NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

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NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-1 - Definitions

0.0 INTRODUCTION

This lesson will define specific heat, change of state of a substance, sensible heat, and superheat.

1.0 INFORMATION

We know that in order to raise the temperature of one pound of a substance by one degree fahrenheit, we have to add a certain amount of Heat. The amount of heat required to raise the temperature of equal weights of various substances by one degree fahrenheit depends on the "Specific Heat" of the substances. Therefore, we can define Specific Heat as follows:

"Specific Heat" - The amount of heat that must be added or removed in order to change the temperature of one pound of a substance by one degree Fahrenheit.

The Specific Heat constant is usually denoted with the letter 'C'. The units used in engineering in this country are British Thermal Units per pound per degree Fahrenheit (BTU's/lb/°F). Water which is one of the most common substances has a specific heat of 1.0 BTU's/lb/°F.

As an example, let's calculate the amount of heat required to raise the temperature of 40 pounds of water by 50°F. As previously stated, the Specific Heat for water is C = 1.0 BTU's/lb/°F. Then:

to raise the temperature of 1 pound of water by 1°F, we need 1 x 1 x 1 = 1 BTU.

to raise the temperature of 40 pounds of water by 1°F, we need 40 x 1 x 1 = 40 BTU's.

to raise the temperature of 40 pounds of water by 50°F, we need 40 x 50 x 1 = 2000 BTU's.

Therefore, the amount of heat to be added or removed to raise or lower the temperature of "W" pounds of a substance by ΔT degrees Fahrenheit when the specific heat of the substance is 'C' BTU's/lb/°F would be 'Q' BTU's.

Thus we can write the formula.

$$Q = W \times \Delta T \times C \quad \text{............}(1)$$

where:

Q = Total heat transferred in BTU's.
W = Weight of substance in pounds
$\Delta T = T_1 - T_o$ = Temperature change in the substance in °F
C = Specific Heat constant in BTU's/lb/°F.

Sample Problem

Find the amount of heat to be added to a boiler feed pump to raise its metal temperature from 75°F to 175°F. Assuming that the effective weight of the pump metal is 1000 pounds and that all of its components are made of steel having a specific heat constant C = 0.11 BTU's/lb/°F.

Solution:

Using equation (1), we have:

$$Q = W \times \Delta T \times C$$

$$= 1000 \times 100 \times 0.11$$

$$= 11{,}000 \text{ BTU's are to be added.}$$

1.1 Change of State

The majority of substances can exist in three different states, i.e., solid, liquid and gaseous.

To change a substance from a solid to a liquid state heat has to be added. Conversely, when changing from a liquid to solid, heat has to be extracted. This change of state can only take place at a certain temperature - namely, the melting point (also known as freezing point) for the substance. The amount of heat required to be transferred per pound of substance to change it from solid to liquid or liquid to solid is called latent heat of fusion.

Similarly, to change a substance from a liquid to a gaseous or vapor state, heat has to be added. Going in the reverse direction, when condensing gas (vapor) to liquid, heat has to be extracted.

Again this change of state can take place only at a certain temperature - i.e. at the boiling point. (Other commonly known names for this very same temperature are: saturation temperature or condensation temperature.) The amount of heat required to be transferred per pound of a substance to change it from liquid to vapor or vapor to liquid is called latent heat of vaporization.

Two important points regarding the above discussion should be noted:

a) The freezing point temperatures and boiling point temperatures of substances vary as pressure varies; e.g. at atmospheric pressure, water boils at 212°F, at 400 psia water boils at 444.58°F.

b) The temperature of the substance remains constant during the time that the transfer of heat involved in latent heat of fusion and latent heat of vaporization takes place. Later lessons will deal with this subject in greater detail.

1.2 Sensible Heat

In the preceding paragraphs, we have mentioned what occurs at the freezing point and boiling point of a substance, but nothing about what happens in between.

Let us consider water as an example. At atmospheric pressure its freezing point is 32°F and boiling point 212°F. i.e. if water is at its freezing point, an increase of 180°F is required to bring it to a boil. From our definition of specific heat you will notice that to raise 1 lb. of water from 32°F to 212°F (at atmospheric pressure) requires 180 BTU's of heat.

We can say then, that this addition of heat results in a change of temperature which can be "sensed" by a thermometer, or by your hand if you stick it into the water. We can, therefore, make the following definition:

Sensible Heat is the quantity of heat required to be transferred per pound of a substance in changing its temperature from freezing point (or any temperature above the freezing point) to the boiling point (or vice versa).

This quantity of heat is sometimes also referred to as "liquid heat" since it takes place when the substance is in a truly liquid state. However, the term "sensible heat" will be used in these lessons.

1.3 Superheat

Up to this point we have dealt with changing a substance from a solid to a liquid and from a liquid to a vapor. This vapor is still at the boiling point temperature.

If further heat is added so that the temperature rises above the boiling point, then we say that the vapor is superheated. Superheated vapor is vapor at some temperature above the boiling point temperature (saturation temperature).

To define the state of a superheated vapor, it is important to specify both the temperature and pressure. Often we speak of "degrees of superheat" which is the difference between the actual temperature of the superheated vapor and the boiling point temperature for the existing pressure.

For example, let us say we have water at a pressure of 400 psia. The boiling temperature at this pressure is 444.58°F. However, if we find that the actual temperature is 520°F at this pressure, then we would say we have: 520°F - 444.58°F = 75.42°F superheat.

You might say that degrees superheat can also be "sensed" by a thermometer and therefore we should also refer to it as "sensible heat". This is true, but in order to distinguish between heat in a liquid and heat in a vapor state,convention has established that heat in vapor above the boiling point temperature shall be known as superheat.

1.4 Gas and Vapor

You will notice from the preceding definitions that the terms vapor and gas have been used interchangeably. In thermodynamics, the distinction between gas and vapor is somewhat vague.

However, the following can be used as a guide.

If the temperature of the substance is just slightly above the temperature at which it would condense or turn into liquid, then it is known as "vapor". If the temperature of the substance is considerably above the temperature at which it would liquify, then it is known as "gas".

A gas generally follows the perfect gas laws, whereas a vapor does not.

For example, oxygen, nitrogen, etc., at ordinary temperatures are gases; whereas, water or alcohol, on evaporation would furnish vapors. Steam with high degrees of superheat will behave as a gas.

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-1 - Definitions

A - Assignment

1. Define "Specific Heat".
2. Define "Latent Heat of Fusion".
3. Define "Latent Heat of Vaporization".
4. Explain what is meant by "sensible heat".
5. Define superheat.

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-2 - Changes of State of Water

0.0 INTRODUCTION

Part of the previous lesson dealt with the change of state as applied to any substance. This lesson will deal with the change of state for water and expand specifically the concept of latent heat of fusion and latent heat of vaporization.

1.0 INFORMATION

1.1 Latent Heat of Fusion

We know that in order to melt 1 lb. block of ice we have to supply heat to it; the outside surface will arrive at a temperature of 32°F, at which time the solid will start turning to liquid. If this block of ice is in a container, the water formed will remain at 32°F until all the ice is melted, even though heat is being added all the time.

In accordance with our lesson on heat definitions, the heat added to one pound of ice while it completely changes to water at 32°F is called latent heat of fusion.

By the same token, to change one pound of water at 32°F to ice, at 32°F, we will have to remove this same amount of heat.

1.2 Latent Heat of Vaporization

Again let us consider the same pound of water, used in the previous example, which we now want to change into a gaseous state - i.e. vaporize. Convention has established another way of saying the same thing which is to change water to steam.

Suppose this pound of water is still at 32°F. In order to produce steam, we first have to add 180 BTU's of sensible heat to raise it 180°F - i.e. 32°F + 180°F = 212°F, which, as you know, is the boiling point for water at atmospheric pressure. If no more heat is added, the water will not boil and steam will not be produced. Water at the boiling point temperature - i.e. when it has been saturated with sensible heat but does not contain any latent heat of vaporization as yet, is said to be "saturated water".

However, if we keep on adding heat to this pound of water, it will eventually all end up as steam.

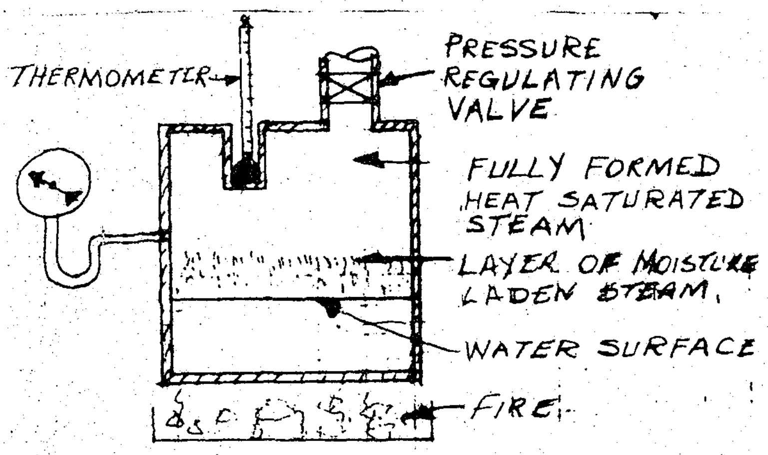

Fig. 1

Referring to Figure 1, let us analyze more closely what happens when water changes to steam.

