{m} = V_{av} A_o$

Cycle efficiency = (Net work out)/(Energy in)

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

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

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

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

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

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

$TVL = 1.3/\mu$

$HVL = -0.693/\mu$

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

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

$CR_1(1 - K_{eff1}) = CR_2(1 - K_{eff2})$

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

$M = (1 - K_{effo})/(1 - K_{eff1})$

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

$\ell^* = 10^{-4}$ seconds

$\bar{\lambda} = 0.1$ seconds^{-1}

$I_1 d_1 = I_2 d_2$

$I_1 d_1^{\ 2} = I_2 d_2^{\ 2}$

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

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

Water Parameters

1 gal. = 8.345 lbm.
1 gal. = 3.78 liters
1 ft^3 = 7.48 gal.
Density = 62.4 lbm/ft^3
Density = 1 gm/cm^3
Heat of vaporization = 970 Btu/lbm
Heat of fusion = 144 Btu/lbm
1 Atm = 14.7 psi = 29.9 in. Hg.
1 ft. H_2O = 0.4335 lbf/in.

Miscellaneous Conversions

1 curie = 3.7×10^{10} aps
1 kg = 2.21 lbm
1 hp = 2.54×10^3 Btu/hr
1 mw = 3.41×10^6 Btu/hr
1 in = 2.54 cm
°F = 9/5°C + 32
°C = 5/9 (°F-32)
1 BTU = 778 ft-lbf
e = 2.718

Temp F	Press. psia	Volume, ft³/lb			Enthalpy, Btu/lb			Entropy, Btu/lb x F			Temp F
		Water v_f	Evap v_{fg}	Steam v_g	Water h_f	Evap h_{fg}	Steam h_g	Water s_f	Evap s_{fg}	Steam s_g	
32	0.08859	0.01602	3305	3305	-0.02	1075.5	1075.5	0.0000	2.1873	2.1873	32
35	0.09991	0.01602	2948	2948	3.00	1073.8	1076.8	0.0061	2.1706	2.1767	35
40	0.12163	0.01602	2446	2446	8.03	1071.0	1079.0	0.0162	2.1432	2.1594	40
45	0.1474	0.01602	2037.7	2037.8	13.04	1068.1	1081.2	0.0262	2.1164	2.1426	45
50	0.1779	0.01602	1704.8	1704.8	18.05	1065.3	1083.4	0.0361	2.0901	2.1262	50
60	0.2561	0.01603	1207.6	1207.6	28.06	1059.7	1087.7	0.0555	2.0391	2.0946	60
70	0.3629	0.01605	868.3	868.4	38.05	1054.0	1092.1	0.0745	1.9900	2.0645	70
80	0.5068	0.01607	633.3	633.3	48.04	1048.4	1096.4	0.0932	1.9426	2.0359	80
90	0.6981	0.01610	468.1	468.1	58.02	1042.7	1100.8	0.1115	1.8970	2.0086	90
100	0.9492	0.01613	350.4	350.4	68.00	1037.1	1105.1	0.1295	1.8530	1.9825	100
110	1.2750	0.01617	265.4	265.4	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110
120	1.6927	0.01620	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120
130	2.2230	0.01625	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130
140	2.8892	0.01629	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140
150	3.718	0.01634	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150
160	4.741	0.01640	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160
170	5.993	0.01645	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170
180	7.511	0.01651	50.21	50.22	148.00	990.2	1138.2	0.2631	1.5480	1.8111	180
190	9.340	0.01657	40.94	40.96	158.04	984.1	1142.1	0.2787	1.5148	1.7934	190
200	11.526	0.01664	33.62	33.64	168.09	977.9	1146.0	0.2940	1.4824	1.7764	200
210	14.123	0.01671	27.80	27.82	178.15	971.6	1149.7	0.3091	1.4509	1.7600	210
212	14.696	0.01672	26.78	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	212
220	17.186	0.01678	23.13	23.15	188.23	965.2	1153.4	0.3241	1.4201	1.7442	220
230	20.779	0.01685	19.364	19.381	198.33	958.7	1157.1	0.3388	1.3902	1.7290	230
240	24.968	0.01693	16.304	16.321	208.45	952.1	1160.6	0.3533	1.3609	1.7142	240
250	29.825	0.01701	13.802	13.819	218.59	945.4	1164.0	0.3677	1.3323	1.7000	250
260	35.427	0.01709	11.745	11.762	228.76	938.6	1167.4	0.3819	1.3043	1.6862	260
270	41.856	0.01718	10.042	10.060	238.95	931.7	1170.6	0.3960	1.2769	1.6729	270
280	49.200	0.01726	8.627	8.644	249.17	924.6	1173.8	0.4098	1.2501	1.6599	280
290	57.550	0.01736	7.443	7.460	259.4	917.4	1176.8	0.4236	1.2238	1.6473	290
300	67.005	0.01745	6.448	6.466	269.7	910.0	1179.7	0.4372	1.1979	1.6351	300
310	77.67	0.01755	5.609	5.626	280.0	902.5	1182.5	0.4506	1.1726	1.6232	310
320	89.64	0.01766	4.896	4.914	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320
340	117.99	0.01787	3.770	3.788	311.3	878.8	1190.1	0.4902	1.0990	1.5892	340
360	153.01	0.01811	2.939	2.957	332.3	862.1	1194.4	0.5161	1.0517	1.5678	360
380	195.73	0.01836	2.317	2.335	353.6	844.5	1198.0	0.5416	1.0057	1.5473	380
400	247.26	0.01864	1.8444	1.8630	375.1	825.9	1201.0	0.5667	0.9607	1.5274	400
420	308.78	0.01894	1.4808	1.4997	396.9	806.2	1203.1	0.5915	0.9165	1.5080	420
440	381.54	0.01926	1.1976	1.2169	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440
460	466.9	0.0196	0.9746	0.9942	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460
480	566.2	0.0200	0.7972	0.8172	464.5	739.6	1204.1	0.6648	0.7871	1.4518	480
500	680.9	0.0204	0.6545	0.6749	487.9	714.3	1202.2	0.6890	0.7443	1.4333	500
520	812.5	0.0209	0.5386	0.5596	512.0	687.0	1199.0	0.7133	0.7013	1.4146	520
540	962.8	0.0215	0.4437	0.4651	536.8	657.5	1194.3	0.7378	0.6577	1.3954	540
560	1133.4	0.0221	0.3651	0.3871	562.4	625.3	1187.7	0.7625	0.6132	1.3757	560
580	1326.2	0.0228	0.2994	0.3222	589.1	589.9	1179.0	0.7876	0.5673	1.3550	580
600	1543.2	0.0236	0.2438	0.2675	617.1	550.6	1167.7	0.8134	0.5195	1.3330	600
620	1786.9	0.0247	0.1962	0.2208	646.9	506.3	1153.2	0.8403	0.4699	1.3092	620
640	2059.9	0.0260	0.1543	0.1802	679.1	454.6	1133.7	0.8686	0.4134	1.2821	640
660	2365.7	0.0277	0.1166	0.1443	714.9	392.1	1107.0	0.8995	0.3502	1.2498	660
680	2708.6	0.0304	0.0808	0.1112	758.5	310.1	1068.5	0.9365	0.2720	1.2086	680
700	3094.3	0.0366	0.0386	0.0752	822.4	172.7	995.2	0.9901	0.1490	1.1390	700
705.5	3208.2	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1.0612	705.5

TABLE A.2 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (TEMPERATURE)

Press. psia	Temp F	Volume, ft³/lb			Enthalpy, Btu/lb			Entropy, Btu/lb x F			Energy, Btu/lb		Press. psia
		Water	Evap	Steam	Water	Evap	Steam	Water	Evap	Steam	Water	Steam	
		v_f	v_{fg}	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	u_f	u_g	
0.0886	32.018	0.01602	3302.4	3302.4	0.00	1075.5	1075.5	0	2.1872	2.1872	0	1021.3	0.0886
0.10	35.023	0.01602	2945.5	2945.5	3.03	1073.8	1076.8	0.0061	2.1705	2.1766	3.03	1022.3	0.10
0.15	45.453	0.01602	2004.7	2004.7	13.50	1067.9	1081.4	0.0271	2.1140	2.1411	13.50	1025.7	0.15
0.20	53.160	0.01603	1526.3	1526.3	21.22	1063.5	1084.7	0.0422	2.0738	2.1160	21.22	1028.3	0.20
0.30	64.484	0.01604	1039.7	1039.7	32.54	1057.1	1089.7	0.0641	2.0168	2.0809	32.54	1032.0	0.30
0.40	72.869	0.01606	792.0	792.1	40.92	1052.4	1093.3	0.0799	1.9762	2.0562	40.92	1034.7	0.40
0.5	79.586	0.01607	641.5	641.5	47.62	1048.6	1096.3	0.0925	1.9446	2.0370	47.62	1036.9	0.5
0.6	85.218	0.01609	540.0	540.1	53.25	1045.5	1098.7	0.1028	1.9186	2.0215	53.24	1038.7	0.6
0.7	90.09	0.01610	466.93	466.94	58.10	1042.7	1100.8	0.3	1.8966	2.0083	58.10	1040.3	0.7
0.8	94.38	0.01611	411.67	411.69	62.39	1040.3	1102.6	0.1117	1.8775	1.9970	62.39	1041.7	0.8
0.9	98.24	0.01612	368.41	368.43	66.24	1038.1	1104.3	0.1264	1.8606	1.9870	66.24	1042.9	0.9
1.0	101.74	0.01614	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	69.73	1044.1	1.0
2.0	126.07	0.01623	173.74	173.76	94.03	1022.1	1116.2	0.1750	1.7450	1.9200	94.03	1051.8	2.0
3.0	141.47	0.01630	118.71	118.73	109.42	1013.2	1122.6	0.2009	1.6854	1.8864	109.41	1056.7	3.0
4.0	152.96	0.01636	90.63	90.64	120.92	1006.4	1127.3	0.2199	1.6428	1.8626	120.90	1060.2	4.0
5.0	162.24	0.01641	73.515	73.53	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	130.18	1063.1	5.0
6.0	170.05	0.01645	61.967	61.98	138.03	996.2	1134.2	0.2474	1.5820	1.8294	138.01	1065.4	6.0
7.0	176.84	0.01649	53.634	53.65	144.83	992.1	1136.9	0.2581	1.5587	1.8168	144.81	1067.4	7.0
8.0	182.86	0.01653	47.328	47.35	150.87	988.5	1139.3	0.2676	1.5384	1.8060	150.84	1069.2	8.0
9.0	188.27	0.01656	42.385	42.40	156.30	985.1	1141.4	0.2760	1.5204	1.7964	156.28	1070.8	9.0
10	193.21	0.01659	38.404	38.42	161.26	982.1	1143.3	0.2836	1.5043	1.7879	161.23	1072.3	10
14.696	212.00	0.01672	26.782	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	180.12	1077.6	14.696
15	213.03	0.01673	26.274	26.29	181.21	969.7	1150.9	0.3137	1.4415	1.7552	181.16	1077.9	15
20	227.96	0.01683	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	196.21	1082.0	20
30	250.34	0.01701	13.7266	13.744	218.9	945.2	1164.1	0.3682	1.3313	1.6995	218.8	1087.9	30
40	267.25	0.01715	10.4794	10.497	236.1	933.6	1169.8	0.3921	1.2844	1.6765	236.0	1092.1	40
50	281.02	0.01727	8.4967	8.514	250.2	923.9	1174.1	0.4112	1.2474	1.6586	250.1	1095.3	50
60	292.71	0.01738	7.1562	7.174	262.2	915.4	1177.6	0.4273	1.2167	1.6440	262.0	1098.0	60
70	302.93	0.01748	6.1875	6.205	272.7	907.8	1180.6	0.4411	1.1905	1.6316	272.5	1100.2	70
80	312.04	0.01757	5.4536	5.471	282.1	900.9	1183.1	0.4534	1.1675	1.6208	281.9	1102.1	80
90	320.28	0.01766	4.8777	4.895	290.7	894.6	1185.3	0.4643	1.1470	1.6113	290.4	1103.7	90
100	327.82	0.01774	4.4133	4.431	298.5	888.6	1187.2	0.4743	1.1284	1.6027	298.2	1105.2	100
120	341.27	0.01789	3.7097	3.728	312.6	877.8	1190.4	0.4919	1.0960	1.5879	312.2	1107.6	120
140	353.04	0.01803	3.2010	3.219	325.0	868.0	1193.0	0.5071	1.0681	1.5752	324.5	1109.6	140
160	363.55	0.01815	2.8155	2.834	336.1	859.0	1195.1	0.5206	1.0435	1.5641	335.5	1111.2	160
180	373.08	0.01827	2.5129	2.531	346.2	850.7	1196.9	0.5328	1.0215	1.5543	345.6	1112.5	180
200	381.80	0.01839	2.2689	2.287	355.5	842.8	1198.3	0.5438	1.0016	1.5454	354.8	1113.7	200
250	400.97	0.01865	1.8245	1.8432	376.1	825.0	1201.1	0.5679	0.9585	1.5264	375.3	1115.8	250
300	417.35	0.01889	1.5238	1.5427	394.0	808.9	1202.9	0.5882	0.9223	1.5105	392.9	1117.2	300
350	431.73	0.01913	1.3064	1.3255	409.8	794.2	1204.0	0.6059	0.8909	1.4968	408.6	1118.1	350
400	444.60	0.0193	1.14162	1.1610	424.2	780.4	1204.6	0.6217	0.8630	1.4847	422.7	1118.7	400
450	456.28	0.0195	1.01224	1.0318	437.3	767.5	1204.8	0.6360	0.8378	1.4738	435.7	1118.9	450
500	467.01	0.0198	0.90787	0.9276	449.5	755.1	1204.7	0.6490	0.8148	1.4639	447.7	1118.8	500
550	476.94	0.0199	0.82183	0.8418	460.9	743.3	1204.3	0.6611	0.7936	1.4547	458.9	1118.6	550
600	486.20	0.0201	0.74962	0.7698	471.7	732.0	1203.7	0.6723	0.7738	1.4461	469.5	1118.2	600
700	503.08	0.0205	0.63505	0.6556	491.6	710.2	1201.8	0.6928	0.7377	1.4304	488.9	1116.9	700
800	518.21	0.0209	0.54809	0.5690	509.8	689.6	1199.4	0.7111	0.7051	1.4163	506.7	1115.2	800
900	531.95	0.0212	0.47968	0.5009	526.7	669.7	1196.4	0.7279	0.6753	1.4032	523.2	1113.0	900
1000	544.55	0.0216	0.42435	0.4460	542.6	650.4	1192.9	0.7434	0.6476	1.3910	538.6	1110.4	1000
1100	556.26	0.0220	0.37863	0.4006	557.5	631.5	1189.1	0.7578	0.6216	1.3794	553.1	1107.5	1100
1200	567.19	0.0223	0.34013	0.3625	571.9	613.0	1184.8	0.7714	0.5969	1.3683	566.9	1104.3	1200
1300	577.42	0.0227	0.30722	0.3299	585.6	594.6	1180.2	0.7843	0.5733	1.3577	580.1	1100.9	1300
1400	587.07	0.0231	0.27871	0.3018	598.8	576.9	1175.3	0.7966	0.5507	1.3474	592.9	1097.1	1400
1500	596.20	0.0235	0.25372	0.2772	611.7	558.4	1170.1	0.8085	0.5288	1.3373	605.2	1093.1	1500
2000	635.80	0.0257	0.16260	0.1883	672.1	466.2	1138.3	0.8603	0.4256	1.2881	662.6	1068.6	2000
2500	668.11	0.0286	0.10209	0.1307	731.7	361.6	1093.3	0.9139	0.3206	1.2345	718.5	1032.9	2500
3000	695.33	0.0343	0.05073	0.0850	801.8	218.4	1020.3	0.9728	0.1891	1.1619	782.8	973.1	3000
3208.2	705.47	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1.0612	875.9	875.9	3208.2

TABLE A.3 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (PRESSURE)

Abs press. lb/sq in. (sat. temp)		Temperature, F													
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
1 (101.74)	v	0.0161	392.5	452.3	511.9	571.5	631.1	690.7								
	h	68.00	1150.2	1195.7	1241.8	1288.6	1336.1	1384.5								
	s	0.1295	2.0509	2.1152	2.1722	2.2237	2.2708	2.3144								
5 (162.24)	v	0.0161	78.14	90.24	102.24	114.21	126.15	138.08	150.01	161.94	173.86	185.78	197.70	209.62	221.53	233.45
	h	68.01	1148.6	1194.8	1241.3	1288.2	1335.9	1384.3	1433.6	1483.7	1534.7	1586.7	1639.6	1693.3	1748.0	1803.5
	s	0.1295	1.8716	1.9369	1.9943	2.0460	2.0932	2.1369	2.1776	2.2159	2.2521	2.2866	2.3194	2.3509	2.3811	2.4101
10 (193.21)	v	0.0161	38.84	44.93	51.03	57.04	63.03	69.00	74.98	80.94	86.91	92.87	98.84	104.80	110.76	116.72
	h	68.02	1146.6	1193.7	1240.6	1287.8	1335.5	1384.0	1433.4	1483.5	1534.6	1586.6	1639.5	1693.3	1747.9	1803.4
	s	0.1295	1.7928	1.8593	1.9173	1.9692	2.0166	2.0603	2.1011	2.1394	2.1757	2.2101	2.2430	2.2744	2.3046	2.3337
15 (213.03)	v	0.0161	0.0166	29.899	33.963	37.985	41.986	45.978	49.964	53.946	57.926	61.905	65.882	69.858	73.833	77.807
	h	68.04	168.09	1192.5	1239.9	1287.3	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4	1693.2	1747.8	1803.4
	s	0.1295	0.2940	1.8134	1.8720	1.9242	1.9717	2.0155	2.0563	2.0946	2.1309	2.1653	2.1982	2.2297	2.2599	2.2890
20 (227.96)	v	0.0161	0.0166	22.356	25.428	28.457	31.466	34.465	37.458	40.447	43.435	46.420	49.405	52.388	55.370	58.352
	h	68.05	168.11	1191.4	1239.2	1286.9	1334.9	1383.5	1432.9	1483.2	1534.3	1586.3	1639.3	1693.1	1747.8	1803.3
	s	0.1295	0.2940	1.7805	1.8397	1.8921	1.9397	1.9836	2.0244	2.0628	2.0991	2.1336	2.1665	2.1979	2.2282	2.2572
40 (267.25)	v	0.0161	0.0166	11.035	12.624	14.165	15.685	17.195	18.699	20.199	21.697	23.194	24.689	26.183	27.676	29.168
	h	68.10	168.15	1186.6	1236.4	1285.0	1333.6	1382.5	1432.1	1482.5	1533.7	1585.8	1638.8	1992.7	1747.5	1803.0
	s	0.1295	0.2940	1.6992	1.7608	1.8143	1.8624	1.9065	1.9476	1.9860	2.0224	2.0569	2.0899	2.1224	2.1516	2.1807
60 (292.71)	v	0.0161	0.0166	7.257	8.354	9.400	10.425	11.438	12.446	13.450	14.452	15.452	16.450	17.448	18.445	19.441
	h	68.15	168.20	1181.6	1233.5	1283.2	1332.3	1381.5	1431.3	1481.8	1533.2	1585.3	1638.4	1692.4	1747.1	1802.8
	s	0.1295	0.2939	1.6492	1.7134	1.7681	1.8168	1.8612	1.9024	1.9410	1.9774	2.0120	2.0450	2.0765	2.1068	2.1359
80 (312.04)	v	0.0161	0.0166	0.0175	5.218	7.018	7.794	8.560	9.319	10.075	10.829	11.581	12.331	13.081	13.829	14.577
	h	68.21	168.24	269.74	1230.5	1281.3	1330.9	1380.5	1430.5	1481.1	1532.6	1584.9	1638.0	1692.0	1746.8	1802.5
	s	0.1295	0.2939	0.4371	1.6790	1.7349	1.7842	1.8289	1.8702	1.9089	1.9454	1.9800	2.0131	2.0446	2.0750	2.1041
100 (327.82)	v	0.0161	0.0166	0.0175	4.935	5.588	6.216	6.833	7.443	8.050	8.655	9.258	9.860	10.460	11.060	11.659
	h	68.26	168.29	269.77	1227.4	1279.3	1329.6	1379.5	1429.7	1480.4	1532.0	1584.4	1637.6	1691.6	1746.5	1802.2
	s	0.1295	0.2939	0.4371	1.6516	1.7088	1.7586	1.8036	1.8451	1.8839	1.9205	1.9552	1.9883	2.0199	2.0502	2.0794
120 (341.27)	v	0.0161	0.0166	0.0175	4.0786	4.6341	5.1637	5.6831	6.1929	6.7006	7.2060	7.7096	8.2119	8.7130	9.2134	9.7130
	h	68.31	168.33	269.81	1224.1	1277.4	1328.1	1378.4	1428.8	1479.8	1531.4	1583.9	1637.1	1691.3	1746.2	1802.0
	s	0.1295	0.2939	0.4371	1.6286	1.6872	1.7376	1.7829	1.8246	1.8635	1.9001	1.9349	1.9680	1.9996	2.0300	2.0592
140 (353.04)	v	0.0161	0.0166	0.0175	3.4651	3.9526	4.4119	4.8585	5.2995	5.7364	6.1709	6.6036	7.0349	7.4652	7.8946	8.3233
	h	68.37	168.38	269.85	1220.8	1275.3	1326.8	1377.4	1428.0	1479.1	1530.8	1583.4	1636.7	1690.9	1745.9	1801.7
	s	0.1295	0.2939	0.4370	1.6085	1.6686	1.7196	1.7652	1.8071	1.8461	1.8828	1.9176	1.9508	1.9825	2.0129	2.0421
160 (363.55)	v	0.0161	0.0166	0.0175	3.0060	3.4413	3.8480	4.2420	4.6295	5.0132	5.3945	5.7741	6.1522	6.5293	6.9055	7.2811
	h	68.42	168.42	269.89	1217.4	1273.3	1325.4	1376.4	1427.2	1478.4	1530.3	1582.9	1636.3	1690.5	1745.6	1801.4
	s	0.1294	0.2938	0.4370	1.5906	1.6522	1.7039	1.7499	1.7919	1.8310	1.8678	1.9027	1.9359	1.9676	1.9980	2.0273
180 (373.08)	v	0.0161	0.0166	0.0174	2.6474	3.0433	3.4093	3.7621	4.1084	4.4505	4.7907	5.1289	5.4657	5.8014	6.1363	6.4704
	h	68.47	168.47	269.92	1213.8	1271.2	1324.0	1375.3	1426.3	1477.7	1529.7	1582.4	1635.9	1690.2	1745.3	1801.2
	s	0.1294	0.2938	0.4370	1.5743	1.6376	1.6900	1.7362	1.7784	1.8176	1.8545	1.8894	1.9227	1.9545	1.9849	2.0142
200 (381.80)	v	0.0161	0.0166	0.0174	2.3598	2.7247	3.0583	3.3783	3.6915	4.0008	4.3077	4.6128	4.9165	5.2191	5.5209	5.8219
	h	68.52	168.51	269.96	1210.1	1269.0	1322.6	1374.3	1425.5	1477.0	1529.1	1581.9	1635.4	1689.8	1745.0	1800.9
	s	0.1294	0.2938	0.4369	1.5593	1.6242	1.6776	1.7239	1.7663	1.8057	1.8426	1.8776	1.9109	1.9427	1.9732	2.0025
250 (400.97)	v	0.0161	0.0166	0.0174	0.0186	2.1504	2.4662	2.6872	2.9410	3.1909	3.4382	3.6837	3.9278	4.1709	4.4131	4.6546
	h	68.66	168.63	270.05	375.10	1263.5	1319.0	1371.6	1423.4	1475.3	1527.6	1580.6	1634.4	1688.9	1744.2	1800.2
	s	0.1294	0.2937	0.4368	0.5667	1.5951	1.6502	1.6976	1.7405	1.7801	1.8173	1.8524	1.8858	1.9177	1.9482	1.9776
300 (417.35)	v	0.0161	0.0166	0.0174	0.0186	1.7665	2.0044	2.2263	2.4407	2.6509	2.8585	3.0643	3.2688	3.4721	3.6746	3.8764
	h	68.79	168.74	270.14	375.15	1257.7	1315.2	1368.9	1421.3	1473.6	1526.2	1579.4	1633.3	1688.0	1743.4	1799.6
	s	0.1294	0.2937	0.4367	0.5665	1.5703	1.6274	1.6758	1.7192	1.7591	1.7964	1.8317	1.8652	1.8972	1.9278	1.9572
350 (431.73)	v	0.0161	0.0166	0.0174	0.0186	1.4913	1.7028	1.8970	2.0332	2.2652	2.4445	2.6219	2.7980	2.9730	3.1471	3.3205
	h	68.92	168.85	270.24	375.21	1251.5	1311.4	1366.2	1419.2	1471.8	1524.7	1578.2	1632.3	1687.1	1742.6	1798.9
	s	0.1293	0.2936	0.4367	0.5664	1.5483	1.6077	1.6571	1.7009	1.7411	1.7787	1.8141	1.8477	1.8798	1.9105	1.9400
400 (444.60)	v	0.0161	0.0166	0.0174	0.0162	1.2841	1.4763	1.6490	1.8151	1.9759	2.1339	2.2901	2.4450	2.5987	2.7515	2.9037
	h	69.05	168.97	270.33	375.27	1245.1	1307.4	1363.4	1417.0	1470.1	1523.3	1576.9	1631.2	1686.2	1741.9	1798.2
	s	0.1293	0.2935	0.4365	0.5663	1.5282	1.5901	1.6406	1.6850	1.7255	1.7632	1.7988	1.8325	1.8647	1.8955	1.9250
500 (457.01)	v	0.0161	0.0166	0.0174	0.0186	0.9919	1.1584	1.2037	1.4397	1.5708	1.6992	1.8256	1.9507	2.0746	2.1977	2.3200
	h	69.32	169.19	270.51	375.38	1231.2	1299.1	1357.7	1412.7	1466.6	1520.3	1574.4	1629.1	1684.4	1740.3	1796.9
	s	0.1292	0.2934	0.4364	0.5660	1.4921	1.5595	1.6123	1.6578	1.6990	1.7371	1.7730	1.8069	1.8393	1.8702	1.8998

TABLE A.4 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE)

Abs press. lb/sq in. (sat. temp)		Temperature, F														
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
	v	0.0161	0.0166	0.0174	0.0186	0.7944	0.9456	1.0726	1.1892	1.3008	1.4095	1.5160	1.6211	1.7252	1.8284	1.9309
600	h	69.58	169.42	270.70	375.49	1215.9	1290.3	1351.8	1408.3	1463.0	1517.4	1571.9	1627.0	1682.6	1738.8	1795.6
(486.20)	s	0.1292	0.2933	0.4362	0.5657	1.4590	1.5329	1.5844	1.6351	1.6769	1.7155	1.7517	1.7859	1.8184	1.8494	1.8792
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.7928	0.9072	1.0102	1.1078	1.2023	1.2948	1.3858	1.4757	1.5647	1.6530
700	h	69.04	169.65	270.89	375.61	487.93	1281.0	1345.6	1403.7	1459.4	1514.4	1569.4	1624.8	1680.7	1737.2	1794.3
(503.08)	s	0.1291	0.2932	0.4360	0.5655	0.6889	1.5090	1.5673	1.6154	1.6580	1.6970	1.7335	1.7679	1.8006	1.8318	1.8617
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.5774	0.7888	0.8759	0.9631	1.0470	1.1289	1.2093	1.2885	1.3669	1.4446
800	h	70.11	169.88	271.07	375.73	487.88	1271.1	1339.2	1399.1	1455.8	1511.4	1566.9	1622.7	1678.9	1735.0	1792.9
(518.2.)	s	0.1290	0.2930	0.4358	0.5652	0.6885	1.4869	1.5484	1.5980	1.6413	1.6807	1.7175	1.7522	1.7851	1.8164	1.8464
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.5869	0.6858	0.7713	0.8504	0.9262	0.9998	1.0720	1.1430	1.2131	1.2825
900	h	70.37	170.10	271.26	375.84	487.83	1260.6	1332.7	1394.4	1452.2	1508.5	1564.4	1620.6	1677.1	1734.1	1791.6
(531.95)	s	0.1290	0.2929	0.4357	0.5649	0.6881	1.4659	1.5311	1.5822	1.6263	1.6662	1.7033	1.7382	1.7713	1.8028	1.8329
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.5107	0.6080	0.6875	0.7603	0.8295	0.8966	0.9622	1.0266	1.0901	1.1529
1000	h	70.63	170.33	271.44	375.96	487.79	1249.3	1325.9	1389.6	1448.5	1504.4	1561.9	1618.4	1675.3	1732.5	1790.3
(544.58)	s	0.1289	0.2928	0.4355	0.5647	0.6876	1.4457	1.5149	1.5677	1.6126	1.6530	1.6905	1.7256	1.7589	1.7905	1.8207
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.4531	0.5440	0.6188	0.6865	0.7505	0.8121	0.8723	0.9313	0.9894	1.0468
1100	h	70.90	170.56	271.63	376.08	487.75	1237.3	1318.8	1384.7	1444.7	1502.4	1559.4	1616.3	1673.5	1731.0	1789.0
(556.28)	s	0.1289	0.2927	0.4353	0.5644	0.6872	1.4259	1.4996	1.5542	1.6000	1.6410	1.6787	1.7141	1.7475	1.7793	1.8097
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.4016	0.4905	0.5615	0.6250	0.6845	0.7418	0.7974	0.8519	0.9055	0.9584
1200	h	71.16	170.78	271.82	376.20	487.72	1224.2	1311.5	1379.7	1440.9	1449.4	1556.9	1614.2	1671.6	1729.4	1787.6
(567.19)	s	0.1288	0.2926	0.4351	0.5642	0.6868	1.4061	1.4851	1.5415	1.5883	1.6298	1.6679	1.7035	1.7371	1.7691	1.7996
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.3176	0.4059	0.4712	0.5282	0.5809	0.6311	0.6798	0.7272	0.7737	0.8195
1400	h	71.68	171.24	272.19	376.44	487.65	1194.1	1296.1	1369.3	1433.2	1493.2	1551.8	1609.9	1668.0	1726.3	1785.0
(587.07)	s	0.1287	0.2923	0.4348	0.5636	0.6859	1.3652	1.4575	1.5182	1.5670	1.6096	1.6484	1.6845	1.7185	1.7508	1.7815
	v	0.0161	0.0166	0.0173	0.0185	0.0202	0.0236	0.3415	0.4032	0.4555	0.5031	0.5482	0.5915	0.6336	0.6748	0.7153
1600	h	72.21	171.69	272.57	376.69	487.60	616.77	1279.4	1358.5	1425.2	1486.9	1546.6	1605.6	1664.3	1723.2	1782.3
(604.87)	s	0.1286	0.2921	0.4344	0.5631	0.6851	0.8129	1.4312	1.4968	1.5478	1.5916	1.6312	1.6678	1.7022	1.7344	1.7657
	v	0.0160	0.0165	0.0173	0.0185	0.0202	0.0235	0.2906	0.3500	0.3988	0.4426	0.4836	0.5229	0.5609	0.5980	0.6343
1800	h	72.73	172.15	272.95	376.93	487.56	615.58	1261.1	1347.2	1417.1	1480.6	1541.1	1601.2	1660.7	1720.1	1779.7
(621.02)	s	0.1284	0.2918	0.4341	0.5626	0.6843	0.8109	1.4054	1.4768	1.5302	1.5753	1.6156	1.6528	1.6876	1.7204	1.7516
	v	0.0160	0.0165	0.0173	0.0184	0.0201	0.0233	0.2488	0.3072	0.3534	0.3942	0.4320	0.4680	0.5027	0.5365	0.5695
2000	h	73.26	172.60	273.32	377.19	487.53	614.48	1240.9	1353.4	1408.7	1447.1	1536.2	1596.9	1657.0	1717.0	1777.1
(635.80)	s	0.1283	0.2916	0.4337	0.5621	0.6834	0.8091	1.3794	1.4578	1.5138	1.5603	1.6014	1.6391	1.6743	1.7075	1.7389
	v	0.0160	0.0165	0.0173	0.0184	0.0200	0.0230	0.1681	0.2293	0.2712	0.3068	0.3390	0.3692	0.3980	0.4259	0.4529
2500	h	74.57	173.74	274.27	377.82	487.50	612.08	1176.7	1303.4	1386.7	1457.9	1522.9	1585.9	1647.8	1709.2	1770.4
(668.11)	s	0.1280	0.2910	0.4329	0.5609	0.6815	0.8048	1.3076	1.4129	1.4766	1.5269	1.5703	1.6094	1.6456	1.6796	1.7116
	v	0.0160	0.0165	0.0172	0.0183	0.0200	0.0228	0.0982	0.1759	0.2161	0.2484	0.2770	0.3033	0.3282	0.3522	0.3753
3000	h	75.83	174.88	275.22	378.47	487.52	610.08	1060.5	1267.0	1363.2	1440.2	1509.4	1574.8	1638.5	1701.4	1761.8
(695.33)	s	0.1277	0.2904	0.4320	0.5597	0.6796	0.8028	1.1966	1.3692	1.4429	1.4976	1.5434	1.5841	1.6214	1.6561	1.6888
	v	0.0160	0.0165	0.0172	0.0183	0.0199	0.0227	0.0335	0.1588	0.1987	0.2301	0.2576	0.2827	0.3065	0.3291	0.3510
3200	h	76.4	175.3	275.6	378.7	487.5	609.4	800.8	1250.9	1353.4	1433.1	1503.8	1570.3	1634.8	1698.3	1761.2
(705.08)	s	0.1276	0.2902	0.4317	0.5592	0.6788	0.7994	0.9708	1.3515	1.4300	1.4866	1.5335	1.5749	1.6126	1.6477	1.6806
	v	0.0160	0.0164	0.0172	0.0183	0.0199	0.0225	0.0307	0.1364	0.1764	0.2066	0.2326	0.2563	0.2784	0.2995	0.3198
3500	h	77.2	176.0	276.2	379.1	487.6	608.4	779.4	1224.6	1338.2	1422.2	1495.5	1563.3	1629.2	1693.6	1757.2
	s	0.1274	0.2899	0.4312	0.5585	0.6777	0.7973	0.9508	1.3242	1.4112	1.4709	1.5194	1.5618	1.6002	1.6358	1.6691
	v	0.0159	0.0164	0.0172	0.0182	0.0198	0.0223	0.0287	0.1052	0.1463	0.1752	0.1994	0.2210	0.2411	0.2601	0.2783
4000	h	78.5	177.2	277.1	379.8	487.7	606.5	763.0	1178.3	1311.6	1403.0	1481.3	1552.2	1619.8	1685.7	1750.6
	s	0.1271	0.2893	0.4304	0.5573	0.6760	0.7940	0.9343	1.2754	1.3807	1.4461	1.4970	1.5417	1.5812	1.6177	1.6516
	v	0.0159	0.0164	0.0171	0.0181	0.0196	0.0219	0.0268	0.0591	0.1038	0.1312	0.1529	0.1718	0.1890	0.2050	0.2203
5000	h	81.1	179.5	279.1	381.2	488.1	604.6	746.0	1042.9	1252.9	1364.0	1452.1	1529.1	1600.9	1670.0	1737.4
	s	0.1265	0.2881	0.4287	0.5550	0.6726	0.7880	0.9153	1.1593	1.3207	1.4001	1.4582	1.5061	1.5481	1.5863	1.6216
	v	0.0159	0.0163	0.0170	0.0180	0.0195	0.0216	0.0256	0.0397	0.0727	0.1020	0.1221	0.1391	0.1544	0.1684	0.1817
6000	h	83.7	181.7	281.0	382.7	488.6	602.9	736.1	945.1	1186.8	1323.6	1422.3	1505.9	1582.0	1654.2	1724.2
	s	0.1258	0.2870	0.4271	0.5528	0.6693	0.7826	0.9026	1.0176	1.2615	1.3574	1.4229	1.4748	1.5194	1.5593	1.5962
	v	0.0158	0.0163	0.0170	0.0180	0.0193	0.0213	0.0248	0.0334	0.0573	0.0816	0.1004	0.1160	0.1298	0.1424	0.1542
7000	h	86.2	184.4	283.0	384.2	489.3	601.7	729.3	901.8	1124.9	1281.7	1392.2	1482.6	1563.1	1639.6	1711.1
	s	0.1252	0.2859	0.4256	0.5507	0.6663	0.7777	0.8926	1.0350	1.2055	1.3171	1.3904	1.4486	1.4938	1.5345	1.5735

TABLE A.4 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE) (CONTINUED)

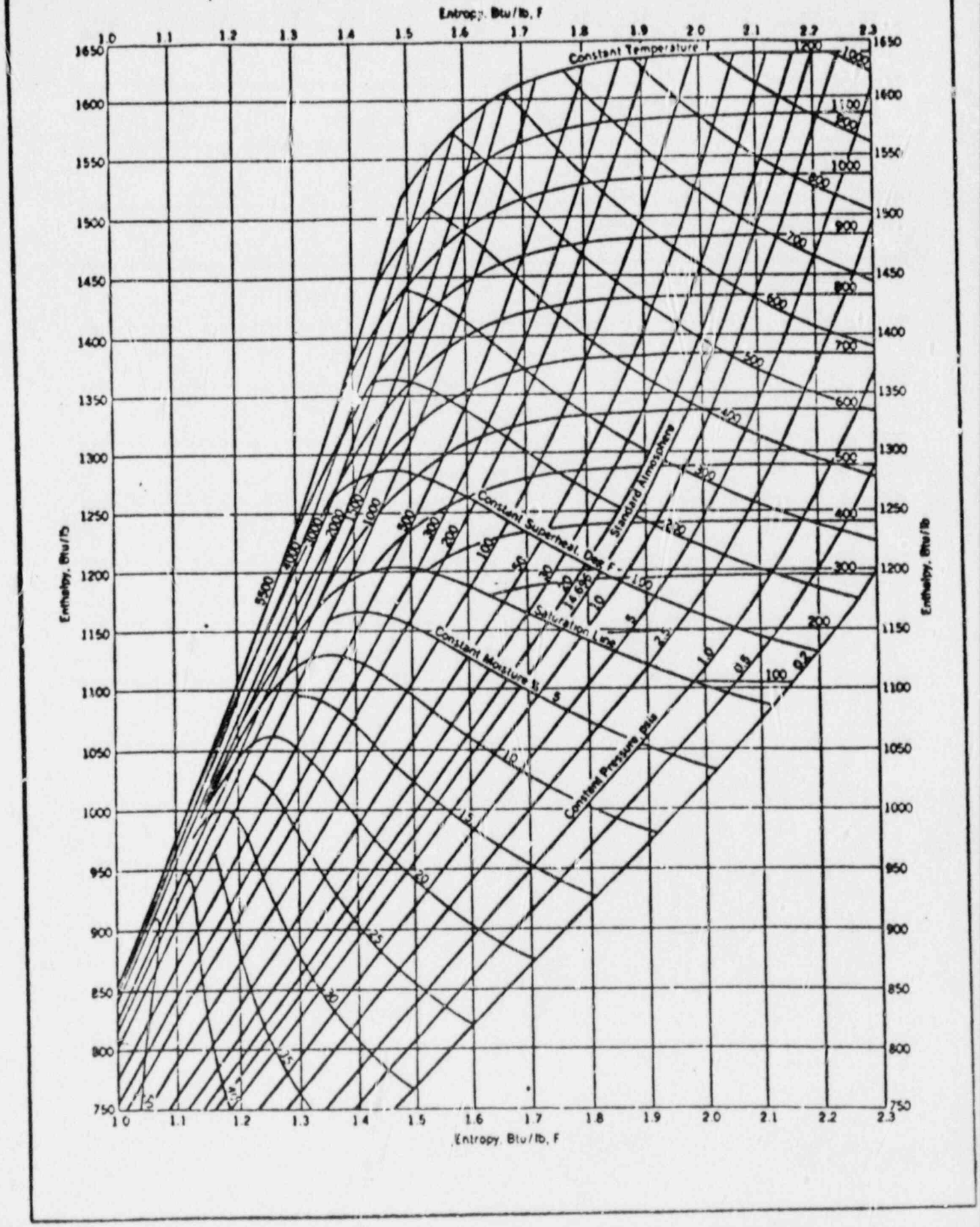


FIGURE A.5 MOLLIER ENTHALPY-ENTROPY DIAGRAM

PROPERTIES OF WATER

Density ρ
(lbs/ft³)

Temp (°F)	Saturated Liquid	PSIA 1000	2000	2100	2200	2300	2400	2500	3000
32	62.414	62.637	62.846	62.867	62.888	62.909	62.93	62.951	63.056
50	62.38	62.55	62.75	62.774	62.798	62.822	62.846	62.87	62.99
100	61.989	62.185	62.371	62.390	62.409	62.427	62.446	62.465	62.559
200	60.118	60.314	60.511	60.53	60.549	60.568	60.587	60.606	60.702
300	57.310	57.537	57.767	57.79	57.813	57.836	57.859	57.882	57.998
400	53.651	53.903	54.218	54.249	54.28	54.311	54.342	54.373	54.529
410	53.248	53.475	53.79	53.825	53.86	53.89	53.925	53.95	54.11
420	52.798	53.025	53.36	53.40	53.425	53.46	53.50	53.53	53.69
430	52.356	52.575	52.925	52.95	52.99	53.02	53.065	53.09	53.265
440	51.921	52.125	52.42	52.45	52.475	52.51	52.54	52.56	52.275
450	51.546	51.66	52.025	52.065	52.10	52.14	52.175	52.21	52.41
460	51.020	51.175	51.56	51.61	51.64	51.68	51.725	51.76	51.96
470	50.505	50.70	51.1	51.14	51.175	51.22	51.25	51.30	51.50
480	50.00	50.20	50.62	50.66	50.7	50.74	50.78	50.825	51.035
490	49.505	49.685	50.13	50.175	50.22	50.265	50.31	50.35	50.575
500	48.943	49.097	49.618	49.666	49.714	49.762	49.81	49.858	50.098
510	48.31	48.51	49.05	49.101	49.152	49.203	49.254	49.305	49.56
520	47.85	47.91	48.46	48.515	48.57	48.625	48.68	48.735	49.01
530	47.17	47.29	47.86	47.919	47.978	48.037	48.096	48.155	48.45
540	46.51		47.23	47.296	47.362	47.428	47.494	47.56	47.89
550	45.87		46.59	46.658	46.726	46.794	46.862	46.93	47.27
560	45.25		45.92	45.994	46.068	46.142	46.216	46.29	46.66
570	44.64		45.22	45.30	45.38	45.46	45.54	45.62	46.02
580	43.86		44.50	44.586	44.672	44.758	44.844	44.93	45.36
590	43.10		43.73	43.825	43.92	44.015	44.11	44.205	44.68
600	42.321		42.913	43.017	43.122	43.226	43.33	43.434	43.956
610	41.49		41.96	42.08	42.196	42.314	42.432	42.55	43.14
620	40.552		40.950	41.083	41.217	41.35	41.483	41.616	42.283
630	39.53								41.44
640	38.491								40.388
650	37.31								39.26
660	36.01								38.008
670	34.48								36.52
680	32.744								34.638
690	30.516								32.144

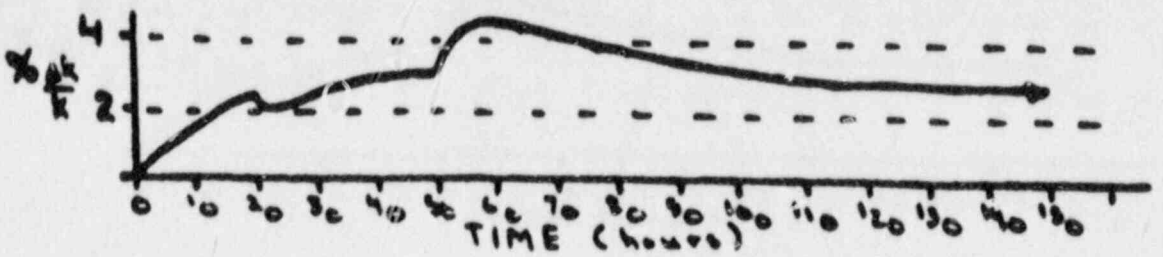
TABLE A.6 PROPERTIES OF WATER, DENSITY

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	0.016027	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	0.11245	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	0.13141	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
107.6	1.2030	0.016158	280.28	280.30	75.98	1032.5	1108.5	0.1437	1.8188	1.9626	108.0
110.0	1.2750	0.016165	265.37	265.39	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110.0
112.0	1.3505	0.016173	251.37	251.38	79.98	1030.2	1110.2	0.1507	1.8021	1.9528	112.0
114.0	1.4299	0.016180	238.21	238.22	81.97	1029.1	1111.0	0.1542	1.7938	1.9480	114.0
116.0	1.5133	0.016188	225.84	225.85	83.97	1027.9	1111.9	0.1577	1.7856	1.9433	116.0
118.0	1.6009	0.016196	214.20	214.21	85.97	1026.8	1112.7	0.1611	1.7774	1.9386	118.0
120.0	1.6927	0.016204	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120.0
122.0	1.7891	0.016213	192.94	192.95	89.96	1024.5	1114.4	0.1680	1.7613	1.9293	122.0
124.0	1.8901	0.016221	183.23	183.24	91.96	1023.3	1115.3	0.1715	1.7533	1.9247	124.0
126.0	1.9959	0.016229	174.08	174.09	93.96	1022.2	1116.1	0.1749	1.7453	1.9202	126.0
128.0	2.1068	0.016238	165.45	165.47	95.96	1021.0	1117.0	0.1783	1.7374	1.9157	128.0
130.0	2.2230	0.016247	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130.0
132.0	2.3445	0.016256	149.64	149.66	99.95	1018.7	1118.6	0.1851	1.7217	1.9068	132.0
134.0	2.4717	0.016265	142.40	142.41	101.95	1017.5	1119.5	0.1884	1.7140	1.9024	134.0	
136.0	2.6047	0.016274	135.55	135.57	103.95	1016.4	1120.3	0.1918	1.7063	1.8980	136.0
138.0	2.7438	0.016284	129.09	129.11	105.95	1015.2	1121.1	0.1951	1.6986	1.8937	138.0
140.0	2.8892	0.016293	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140.0
142.0	3.0411	0.016303	117.21	117.22	109.95	1012.9	1122.8	0.2018	1.6834	1.8852	142.0
144.0	3.1997	0.016312	111.74	111.76	111.95	1011.7	1123.6	0.2051	1.6758	1.8810	144.0
146.0	3.3653	0.016322	106.58	106.59	113.95	1010.5	1124.5	0.2084	1.6684	1.8769	146.0
148.0	3.5381	0.016332	101.68	101.70	115.95	1009.3	1125.3	0.2117	1.6610	1.8727	148.0
150.0	3.7184	0.016343	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150.0
152.0	3.9065	0.016353	92.66	92.68	119.95	1007.0	1126.9	0.2183	1.6463	1.8646	152.0
154.0	4.1025	0.016363	88.50	88.52	121.95	1005.8	1127.7	0.2216	1.6390	1.8606	154.0
156.0	4.3068	0.016374	84.56	84.57	123.95	1004.6	1128.6	0.2248	1.6318	1.8566	156.0
158.0	4.5197	0.016384	80.82	80.83	125.96	1003.4	1129.4	0.2281	1.6245	1.8526	158.0
160.0	4.7414	0.016395	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160.0
162.0	4.9722	0.016406	73.90	73.92	129.96	1001.0	1131.0	0.2345	1.6103	1.8448	162.0
164.0	5.2124	0.016417	70.70	70.72	131.96	999.8	1131.8	0.2377	1.6032	1.8409	164.0
166.0	5.4623	0.016428	67.67	67.68	133.97	998.6	1132.6	0.2409	1.5961	1.8371	166.0
168.0	5.7223	0.016440	64.78	64.80	135.97	997.4	1133.4	0.2441	1.5892	1.8333	168.0
170.0	5.9926	0.016451	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2736	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5656	0.016474	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8690	0.016486	54.59	54.61	143.99	992.6	1136.5	0.2568	1.5616	1.8184	176.0
177.4	7.1840	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

*The table shows the freezing point of water.

a.