Assume that we have a glass window in the container, so we can observe what goes on inside and also that the pressure regulating valve is open so that the pressure will remain atmospheric through the process.

As heat is added to the water at 212°F, it will begin to boil. Looking through the glass window at the surface of the water, it would be seen that, as the bubbles of steam break through the water surface, they carry with them small droplets of water, and in the same space immediately above the water, would be a layer of steam which held entrained, finely divided particles of water not yet fully converted into steam. Although these small particles of water have received a full quota of sensible heat and are at a temperature of 212°F, they have not yet taken up enough latent heat to turn them into steam. On the other hand, the steam in which they are carried has received the required amount of both sensible and latent heat.

This layer of steam which contains fine particles of water and is in contact with the surface of the water is called <u>wet steam</u>.

Assuming that the water is boiling gently, this layer of wet steam would remain fairly close to the surface of the water. Above this layer would be steam which contains no fine particles of water. This is steam which has received the full quota of both sensible and latent heat and in which all water has been fully converted into steam. Steam in this state is called <u>saturated steam</u> because it is in fact, saturated with the full quota of latent heat and is fully formed steam.

Note especially, that steam which contains moisture is not <u>saturated steam</u>, but <u>wet steam</u>, because it is not fully formed or heat saturated.

In accordance with our lessons on definitions, for this particular example, the amount of heat added to vaporize one pound of water, the temperature remaining constant, is what is known as the <u>latent heat of vaporization</u>.

If this pound of water were heated still more after it had all evaporated, then, of course, we would be producing superheated steam.

1.3 Condensing

A vapor can be changed back to a solid by extracting heat - i.e. by cooling. Extracting heat from superheated steam at constant pressure drops its temperature until it becomes saturated steam. It then condenses at constant temperature until it becomes saturated water. Cooling the water at constant pressure reduces its temperature, and it is then known as subcooled liquid. Finally the subcooled liquid freezes at constant temperature until it becomes ice.

1.4 Definition of Symbols

The units used for latent heat of fusion, sensible heat, latent heat of vaporization and superheat are BTU's/lb. This unit has been defined in Lesson T.T.4-2.5.2.2.

The following symbols have been accepted by convention to represent the various quantities of heat referred to in this lesson:

L = latent heat of fusion BTU's/lb.

h_f = enthalpy of saturated liquid (sensible heat) BTU/lb. (f = fluid)

h_{fg} = latent heat of vaporization BTU's/lb (fg = fluid to gas).

h_g = enthalpy of saturated steam BTU's/lb = $h_f + h_{fg}$ (g = gas).

h = total enthalpy of superheated steam BTU's/lb.

W = weight of ice, water or steam in lbs.

q = total amount of heat to be transferred BTU's

Knowing the above, we can write the following equations:

a) For latent heat of fusion: $q = W \times L$.

b) For sensible heat: $q = W \times h_f = W \times C\ (T_B - T_o)$

where: C = Specific heat constant BTU's/lb/°F. (for water C = 1)

T_B = Boiling Point Temperature °F.

T_o = Original liquid temperature °F.

c) For latent heat of vaporization: $q = W \times h_{fg}$

d) For enthalpy of saturated steam: $q = W(h_f + h_{fg}) = W \times h_g$.

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-2 - Changes of State of Water

A - Assignment

1. Explain:

   (a) saturated water
   (b) wet steam
   (c) saturated steam

2. For water at atmospheric pressure, what is the value in BTU's/lb of:

   (a) Latent heat of fusion
   (b) Latent heat of vaporization.

3. Define L, h_f, h_{fg}, h_g, and h.

4. A 75 lb. block of ice is at atmospheric pressure and a temperature of -18°F. If you were required to change this to dry saturated steam at atmospheric pressure, how much heat would you have to add to this block of ice?

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-3 - Uses of Thermal Expansion Effects

0.0 INTRODUCTION

In this lesson we will discuss some of the ways in which "Thermal Expansion Effects" are used in practice.

1.0 INFORMATION

Let us first refresh our memory on the way in which objects expand linearily and volumetrically. This had been covered in the T.T.4 lesson on Thermal Expansion.

An object expands linearily according to the following equation:

$$L_1 = L_o \left[1 + C_L(t_1 - t_o)\right] \quad \ldots\ldots\ldots(1)$$

The volumetric expansion of an object is expressed by an equation as follows:

$$V_1 = V_o \left[1 + C_V(t_1 - t_o)\right] \quad \ldots\ldots\ldots(2)$$

1.1 Applications of Linear Expansion

Sample Problem No. 1

Let us assume that we have to shrink a gear onto a shaft and that the inside diameter of the gear is 2000 inches and that the shaft has an outside diameter of 2.002 inches. Both the gear and the shaft being at the same temperature.

The linear expansion coefficient for the shaft and the gear will be taken as:

$$C_L = 6.0 \times 10^{-6} \text{ per } °F.$$

We shall now calculate the temperature difference $(t_g - t_s)$ between the gear and the shaft required to expand the gear's internal diameter to 2.002 inches.

$$L_1 = L_o \left[1 + C_L(t_G - t_s)\right]$$

$$2.002 = 2.000 \left[1 + C_L(t_G - t_s)\right]$$

$$= 2.000 \left[1 + 0.000006\,(t_G - t_s)\right]$$

$$\frac{2.002}{2.000} = 1 + 0.000006\,(t_G - t_s)$$

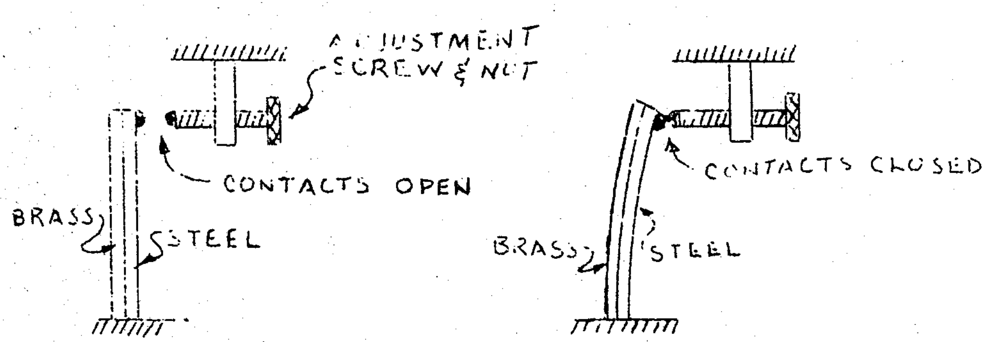
$$1.001 = 1 + 0.000006\,(t_G - t_s)$$

$$0.001 = 0.000006\,(t_G - t_s)$$

$$\therefore t_G - t_s = \frac{0.001}{0.000006} = \frac{1}{0.006} = \underline{\underline{167^\circ F}}.$$

Therefore, we have found that we must either increase the gear metal temperature by 167°F or more by heating it, or lower the shaft metal temperature by 167°F or more by cooling it with liquid nitrogen. I should be noticed that it is only important to have the temperature difference between the gear and the shaft to be equal to or greater than 167°F.

The linear expansion effect is also employed in bimetallic metal strips which are used in different types of temperature switches and thermometres. Here two dissimilar metal strips are joined by rivets or by welding. Due to the difference in expansion coefficients of the two different metals, the bimetallic strip will bend when heated, since one of the strips will expand more than the other. This is illustrated diagramatically below.



'COLD CONDITION' 'HOT CONDITION'

1.2 Application of Volumetric Expansion

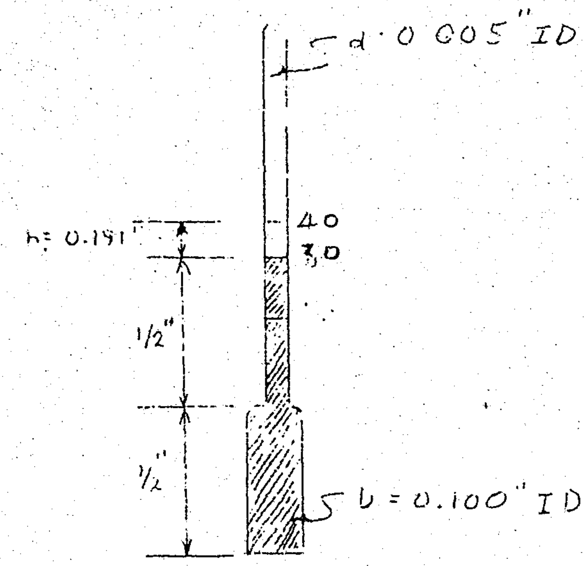
We shall now consider volumetric expansion and see how it is used in practice.