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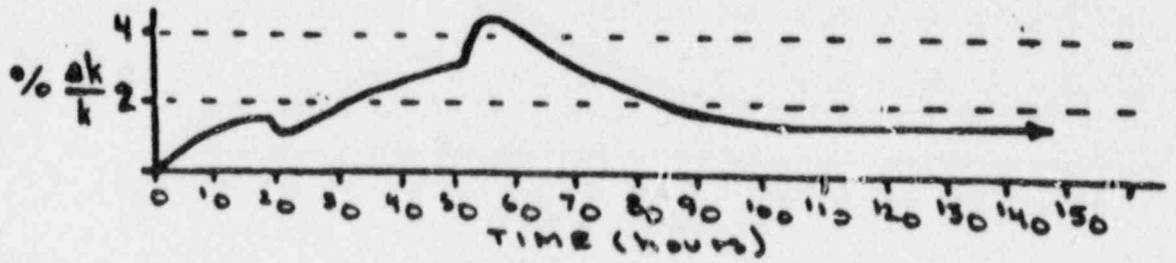

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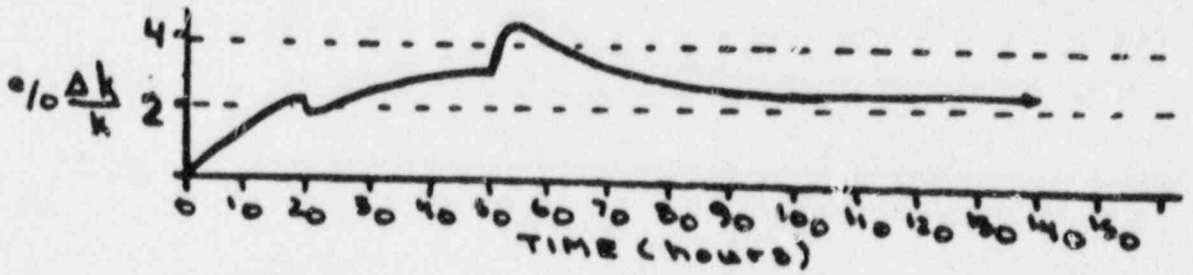

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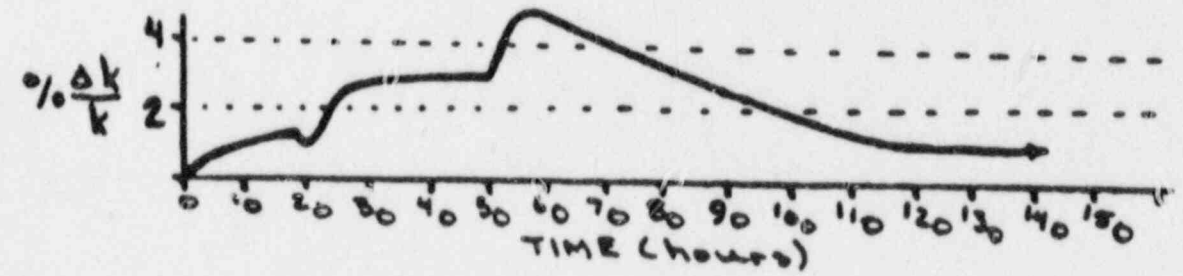

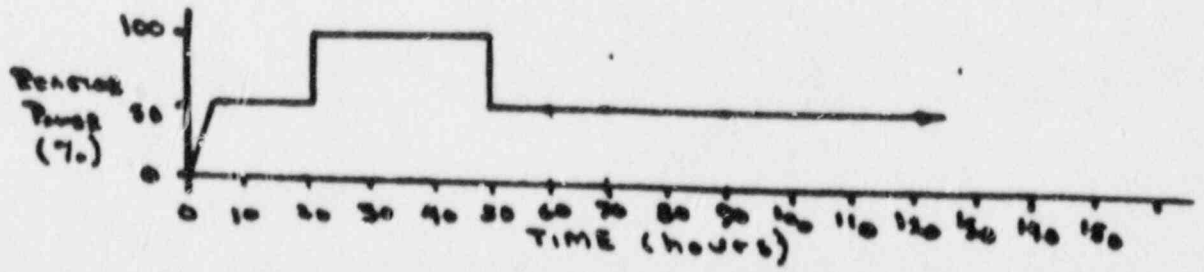

FIGURE A 219

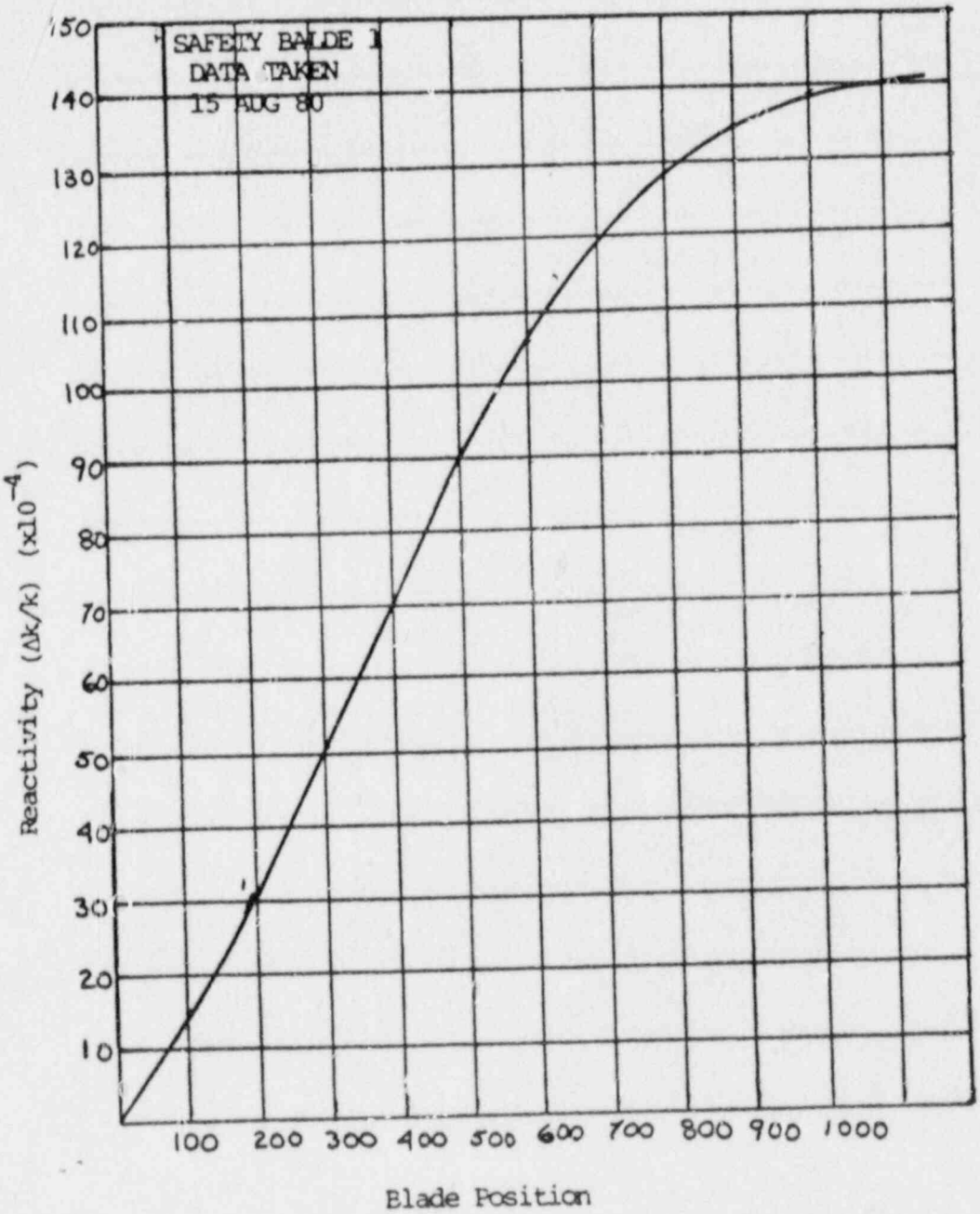

Figure 4-26. Reactivity Integral Rod Worth Curve for UFTR Safety Blade #1.

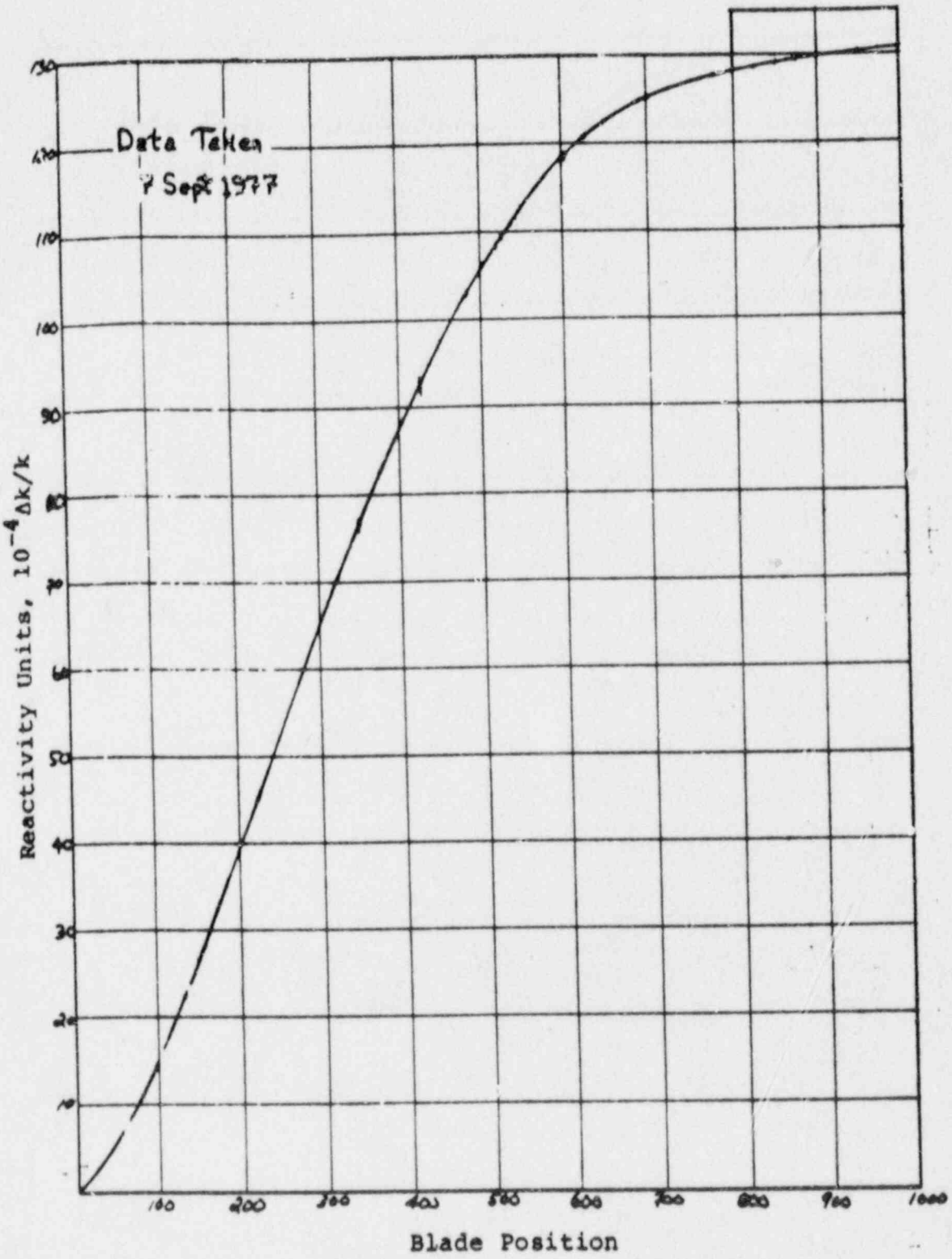

Figure 4-27. Integral Rod Worth Curve for UFTR Safety Blade #2.

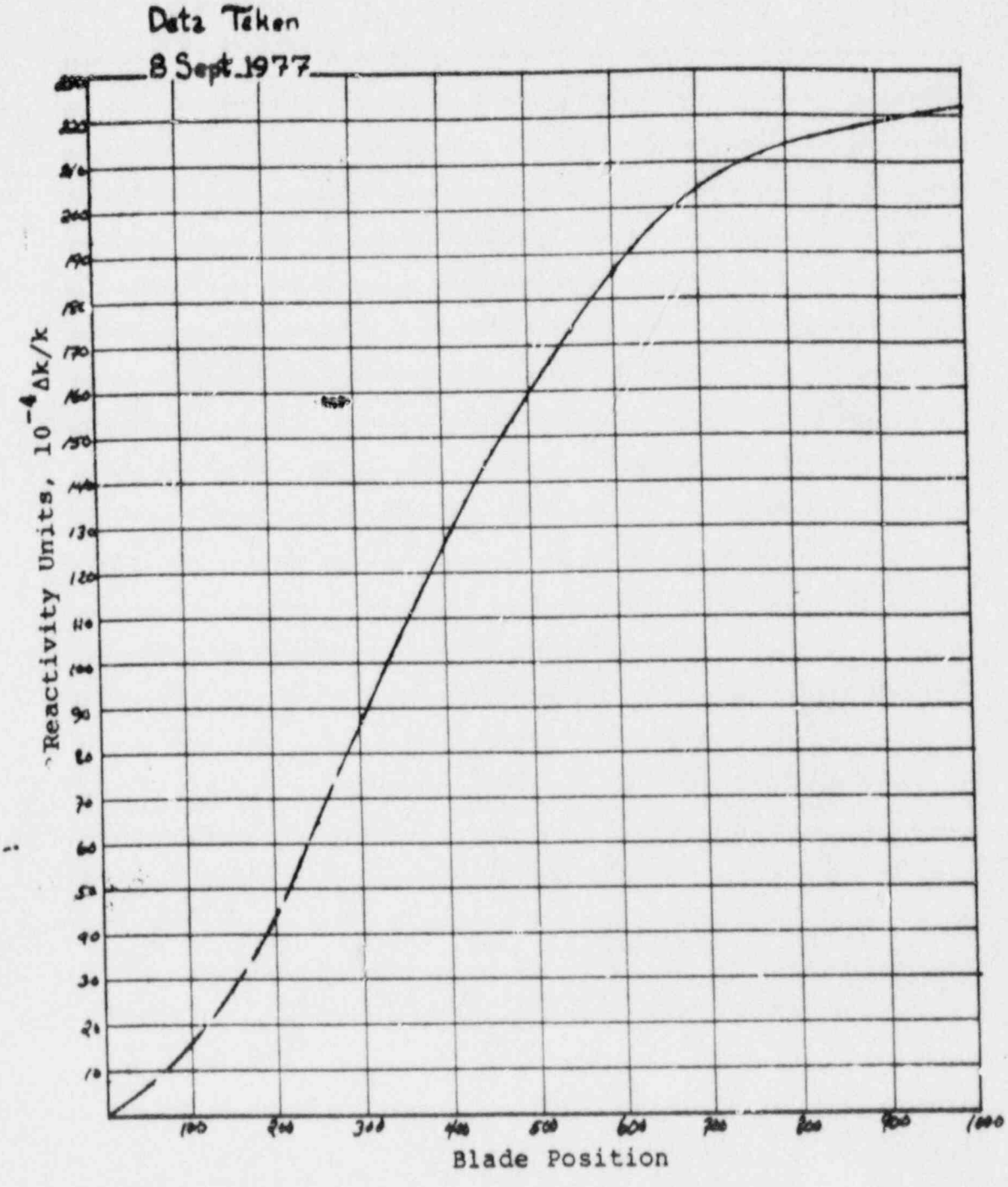

Figure 4-28. Integral Rod Worth Curve for UFTR Safety Blade #3.

Data Taken
15 Aug 1977

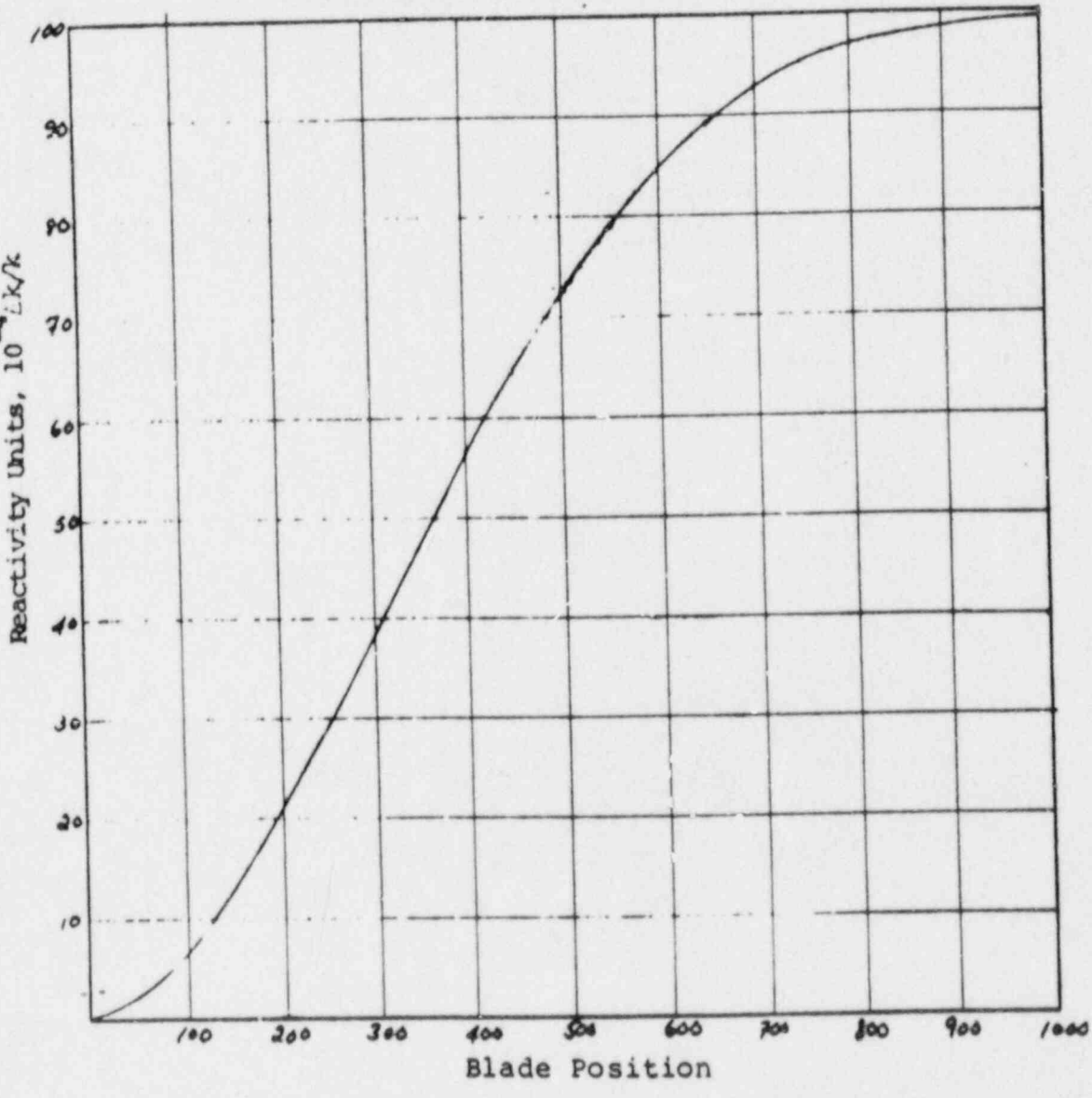

Figure 4-29. Integral Rod ...ch Curve for UFTR Regulating Blade

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

FACILITY: UNIVERSITY OF FLORIDA

REACTOR TYPE: TEST

DATE ADMINISTERED: 88/06/09

EXAMINER: ARILDSEN, J.

CANDIDATE: _____

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. Examination papers will be picked up six (6) hours after the examination starts.

CATEGORY VALUE	% OF TOTAL	CANDIDATE'S SCORE	% OF CATEGORY VALUE		CATEGORY
20.50	20.50	_____	_____	H.	REACTOR THEORY
19.75	19.75	_____	_____	I.	RADIOACTIVE MATERIALS HANDLING DISPOSAL AND HAZARDS
19.75	19.75	_____	_____	J.	SPECIFIC OPERATING CHARACTERISTICS
19.00	19.00	_____	_____	K.	FUEL HANDLING AND CORE PARAMETERS
~~21.00~~	~~21.00~~	_____	_____	L.	ADMINISTRATIVE PROCEDURES, CONDITIONS AND LIMITATIONS
~~100.00~~		_____	_____ %		Totals
		Final Grade			

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

_____
Candidate's Signature

NRC RULES AND GUIDELINES FOR LICENSE EXAMINATIONS

During the administration of this examination the following rules apply:

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

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

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

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

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

6. Use only the paper provided for answers.

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

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

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

10. Skip at least three lines between each answer.

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

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

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

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

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

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

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

18. When you complete your examination, you shall:

a. Assemble 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 H.01 (1.00)

A reactor has been operating for an extended period of time at 50% reactor power. WHICH ONE of the following statements most accurately describes the concentration of samarium-149 if power were increased to and maintained at 75% reactor power?

a. The concentration of Sm-149 initially increases and then levels off to a new equilibrium level higher than the equilibrium level at 50% reactor power.

b. The concentration of Sm-149 initially increases but then decreases to an equilibrium level equal to the equilibrium level at 50% reactor power.

c. The concentration of Sm-149 initially decreases and then levels off to a new equilibrium level lower than the equilibrium level at 50% reactor power.

d. The concentration of Sm-149 initially decreases but then increases to an equilibrium level equal to the equilibrium level at 50% reactor power.

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

QUESTION H.02 (1.50)

a. DEFINE "delayed neutron". (0.5)

b. EXPLAIN WHY delayed neutrons are important. (1.0)

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

QUESTION H.03 (1.50)

a. DEFINE "thermal nonleakage factor". (0.5)

b. EXPLAIN HOW the thermal nonleakage factor can be greater than one. (1.0)

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

QUESTION H.04 (1.00)

Reactor power is 100 watts and increasing with a constant reactor period. FOUR (4) minutes later, reactor power is 2 KW. CALCULATE the reactor period during the last four minutes. SHOW ALL WORK!

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

QUESTION H.05 (2.00)

Reactivity in the core has been determined to be -0.1230 delta k/k. CALCULATE how much the Safety Blades must be withdrawn to increase the present count rate by 50%. SHOW ALL WORK!

NOTE: APPLICABLE CURVES ARE ATTACHED FOR REFERENCE
ASSUME ALL RODS WERE INITIALLY FULLY INSERTED
ASSUME ALL ROD WITHDRAWALS ARE PERFORMED IN SEQUENCE AND THAT THE FIRST ROD IS FULLY WITHDRAWN BEFORE THE NEXT ROD BEGINS ANY WITHDRAWAL

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

QUESTION H.06 (1.00)

WHICH ONE of the following is the reason for the -80 second period following a reactor scram?

a. The doppler effect adding positive reactivity due to the temperature decrease following a scram.

b. The ability of U-235 to fission with source neutrons.

c. The amount of negative reactivity added on a scram being greater than the Shutdown Margin.

d. The decay constant of the longest-lived group of delayed neutrons.

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

QUESTION H.07 (2.00)

For each of the following definitions, STATE the term that is defined.

a. The factor by which neutron population changes between generations (from fission).

b. The decay of an excited nucleus into a stable nucleus with the simultaneous ejection of electromagnetic energy.

c. The amount of time required for the neutron population to increase by a factor of "e" (2.718).

d. A gamma ray causes the ejection of an electron from a target atom; the gamma ray's energy is totally transmitted to the electron for ejection.

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

QUESTION H.08 (1.00)

Which one of the following describes the beta decay of a nuclide?

a. Atomic Mass # decreases by 1, number of protons remains constant

b. Atomic Mass # remains the same, number of protons increases by 1

c. Atomic Mass # remains the same, number of protons remains constant

d. Atomic Mass # decreases by 1, number of protons decreases by 1

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

QUESTION H.09 (1.00)

Attached Figure # 219 shows a POWER HISTORY and four possible XENON traces (Reactivity vs. Time). SELECT the most accurate curve for displaying the expected XENON transient.

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

QUESTION H.10 (1.00)

Explain how neutrons are produced from the Plutonium-Beryllium (PuBe) source.

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

QUESTION H.11 (1.00)

Which one of the following terms of the six factor formula is most affected by "Poisons".

a. Fast Fission Factor

b. Thermal Utilization Factor

c. Thermal Non-Leakage Probability

d. Reproduction Factor

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

QUESTION H.12 (1.00)

MATCH the terms in Column A with the correct relationship in column B.

Column A	Column B
a) Specific Entropy	1) BTU/deg F
b) Enthalpy	2) Ratio of local $\dot{Q}$ to Critical Heat Flux
	3) Internal energy of a substance
	4) % steam mass to total steam & water mass
	5) BTU/lbm-deg R
	6) Ratio of Critical Heat Flux to local $\dot{Q}$
	7) Internal Energy plus Flow Energy of a substance
	8) % steam volume to total steam & water volume

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

QUESTION H.13 (1.00)

The ratio of Pu-239 and Pu-240 atoms to U-235 atoms changes over core life.

Which one of the following pairs of parameters is most affected by this change?

a). Moderator Temperature coefficient and Doppler Coefficient

b). Doppler Coefficient and Beta

c). Beta and Moderator Temperature Coefficient

d). Moderator Temperature Coefficient and Neutron Generation Time

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

QUESTION H.14 (1.00)

Indicate whether each of the following will cause the Differential Rod Worth to INCREASE, DECREASE or have NO EFFECT. (Consider each case separately)

a). An adjacent rod is inserted to the same height.

b). Moderator Temperature is INCREASED.

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

QUESTION H.15 (1.00)

Which statement below describes centrifugal pump RUNOUT conditions?

a. High Pressure, Low Flow, High Power Demand

b. High Pressure, Low Flow, Low Power Demand

c. Low Pressure, High Flow, High Power Demand

d. Low Pressure, High Flow, Low Power Demand

e. Low Pressure, Low Flow, High Power Demand

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

QUESTION H.16 (2.5)

DEFINE EACH of the following terms:

a. Subcritical multiplication

b. Reflector

c. Xenon burnout

d. Decay heat

e. Differential rod worth

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

QUESTION I.01 (1.00)

If you are in an 80 mRad/hr neutron radiation field (neutron energy 20 Mev), what is the dose in mREM that you would receive after 45 minutes?

a. 60 mREM

b. 120 mREM

c. 180 mREM

d. 600 mREM

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

QUESTION I.02 (.50)

ANSWER whether the following statement is TRUE or FALSE.
Shortly after power operations, a few drops of primary coolant could contaminate a swipe to 450 cpm beta-gamma activity. Adjusting for detector efficiency, this indicates approximately ten times the permissible UFTR limit.

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

QUESTION I.03 (.50)

ANSWER whether the following statement is TRUE or FALSE.
Samples, NOT LEAVING the UFTR building complex, that were irradiated via the pneumatic rapid sample transfer (RABBIT) system are required to have processed a completed UFTR form SOP-D.4B, Sample Record Index.

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

QUESTION I.04 (1.00)

What UFTR form must be used to assure that all requirements have been met before containers holding radioactive reactor waste are transferred to a carrier or licensed waste processor.

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

QUESTION I.05 (1.00)

STATE the unshielded sample radiation levels (two) beyond which the Radiation Control Officer or his designated alternate must authorize transfer.

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

QUESTION I.06 (2.50)

a. LIST the two (2) conditions specified by UFTR Technical Specifications in which the reactor vent system is required to be operated.

b. LIST the three (3) failure(s) or indication(s) that UFTR Technical Specification 3.4.3 requires for the reactor vent system to be immediately secured.

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

QUESTION I.07 (2.00)

a. STATE the maximum permissible concentration (MPC) of the gaseous effluent discharge of Argon-41 as specified in UFTR SOP-E.6 and UFTR Technical Specifications.

b. STATE whether the associated sample of the core ventilation flow is taken PRIOR TO or AFTER dilution by the diluting fan.

c. What factor is used to account for atmospheric dilution of Argon-41 in the determination of stack effluent concentrations as per UFTR Technical Specifications?

d. STATE the minimum time required after a reactor startup to allow for the Argon-41 emission level indicated by the stack monitor to stabilize.

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

QUESTION I.08 (1.00)

Who's approval (if any) is required prior to the performance of any maintenance to CORRECT a significant primary coolant leak.

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

QUESTION I.09 (2.00)

LIST the four (4) actions which must be taken in the event that radiation levels following shielding alterations are found to be significantly in excess of anticipated radiation levels.

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

QUESTION I.10 (1.00)

STATE the criterion (dpm/cm^2 above background) used to permit the return to normal use of a potentially contaminated area that had been isolated.

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

QUESTION I.11 (1.00)

A point source of gamma radiation gives an exposure rate of 90 mR/hr at ONE meter, CALCULATE the exposure rate at THREE meters.

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

QUESTION I.12 (1.50)

What radiation reading would prohibit the changing of primary resins? (Identify the type instrument used, level, and location.)

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

QUESTION I.13 (1.00)

State the shield water tank water resistivity (kilohm-cm) at which the demineralizer cartridge needs replacement.

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

QUESTION I.14 (1.00)

a. STATE the maximum reactor power level at which the opening of the vertical ports for sample irradiation shall be considered a routine operation.

b. Would such a routine operation require an RWP?

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

QUESTION I.15 (1.50)

STATE the normal working dose rates (in mREM/wk for whole body, extremities, and skin) which require preparation of a radiation work permit (RWP) and compliance with the provisions of UFTR SOP-D.2 prior to commencement of work or operations which have the potential of exceeding those rates.

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

QUESTION I.16 (1.25)

STATE the specific definitions of a "RADIATION AREA" and of a "HIGH RADIATION AREA."

(***** END OF CATEGORY I *****)

QUESTION J.01 (2.00)

ANSWER EACH of the following questions TRUE or FALSE.

a. The console " Power ON " switch controls power to all parts of the control circuits and nuclear instrumentation channels.

b. Control Blade magnet power is controlled through the 3-position " OPERATE " key switch.

c. Depressing a Control Blade backlit ON switch will cause that Blade to return to the full in position.

d. A key operated switch on the back of the console controls the Secondary System City Water Valve.

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

QUESTION J.02 (1.00)

STATE the purpose of the sixteen (16) vertical foil slots in the Reactor.

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

QUESTION J.03 (2.00)

ANSWER EACH of the following questions concerning the Core Vent System.

a. STATE the purpose of the Vacuum Breaker Vent Lines. (1.0)

b. Where is the Effluent Gamma Detector located ? (0.5)

c. The Vent Damper is electrically interlocked so that it cannot be opened unless the dilution fan is energized. STATE the purpose of this interlock. (0.5)

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

QUESTION J.04 (1.00)

STATE two (2) purposes of the graphite blocks in the core.

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

QUESTION J.05 (2.50)

LIST five (5) conditions which will initiate a Full Trip of the Reactor and STATE the Nuclear Instrument Channel that is associated with each Trip. (#1,#2, both, or none)
(NOTE: INCLUDE SETPOINTS IN YOUR ANSWER)

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

QUESTION J.06 (1.00)

STATE the interlock that is associated with starting the Primary Coolant Pump.

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

QUESTION J.07 (2.50)

LIST five (5) conditions/interlocks that will function to prevent Control Blade withdrawal.

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

QUESTION J.08 (1.50)

LIST ALL ot the conditions that should result in both MANUAL and AUTOMATIC actuation of the Evacuation Alarm.

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

QUESTION J.09 (1.5%)

City tap water is used for makeup to the Primary System. EXPLAIN HOW this water is purified to comply with Tech Spec requirements. Include in your answer a discussion of the physical processes by which the water is purified.

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

QUESTION J.10 (2.25)

a. DESCRIBE HOW the resistivity of the Primary Coolant is measured.
NOTE: INCLUDE IN YOUR ANSWER THE LOCATION OF ANY COMPONENTS USED.

b. EXPLAIN HOW flow is maintained through the Purification System when the Purification pump is secured.

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

QUESTION J.1i (1.50)

EXPLAIN WHY the Reactor Protection System is Fail Safe and requires no auxilliary power to ensure shutdown. INCLUDE in your answer a complete description of how the Reactor Trips on loss of Offsite Power.

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

QUESTION J.12 (1.00)

DESCRIBE the Power Supply to the Area Radiation Monitors.

(***** END OF CATEGORY J *****)

QUESTION K.01 (2.00)

ANSWER EACH of the following statements as TRUE or FALSE.

a. Partial elements from which new fuel elements can be assembled may be fastened together with non-standard material.

b. The Reactor Manager may authorize special tests with irradiated fuel to be performed outside of the shield tank.

c. During fuel element disassembly, the Clamp Operating Tool is used to permit the clamp jaws to grapple only the bottom plate.

d. Only a licensed operator or a trainee under the direct supervision of a licensed operator may insert fuel into the reactor.

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

QUESTION K.02 (.50)

Answer whether the following statement is TRUE or FALSE.
Placing an unaltered fuel assembly in its original position in the core after having removed it for inspection is not considered to be fuel loading.

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

QUESTION K.03 (3.00)

FILL IN THE BLANKS with the appropriate numbers.

a. The fuel plate uranium enrichment is _____ percent.

b. The core is presently composed of _____ fuel bundles and _____ dummy bundles arranged in _____ water filled aluminum boxes.

c. Each fuel bundle is composed of _____ fuel plates.

d. The ACTUAL available excess reactivity in the present configuration is about _____ percent delta K / K.

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

QUESTION K.04 (1.00)

The immediate actions in the event of a Radiological Emergency per SOP-B.1 are independently specified for WORKING and NON-WORKING HOURS. In this regard, what is the definition of WORKING HOURS?

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

QUESTION K.05 (1.00)

State the limit of Keff (under optimum conditions of moderation and reflection) for the geometry of fuel element or fuel device storage and handling out of the core.

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

QUESTION K.06 (1.00)

What weight limit is placed on loads lifted over the control blade drive units when all the control blades are not fully inserted?

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

QUESTION K.07 (1.00)

State the manner of designation and required qualification for the "Supervisor-in-Charge" of directing irradiated fuel transfer.

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

QUESTION K.08 (1.00)

State what are used and where they are placed in order to separate and secure fuel assemblies to prevent lateral and vertical movement to assure proper flow and a constant fuel-to-moderator ratio.

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

QUESTION K.09 (2.00)

State the minimum staffing requirements for fuel transfer operations.

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

QUESTION K.10 (1.50)

State specifically how the fuel handling tool disengagement from the fuel assembly is verified following a fuel transfer from the transfer cask to the spent fuel pit.

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

QUESTION K.11 (2.00)

In accordance with fuel loading procedure UFTR: SOP-C.2,

a. State the required number of independent neutron monitoring channels that must be installed and operational for monitoring the approach-to-criticality.

b. State the number of independent neutron monitoring channels available as permanently installed control console nuclear instrumentation.

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

QUESTION K.12 (1.00)

State the radiological limitation(s), if any, pertaining to the readjustment of the fuel assembly jig table level with an irradiated element or plate on the jig table.

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

QUESTION K.13 (1.00)

Describe how the fuel handling tool is designed to prevent the inadvertent dropping of a fuel element.

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

QUESTION K.14 (1.00)

Describe how the HEX HEAD NUTS presently installed on some fuel elements are removed during fuel element disassembly.

(***** END OF CATEGORY K *****)

QUESTION L.01 (1.00)

Which one of the following items is NOT required to be posted in the control room?

a. Form NRC-3, "Notice to Employees"

b. All UFTR Emergency Call Lists (#1, #2, and #3)

c. Current Operator Licenses for all operators

d. Limits on energy production for Argon-41 effluent

e. Form RC-4, "Safety Rules for a Radioisotope Laboratory"

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

QUESTION L.02 (1.00)

Which one of the following is NOT always a reportable occurrence?

a. A violation of Safety Limits

b. An unanticipated change in reactivity greater than one dollar (not resulting from a reactor trip due to a known cause)

c. A Reactor Safety System Component malfunction that renders the system incapable of performing its intended safety function that was discovered during a maintenance test

d. An observed inadequacy in the implementation of administrative controls such that the inadequacy could have caused the existence or development of an unsafe condition with regard to reactor operations

e. Operation with actual Safety System Settings for required systems less conservative than the Limiting Safety System Settings (LSSS) specified in Technical Specifications

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

QUESTION L.03 (.50)

ANSWER whether the following statement is TRUE or FALSE.

The Secondary Flow by the City Water System has an associated Reactor Trip set at 8 gpm (as measured by a flow switch) to initiate at or above 1KW after a 10-second warning.

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

QUESTION L.04 ~~(3.00)~~ (2.50)

Match the evolution / function in Column A to the ONE responsible person(s) in Column B (Answers in Column B may be used more than once.)

Column A		Column B
1. _____	designates personnnel for the performance of maintenance	A. Licensed Reactor Operator
2. _____	circuit breaker operation	B. Reactor Manager
3. _____	indicates specific codes, standards, and regulations to be used or referenced in the various phases of a modification	C. Radiation Control Officer
DELETED ~~4. _____~~	~~required to sign only certain Level I RWP's and all Level II RWP's~~	D. Reactor Safety Review Subcommittee
5. _____	completion of a TRIP EVENT DATA ANALYSIS AND EVALUATION	
6. _____	grants written authorization of major maintenance items	

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

QUESTION L.05 (1.00)

ANSWER EACH of the following concerning reporting and recording events. (FILL IN THE BLANKS)

a. The NRC Operations Center shall be notified by telephone within _____ minutes after discovery of any accidental criticality.

b. The initial telephone notification (stated above) shall be followed within a period of _____ days by a written report.

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

QUESTION L.06 (1.00)

With what publication are the Special Test Procedures (having attached Special Test Control coversheets) that have general or repeated applicability maintained?

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

QUESTION L.07 (3.00)

State the minimum staffing required by UFTR Technical Specifications when the reactor is not secured (FOR EACH POSITION include personnel qualification requirements, personnel location requirements, and the time limits of when required to be at the location).

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

QUESTION L.08 (2.00)

Answer the following questions concerning making changes to procedures.

a. Who is permitted to make minor modifications to original procedures which DO NOT change their original intent?

b. What approval requirement must follow (include time requirement)?

c. Who is permitted to make Temporary deviations from procedures in order to deal with special or unusual circumstances or conditions?

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

QUESTION L.09 (1.00)

State the response(s) and / or notification(s) required by the UFTR Emergency Plan upon receipt of "vague threats" via advisories from friendly agencies such as the Sheriff's Office.

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

QUESTION L.10 (1.00)

State who activates the emergency organization in the event of a Notification of Unusual Event, and to whom (phone # or organization) the request for support external to the UFTR facility is made.

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

QUESTION L.11 (2.00)

STATE the three (3) actions (in order) that are required if the Reactor is operating at 100 KWth and stack counts indicate SIGNIFICANTLY above the maximum equilibrium level.

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

QUESTION L.12 (1.50)

LIST the three (3) actions that are required if radiation level indications of about 1.5 mr/hr are indicated by the Area Radiation Monitors while at 5 KWth power.

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

QUESTION L.13 (1.00)

During Reactor Power operations, what is the maximum period of time that the Primary Coolant demineralizer System can remain secured ?

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

QUESTION L.14 (1.00)

a. STATE the time within which a record must be made of any discovered vulnerability in the Safeguards System that could have allowed undetected access to the Reactor Cell had compensatory measures not been established.

b. Does this time limit INCLUDE TIME FOR DISCOVERY by UFTR staff personnel or by University Police Department personnel acting on behalf of the staff. (YES or NO)

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

QUESTION L.15 (1.00)

What is used to determine the efficiency of the detector system used to measure the Argon-41 activity in the UFTR Core Vent air samples.

(***** END OF CATEGORY L *****)
(********** END OF EXAMINATION **********)

ANSWER H.01 (1.00)

d

REFERENCE

Westinghouse Design Technical Manual, Chapter 2

ANSWER H.02 (1.50)

a. A neutron born sometime after fission (time greater than 10E-14 sec) from the decay of fission fragments (delayed neutron precursor).

b. Delayed neutrons allow control of the reactor by increasing the average neutron lifetime.

REFERENCE

General Electric, Reactor Theory, Chap. 4

ANSWER H.03 (1.50)

a. The fraction of thermal neutrons that escape leakage while thermal. (0.5)

b. If a reactor had a reflector, fast neutrons which escaped from the core can be thermalized and then reflected back into the core (0.5). The net result can be that more thermal neutrons enter the core than leak from it. (0.5)

REFERENCE

General Electric, Reactor Theory, App. G

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/03-ARILDSEN, J.

ANSWER H.04 (1.00)

P = Po*exp (t/T) (0.4)

T = t/ln(P/Po) (0.4)

T = 240/ln(2000/100) = 80 sec (0.2)

REFERENCE

General Electric, Reactor Theory, Chap. 3

ANSWER H.05 (2.00)

Subscript 1 refers to values when all rods are inserted. Subscript 2 refers to values when Rod A is withdrawn.

Keff1 = 1/(1-p1)
= 1/(1+0.1230)
= 0.89 (0.4)

CR1/CR2 = (1-Keff2)/(1-Keff1) =>
Keff2 = 1-[CR1/CR2 * (1-Keff1)]
= 1-[2/3 * (1-0.89)]
= 0.927 (0.6)

p2 = (Keff2-1)/Keff2
= (0.927-1)/0.927
= -0.0790 (0.4)

Required reactivity addition needed = p2 - p1 = +0.0440 (0.2)

From IRW curve, SB 1 must be ~~100% (+- 0%) withdrawn~~ withdrawn (to position 560) (0.2)
SB 2 must be ~~100% (+-0%)~~ withdrawn (to position 560) (0.2)
SB 3 must be ~~54% (+-2%)~~ 0 withdrawn (to position 560) (0.2)
RB must be withdrawn to position 380 (± 20) (0.1)

REFERENCE

General Electric, Reactor Theory, Chap. 3
UFTR: FSAR

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER H.06 (1.00)

(d)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p. 106
VEGP, Training Text, Vol. 9, p. 21-47
Westinghouse Reactor Physics, pp. 1-3.17 & 19

ANSWER H.07 (2.00)

a. K-effective (0.5 each)

b. Gamma Decay

c. Period (Fermi Age)

d. Photoelectric Effect -or- Target atom ionization

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p.56,89
General Electric, Reactor Theory, Chapters 1, 3

ANSWER H.08 (1.00)

(b)

REFERENCE
NUS, Vol 2, pp 7.3-2

ANSWER H.09 (1.00)

(c)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p.163
General Electric, Reactor Theory, Chapter 6
EIH: GPNT,Vol VII, Chapter 10.1-83-86
BSEP: L/P 02-2/3-A, pp 172 - 176; 02-OG-A, pp 57 - 60

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/[illegible]N, J.