Sample Problem No. 2

Let us assume that we are to calibrate a mercury thermometer. The thermometer consists of a glass tube which has a uniform diameter bore, and a cylindrical glass tube for a reservoir at its bottom end. The resevoir and part of the thermometer tube are filled with mercury. The air is then removed from above the mercury column and the top end is capped. For simplicity we assume that the expansion of the glass tube and reservoir is negligible.

Assume that the mercury and the glass tube are initially at a temperature of 30°F and the height of the mercury column is exactly 1".

$$C_v = 0.10 \times 10^{-3} \text{ per °F for mercury.}$$



The volume of mercury in the thermometer at 30°F is

$$V_o = \text{AREA} \times \text{HEIGHT} = \frac{\pi D^2}{4} H + \frac{\pi D^2}{4} h$$

$$V_o = \frac{\pi \times 0.10^2}{4} \times 0.5 + \frac{\pi \times 0.005^2}{4} \times 0.5$$

$$= \frac{0.5 \times 3.14}{4} (0.1^2 + 0.005^2) = 0.3925 (0.01+0.000025)$$

$$= 0.3925 (0.010025) = 0.0039348125 \text{ in}^3$$

$$= 0.0039348 \text{ in}^3$$

Now let us calculate the distance at which the 40°F mark has to be etched from the 30°F mark by using equation (2)

$$V_1 = V_o \left[1 + c_v (t_1 - t_o)\right]$$

$$= 0.0039348 \left[1 + 0.0001 (40 - 30)\right]$$

$$= 0.0039348 \left[1 + 0.001\right]$$

$$= 0.0039348 \times 1.001$$

$$= 0.0039387348 \text{ in}^3 = 0.0039387 \text{ in}^3$$

Increase in volume $V_1 - V_o = (0.0039387 - 0.0039348) \text{ in}^3$

$$= 0.0000039 \text{ in}^3$$

The cross-sectional area of the small diameter portion of the glass tube is:

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

$$= \frac{\pi \times 0.005^2}{4} = \frac{25 \times 10^{-6} \times 3.14}{4} = 19.625 \times 10^{-6}$$

$$= 0.000019625 \text{ in}^2$$

The distance between the 30°F and 40°F lines is then:

$$h_1 = \frac{V_1 - V_o}{A} = \frac{0.0000039}{0.000019625} = \underline{\underline{0.198''}}$$

By changing the diameter ratio D/d we can vary the distance between the adjacent graduation lines on the thermometer as desired.

The volumetric expansion principle is also used in many other devices, especially in various controls like temperature control valves, copes single element feed water control valves, etc.

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-3 - Uses of Thermal Expansion Effects

A - Assignment

1. The length of the Harvard Bridge is 2000 feet. Calculate the difference in lengths on a winter day, when the temperature is -20°F and a summer day when the temperature is 80°F. Use $C_L = 6.0 \times 10^{-6}$ per °F for the coefficient of linear expansion for steel.

2. A surveyor's 100 ft. steel tape is correct at a temperature of 65°F. The distance between two points, as measured by this tape on a day when the temperature is 95°F is 86.57 feet. Find the true distance between the points. Use $C_L = 6.0 \times 10^{-6}$ per °F.

3. A steel container holds 100 cubic inches of liquid at 80°F when filled to a certain mark. As the liquid is heated to 180°F, it expands and occupies 110 cubic inches of volume. Find the volumetric expansion coefficient C_V for this liquid. Assume that the volume of the metal container does not change.

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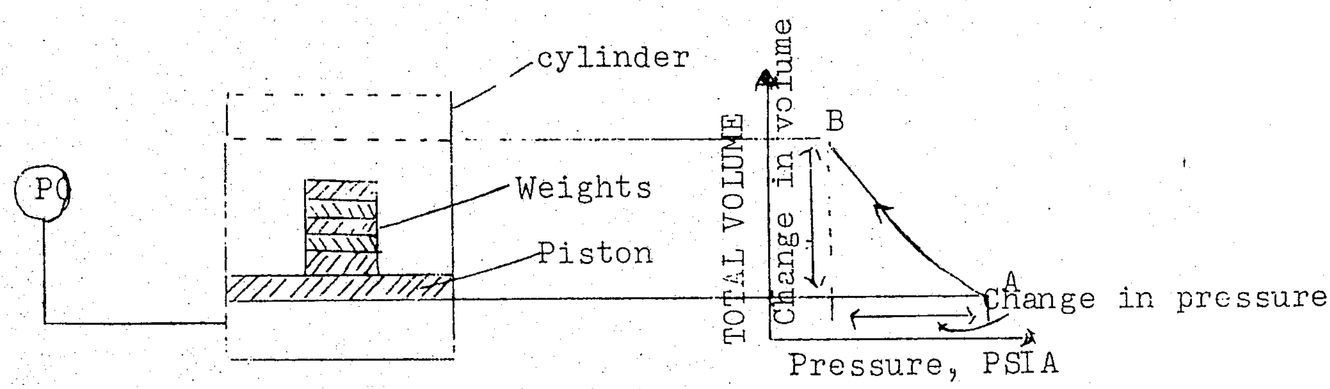
-4 - Expansion of Gases - Gas Laws

0.0 INTRODUCTION

In this lesson we will discuss the expansion of gases.

1.0 INFORMATION

When a gas undergoes expansion or an increase in volume then work is done by the gas. This may be easily illustrated by means of a cylinder fitted with a piston which allows no leakage and which is loaded with a number of weights as shown below.



The number of weights on top of the piston determines the pressure of the gas in the cylinder. Now, if we want the gas to expand we have to reduce its pressure and we can do this by removing weights from the top of the piston. As some weights are removed from the top of the piston the gas will expand, pushing the piston and the remaining weights upward and so does work in lifting these weights. If we take volume and pressure readings as we remove the weights one at a time, we can plot the expansion curve "A" - "B" of the gas as is shown above.

Should we on the other hand add weights to the piston when the latter is in position "B" then we will compress the gas in the cylinder again and the descending weights would do work <u>on</u> the gas.

We shall now define the ratios of expansion and compression.

$$\text{Ratio of Expansion} = \frac{\text{Volume at end of Expansion}}{\text{Volume at beginning of Expansion}}$$

$$\text{Ratio of Compression} = \frac{\text{Volume at beginning of Compression}}{\text{Volume at end of Compression}}$$

It should be noted that both ratios give a value greater than unity, since the larger quantity is in the numerator.

1.1 Gas Laws

A perfect gas is a gas which obeys Boyle's law and to which Joule's law of energy is applicable. Both these laws shall now be dealt with below.

"Boyle's Law": The volume of a given mass of a perfect gas varies inversely as the absolute pressure when the temperature is kept constant.

The above definition can be expressed algebraically as follows:

$$V \propto \frac{1}{P}$$

where P = the absolute pressure of the gas
V = Volume occupied by the gas when the pressure is equal to P.

By introducing a constant = C we can write the above expression in form of a formula as follows:

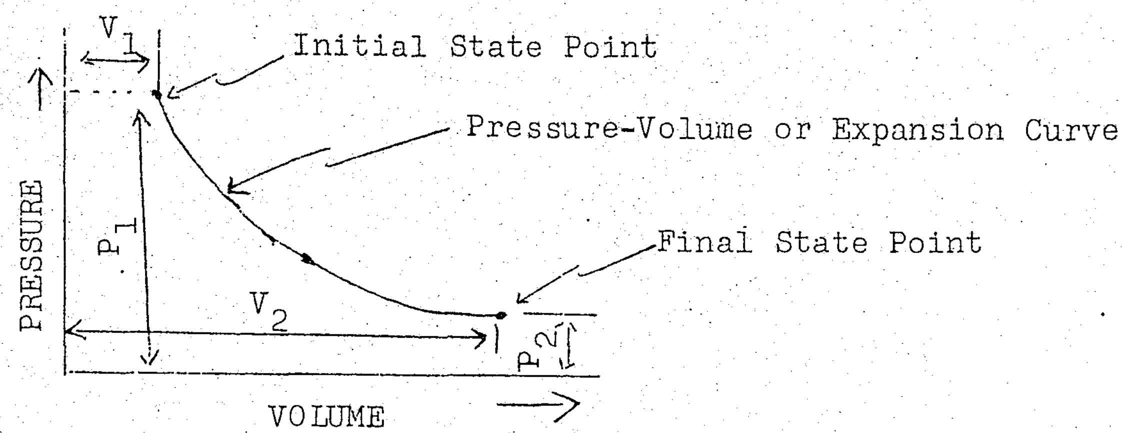
$$V = \frac{C}{P} \quad (1) \qquad \text{or} \qquad V \times P = C \quad (2)$$

The above formula shows that the product of the absolute pressure and volume of a given quantity of gas is constant when the temperature does not change.