ANSWER H.10 (1.00)

$$^{239}_{94}Pu \longrightarrow {}^{235}_{92}U + {}^{4}_{2}\text{alpha} \qquad (0.5)$$

$$^{9}_{4}Be + {}^{4}_{2}\text{alpha} \longrightarrow {}^{12}_{6}C + {}^{1}_{0} \qquad (0.5)$$

REFERENCE
DCP, Fundamentals of Nuclear Reactor Engineering, p.113

ANSWER H.11 (1.00)

(b)

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering, p. 158

ANSWER H.12 (1.00)

a) 5

b) ~~4~~ 7 (0.5 each)

REFERENCE
NUS, Vol 4, pp 1.4-2, 1.4-4, 3.5-4, 6.4-6

ANSWER H.13 (1.00)

b

REFERENCE
CR Training Ltr TRA 85-0013
DPC, Fundamentals of Nuclear Reactor Engineering, p. 38, 39, 146

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER H.14 (1.00)

a). Decrease (0.5 each)
b). Increase

REFERENCE
DPC, Fundamentals of Nuclear Reactor Engineering p. 134-136
SQN/WBN License Requal Training, "Core Poisons"

ANSWER H.15 (1.00)

c

REFERENCE
NUS, Vol 4, pp G-8

ANSWER H.16 (2.50)

a. Steady state neutron level higher than source alone due to the multiplication of fissionable fuel.

b. Material at core edges which reduces neutron leakage by scattering neutrons back into the core.

c. Removal of Xe-135 from the core by absorption of a neutron to Xe-136.

d. Heat produced by the decay of radioactive nuclides.

e. Reactivity change per unit of rod motion.

REFERENCE

General Electric, Reactor Theory, App. G

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER I.01 (1.00)

~~b~~ d QF=10 (80)(45/60)(10)=600 (1.0)

REFERENCE
10 CFR 20.4

ANSWER I.02 (.50)

TRUE (0.5)

REFERENCE
UFTR: SOP-D.3, 4.3

ANSWER I.03 (.50)

FALSE (0.5)

REFERENCE
UFTR: SOP-D.4, 7.7

ANSWER I.04 (1.00)

Radioactive Reactor Waste Shipment Checklist (UFTR form SOP-D.5A) (1.0)

REFERENCE
UFTR: SOP-D.5, 4.12

ANSWER I.05 (1.00)

1.5 R/hr at one foot (0.5) 1.0

~~or~~

(200 mR/hr at the surface of the transfer container) (0.5)

REFERENCE
UFTR: SOP-D.4, 7.3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER I.06 (2.50)

a. 1. During reactor operations
2. Stack monitor indicates greater than 10 cps

b. 1. Failure in the monitoring system
2. Failure of the absolute filter
3. Unanticipated high stack count rate (0.5 each)

REFERENCE
UFTR: Tech. Spec. 3.4.3

ANSWER I.07 (2.00)

a. 4.0 E-8 microC/ml

b. PRIOR TO

c. 200

d. 4 hours (0.5 each)

REFERENCE
UFTR: SOP-E.6
UFTR: Tech. Spec. 3.4.2

ANSWER I.08 (1.00)

The Reactor Manager or his authorized representative (1.0)

REFERENCE
UFTR: SOP-D.3, 4.3.1

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER I.09 (2.00)

1. Shutdown the reactor immediately
2. Promptly replace the shielding
3. Notify the Reactor Manager or his designated representative
4. Evaluate the situation and determine the cause of the higher radiation levels

(0.5 each)

REFERENCE
UFTR: SOP-E.2, 7.1.3

ANSWER I.10 (1.00)

20 dpm/cm^2 (1.0)

REFERENCE
Emergency Plan for the UFTR, 7.1.2.3

ANSWER I.11 (1.00)

10 mR/hr (1.0)

REFERENCE
UFTR: FSAR 12.10

ANSWER I.12 (1.50)

A beta-gamma survey instrument (0.5) indicating 200 mREM/hr (0.5) on contact with the demineralizer (0.5)

REFERENCE
UFTR: SOP-E.1, 4.3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER I.13 (1.00)

600 kilohm-cm (1.0)

REFERENCE

UFTR: SOP-E.3, 7.3

ANSWER I.14 (1.00)

a. 1 KW

b. No (0.5 each)

REFERENCE
UFTR: SOP-E.2, 7.2

ANSWER I.15 (1.50)

75 mREM/wk whole body
500 mREM/wk extremities
400 mREM/wk skin (0.5 each)

REFERENCE
UFTR: SOP-D.1, 4.4

ANSWER I.16 (1.25)

"RADIATION AREA" - Any area accessible to personnel (0.25) in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 5 mREM (0.25) or in any 5 consecutive days a dose in excess of 100 mREM (0.25).

"HIGH RADIATION AREA" - Any area acessible to personnel (0.25) in which there exists radiation at such levels that a major portion of the body could receive in any one hour a dose in excess of 100 mREM (0.25).

REFERENCE
UFTR: SOP-D.1, 3.2.3 and 3.2.4

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER J.01 (2.00)

a. FALSE
b. TRUE
c. TRUE
d. FALSE

REFERENCE
UFTR: FSAR CH 7

ANSWER J.02 (1.00)

Foils are installed in the slots for irradiation (0.5) and are used for flux mapping (0.5).

REFERENCE
UFTR: FSAR CH 4.1.4

ANSWER J.03 (2.00)

a. Allows an air return path to the top of the fuel boxes (0.5) to allow rapid dumping of the water from the boxes (0.5).

b. Located at the base of the stacks before dilution occurs (0.5).

c. Prevents the discharge of undiluted air effluent (0.5).

REFERENCE
UFTR: CH 9.4.2

ANSWER J.04 (1.00)

Functions as both a Moderator (.5) and a Reflector (.5).

REFERENCE
UFTR: Emergency Plan Ch. 1.3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER J.05 (2.50)

1) fast period <= 3 sec	(.25)	ch #1	(.25)
2) high power >= 125 %	(.25)	ch	(.25)
3) reduction of HV to neutron chambers of >= 10 %	(.25)	both	(.25)
4) turning off the console magnet power switch	(.25)	none	(.25)
5) AC power failure	(.25)	none	(.25)

REFERENCE
UFTR: FSAR CH 7

ANSWER J.06 (1.00)

The Purification Pump shuts off when the Primary Coolant Pump is running. (1.0) -OR- The Primary Coolant Pump will not start unless the dump value is closed. (1.0)
REFERENCE
UFTR: FSAR 9.2.4

ANSWER J.07 (2.50)

1. source counts < 2cps
2. reactor period ≤ 10 seconds
3. attempt to raise any two or more Blades simultaneously.
4. Safety Channels 1 and 2 and Wide Range Drawer Calibrate (or Safety 1 Trip Test) switches not in OPERATE.
5. Power is raised in AUTO control at a period faster than 30 sec.

(0.5 each)

REFERENCE
UFTR: FSAR CH 7

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER J.08 ~~(1.50)~~ (1.50)

1) 2 Area Radiation Monitors Alarm in coincidence (at >= 25 mr/hr) ~~(.25)~~ (0.5)
~~Automatic (.25)~~
2) Air Particulate Monitor with valid alarm condition ~~(.25)~~ (0.5)
~~Manual (.25)~~
3) Reactor operator detects a potentially hazardous radiological condition (and preventive actions are required to protect personnel). ~~(.25)~~ (0.5)
~~Manual (.25)~~

REFERENCE
UFTR: TECH SPEC 3.6.1

ANSWER J.09 (1.50)

Tap water is passed through 2 demineralizers in series (0.5) that are filled with nuclear grade resin (amberlite) (0.5). As the water passes through, it undergoes mechanical filtration (.25) and ionic impurities are exchanged with H+ and 0H- Resin ions (through the process of adsorption) (.25).

ANSWER J.10 (2.25)

a. An in line (wall mounted) resistivity bridge (0.5) receives two ~~a~~ signals from ~~a~~ conductivity cells (0.5) located upstream ~~of~~ and downstream of the demineralizer in the Purification System (.25).

b. The Primary Coolant Pump gerneates sufficient driving head to Maintain a flow through the Purification Loop when it is in operation (1.0).

REFERENCE
UFTR: FSAR 5.1.4 , 9.2.4

ANSWER J.11 (1.50)

The loss of Offsite Power drops out the Scram Relays (.25) and deenergizes the Magnetic Clutches (.25) to Trip the Reactor by dropping the Control Rods under gravity completely into the core (.5). It is Fail Safe since a loss of power will result in a Reactor Trip (.5).

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

REFERENCE
UFTR: FSAR CH 8.2

ANSWER J.12 (1.00)

24VDC power supply (0.5) backed up with a floating battery pack (0.5).

REFERENCE
UFTR: FSAR CH 8.4

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER K.01 (2.00)

a. TRUE

b. FALS

c. TRUE

d. FALSE (0.5 each)

REFERENCE
UFTR: SOP-C.4, 4.16.1, 4.12, and 7.3.5.2
SOP-C.2, 4.3

ANSWER K.02 (.50)

TRUE (0.5)

REFERENCE
UFTR: SOP:-C.1, 3.1.1

ANSWER K.03 (3.00)

a. 93.0 (accept + or - 1.0)

b. 21
3
6

c. 11

d. 1.0 (accept + or - 0.5) (0.5 each)

REFERENCE
UFTR: FSAR 4.2

ANSWER K.04 (1.00)

Any time that authorized personnel are in the Reactor Cell. (1.0)

REFERENCE
UFTR: SOP-B.1, 7.1.1

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER K.05 (1.00)

Keff < 0.8 (1.0)

REFERENCE
UFTR: Tech. Spec. 3.7

ANSWER K.06 (1.00)

500 lbs. (1.0)

REFERENCE
UFTR: Tech. Spec. 5.2

ANSWER K.07 (1.00)

Designated by the Reactor Manager

Must hold an SRO license (0.5 each)

REFERENCE
UFTR: SOP-C.1, 3.2.1

ANSWER K.08 (1.00)

Fuel Bundle aluminum wedging pins (0.5) are inserted into the center of the fuel boxes (0.5).

REFERENCE
UFTR: SOP-C.2, 7.4.1.2

ANSWER K.09 (2.00)

Supervisor-in-Charge
Radiation Control Person
Equipment Operator
Control Room Operator (licensed RO) (0.5 each)

REFERENCE
UFTR: SOP-C.1, 4.7

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER K.10 (1.50)

A radiation detector (0.5) is used to check that the fuel does not rise as the tool is removed(~~0.5~~) (1.0).

REFERENCE
UFTR: SOP-C.1, 7.6.10

ANSWER K.11 (2.0)

a. 3

b. 1 (due to a common power supply) (1.0 each)

REFERENCE
UFTR: SOP-C.2, 4.10 and 7.2.1.1.1

ANSWER K.12 (1.00)

The jig table may be readjusted provided that the radiation levels at 6 inches over the water surface (0.5) do not exceed 6 mR/hr (0.5).

REFERENCE
UFTR: SOP-C.4, 7.1.1

ANSWER K.13 (1.00)

Release can only be accomplished by taking the weight of the assembly off the tool by setting the assembly down onto a supporting surface. (1.0)

REFERENCE
UFTR: SOP-C.1, 4.11.3

ANSWER K.14 (1.00)

~~+~~An appropriate long handled operator is ~~not~~ available for the engaging of the HEX HEAD NUTS.~~+ The HEX HEAD NUTS may have to be cut off with a nut splitter.~~ (1.0)

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

REFERENCE
UFTR: SOP-C.4, 7.3.7

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER L.01 (1.00)

b

REFERENCE
UFTR: Quarterly Check of Posting Requirements #6

ANSWER L.02 (1.00)

c (1.0)

REFERENCE
UFTR: SOP-0.6, 3.2.3

ANSWER L.03 (.50)

FALSE (0.5)

REFERENCE
UFTR: FSAR 5.6.2

ANSWER L.04 ~~(3.00)~~ (2.50)

1. B

2. A

3. B

~~4. C~~ DELETED

5. A

6. B (0.5 ea. h)

REFERENCE
UFTR: SOP-0.2, 7.2.2 and 7.2.2.3
SOP-0.2, APPENDIX I
Form 0.2A
SOP-0.3, 3.3.4.1
SOP-0.6, 7.1.2.11

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER L.05 (1.00)

a. 60
b. 30 (0.5 each)

REFERENCE
UFTR: SOP F.8 , 7.1 AND 7.3.1

ANSWER L.06 (1.00)

with the Auxiliary Operating Procedures (1.0)

REFERENCE
UFTR: SOP-0.5, 7.6.3.3.4

ANSWER L.07 (3.00)

1. Certified Reactor Operator (0.5) — in control room (0.25) at all times (0.25)

2. Second Person able to carry out perscribed written instructions (including the first stages of the Emergency Plan) (0.5) — at the facility (0.25) unexpected absence is acceptable provided immediate action is taken to obtain a replacement (0.25)

3. Designated Class A Reactor Operator (SRO) (0.5) — located to be available on call (0.25) capable of getting to the reactor facility within approximately 30 minutes (0.25)

REFERENCE
UFTR: Tech. Spec. 6.2.3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER L.08 ~~(2.00)~~ (1.50)

a. Reactor Manager (Level 3 or higher) (0.5)

b. Approval by Level 2 (or designated alternates) ~~(0.5)~~ (0.25)

within 14 days ~~(0.5)~~ (0.25)

c. Senior operating individual present (0.5)

REFERENCE
UFTR: Tech. Spec. 6.3

ANSWER L.09 (1.00)

The UFTR Staff (0.5) and Campus Police are alerted (0.5).

REFERENCE
Emergency Plan for the UFTR, 7.2.1

ANSWER L.10 (1.00)

Emergency Director (0.5)

The request is made (via the campus emergency system) through UPD Dispatch (dialing 2-1111). (0.5)

REFERENCE
Emergency Plan for the UFTR, 7.3.1

ANSWER L.11 (2.00)

1) Shutdown the Reactor
2) Notify the SRO on call
3) Determine the cause

(Emergency plan actions accepted)
(0.5 each and 0.5 for ~~#3~~ #1 being listed ~~last~~ first)

REFERENCE
UFTR: SOP - A.3 , 4.6.3

ANSWERS -- UNIVERSITY OF FLORIDA -88/06/08-ARILDSEN, J.

ANSWER L.12 (1.50)

1) Determine the cause
2) implement appropriate corrective action.
3) Notify the SRO on call.

(0.5 each)

REFERENCE
UFTR: SOP - A.3 , 4.5.2

ANSWER L.13 (1.00)

3 HRS (1.0)

REFERENCE
UFTR: SOP E.8 4.7.1

ANSWER L.14 (1.00)

a. 24 hrs.
b. YES (0.5 each)

REFERENCE
UFTR: SOP F.8 7.6.2

ANSWER L.15 (1.00)

Co - 60 standard (with two primary gamma energies) (1.0)

REFERENCE
UFTR: FORM SOP - E.6A

QUESTION	VALUE	REFERENCE
H.01	1.00	GTH0000846
H.02	1.50	GTH0000847
H.03	1.50	GTH0000848
H.04	1.00	GTH0000849
H.05	2.00	GTH0000851
H.06	1.00	GTH0000852
H.07	2.00	GTH0000853
H.08	1.00	GTH0000854
H.09	1.00	GTH0000855
H.10	1.00	GTH0000856
H.11	1.00	GTH0000857
H.12	1.00	GTH0000859
H.13	1.00	GTH0000860
H.14	1.00	GTH0000861
H.15	1.00	GTH0000864
H.16	2.50	GTH0000863
	20.50	
I.01	1.00	GTH0000814
I.02	.50	GTH0000816
I.03	.50	GTH0000824
I.04	1.00	GTH0000815
I.05	1.00	GTH0000817
I.06	2.50	GTH0000818
I.07	2.00	GTH0000819
I.08	1.00	GTH0000820
I.09	2.00	GTH0000821
I.10	1.00	GTH0000822
I.11	1.00	GTH0000823
I.12	1.50	GTH0000825
I.13	1.00	GTH0000826
I.14	1.00	GTH0000827
I.15	1.50	GTH0000828
I.16	1.25	GTH0000829
	19.75	
J.01	2.00	GTH0000804
J.02	1.00	GTH0000788
J.03	2.00	GTH0000789
J.04	1.00	GTH0000792
J.05	2.50	GTH0000802
J.06	1.00	GTH0000805
J.07	2.50	GTH0000807
J.08	1.50	GTH0000810
J.09	1.50	GTH0000787
J.10	2.25	GTH0000806
J.11	1.50	GTH0000809
J.12	1.00	GTH0000812

QUESTION	VALUE	REFERENCE
	19.75	
K.01	2.00	GTH0000833
K.02	.50	GTH0000838
K.03	3.00	GTH0000845
K.04	1.00	GTH0000830
K.05	1.00	GTH0000831
K.06	1.00	GTH0000832
K.07	1.00	GTH0000834
K.08	1.00	GTH0000836
K.09	2.00	GTH0000839
K.10	1.50	GTH0000840
K.11	2.00	GTH0000841
K.12	1.00	GTH0000843
K.13	1.00	GTH0000835
K.14	1.00	GTH0000842
	19.00	
L.01	1.00	GTH0000866
L.02	1.00	GTH0000867
L.03	.50	GTH0000875
L.04	3.00	GTH0000870
L.05	1.00	GTH0000878
L.06	1.00	GTH0000865
L.07	3.00	GTH0000868
L.08	2.00	GTH0000869
L.09	1.00	GTH0000871
L.10	1.00	GTH0000872
L.11	2.00	GTH0000873
L.12	1.50	GTH0000874
L.13	1.00	GTH0000877
L.14	1.00	GTH0000879
L.15	1.00	GTH0000876
	21.00	
	100.00	

MASTER
SRO

SRO / RO

UNIVERSITY OF FLORIDA TEST REACTOR

LICENSE EXAMINATION

88/06/08

HANDOUTS

EQUATION SHEET ------ 1 PAGE
STEAM TABLES -------- 7 PAGES
FIGURE #219
FIGURE 4-26
FIGURE 4-27
FIGURE 4-28
FIGURE 4-29

$f = ma$

$w = mg$

$E = mc^2$

$KE = 1/2\ mv^2$

$PE = mgh$

$V_f = V_o + at$

$W = v\ \Delta P$

$\Delta E = 931\ \Delta m$

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

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

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

$Pwr = W_f \Delta h$

$P = P_o 10^{sur(t)}$

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

$SUR = 26.06/T$

$SUR = 26\rho/\ell^* + (\beta - \rho)T$

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

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

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

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

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

$\rho = (\Sigma_a V)/(3 \times 10^{10})$

$\Sigma = \sigma N$

$v = s/t$

$s = V_o t + 1/2\ at^2$

$a = (V_f - V_o)/t$

$w = \theta/t$

$A = \frac{\pi D^2}{4}$

$\dot{m} = V_{av} A \rho$

Cycle efficiency = (Net work out)/(Energy in)

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

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

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

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

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

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

$TVL = 1.3/\mu$

$HVL = -0.693/\mu$

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

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

$CR_1(1 - K_{eff1}) = CR_2(1 - K_{eff2})$

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

$M = (1 - K_{effo})/(1 - K_{eff1})$

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

$\ell^* = 10^{-4}$ seconds

$\bar{\lambda} = 0.1$ seconds^{-1}

$I_1 d_1 = I_2 d_2$

$I_1 d_1^{\ 2} = I_2 d_2^{\ 2}$

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

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

Water Parameters

1 gal. = 8.345 lbm.
1 gal. = 3.78 liters
1 ft^3 = 7.48 gal.
Density = 62.4 lbm/ft^3
Density = 1 gm/cm^3
Heat of vaporization = 970 Btu/lbm
Heat of fusion = 144 Btu/lbm
1 Atm = 14.7 psi = 29.9 in. Hg.
1 ft. H_2O = 0.4335 lbf/in.