Let a quantity of gas at pressure P_1 and volume V_1 change its pressure and volume in a cylinder (expansion) without change of temperature.

Let P_2 and V_2 be the final pressure and volume respectively.

This can be illustrated by the following pressure - volume curve.



Then anywhere on this expansion curve

$$PV = C$$

$\therefore$ $P_1V_1 = C$ and $P_2V_2 = C$

and therefore

$$P_1V_1 = P_2V_2 \qquad (3)$$

Equation (3) is a useful working form of Boyle's law as it avoids the necessity for calculating the value of the constant C.

It is important to remember that volumes V_1 & V_2 must be expressed in identical units and the same applies for pressures P_1 & P_2 when using equation (3).

Sample Problem:

Four cubic feet of a gas at an initial pressure of 120 psia expand at constant temperature until the volume is 20 Ft3. Find the final pressure in pounds per square foot.

Solution:

According to Boyle's law

$P_1V_1 = P_2V_2$ and by transposing we get

$P_2 = \frac{P_1V_1}{V_2}$ where $P_1 = 120$ psia $= \frac{120}{144}$ PSF abs.

$V_1 = 4\ Ft^3$

$V_2 = 20\ Ft^3$

$\therefore P_2 = \frac{120 \times 4}{144 \times 20} = \underline{0.167 \text{ PSF}}$ abs.

"Charles' Law": The total volume of a given quantity of gas varies directly as the absolute temperature when the pressure is kept constant.

This can be expressed algebraically as follows:

$$V \propto T$$

where V = total gas volume in Ft^3
T = gas temperature in °F abs. = 460 + °F

The above expression can be written in an equation form as follows:

$$V = TC^1 \qquad (4)$$

where C^1 is a constant

However, equation (4) can also be written in a more useful way and namely

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} \qquad (5)$$

It should be remembered that volumes V_1 & V_2 must be expressed in identical units. Also Temperatures T_1 & T_2 must be both expressed in °F absolute when using equation (5)

Sample Problem:

Ten cubic feet of gas at 100°F is heated up to 200°F while kept at a constant pressure. Find the new volume that the gas occupies when heated.

Solution:

Using Charles' law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$ and by transposing we get

$$V_2 = \frac{T_2}{T_1} \times V_1$$ where $V_1 = 10\ Ft^3$

T_1 = 100°F = (460+100)°R abs.
T_2 = 200°F 2 (460+200)°R abs.

$$\therefore V_2 = \frac{660}{560} \times 10 = \underline{\underline{11.79\ Ft^3}}$$

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-4 - Expansion of Gases - Gas Laws

A - Assignment

1. a) Define ratio of expansion

   b) Define ratio of compression

2. a) Define "Boyle's Law".

   b) An air receiver has an internal volume of 100 Ft^3. Calculate the pressure in the receiver when 600 Ft^3 of air at 14.7 psia are pumped into the receiver. Assume that the air receiver was initially filled with air at 14.7 psia.

3. a) Define "Charles' Law".

   b) Find the volume of a gas that initially occupied 30 Ft^3 while at 80°F when it was heated to 500°F. Assume that the pressure remained constant.

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-5 - Expansion of Gases - Characteristic Equation of a Gas

0.0 INTRODUCTION

In this lesson, we shall continue discussing gas laws and the work done by expanding gases.

1.0 INFORMATION

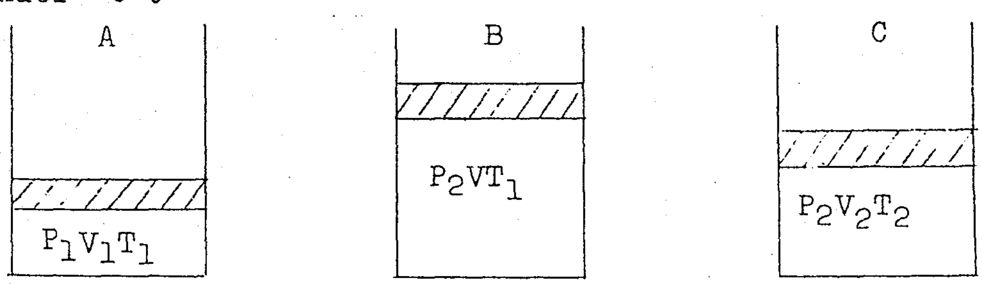
In actual practice the pressure, volume and temperature of a gas may all change at once. In this case, because of pressure changes, Charles' Law will not apply, and, because the temperature changes, Boyle's Law will not apply. On account of this, we require some principle by which to treat this so common and important case.

Let's assume that this change in state is taking place in two stages:

(a) By a change according to Boyle's Law, followed by

(b) A change according to Charles' law.

Let us consider a given quantity of a perfect gas at pressure P_1, volume V_1, and temperature T_1, in a cylinder "A". The same gas is found later to be in the state P_2, V_2, T_2 as in cylinder "C".



We may imagine an intermediate state as having existed, shown at "B". Then, because the temperatures are the same in "A" and "B" the change from "A" to "B" follows Boyle's Law.

Therefore $P_1V_1 = P_2V$

$$\therefore V = \frac{P_1V_1}{P_2} \qquad (1)$$

In the change from "B" to "C", the pressure remains the same, whilst the temperature changes; hence Charles' law applies.

$$\therefore \frac{V}{T_1} = \frac{V_2}{T_2}$$

$$\therefore V = \frac{V_2}{T_2} \times T_1 \qquad (2)$$

In equations 1 and 2, the volume V is the volume in "B" and therefore is the same quantity for both equations. Thus by combining equation 1 and 2, we get

$$\frac{P_1V_1}{P_2} = \frac{V_2}{T_2} \times T_1 \qquad (3)$$

$$\therefore \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \qquad (4)$$

It is obvious, by similar reasoning, that if this quantity of gas underwent a further change to the state P_3, V_3, T_3, the equation 4 could be added to as follows.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} = \frac{P_3V_3}{T_3}$$

We may now express this as follows: The product of the pressure and volume of a quantity of gas divided by its absolute temperature is a constant and we may express this algebraically in the following manner:

$$\frac{PV}{T} = K \text{ or } PV = KT \qquad (5)$$

Where K is a constant.

When we considered Boyle's Law and Charles' Law we said nothing about the weight of the gas concerned.

The weight is important in many calculations because it is needed to calculate heat quantities. The weight depends upon the density, that is, upon the specific volume of a gas.

The density and specific volume of a gas are defined as follows:

> "Density of a gas or vapour is the weight of unit volume at a given temperature and pressure".

The units usually used for density are pounds per cubic foot ($lb./ft^3$).

> "Specific volume of a gas or vapour is the volume of unit weight at some given temperature and pressure".

The units used are usually cubic feet per pound ($ft^3/lb.$)

We will now show that the constant K in equation 5 includes weight of the gas.

Let V_s = specific volume of a particular gas, while P and T are its pressure and temperature.

Then $V = wV_s$ where w = weight of gas used in pounds and since $PV = KT$

$\therefore PwV_s = KT$ and

$$\therefore PV_s = \frac{K}{w}T \qquad (6)$$

where $\frac{K}{w}$ is a new constant. If, then, we deal with 1 pound of gas which is represented by V_s, then the value $\frac{K}{w}$ will always be the same for any given kind of gas.

Letting $\frac{K}{w} = R$ R = a new constant

then $K = wR$ and substituting in equation 5 we get

$$PV = wRT \qquad (7)$$

We may also write equation 7 in the following form

$$PV_s = RT \qquad (8)$$

Both equations 7 and 8 are important ones. Equation 8 is called the "Characteristic equation of a perfect gas", and "R" is called the "Characteristic gas constant".

For air R = 53.3

In using equations 7 and 8 careful attention must be given to the units to be used. The following units should be used.

P = pressure in pounds per square foot absolute
T = temperature in °R absolute.
V_s = specific volume of a gas in cubic feet per pound.
V = volume of gas in cubic feet
w = weight of gas in pounds.

Sample Problem No. 1

Calculate the temperature after a perfect gas has expanded from P_1 = 120 psia, T_1 = 200° F and V_1 = 1 Ft^3 to P_2 = 30 psia and V_2 = 3 Ft^s.

Solution: Using equation 4 we have

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \quad \text{which when transposing gives us}$$

$$\therefore \quad T_2 = \frac{P_2V_2}{P_1V_1} \times T_1 = \frac{30 \times 3}{120 \times 1}(460+200) = 495°\text{F abs.}$$

$$= 495 - 460°\text{F} = \underline{35°\text{F}}$$

Sample Problem No. 2

A cylinder containing a perfect gas has an internal volume V = 2.5 Ft3 and a pressure P_1 = 2000 psia when T_1 = 60° F, calculate the pressure P_2 in the cylinder when the gas temperature was increased to 100° F.

Solution: Using equation 5 and transposing we get

$$P_2 = \frac{P_1V_1T_2}{T_1V_2} \quad \text{where } V_1 = V_= = 2.5 \text{ Ft}^3$$

$$\therefore \quad P_2 = \frac{2000 \times 2.5\ (460+100)}{(460+60)\ 2.5} = \frac{2000 \times 560}{520} = \underline{2154 \text{ psia}}$$

Sample Problem No. 3

Three pounds of a gas at 120 psia and 176°F are placed in a cylinder. What is the volume of the cylinder if R = 53.9

Solution: Using the characteristic gas equation

PV = wRT and transposing we get

$$V = \frac{wRT}{P} = \frac{3 \times 63.9\ (460+176)}{144 \times 120}$$

$$= \frac{3 \times 53.9 \times 636}{144 \times 120} = \underline{5.94 \text{ Ft}^3}$$

Sample Problem No. 4

The specific volume of oxygen at normal temperature pressure (N.T.P.) is 11.21 Ft^3. What weitht of oxygen is contained in a cylinder 5 Ft. long by 5 inches in diameter when the pressure is 1400 psia and temperature is 15° C?

Solution: At N.T.P. the pressure P = 14.7 psia and T = 32° F = (460+32)°R abs.

Therefore by applying equation 8 we can first find the gas constant for oxygen.

$$PV_s = RT$$

$$\therefore \quad R = \frac{PV_s}{T} \quad \frac{(14.7 \times 144) \times 11.21}{492} = 48.3$$

Changing Centigrades to Fahrenheit scale, we get

$$15°C = (\frac{9}{5} \times 15 + 32)°F = 59°F = (460 + 59)°R \text{ abs.}$$
$$= 519°R \text{ abs.}$$

$$\text{Cylinder volume} = \text{Area} \times \text{length} = \frac{5^2 \pi}{4 \times 144} \times 5$$

$$= \frac{125 \pi}{144 \times 4} = 0.682 \text{ Ft}^3$$

Applying now equation 7 we can find the weight of oxygen in the cylinder

$$PV = wRT$$

$$\therefore \quad w = \frac{PV}{RT} = \frac{(1400 \times 144) \times 0.682}{48.3 \times 519} = \underline{5.5 \text{ pounds}}$$

D. Dueck

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals

5 - Heat & Thermodynamics

-5 - Expansion of Gases - Characteristic Equation of a Gas

A - Assignment

1. A volume of air, 12.39 Ft^3 at 32°F and 14.7 psia is raised to a temperature of 68°F without change of pressure. Find the new volume, and the work done by the air during the expansion in foot-pounds. [Work a P $(V_2 - V_1)$].

2. (a) Calculate the volume of 15 pounds of air at 100 psia pressure and at a temperature of 25°C.

   (b) If this air is now heated to 50°C at constant volume, what will be its new pressure?

3. Two pounds of air at 80°F and 100 psia are placed into a space. Find the volume of the space when the gas constant for air is 53.3.

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-6 - Graphs

0.0 INTRODUCTION

Work in Nuclear Power Plants involves a great quantity of variable data. This data can be presented in table form or on charts in graph form. Tables or specifically, steam tables will be dealt with in a later lesson. This lesson will deal with graph making.

Generally speaking, tables are of great value, but it is difficult to take in all the facts at a glance. In other words, it is not easy, for example, to compare quickly the rate of change of the boiling point with the rate of variation of pressure. As an alternative to tables, a graph can be drawn in which the figures are shown as a line drawn between selected points. After a little practice, it is possible to appreciate the knowledge the table of figures contains by a single glance at a graph of this sort. For detailed accurate calculations, the tables are preferable, but it is the object of this lesson to convey general impressions and an understanding of graphs will be of assistance.

1.0 INFORMATION

Temperature Pressure Graph

In the lesson on definitions, we mentioned that the boiling point temperature of a liquid changes as pressure changes. This fact will be used as an example to illustrate the method by which graphs are constructed.

The following table lists a number of different pressures in psia (pounds per square inch absolute) and the boiling point temperatures for these pressures. The values have been arrived at by specialists in this field through carefully controlled experiments:

Pressure (PSIA)	14.7	100	200	300	400	500	600	800	1000
Boiling Temperature °F	212	327.8	381.8	417.3	444.6	467.0	486.2	518.2	544.6

First Step

Graphs are generally plotted on squared paper, as in Figure 1 which for this case is 10 x 10 squares per cm. As a first step, two lines are drawn, one horizontal which is called the "abscissa", and the other vertical which is called the "ordinate". When referring to both lines, at the same time, we say that they are "co-ordinates" of the graph.

The variables in this case are pressure and temperature. In order to plot these variables on a graph, we have to lay out suitable scales, one for temperature and one for pressure along the ordinate and abscissa respectively. With few exceptions, the scales always start off from zero at the point where the ordinate and abscissa meet. We notice then from the above table that the range of the pressure scale will have to be from 0 to 1000 psia, and the temperature scale from 0 to approximately 550°F. Obviously, the pressure scale will have to be the longer one, therefore, we use the line along the longer side of the sheet of Figure 1. for pressure and let us say that we designate it as the horizontal line or abscissa.

In this particular case, a distance of 2 cm for 100 psi has been used since the total length of scale thus fits conveniently along the sheet.

Similarly, 2 cm. for 100°F works out as a convenient length on the vertical temperature scale but we have to extend it to 600°F in order to be able to plot the 544.6°F figure.

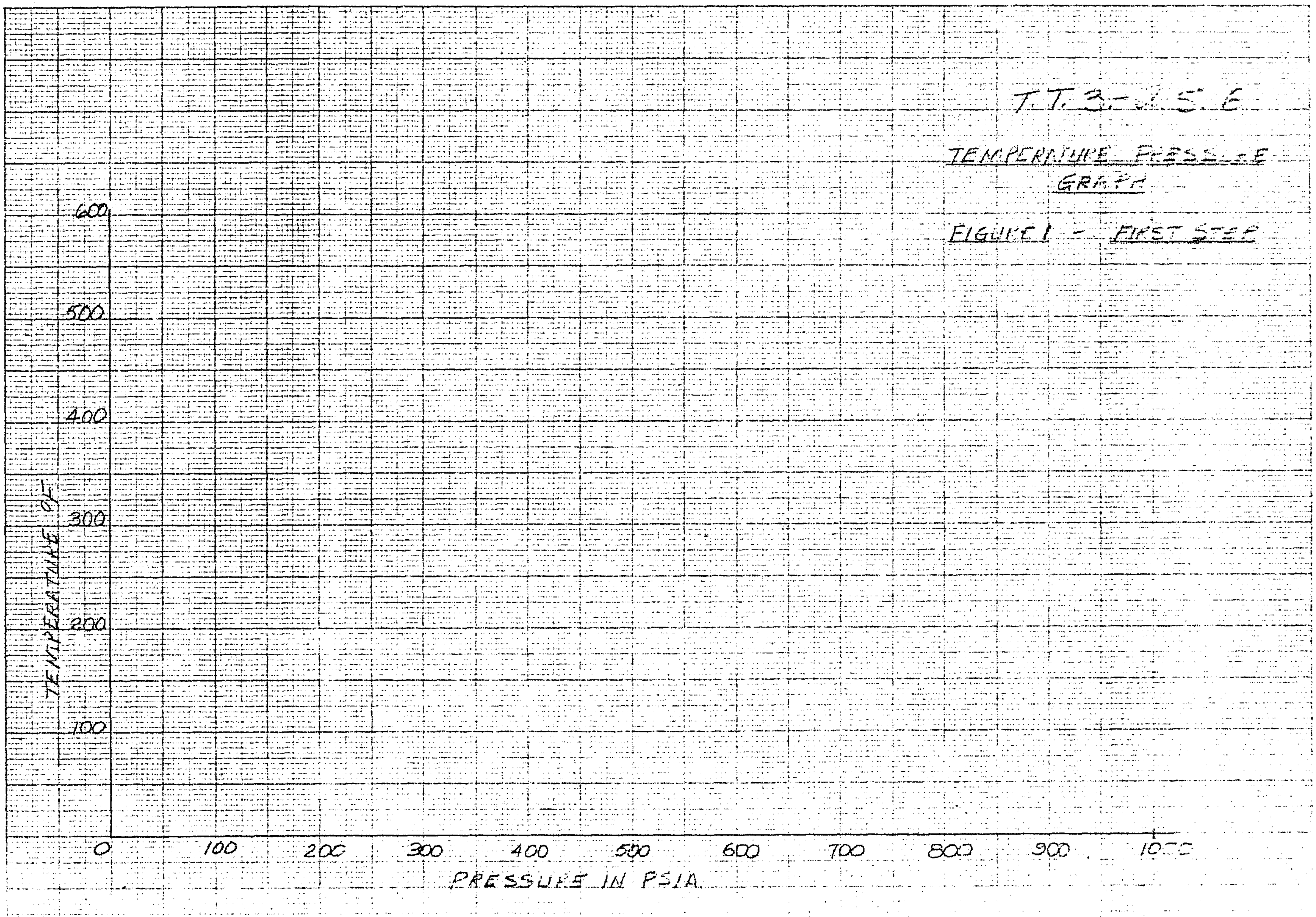
Second Step

Now that we have established scales on the squared sheet, we can proceed to the second step, figure 2, and that is to plot the pressure-temperature points.