Miscellaneous Conversions

1 curie = 3.7×10^{10} aps
1 kg = 2.21 lbm
1 hp = 2.54×10^3 Btu/hr
1 mw = 3.41×10^6 Btu/hr
1 in = 2.54 cm
°F = 9/5°C + 32
°C = 5/9 (°F-32)
1 BTU = 778 ft-lbf

e = 2.718

Temp F	Press. psia	Volume, ft³/lb			Enthalpy, Btu/lb			Entropy, Btu/lb x F			Temp F
		Water v_f	Evap v_{fg}	Steam v_g	Water h_f	Evap h_{fg}	Steam h_g	Water s_f	Evap s_{fg}	Steam s_g	
32	0.08859	0.01602	3305	3305	-0.02	1075.5	1075.5	0.0000	2.1873	2.1873	32
35	0.09991	0.01602	2948	2948	3.00	1073.8	1076.8	0.0061	2.1706	2.1767	35
40	0.12163	0.01602	2446	2446	8.03	1071.0	1079.0	0.0162	2.1432	2.1594	40
45	0.14744	0.01602	2037.7	2037.8	13.04	1068.1	1081.2	0.0262	2.1164	2.1426	45
50	0.17795	0.01602	1704.8	1704.8	18.05	1065.3	1083.4	0.0361	2.0901	2.1262	50
60	0.2561	0.01603	1207.6	1207.6	28.06	1059.7	1087.7	0.0555	2.0391	2.0946	60
70	0.3629	0.01605	868.3	868.4	38.05	1054.0	1092.1	0.0745	1.9900	2.0645	70
80	0.5068	0.01607	633.3	633.3	48.04	1048.4	1096.4	0.0932	1.9426	2.0359	80
90	0.6981	0.01610	468.1	468.1	58.02	1042.7	1100.8	0.1115	1.8970	2.0086	90
100	0.9492	0.01613	350.4	350.4	68.00	1037.1	1105.1	0.1295	1.8530	1.9825	100
110	1.2750	0.01617	265.4	265.4	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110
120	1.6927	0.01620	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120
130	2.2230	0.01625	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130
140	2.8892	0.01629	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140
150	3.718	0.01634	97.05	97.07	117.95	1008.2	1126.1	0.2150	1.6536	1.8686	150
160	4.741	0.01640	77.27	77.29	127.96	1002.2	1130.2	0.2313	1.6174	1.8487	160
170	5.993	0.01645	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170
180	7.511	0.01651	50.21	50.22	148.00	990.2	1138.2	0.2631	1.5480	1.8111	180
190	9.340	0.01657	40.94	40.96	158.04	984.1	1142.1	0.2787	1.5148	1.7934	190
200	11.526	0.01664	33.62	33.64	168.09	977.9	1146.0	0.2940	1.4824	1.7764	200
210	14.123	0.01671	27.80	27.82	178.15	971.6	1149.7	0.3091	1.4509	1.7600	210
212	14.696	0.01672	26.78	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	212
220	17.186	0.01678	23.13	23.15	188.23	965.2	1153.4	0.3241	1.4201	1.7442	220
230	20.779	0.01685	19.36	19.381	198.33	958.7	1157.1	0.3388	1.3902	1.7290	230
240	24.968	0.01693	16.304	16.321	208.45	952.1	1160.6	0.3533	1.3609	1.7142	240
250	29.825	0.01701	13.802	13.819	218.59	945.4	1164.0	0.3677	1.3323	1.7000	250
260	35.427	0.01709	11.745	11.762	228.76	938.6	1167.4	0.3819	1.3043	1.6862	260
270	41.856	0.01718	10.042	10.060	238.95	931.7	1170.6	0.3960	1.2769	1.6729	270
280	49.200	0.01726	8.627	8.644	249.17	924.6	1173.8	0.4098	1.2501	1.6599	280
290	57.550	0.01736	7.443	7.460	259.4	917.4	1176.8	0.4236	1.2238	1.6473	290
300	67.005	0.01745	6.448	6.466	269.7	910.0	1179.7	0.4372	1.1979	1.6351	300
310	77.67	0.01755	5.609	5.626	280.0	902.5	1182.5	0.4506	1.1726	1.6232	310
320	89.64	0.01766	4.896	4.914	290.4	894.8	1185.2	0.4640	1.1477	1.6116	320
340	117.99	0.01787	3.770	3.788	311.3	878.8	1190.1	0.4902	1.0990	1.5892	340
360	153.01	0.01811	2.939	2.957	332.3	862.1	1194.4	0.5161	1.0517	1.5678	360
380	195.73	0.01836	2.317	2.335	353.6	844.5	1198.0	0.5416	1.0057	1.5473	380
400	247.26	0.01864	1.8444	1.8630	375.1	825.9	1201.0	0.5667	0.9607	1.5274	400
420	308.78	0.01894	1.4808	1.4997	396.9	806.2	1203.1	0.5915	0.9165	1.5080	420
440	381.54	0.01926	1.1976	1.2169	419.0	785.4	1204.4	0.6161	0.8729	1.4890	440
460	466.9	0.0196	0.9746	0.9942	441.5	763.2	1204.8	0.6405	0.8299	1.4704	460
480	566.2	0.0200	0.7972	0.8172	464.5	739.6	1204.1	0.6648	0.7871	1.4518	480
500	680.9	0.0204	0.6545	0.6749	487.9	714.3	1202.2	0.6890	0.7443	1.4333	500
520	812.5	0.0209	0.5386	0.5596	512.0	687.0	1199.0	0.7133	0.7013	1.4146	520
540	962.8	0.0215	0.4437	0.4651	536.8	657.5	1194.3	0.7378	0.6577	1.3954	540
560	1133.4	0.0221	0.3651	0.3871	562.4	625.3	1187.7	0.7625	0.6132	1.3757	560
580	1326.2	0.0228	0.2994	0.3222	589.1	589.9	1179.0	0.7876	0.5673	1.3550	580
600	1543.2	0.0236	0.2438	0.2675	617.1	550.6	1167.7	0.8134	0.5196	1.3330	600
620	1786.9	0.0247	0.1962	0.2208	646.9	506.3	1153.2	0.8403	0.4689	1.3092	620
640	2059.9	0.0260	0.1543	0.1802	679.1	454.6	1133.7	0.8686	0.4134	1.2821	640
660	2365.7	0.0277	0.1166	0.1443	714.9	392.1	1107.0	0.8995	0.3502	1.2498	660
680	2708.6	0.0304	0.0808	0.1112	758.5	310.1	1068.5	0.9365	0.2720	1.2086	680
700	3094.3	0.0366	0.0386	0.0752	822.4	172.7	995.2	0.9901	0.1490	1.1390	700
705.5	3208.2	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1.0612	705.5

TABLE A.2 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (TEMPERATURE)

Press. psia	Temp F	Volume, ft³/lb			Enthalpy, Btu/lb			Entropy, Btu/lb x F			Energy, Btu/lb		Press. psia
		Water	Evap	Steam	Water	Evap	Steam	Water	Evap	Steam	Water	Steam	
		v_f	v_{fg}	v_g	h_f	h_{fg}	h_g	s_f	s_{fg}	s_g	u_f	u_g	
0.0886	32.018	0.01602	3302.4	3302.4	0.00	1075.5	1075.5	0	2.1872	2.1872	0	1021.3	0.0886
0.10	35.023	0.01602	2945.5	2945.5	3.03	1073.8	1076.8	0.0061	2.1705	2.1766	3.03	1022.9	0.10
0.15	45.453	0.01602	2004.7	2004.7	13.50	1067.9	1081.4	0.0271	2.1140	2.1411	13.50	1025.7	0.15
0.20	53.160	0.01603	1526.3	1526.3	21.22	1063.5	1084.7	0.0422	2.0738	2.1160	21.22	1028.3	0.20
0.30	64.484	0.01604	1039.7	1039.7	32.54	1057.1	1089.7	0.0641	2.0168	2.0809	32.54	1032.0	0.30
0.40	72.869	0.01606	792.0	792.1	40.92	1052.4	1093.3	0.0799	1.9762	2.0562	40.92	1034.7	0.40
0.5	79.586	0.01607	641.5	641.5	47.62	1048.6	1096.3	0.0925	1.9446	2.0370	47.62	1036.9	0.5
0.6	85.218	0.01609	540.0	540.1	53.25	1045.5	1098.7	0.1028	1.9186	2.0215	53.24	1038.7	0.6
0.7	90.09	0.01610	466.93	466.94	58.10	1042.7	1100.8	0.3	1.8966	2.0083	58.10	1040.3	0.7
0.8	94.38	0.01611	411.67	411.69	62.39	1040.3	1102.6	0.1117	1.8775	1.9970	62.39	1041.7	0.8
0.9	98.24	0.01612	368.41	368.43	66.24	1038.1	1104.3	0.1264	1.8606	1.9870	66.24	1042.9	0.9
1.0	101.74	0.01614	333.59	333.60	69.73	1036.1	1105.8	0.1326	1.8455	1.9781	69.73	1044.1	1.0
2.0	126.07	0.01623	173.74	173.76	94.03	1022.1	1116.2	0.1750	1.7450	1.9200	94.03	1051.8	2.0
3.0	141.47	0.01630	118.71	118.73	109.42	1013.2	1122.6	0.2009	1.6854	1.8864	109.41	1056.7	3.0
4.0	152.96	0.01636	90.63	90.64	120.92	1006.4	1127.3	0.2199	1.6428	1.8626	120.90	1060.2	4.0
5.0	162.24	0.01641	73.515	73.53	130.20	1000.9	1131.1	0.2349	1.6094	1.8443	130.18	1063.1	5.0
6.0	170.05	0.01645	61.967	61.98	138.03	996.2	1134.2	0.2474	1.5820	1.8294	138.01	1065.4	6.0
7.0	176.84	0.01649	53.634	53.65	144.83	992.1	1136.9	0.2581	1.5587	1.8168	144.81	1067.4	7.0
8.0	182.86	0.01653	47.328	47.35	150.87	988.5	1139.3	0.2676	1.5384	1.8060	150.84	1069.2	8.0
9.0	188.27	0.01656	42.385	42.40	156.30	985.1	1141.4	0.2760	1.5204	1.7964	156.28	1070.8	9.0
10	193.21	0.01659	38.404	38.42	161.26	982.1	1143.3	0.2836	1.5043	1.7879	161.23	1072.3	10
14.696	212.00	0.01672	26.782	26.80	180.17	970.3	1150.5	0.3121	1.4447	1.7568	180.12	1077.6	14.696
15	213.03	0.01673	26.274	26.29	181.21	969.7	1150.9	0.3137	1.4415	1.7552	181.16	1077.9	15
20	227.96	0.01683	20.070	20.087	196.27	960.1	1156.3	0.3358	1.3962	1.7320	196.21	1082.0	20
30	250.34	0.01701	13.7266	13.744	218.9	945.2	1164.1	0.3682	1.3313	1.6995	218.8	1087.9	30
40	267.25	0.01715	10.4794	10.497	236.1	933.6	1169.8	0.3921	1.2844	1.6765	236.0	1092.1	40
50	281.02	0.01727	8.4967	8.514	250.2	923.9	1174.1	0.4112	1.2474	1.6586	250.1	1095.3	50
60	292.71	0.01738	7.1562	7.174	262.2	915.4	1177.6	0.4273	1.2167	1.6440	262.0	1098.0	60
70	302.93	0.01748	6.1875	6.205	272.7	907.8	1180.6	0.4411	1.1905	1.6316	272.5	1100.2	70
80	312.04	0.01757	5.4536	5.471	282.1	900.9	1183.1	0.4534	1.1675	1.6208	281.9	1102.1	80
90	320.28	0.01766	4.8777	4.895	290.7	894.6	1185.3	0.4643	1.1470	1.6113	290.4	1103.7	90
100	327.82	0.01774	4.4133	4.431	298.5	888.6	1187.2	0.4743	1.1284	1.6027	298.2	1105.2	100
120	341.27	0.01789	3.7097	3.728	312.6	877.8	1190.4	0.4919	1.0960	1.5879	312.2	1107.6	120
140	353.04	0.01803	3.2010	3.219	325.0	868.0	1193.0	0.5071	1.0681	1.5752	324.5	1109.6	140
160	363.55	0.01815	2.8155	2.834	336.1	859.0	1195.1	0.5206	1.0435	1.5641	335.5	1111.2	160
180	373.08	0.01827	2.5129	2.531	346.2	850.7	1196.9	0.5328	1.0215	1.5543	345.6	1112.5	180
200	381.80	0.01839	2.2689	2.287	355.5	842.8	1198.3	0.5438	1.0016	1.5454	354.8	1113.7	200
250	400.97	0.01865	1.8245	1.8432	376.1	825.0	1201.1	0.5679	0.9585	1.5264	375.3	1115.8	250
300	417.35	0.01889	1.5238	1.5427	394.0	808.9	1202.9	0.5882	0.9223	1.5105	392.9	1117.2	300
350	431.73	0.01913	1.3064	1.3255	409.8	794.2	1204.0	0.6059	0.8909	1.4968	408.6	1118.1	350
400	444.60	0.0193	1.14162	1.1610	424.2	780.4	1204.6	0.6217	0.8630	1.4847	422.7	1118.7	400
450	456.28	0.0195	1.01224	1.0318	437.3	767.5	1204.8	0.6360	0.8378	1.4738	435.7	1118.9	450
500	467.01	0.0198	0.90787	0.9276	449.5	755.1	1204.7	0.6490	0.8148	1.4639	447.7	1118.8	500
550	476.94	0.0199	0.82183	0.8418	460.9	743.3	1204.3	0.6611	0.7936	1.4547	458.9	1118.6	550
600	486.20	0.0201	0.74962	0.7698	471.7	732.0	1203.7	0.6723	0.7738	1.4461	469.5	1118.2	600
700	503.08	0.0205	0.63505	0.6556	491.6	710.2	1201.8	0.6928	0.7377	1.4304	488.9	1116.9	700
800	518.21	0.0209	0.54809	0.5690	509.8	689.6	1199.4	0.7111	0.7051	1.4163	506.7	1115.2	800
900	531.95	0.0212	0.47968	0.5009	526.7	669.7	1196.4	0.7279	0.6753	1.4032	523.2	1113.0	900
1000	544.58	0.0216	0.42436	0.4460	542.6	650.4	1192.9	0.7434	0.6476	1.3910	538.6	1110.4	1000
1100	556.28	0.0220	0.37863	0.4006	557.5	631.5	1189.1	0.7578	0.6216	1.3794	553.1	1107.5	1100
1200	567.19	0.0223	0.34013	0.3625	571.9	613.0	1184.8	0.7714	0.5969	1.3683	566.9	1104.3	1200
1300	577.42	0.0227	0.30722	0.3299	585.6	594.6	1180.2	0.7843	0.5733	1.3577	580.1	1100.9	1300
1400	587.07	0.0231	0.27871	0.3018	598.8	576.5	1175.3	0.7966	0.5507	1.3474	592.9	1097.1	1400
1500	596.20	0.0235	0.25372	0.2772	611.7	558.4	1170.1	0.8085	0.5288	1.3373	605.2	1093.1	1500
2000	635.80	0.0257	0.16260	0.1883	672.1	466.2	1138.3	0.8629	0.4256	1.2881	662.6	1068.6	2000
2500	668.11	0.0285	0.10209	0.1307	731.7	361.6	1093.3	0.9139	0.3206	1.2345	718.5	1032.9	2500
3000	695.33	0.0343	0.05073	0.0850	801.8	218.4	1020.3	0.9728	0.1891	1.1619	782.8	973.1	3000
3208.2	705.47	0.0508	0	0.0508	906.0	0	906.0	1.0612	0	1.0612	875.9	875.9	3208.2

TABLE A.3 PROPERTIES OF SATURATED STEAM AND SATURATED WATER (PRESSURE)

Abs press. lb/sq in. (sat. temp)		Temperature, F													
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
1 (101.74)	v	0.0161	392.5	452.3	511.9	571.5	631.1	690.7								
	h	68.00	1150.2	1195.7	1241.8	1288.6	1336.1	1384.5								
	s	0.1295	2.0509	2.1152	2.1722	2.2237	2.2706	2.3144								
5 (162.24)	v	0.0161	78.14	90.24	102.24	114.21	126.15	138.08	150.01	161.94	173.86	185.78	197.70	209.62	221.53	233.45
	h	68.01	1148.6	1194.8	1241.3	1288.2	1335.9	1384.3	1433.6	1483.7	1534.7	1586.7	1639.6	1693.3	1748.0	1803.5
	s	0.1295	1.8716	1.9369	1.9943	2.0460	2.0932	2.1369	2.1776	2.2159	2.2521	2.2866	2.3194	2.3509	2.3811	2.4101
10 (193.21)	v	0.0161	38.84	44.93	51.03	57.04	63.03	69.00	74.98	80.94	86.91	92.87	98.84	104.80	110.76	116.72
	h	68.02	1146.6	1193.7	1240.6	1287.8	1335.5	1384.0	1433.4	1483.5	1534.6	1586.6	1639.5	1693.3	1747.9	1803.4
	s	0.1295	1.7928	1.8593	1.9173	1.9692	2.0166	2.0603	2.1011	2.1394	2.1757	2.2101	2.2430	2.2744	2.3046	2.3337
15 (213.03)	v	0.0161	0.0166	29.899	33.963	37.985	41.986	45.978	49.964	53.946	57.926	61.905	65.882	69.858	73.833	77.807
	h	68.04	168.09	1192.5	1239.9	1287.3	1335.2	1383.8	1433.2	1483.4	1534.5	1586.5	1639.4	1693.2	1747.8	1803.4
	s	0.1295	0.2940	1.8134	1.8720	1.9242	1.9717	2.0155	2.0563	2.0946	2.1309	2.1653	2.1982	2.2297	2.2599	2.2890
20 (227.96)	v	0.0161	0.0166	22.356	25.428	28.457	31.466	34.465	37.458	40.447	43.435	46.420	49.405	52.388	55.370	58.352
	h	68.05	168.11	1191.4	1239.2	1286.9	1334.9	1383.5	1432.9	1483.2	1534.3	1586.3	1639.3	1693.1	1747.8	1803.3
	s	0.1295	0.2940	1.7805	1.8397	1.8921	1.9397	1.9836	2.0244	2.0628	2.0991	2.1336	2.1665	2.1979	2.2282	2.2572
40 (267.25)	v	0.0161	0.0166	11.035	12.624	14.165	15.685	17.195	18.699	20.199	21.697	23.194	24.689	26.183	27.676	29.168
	h	68.10	168.15	1186.6	1236.4	1285.0	1333.6	1382.5	1432.1	1482.5	1533.7	1585.8	1638.8	1992.7	1747.5	1803.0
	s	0.1295	0.2940	1.6992	1.7608	1.8143	1.8624	1.9065	1.9476	1.9860	2.0224	2.0569	2.0899	2.1224	2.1516	2.1807
60 (292.71)	v	0.0161	0.0166	7.257	8.354	9.400	10.425	11.438	12.446	13.450	14.452	15.452	16.450	17.448	18.445	19.441
	h	68.15	168.20	1181.6	1233.5	1283.2	1332.3	1381.5	1431.3	1481.8	1533.2	1585.3	1638.4	1692.4	1747.1	1802.8
	s	0.1295	0.2939	1.6492	1.7134	1.7681	1.8168	1.8612	1.9024	1.9410	1.9774	2.0120	2.0450	2.0765	2.1068	2.1359
80 (312.04)	v	0.0161	0.0166	0.0175	6.218	7.018	7.794	8.560	9.319	10.075	10.829	11.581	12.331	13.081	13.829	14.577
	h	68.21	168.24	269.74	1230.5	1281.3	1330.9	1380.5	1430.5	1481.1	1532.6	1584.9	1638.0	1692.0	1746.8	1802.5
	s	0.1295	0.2939	0.4371	1.6790	1.7349	1.7842	1.8289	1.8702	1.9089	1.9454	1.9800	2.0131	2.0446	2.0750	2.1041
100 (327.82)	v	0.0161	0.0166	0.0175	4.935	5.588	6.216	6.833	7.443	8.050	8.655	9.258	9.860	10.460	11.060	11.659
	h	68.26	168.29	269.77	1227.4	1279.3	1329.6	1379.5	1429.7	1480.4	1532.0	1584.4	1637.6	1691.6	1746.5	1802.2
	s	0.1295	0.2939	0.4371	1.6516	1.7088	1.7586	1.8036	1.8451	1.8839	1.9205	1.9552	1.9883	2.0199	2.0502	2.0794
120 (341.27)	v	0.0161	0.0166	0.0175	4.0786	4.6341	5.1637	5.6831	6.1928	6.7006	7.2060	7.7096	8.2119	8.7130	9.2134	9.7130
	h	68.31	168.35	269.81	1224.1	1277.4	1328.1	1378.4	1428.8	1479.8	1531.4	1583.9	1637.1	1691.3	1746.2	1802.0
	s	0.1295	0.2939	0.4371	1.6286	1.6872	1.7376	1.7829	1.8246	1.8635	1.9001	1.9349	1.9680	1.9996	2.0300	2.0592
140 (353.04)	v	0.0161	0.0166	0.0175	3.4651	3.9526	4.4119	4.8585	5.2995	5.7364	6.1709	6.6036	7.0349	7.4652	7.8946	8.3233
	h	68.37	168.38	269.85	1220.8	1275.3	1326.8	1377.4	1428.0	1479.1	1530.8	1583.4	1636.7	1690.9	1745.9	1801.7
	s	0.1295	0.2939	0.4370	1.6085	1.6686	1.7196	1.7652	1.8071	1.8461	1.8828	1.9176	1.9508	1.9825	2.0129	2.0421
160 (363.55)	v	0.0161	0.0166	0.0175	3.0060	3.4413	3.8480	4.2420	4.6295	5.0132	5.3945	5.7741	6.1522	6.5293	6.9055	7.2811
	h	68.42	168.42	269.89	1217.4	1273.3	1325.4	1376.4	1427.2	1478.4	1530.3	1582.9	1636.3	1690.5	1745.6	1801.4
	s	0.1294	0.2938	0.4370	1.5906	1.6522	1.7039	1.7499	1.7919	1.8310	1.8678	1.9027	1.9359	1.9676	1.9980	2.0273
180 (373.08)	v	0.0161	0.0166	0.0174	2.6474	3.0433	3.4093	3.7621	4.1084	4.4505	4.7907	5.1289	5.4657	5.8014	6.1363	6.4704
	h	68.47	168.47	269.92	1213.8	1271.2	1324.0	1375.3	1426.3	1477.7	1529.7	1582.4	1635.9	1690.2	1745.3	1801.2
	s	0.1294	0.2938	0.4370	1.5743	1.6376	1.6900	1.7362	1.7784	1.8176	1.8545	1.8894	1.9227	1.9545	1.9849	2.0142
200 (381.80)	v	0.0161	0.0166	0.0174	2.3598	2.7247	3.0583	3.3783	3.6915	4.0008	4.3077	4.6128	4.9165	5.2191	5.5209	5.8219
	h	68.52	168.51	269.96	1210.1	1269.0	1322.6	1374.3	1425.5	1477.0	1529.1	1581.9	1635.4	1689.8	1745.0	1800.9
	s	0.1294	0.2938	0.4369	1.5593	1.6242	1.6770	1.7239	1.7663	1.8057	1.8426	1.8776	1.9109	1.9427	1.9732	2.0025
250 (400.97)	v	0.0161	0.0166	0.0174	0.0186	2.1504	2.4662	2.6872	2.9410	3.1909	3.4382	3.6837	3.9278	4.1709	4.4131	4.6546
	h	68.65	168.63	270.05	375.10	1263.5	1319.0	1371.6	1423.4	1475.3	1527.6	1580.6	1634.4	1688.9	1744.2	1800.2
	s	0.1294	0.2937	0.4368	0.5667	1.5951	1.6502	1.6976	1.7405	1.7801	1.8173	1.8524	1.8858	1.9177	1.9482	1.9776
300 (417.35)	v	0.0161	0.0166	0.0174	0.0186	1.7665	2.0044	2.2263	2.4407	2.6509	2.8585	3.0643	3.2688	3.4721	3.6746	3.8764
	h	68.79	168.74	270.14	375.15	1257.7	1315.2	1368.9	1421.3	1473.6	1526.2	1579.4	1633.3	1688.0	1743.4	1799.6
	s	0.1294	0.2937	0.4367	0.5665	1.5703	1.6274	1.6758	1.7192	1.7591	1.7964	1.8317	1.8652	1.8972	1.9278	1.9572
350 (431.73)	v	0.0161	0.0166	0.0174	0.0186	1.4913	1.7028	1.8970	2.0832	2.2652	2.4445	2.6219	2.7980	2.9730	3.1471	3.3205
	h	68.92	168.85	270.24	375.21	1251.5	1311.4	1366.2	1419.2	1471.8	1524.7	1578.2	1632.3	1687.1	1742.6	1798.9
	s	0.1293	0.2936	0.4367	0.5664	1.5483	1.6077	1.6571	1.7009	1.7411	1.7787	1.8141	1.8477	1.8798	1.9105	1.9400
400 (444.60)	v	0.0161	0.0166	0.0174	0.0162	1.2841	1.4763	1.6490	1.8151	1.9759	2.1339	2.2901	2.4450	2.5987	2.7515	2.9037
	h	69.05	168.97	270.33	375.27	1245.1	1307.4	1363.4	1417.0	1470.1	1523.3	1576.9	1631.2	1686.2	1741.9	1798.2
	s	0.1293	0.2935	0.4366	0.5663	1.5282	1.5901	1.6406	1.6850	1.7255	1.7632	1.7988	1.8325	1.8647	1.8955	1.9250
500 (467.01)	v	0.0161	0.0166	0.0174	0.0186	0.9919	1.1584	1.3037	1.4397	1.5708	1.6992	1.8256	1.9507	2.0746	2.1977	2.3200
	h	69.32	169.19	270.51	375.38	1231.2	1299.1	1357.7	1412.7	1466.6	1520.3	1574.4	1629.1	1684.4	1740.3	1796.9
	s	0.1292	0.2934	0.4364	0.5660	1.4921	1.5595	1.6123	1.6578	1.6990	1.7371	1.7730	1.8069	1.8393	1.8702	1.8998

TABLE A.4 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE)