Referring to the above table, the first pressure value is 14.7 psia. Select the point along the horizontal scale corresponding with 14.7 psia and erect a vertical dotted line. The boiling temperature for this pressure is 212°F.; select the point on the vertical scale corresponding to this temperature and draw a dotted horizontal line. The point where these two dotted lines intersect is one point on the graph. Mark it with an X. Continue this process for the remaining set of values and the graph is beginning to take shape with a series of X's as in Figure 2.

Third Step

Connect all the X's with a smooth curve as shown in figure 3. This new line shows the relationship between pressure and temperature and can be used to find the temperature of the boiling point at any pressure by running vertically from the pressure chosen, to

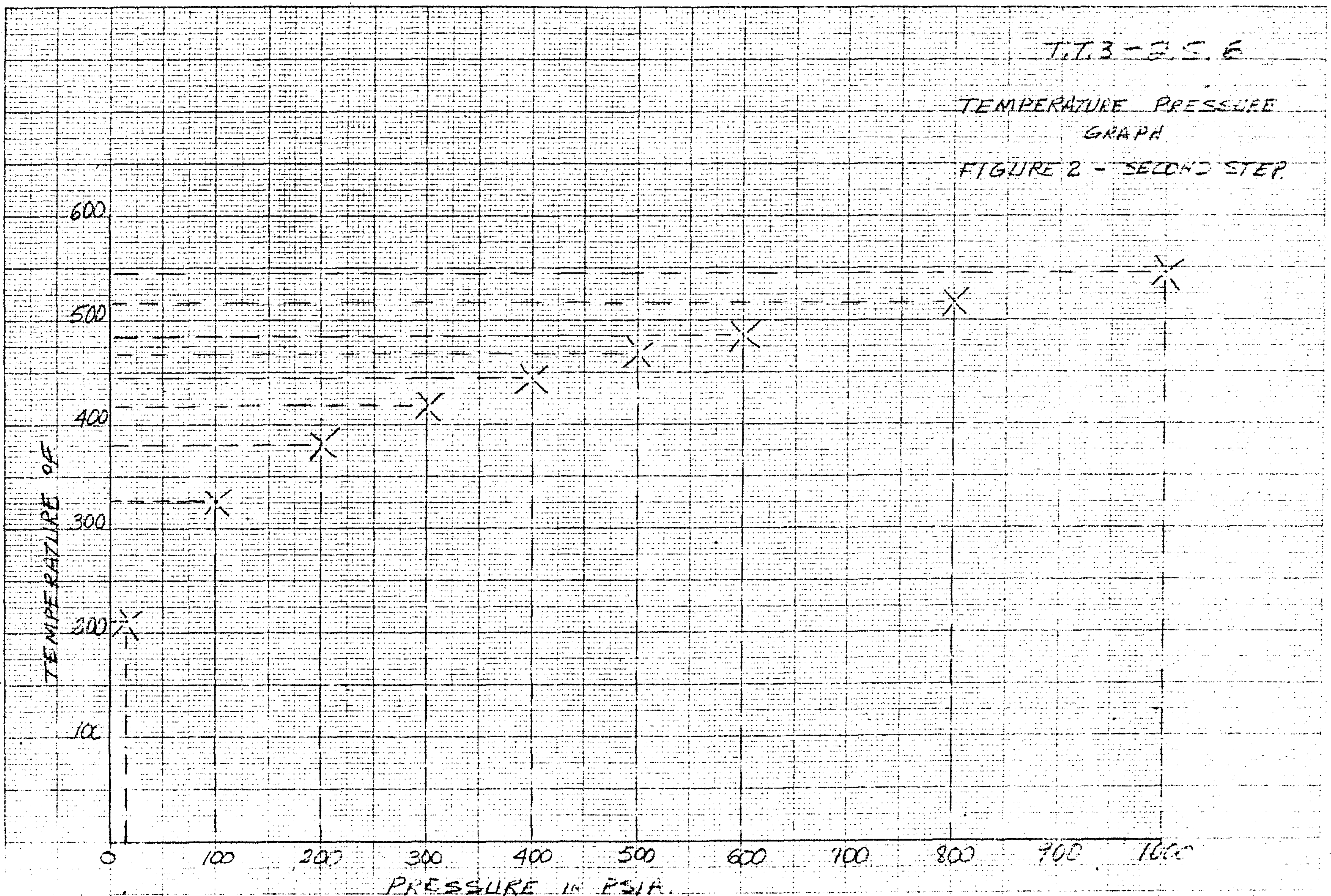

T. T. 3- . S. E
TEMPERATURE PRESSURE
GRAPH
FIGURE 1 - FIRST STEP
TEMPERATURE °F
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN PSIA

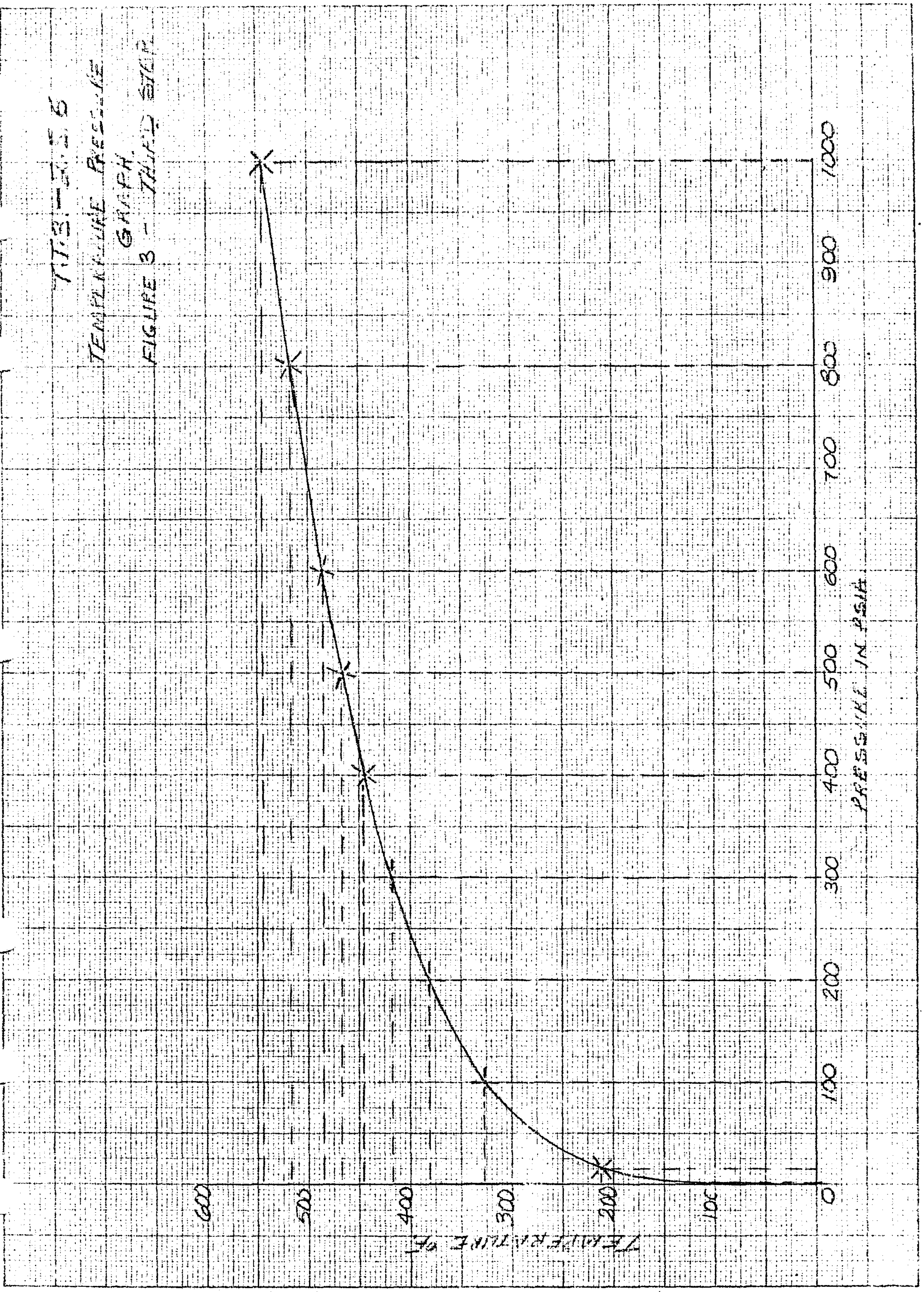
the curve and then horizontally to the temperature line. The point on the temperature line will indicate the temperature of boiling point for the pressure chosen.

The dotted lines are used in this example for clarity but normally they are omitted when using squared paper.