Abs press. lb/sq in. (sat. temp)		Temperature, F														
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500
	v	0.0161	0.0166	0.0174	0.0186	0.7944	0.9456	1.0726	1.1892	1.3008	1.4093	1.5160	1.6211	1.7252	1.8284	1.9309
600	h	69.58	169.42	270.70	375.49	1215.9	1290.3	1351.8	1408.3	1463.0	1517.4	1571.9	1627.0	1682.6	1738.8	1795.6
(486.20)	s	0.1292	0.2933	0.4362	0.5657	1.4590	1.5329	1.5844	1.6351	1.6769	1.7155	1.7517	1.7859	1.8184	1.8494	1.8792
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.7928	0.9072	1.0102	1.1078	1.2023	1.2948	1.3858	1.4757	1.5647	1.6530
700	h	69.04	169.65	270.89	375.61	487.93	1281.0	1345.6	1403.7	1459.4	1514.4	1569.4	1624.8	1680.7	1737.2	1794.3
(503.08)	s	0.1291	0.2932	0.4360	0.5655	0.6889	1.5090	1.5673	1.6154	1.6580	1.6970	1.7335	1.7679	1.8006	1.8318	1.8617
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.6774	0.7828	0.8759	0.9631	1.0470	1.1289	1.2093	1.2885	1.3669	1.4446
800	h	70.11	169.88	271.07	375.73	487.88	1271.1	1339.2	1399.1	1455.8	1511.4	1566.9	1622.7	1678.9	1735.0	1792.9
(518.2.)	s	0.1290	0.2930	0.4358	0.5652	0.6885	1.4869	1.5484	1.5980	1.6413	1.6807	1.7175	1.7522	1.7851	1.8164	1.8464
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.5869	0.6858	0.7713	0.8504	0.9262	0.9998	1.0720	1.1430	1.2131	1.2825
900	h	70.37	170.10	271.26	375.84	487.83	1260.6	1332.7	1394.4	1452.2	1508.5	1564.4	1620.6	1677.1	1734.1	1791.6
(531.98)	s	0.1290	0.2929	0.4357	0.5649	0.6881	1.4659	1.5311	1.5822	1.6263	1.6662	1.7033	1.7382	1.7713	1.8028	1.8329
	v	0.0161	0.0166	0.0174	0.0186	0.0204	0.5137	0.6080	0.6875	0.7603	0.8295	0.8966	0.9622	1.0266	1.0901	1.1529
1000	h	70.63	170.33	271.44	375.96	487.79	1249.3	1325.9	1389.6	1448.5	1504.4	1561.9	1618.4	1675.3	1732.5	1790.3
(544.58)	s	0.1289	0.2928	0.4355	0.5647	0.6876	1.4457	1.5149	1.5677	1.6126	1.6530	1.6905	1.7256	1.7589	1.7905	1.8207
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.4531	0.5440	0.6188	0.6865	0.7505	0.8121	0.8723	0.9313	0.9894	1.0468
1100	h	70.90	170.56	271.63	376.08	487.75	1237.3	1318.8	1384.7	1444.7	1502.4	1559.4	1616.3	1673.5	1731.0	1789.0
(556.28)	s	0.1289	0.2927	0.4353	0.5644	0.6872	1.4259	1.4996	1.5542	1.6000	1.6410	1.6787	1.7141	1.7475	1.7793	1.8097
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.4016	0.4905	0.5615	0.6250	0.6845	0.7418	0.7974	0.8519	0.9055	0.9584
1200	h	71.16	170.78	271.82	376.20	487.72	1224.2	1311.5	1379.7	1440.9	1449.4	1556.9	1614.2	1671.6	1729.4	1787.6
(567.19)	s	0.1288	0.2926	0.4351	0.5642	0.6868	1.4061	1.4851	1.5415	1.5883	1.6298	1.6679	1.7035	1.7371	1.7691	1.7996
	v	0.0161	0.0166	0.0174	0.0185	0.0203	0.3176	0.4059	0.4712	0.5282	0.5809	0.6311	0.6798	0.7272	0.7737	0.8195
1400	h	71.68	171.24	272.19	376.44	487.65	1194.1	1296.1	1369.3	1433.2	1493.2	1551.8	1609.9	1668.0	1726.3	1785.0
(587.07)	s	0.1287	0.2923	0.4348	0.5636	0.6859	1.3652	1.4575	1.5182	1.5670	1.6096	1.6484	1.6845	1.7185	1.7508	1.7815
	v	0.0161	0.0166	0.0173	0.0185	0.0202	0.0236	0.3415	0.4032	0.4555	0.5031	0.5482	0.5915	0.6336	0.6748	0.7153
1600	h	72.21	171.69	272.57	376.69	487.60	616.77	1279.4	1358.5	1425.2	1486.9	1546.6	1605.6	1664.3	1723.2	1782.3
(604.87)	s	0.1286	0.2921	0.4344	0.5631	0.6851	0.8129	1.4312	1.4968	1.5478	1.5916	1.6312	1.6678	1.7022	1.7344	1.7657
	v	0.0160	0.0165	0.0173	0.0185	0.0202	0.0235	0.2906	0.3500	0.3988	0.4426	0.4836	0.5229	0.5609	0.5980	0.6343
1800	h	72.73	172.15	272.95	376.93	487.56	615.58	1261.1	1347.2	1417.1	1480.6	1541.1	1601.2	1660.7	1720.1	1779.7
(621.02)	s	0.1284	0.2918	0.4341	0.5626	0.6843	0.8109	1.4054	1.4768	1.5302	1.5753	1.6156	1.6528	1.6876	1.7204	1.7516
	v	0.0160	0.0165	0.0173	0.0184	0.0201	0.0233	0.2488	0.3072	0.3534	0.3942	0.4320	0.4680	0.5027	0.5365	0.5695
2000	h	73.26	172.60	273.32	377.19	487.53	614.48	1240.9	1353.4	1408.7	1447.1	1536.2	1596.9	1657.0	1717.0	1777.1
(635.80)	s	0.1283	0.2916	0.4337	0.5621	0.6834	0.8091	1.3794	1.4578	1.5138	1.5603	1.6014	1.6391	1.6743	1.7075	1.7389
	v	0.0160	0.0165	0.0173	0.0184	0.0200	0.0230	0.1681	0.2293	0.2712	0.3068	0.3390	0.3692	0.3980	0.4259	0.4529
2500	h	74.57	173.74	274.27	377.82	487.50	612.08	1176.7	1303.4	1386.7	1457.5	1522.9	1585.9	1647.8	1709.2	1770.4
(668.11)	s	0.1280	0.2910	0.4329	0.5609	0.6815	0.8048	1.3076	1.4129	1.4766	1.5269	1.5703	1.6094	1.6456	1.6796	1.7116
	v	0.0160	0.0165	0.0172	0.0183	0.0200	0.0228	0.0982	0.1759	0.2161	0.2484	0.2770	0.3033	0.3282	0.3522	0.3753
3000	h	75.83	174.88	275.22	378.47	487.52	610.08	1060.5	1267.0	1363.2	1440.2	1509.4	1574.8	1638.5	1701.4	1761.8
(695.33)	s	0.1277	0.2904	0.4320	0.5597	0.6796	0.8009	1.1966	1.3692	1.4429	1.4975	1.5434	1.5841	1.6214	1.6561	1.6888
	v	0.0160	0.0165	0.0172	0.0183	0.0199	0.0227	0.0335	0.1588	0.1987	0.2301	0.2576	0.2827	0.3065	0.3291	0.3510
3200	h	76.4	175.3	275.6	378.7	487.5	609.4	800.8	1250.9	1353.4	1433.1	1503.8	1570.3	1634.8	1698.3	1761.2
(705.08)	s	0.1276	0.2902	0.4317	0.5592	0.6788	0.7994	0.9708	1.3515	1.4300	1.4866	1.5335	1.5749	1.6126	1.6477	1.6806
	v	0.0160	0.0164	0.0172	0.0183	0.0199	0.0225	0.0307	0.1364	0.1764	0.2066	0.2326	0.2563	0.2784	0.2995	0.3198
3500	h	77.2	176.0	276.2	379.1	487.6	608.4	779.4	1224.6	1338.2	1422.2	1495.5	1563.3	1629.2	1693.6	1757.2
	s	0.1274	0.2899	0.4312	0.5585	0.6777	0.7973	0.9508	1.3242	1.4112	1.4709	1.5194	1.5618	1.6002	1.6358	1.6691
	v	0.0159	0.0164	0.0172	0.0182	0.0198	0.0223	0.0287	0.1052	0.1463	0.1752	0.1994	0.2210	0.2411	0.2601	0.2783
4000	h	76.5	177.2	277.1	379.8	487.7	606.5	763.0	1174.3	1311.6	1403.0	1481.3	1552.2	1619.8	1685.7	1750.6
	s	0.1271	0.2893	0.4304	0.5573	0.6760	0.7940	0.9343	1.2754	1.3807	1.4461	1.4970	1.5417	1.5812	1.6177	1.6516
	v	0.0159	0.0164	0.0171	0.0181	0.0196	0.0219	0.0268	0.0591	0.1038	0.1312	0.1529	0.1718	0.1890	0.2050	0.2203
5000	h	81.1	179.5	279.1	381.2	488.1	604.6	746.0	1042.9	1252.9	1384.0	1452.1	1529.1	1600.9	1670.0	1737.4
	s	0.1265	0.2881	0.4287	0.5550	0.6726	0.7880	0.9153	1.1593	1.3207	1.4001	1.4582	1.5061	1.5481	1.5863	1.6216
	v	0.0159	0.0163	0.0170	0.0180	0.0195	0.0216	0.0256	0.0397	0.0757	0.1020	0.1221	0.1391	0.1544	0.1684	0.1817
6000	h	83.7	181.7	281.0	382.7	488.6	602.9	736.1	945.1	1188.8	1323.6	1422.3	1505.9	1582.0	1654.2	1724.2
	s	0.1258	0.2870	0.4271	0.5528	0.6693	0.7826	0.9026	1.0176	1.2615	1.3574	1.4229	1.4748	1.5194	1.5593	1.5962
	v	0.0158	0.0163	0.0170	0.0180	0.0193	0.0213	0.0248	0.0334	0.0573	0.0816	0.1004	0.1160	0.1298	0.1424	0.1542
7000	h	86.2	184.4	283.0	384.2	489.3	601.7	729.3	901.8	1124.9	1281.7	1392.2	1482.6	1563.1	1638.6	1711.1
	s	0.1252	0.2859	0.4256	0.5507	0.6663	0.7777	0.8926	1.0350	1.2055	1.3171	1.3904	1.4486	1.4938	1.5345	1.5735

TABLE A.4 PROPERTIES OF SUPERHEATED STEAM AND COMPRESSED WATER (TEMPERATURE AND PRESSURE) (CONTINUED)

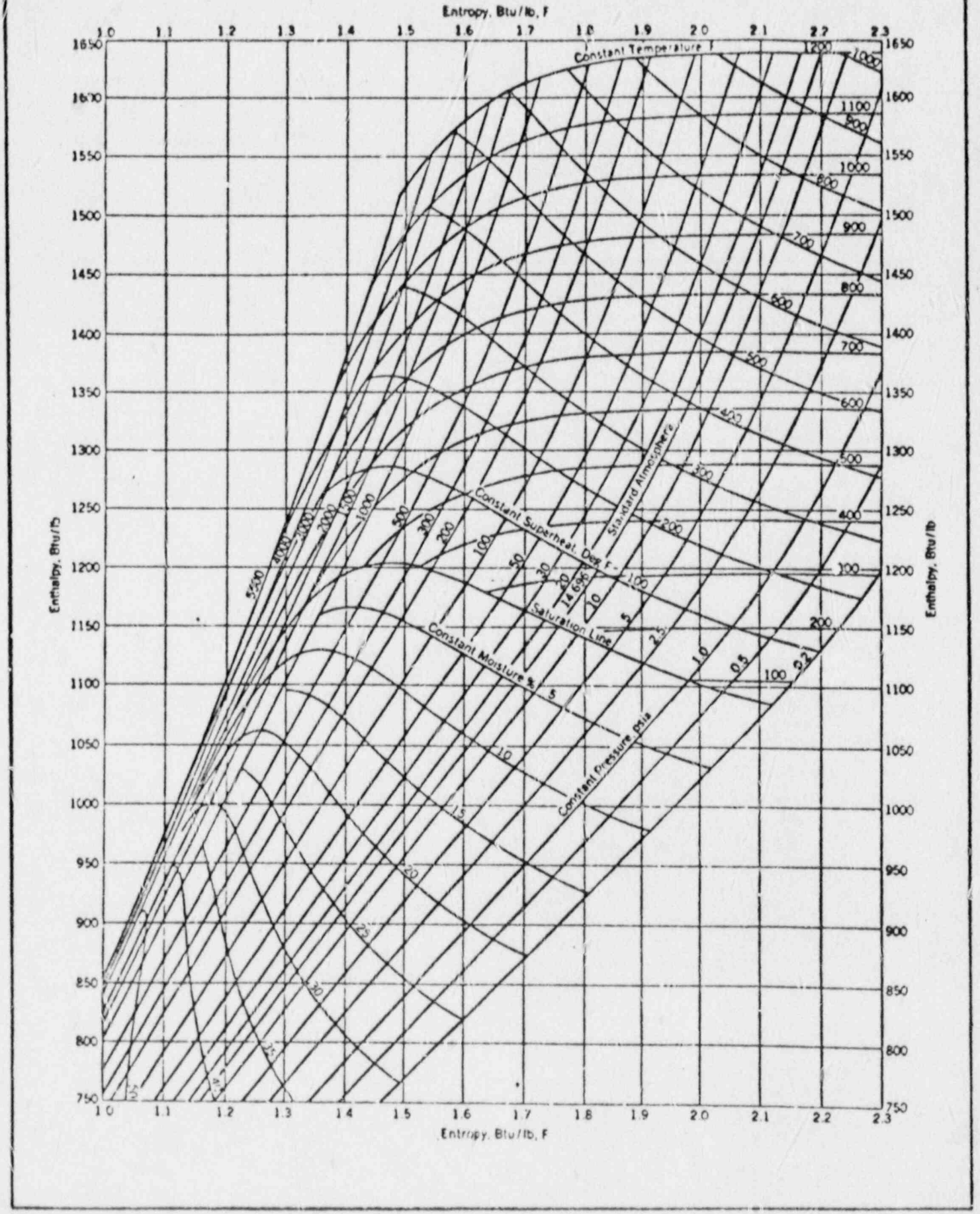


FIGURE A.5 MOLLIER ENTHALPY-ENTROPY DIAGRAM

PROPERTIES OF WATER

Density ρ
(lbs/ft³)

Temp (°F)	Saturated Liquid	PSIA 1000	2000	2100	2200	2300	2400	2500	3000
32	62.414	62.637	62.846	62.867	62.888	62.909	62.93	62.951	63.056
50	62.38	62.55	62.75	62.774	62.798	62.822	62.846	62.87	62.99
100	61.989	62.185	62.371	62.390	62.409	62.427	62.446	62.465	62.559
200	60.118	60.314	60.511	60.53	60.549	60.568	60.587	60.606	60.702
300	57.310	57.537	57.767	57.79	57.813	57.836	57.859	57.882	57.998
400	53.651	53.903	54.218	54.249	54.28	54.311	54.342	54.373	54.529
410	53.248	53.475	53.79	53.825	53.86	53.89	53.925	53.95	54.11
420	52.798	53.025	53.36	53.40	53.425	53.46	53.50	53.53	53.69
430	52.356	52.575	52.925	52.95	52.99	53.02	53.065	53.09	53.265
440	51.921	52.125	52.42	52.45	52.475	52.51	52.54	52.56	52.275
450	51.546	51.66	52.025	52.065	52.10	52.14	52.175	52.21	52.41
460	51.020	51.175	51.56	51.61	51.64	51.68	51.725	51.76	51.96
470	50.505	50.70	51.1	51.14	51.175	51.22	51.25	51.30	51.50
480	50.00	50.20	50.62	50.66	50.7	50.74	50.78	50.825	51.035
490	49.505	49.685	50.13	50.175	50.22	50.265	50.31	50.35	50 575
500	48.943	49.097	49.618	49.666	49.714	49.762	49.81	49.858	50.098
510	48.31	48.51	49.05	49.101	49.152	49.203	49.254	49.305	49.56
520	47.85	47.91	48.46	48.515	48.57	48.625	48.68	48.735	49.01
530	47.17	47.29	47.86	47.919	47.978	48.037	48.096	48.155	48.45
540	46.51		47.23	47.296	47.362	47.428	47.494	47.56	47.89
550	45.87		46.59	46.658	46.726	45.794	46.862	46.93	47.27
560	45.25		45.92	45.994	46.068	46.142	46.216	46.29	46.66
570	44.64		45.22	45.30	45.38	45.46	45.54	45.62	46.02
580	43.86		44.50	44.586	44.672	44.758	44.844	44.93	45.36
590	43.10		43.73	43.825	43.92	44.015	44.11	44.205	44.68
600	42.321		42.913	43.017	43.122	43.226	43.33	43.434	43.956
610	41.49		41.96	42.08	42.196	42.314	42.432	42.55	43.14
620	40.552		40.950	41.083	41.217	41.35	41.483	41.616	42.283
630	39.53								41.44
640	38.491								40.388
650	37.31								39.26
660	36.01								38.008
670	34.48								36.52
680	32.744								34.638
690	30.516								32.144

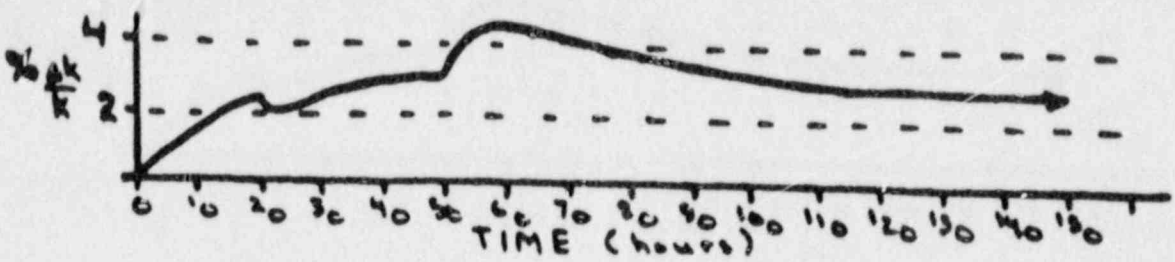
TABLE A.6 PROPERTIES OF WATER, DENSITY

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	0.13141	0.016019	2272.4	2272.4	10.035	1069.8	1079.9	0.0202	2.1325	2.1527	42.0
44.0	0.14192	0.016019	2112.8	2112.8	12.041	1068.7	1080.7	0.0242	2.1217	2.1459	44.0
46.0	0.15314	0.016020	1965.7	1965.7	14.047	1067.6	1081.6	0.0282	2.1111	2.1393	46.0
48.0	0.16514	0.016021	1830.0	1830.0	16.051	1066.4	1082.5	0.0321	2.1006	2.1327	48.0
50.0	0.17796	0.016023	1704.8	1704.8	18.054	1065.3	1083.4	0.0361	2.0901	2.1262	50.0
52.0	0.19165	0.016024	1589.2	1589.2	20.057	1064.2	1084.2	0.0400	2.0798	2.1197	52.0
54.0	0.20625	0.016026	1482.4	1482.4	22.058	1063.1	1085.1	0.0439	2.0695	2.1134	54.0
56.0	0.22183	0.016028	1383.6	1383.6	24.059	1061.9	1086.0	0.0478	2.0593	2.1070	56.0
58.0	0.23843	0.016031	1292.2	1292.2	26.060	1060.8	1086.9	0.0516	2.0491	2.1008	58.0
60.0	0.25611	0.016033	1207.6	1207.6	28.060	1059.7	1087.7	0.0555	2.0391	2.0946	60.0
62.0	0.27494	0.016036	1129.2	1129.2	30.059	1058.5	1088.6	0.0593	2.0291	2.0885	62.0
64.0	0.29497	0.016039	1056.5	1056.5	32.058	1057.4	1089.5	0.0632	2.0192	2.0824	64.0
66.0	0.31626	0.016043	989.0	989.1	34.056	1056.3	1090.4	0.0670	2.0094	2.0764	66.0
68.0	0.33889	0.016046	926.5	926.5	36.054	1055.2	1091.2	0.0708	1.9996	2.0704	68.0
70.0	0.36292	0.016050	868.3	868.4	38.052	1054.0	1092.1	0.0745	1.9900	2.0645	70.0
72.0	0.38844	0.016054	814.3	814.3	40.049	1052.9	1093.0	0.0783	1.9804	2.0587	72.0
74.0	0.41550	0.016058	764.1	764.1	42.046	1051.8	1093.8	0.0821	1.9708	2.0529	74.0
76.0	0.44420	0.016063	717.4	717.4	44.043	1050.7	1094.7	0.0858	1.9614	2.0472	76.0
78.0	0.47461	0.016067	673.8	673.9	46.040	1049.5	1095.6	0.0895	1.9520	2.0415	78.0
80.0	0.50683	0.016072	633.3	633.3	48.037	1048.4	1096.4	0.0932	1.9426	2.0359	80.0
82.0	0.54093	0.016077	595.5	595.5	50.033	1047.3	1097.3	0.0969	1.9334	2.0303	82.0
84.0	0.57702	0.016082	560.3	560.3	52.029	1046.1	1098.2	0.1006	1.9242	2.0248	84.0
86.0	0.61518	0.016087	527.5	527.5	54.026	1045.0	1099.0	0.1043	1.9151	2.0193	86.0
88.0	0.65551	0.016093	496.8	496.8	56.022	1043.9	1099.9	0.1079	1.9060	2.0139	88.0
90.0	0.69813	0.016099	468.1	468.1	58.018	1042.7	1100.8	0.1115	1.8970	2.0086	90.0
92.0	0.74313	0.016105	441.3	441.3	60.014	1041.6	1101.6	0.1152	1.8881	2.0033	92.0
94.0	0.79062	0.016111	416.3	416.3	62.010	1040.5	1102.5	0.1188	1.8792	1.9980	94.0
96.0	0.84072	0.016117	392.9	392.9	64.006	1039.3	1103.3	0.1224	1.8704	1.9928	96.0
98.0	0.89356	0.016123	370.9	370.9	66.003	1038.2	1104.2	0.1260	1.8617	1.9876	98.0
100.0	0.94924	0.016130	350.4	350.4	67.999	1037.1	1105.1	0.1295	1.8530	1.9825	100.0
102.0	1.00789	0.016137	331.1	331.1	69.995	1035.9	1105.9	0.1331	1.8444	1.9775	102.0
104.0	1.06965	0.016144	313.1	313.1	71.992	1034.8	1106.8	0.1366	1.8358	1.9725	104.0
106.0	1.1347	0.016151	296.16	296.18	73.99	1033.6	1107.6	0.1402	1.8273	1.9675	106.0
108.0	1.2030	0.016158	280.28	280.30	75.98	1032.5	1108.5	0.1437	1.8188	1.9626	108.0
110.0	1.2750	0.016165	265.37	265.39	77.98	1031.4	1109.3	0.1472	1.8105	1.9577	110.0
112.0	1.3505	0.016173	251.37	251.38	79.98	1030.2	1110.2	0.1507	1.8021	1.9528	112.0
114.0	1.4299	0.016180	238.21	238.22	81.97	1029.1	1111.0	0.1542	1.7938	1.9480	114.0
116.0	1.5133	0.016188	225.84	225.85	83.97	1027.9	1111.9	0.1577	1.7856	1.9433	116.0
118.0	1.6009	0.016196	214.20	214.21	85.97	1026.8	1112.7	0.1611	1.7774	1.9386	118.0
120.0	1.6927	0.016204	203.25	203.26	87.97	1025.6	1113.6	0.1646	1.7693	1.9339	120.0
122.0	1.7891	0.016213	192.94	192.95	89.96	1024.5	1114.4	0.1680	1.7613	1.9293	122.0
124.0	1.8901	0.016221	183.23	183.24	91.96	1023.3	1115.3	0.1715	1.7533	1.9247	124.0
126.0	1.9959	0.016229	174.08	174.09	93.96	1022.2	1116.1	0.1749	1.7453	1.9202	126.0
128.0	2.1068	0.016238	165.45	165.47	95.96	1021.0	1117.0	0.1783	1.7374	1.9157	128.0
130.0	2.2230	0.016247	157.32	157.33	97.96	1019.8	1117.8	0.1817	1.7295	1.9112	130.0
132.0	2.3445	0.016256	149.64	149.66	99.95	1018.7	1118.6	0.1851	1.7217	1.9068	132.0
134.0	2.4717	0.016265	142.40	142.41	101.95	1017.5	1119.5	0.1884	1.7140	1.9024	134.0
136.0	2.6047	0.016274	135.55	135.57	103.95	1016.4	1120.3	0.1918	1.7063	1.8980	136.0
138.0	2.7438	0.016284	129.09	129.11	105.95	1015.2	1121.1	0.1951	1.6986	1.8937	138.0
140.0	2.8892	0.016293	122.98	123.00	107.95	1014.0	1122.0	0.1985	1.6910	1.8895	140.0
142.0	3.0411	0.016303	117.21	117.22	109.95	1012.9	1122.8	0.2018	1.6834	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	62.04	62.06	137.97	996.2	1134.2	0.2473	1.5822	1.8295	170.0
172.0	6.2736	0.016463	59.43	59.45	139.98	995.0	1135.0	0.2505	1.5753	1.8258	172.0
174.0	6.5656	0.016474	56.95	56.97	141.98	993.8	1135.8	0.2537	1.5684	1.8221	174.0
176.0	6.8690	0.016486	54.59	54.61	143.99	992.6	1136.6	0.2568	1.5616	1.8184	176.0
178.0	7.1840	0.016498	52.35	52.36	145.99	991.4	1137.4	0.2600	1.5548	1.8147	178.0

*The states shown are metastable

a.



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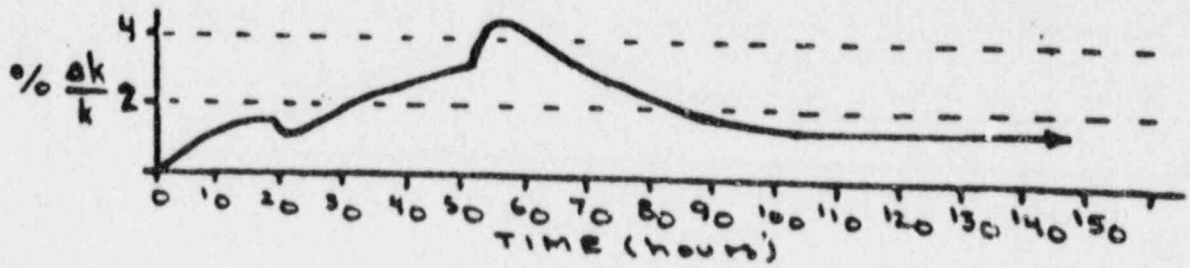

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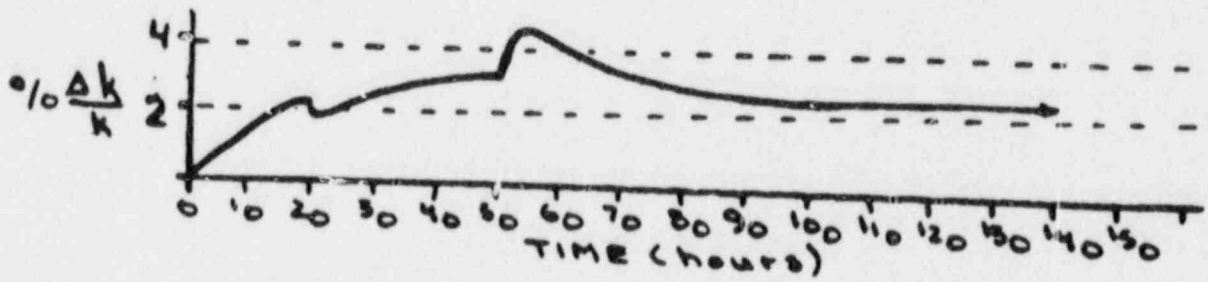

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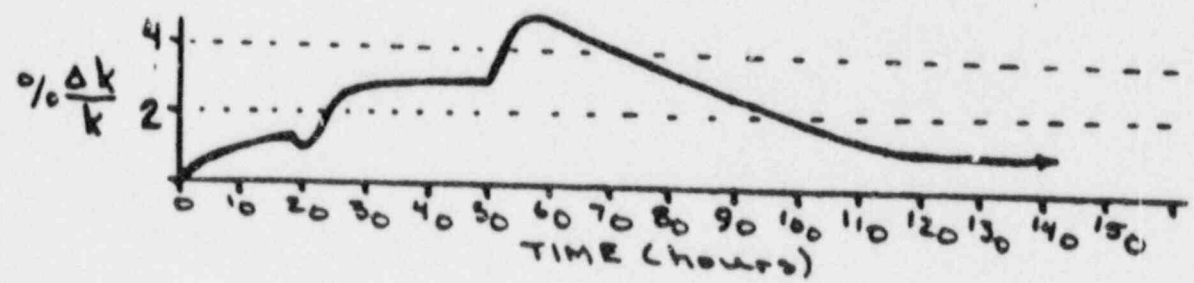

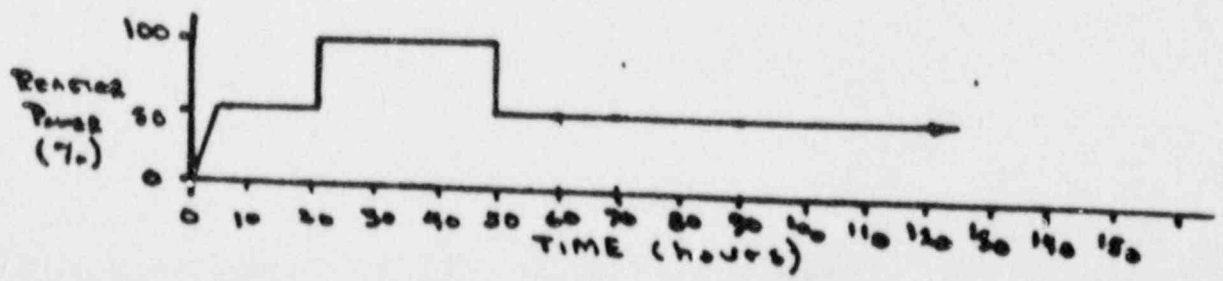

FIGURE # 219

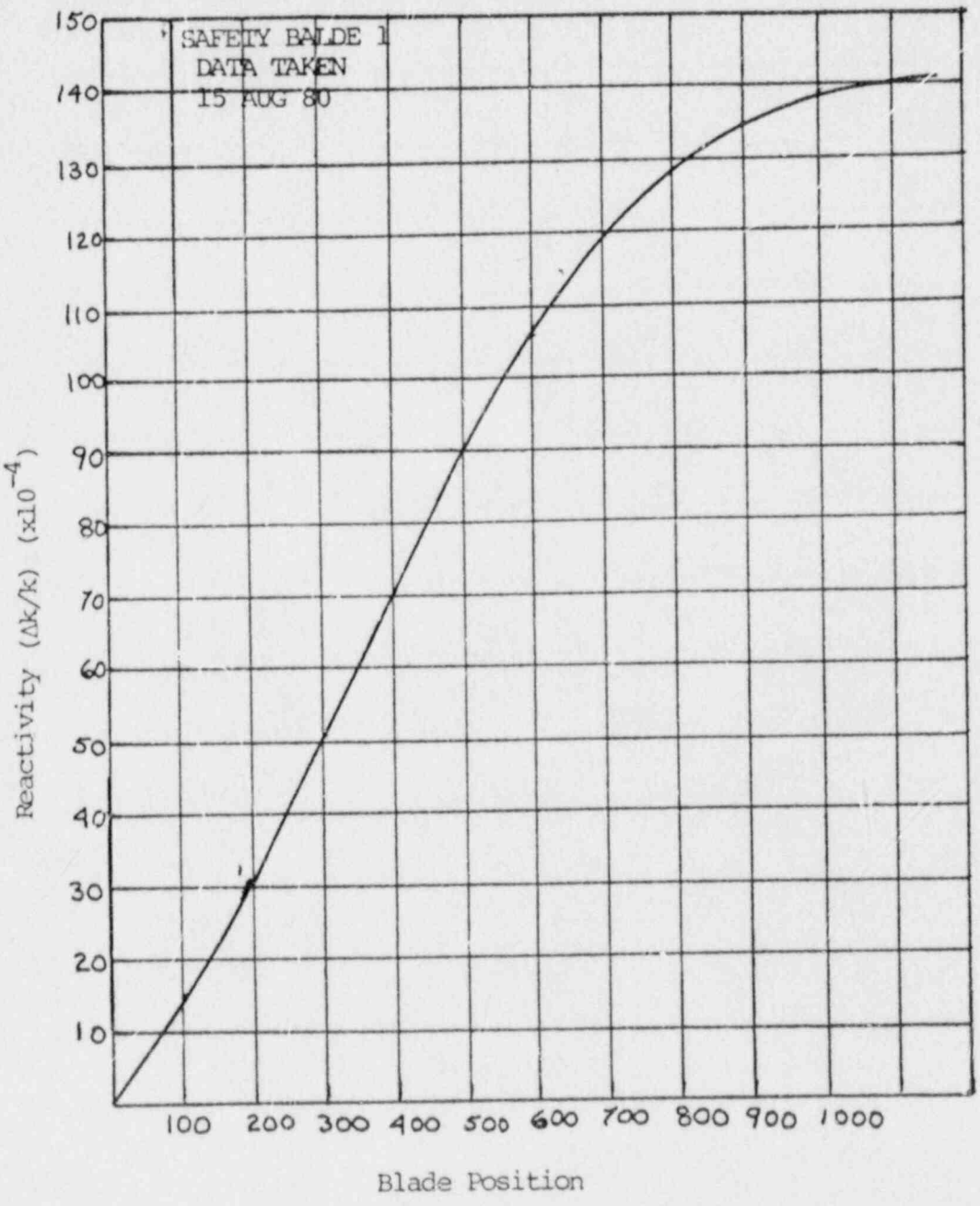

Figure 4-26. Reactivity Integral Rod Worth Curve for UFTR Safety Blade #1.

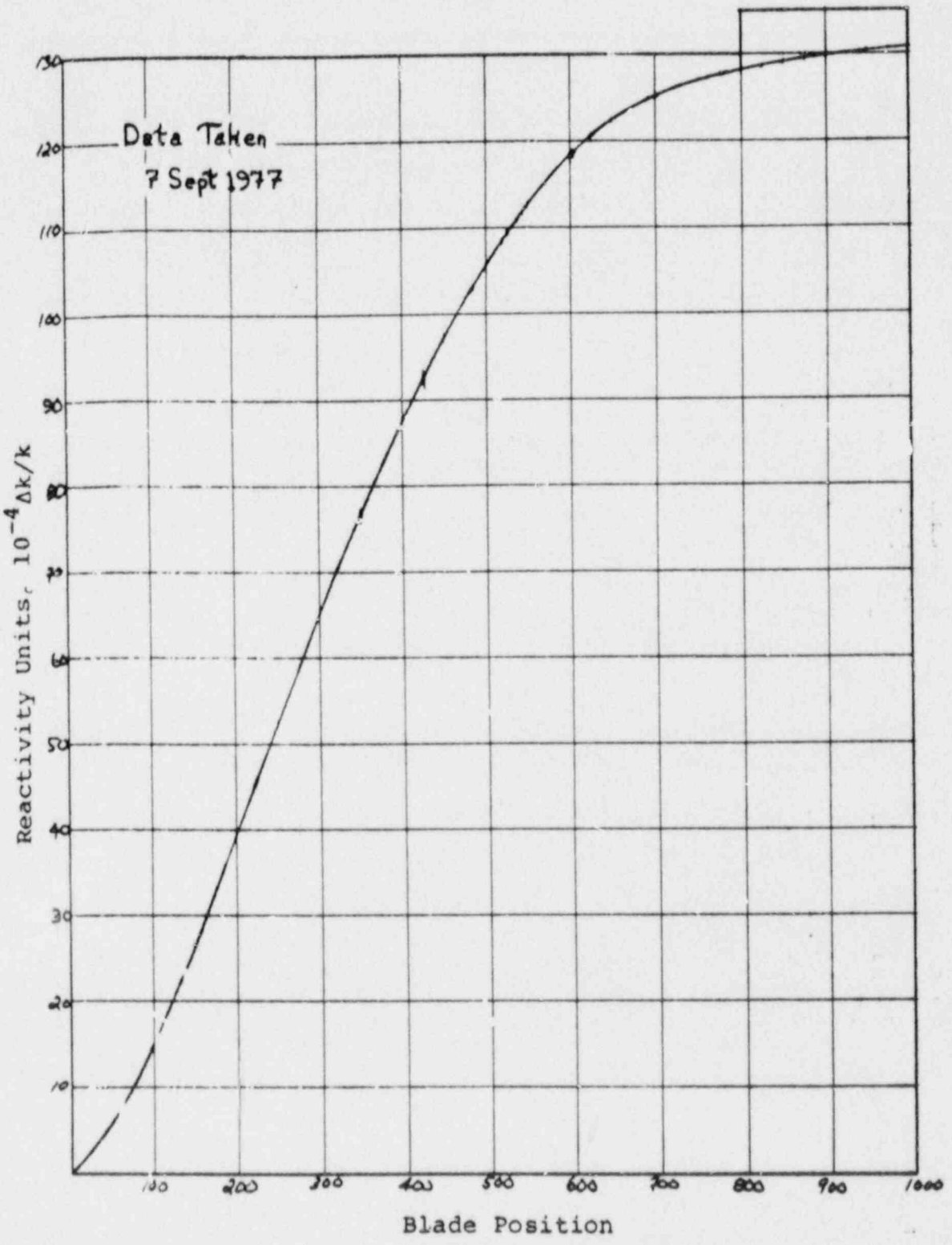

Figure 4-27. Integral Rod Worth Curve for UFTR Safety Blade #2.

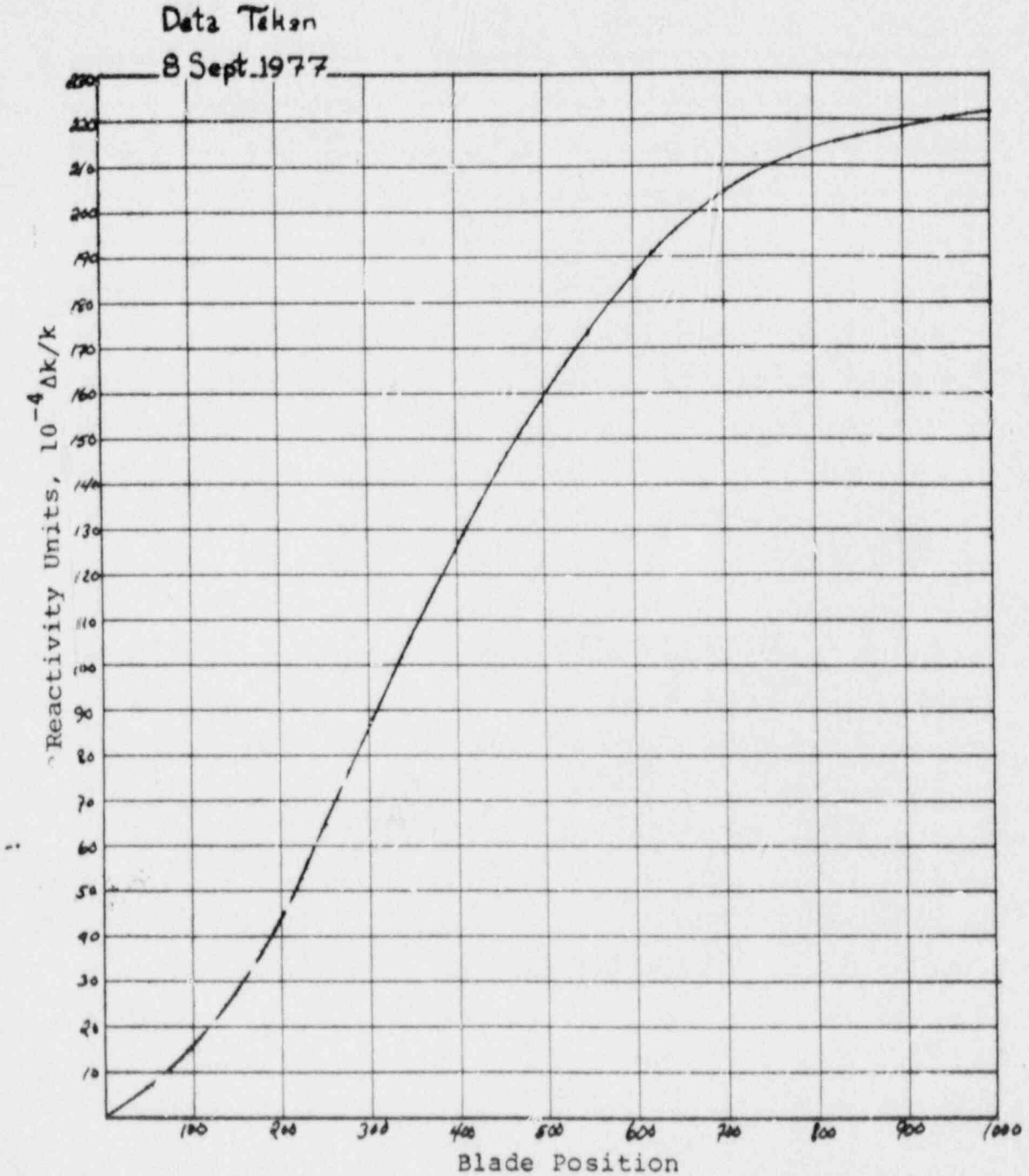

Figure 4-28. Integral Rod Worth Curve for UFTR Safety Blade #3.

Data Taken
15 Aug. 1977

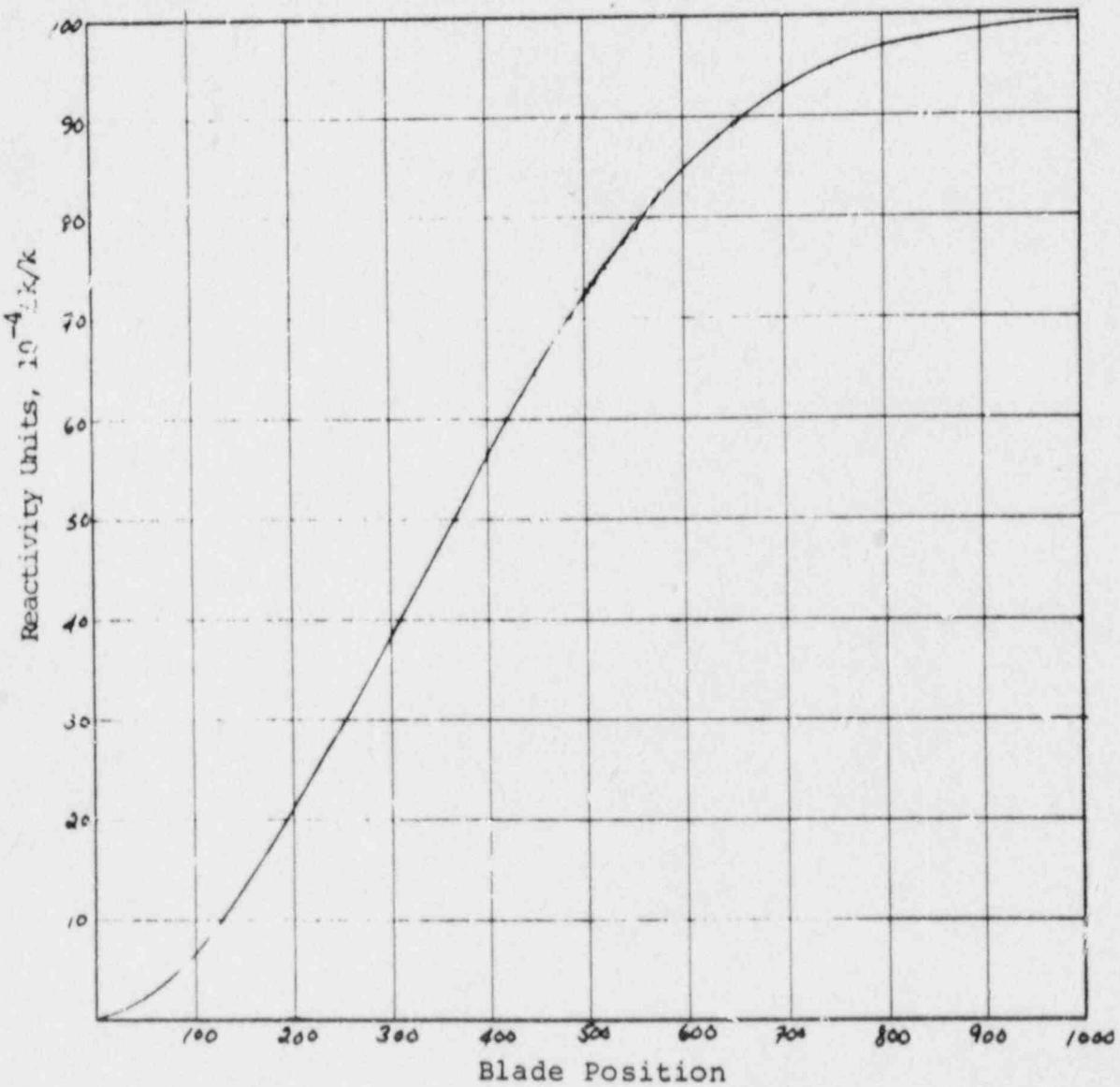

Figure 4-29. Integral Rod Worth Curve for UFTR Regulating Blade