In science and engineering it is very common to compare other variables in this way and the same method may be used to compare temperature and heat as will be illustrated in the next lesson.

D.G. Dueck


T.T.3 - S.S.E
TEMPERATURE PRESSURE GRAPH
FIGURE 2 - SECOND STEP
TEMPERATURE °F
600
500
400
300
200
100
0
100
200
300
400
500
600
700
800
900
1000
PRESSURE IN PSIA.



GRAPH
FIGURE 3 - THIRD STEP
PRESSURE IN PSIA
0
100
200
300
400
500
600
700
800
900
1000
TEMPERATURE °F
100
200
300
400
500
600

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat and Thermodynamics

-6 - Graphs

A - Assignment

1. a) Define abscissa.

   b) Define ordinate.

   c) Define co-ordinates.

2. The following table lists various temperatures (in ascending order) opposite which are given the pressures at which saturated vapor conditions for water exist.

Temperature °F	32	150	250	350	400	450	500
Pressure	0.1	3.7	29.8	134.6	247.2	422.6	680.8

Plot the graph for these values. Label the scales.

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-7 - Steam and Water

0.0 INTRODUCTION

In this lesson we will discuss steam and water behavior, in terms of pressure, temperature and enthalpy and illustrate their relationship in graphical form.

1.0 INFORMATION

You will recall from the lesson on definitions, we defined enthalpy as heat energy and that it is measured in Btu's/lb. Also in that lesson we defined terms such as sensible heat, saturated water, latent heat of vaporization, saturated steam and superheat. We can now illustrate in graphical form how these quantities of heat vary as temperature and pressure vary.

However, before we begin there are two things we should take note of at this point:

1. In all calculations involving steam power plants, conventional and nuclear, enthalpy is arbitrarily taken to be zero for water at 32°F.

   You will recall that previously we had mentioned that in order to produce ice, we had to extract latent heat of fusion and that if we extract still more heat, we will eventually arrive at an absolute zero temperature. For steam and water in steam power plants we disregard ice and melting phases of water since they are insignificant to their operation.

2. The specific enthalpy of steam is not the same as the specific enthalpy of water. 1 lb. of steam does not require quite as much heat as 1 lb. of water to raise it 1°F.

Temperature-Enthalpy Graph

All the properties of steam and water which we are going to discuss in the following pages can be found in steam tables. These will be discussed in a later lesson.

Now then, to proceed with the graphical representation showing the relationship of temperature, enthalpy and pressure construct what is called a temperature-enthalpy graph. The steps involved are similar to the ones outlined in the lesson on graphs We again let our temperature scale say 0 - 700°F, be the ordinate and this time the abscissa will be the enthalpy scale from say 0 - 1400 Btu/lb. as is shown in Figure 1.

Assume we begin with 1 lb. of water at 32°F and at atmospheric pressure. As no heat has as yet been added one of the points on the graph will be 32 on the temperature scale, and 0 on the enthalpy scale. This is shown at point 'A'.

Next, we commence to add heat till the water is heat "saturated" at 212°F. As we stated previously, this is "sensible heat" and the quantity involved at atmospheric pressure is 180 Btu. This establishes a point 'B' where the broken horizontal line at 212°F intersects with the broken vertical line at 180 Btu/lb.

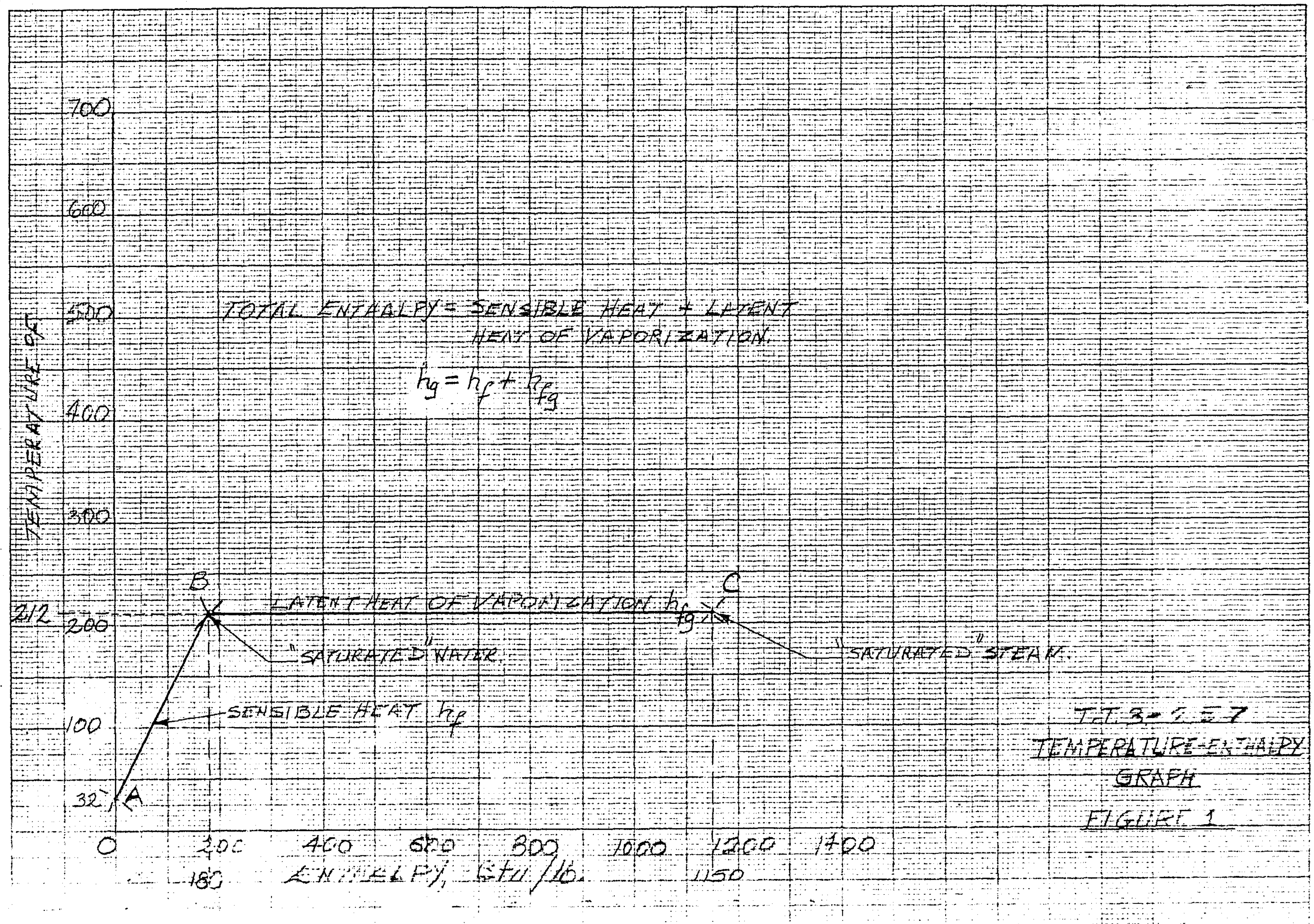
All the water is now at 212°F. To change the state of water to steam, we have to add the latent heat of vaporization as defined previously. With the pressure still being atmospheric the temperature will remain constant during this process. We find we have to add 970 Btu, to completely evaporate one lb. of water; we now have heat "saturated" steam with a total enthalpy of 180 + 970 = 1150 Btu for 1 lb. This establishes another point 'C' on the graph - i.e. where the horizontal broken line at 212°F intersects with the vertical broken line at 1150 Btu/lb.

If we now join points A & B and points B & C with solid lines we have a graph ABC representing diagrametically the job done in adding 1150 Btu to 1 lb. of water at 32°F, at normal atmospheric pressure resulting in the generation of 1 lb. of heat saturated steam at 212°F.

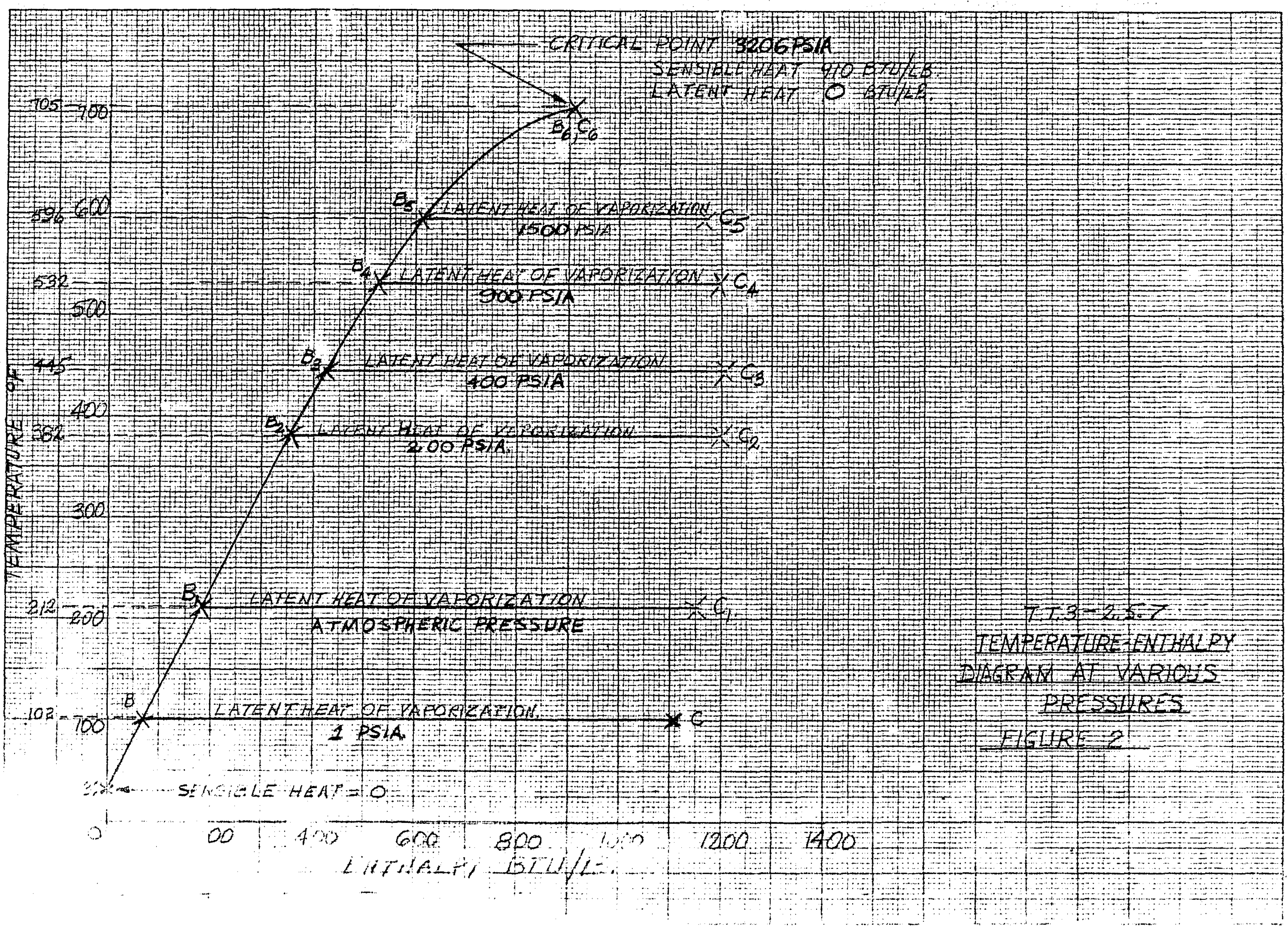
Temperature Enthalpy Diagram at Various Pressures

In earlier lessons, we mentioned that boiling point temperature varies with pressure. Figure 2 is a temperature-enthalpy diagram which has been plotted from data obtained from steam tables. This graph shows that the higher the pressure, the higher the temperature at which water will start boiling.

However, in addition to this fact, you will notice that the higher the pressure, the greater the quantity of sensible heat required to bring the water to its boiling point temperature. On the other hand, the higher the pressure, the smaller is the quantity of latent heat of vaporization required to convert all the water to saturated steam. That is, the line BC gets shorter and shorter as the pressure gets higher and higher, until the pressure reaches 3206 psia which is called the critical point where the latent heat of vaporization required to convert water



T.T. 3-1-E-7
TEMPERATURE-ENTHALPY GRAPH
FIGURE 1



T.T.3-2.5.7

TEMPERATURE-ENTHALPY DIAGRAM AT VARIOUS PRESSURES

FIGURE 2

to saturated steam is equal to zero. When water at this pressure reaches 705°F, it changes instantly into steam without the addition of any further heat. For pressures and temperatures equal to or higher than the critical point there is no visible difference between liquid and vapor. There are no steam plants in Canada (conventional or nuclear) operating at these high pressures and this information is given as a point of interest only.

Temperature Enthalpy Diagram for Superheat

So far we have discussed the formation of steam only up to the point where it is saturated vapor - i.e. still at the boiling point temperature, but containing no water droplets. Boilers in our nuclear stations produce steam at or near saturated vapor conditions. You can see that as soon as some of the heat is extracted from the steam as it passes through a turbine, that water droplets will start to form bringing the vapor into the wet steam region. This is the beginning of condensation, Droplets of water passing through a turbine are undesirable because they will erode the blades.

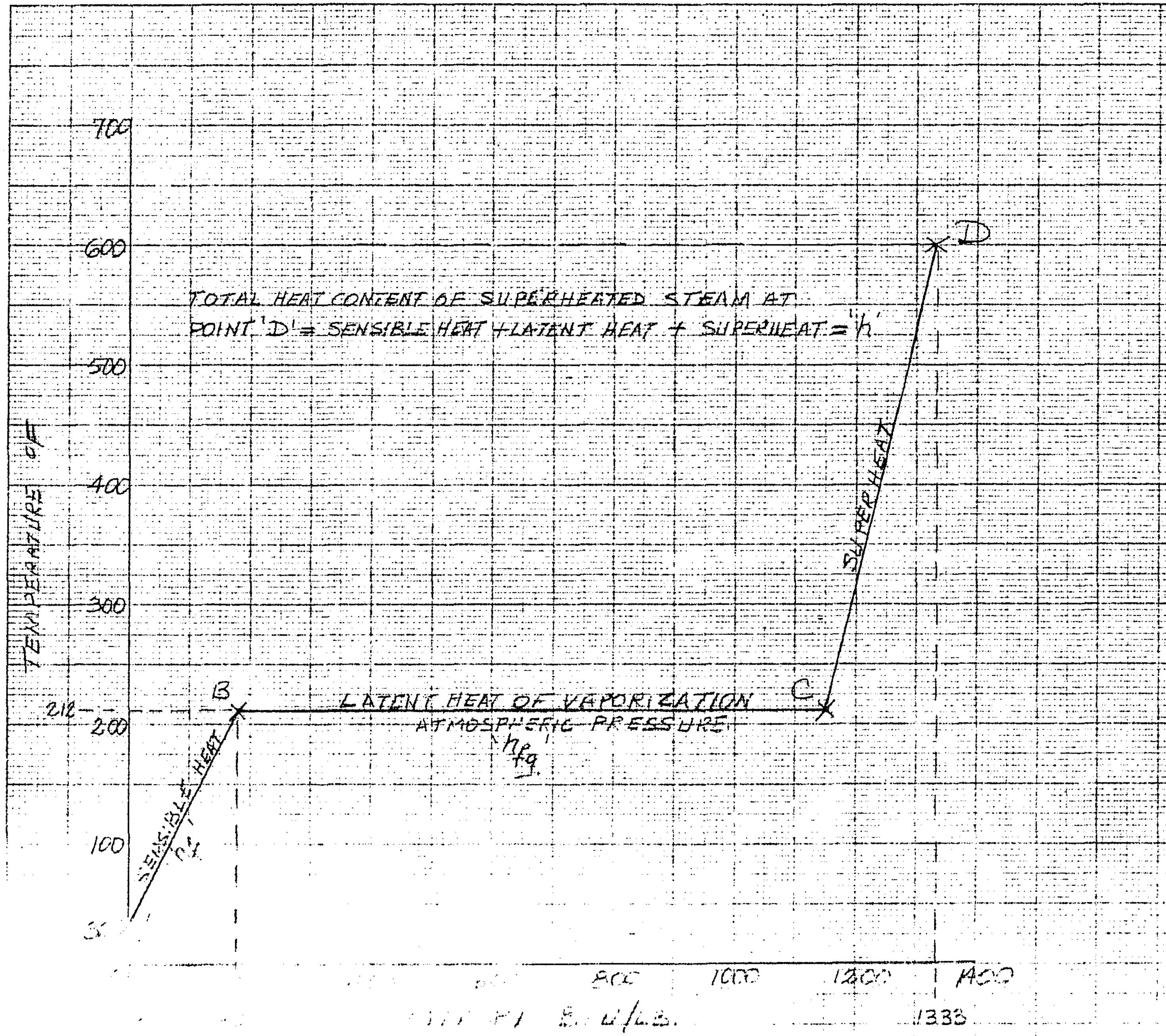
Therefore, it is desirable to add more heat to saturated steam (i.e. raise its temperature above boiling point temperature) so that a lot of energy can be extracted from it before it starts to condense. As we had defined previously, any addition of heat to steam which is already saturated is called superheat and the temperature above saturation temperature for a certain pressure is called degrees of superheat.

To see a graphical illustration of this, refer to figure 3. You will notice that the line ABC is exactly the same graph as in figure 1. Let us say we want to have superheated steam at 600°F and still at atmospheric pressure. The total enthalpy of 1 lb. of steam under these conditions is 1333 Btu. This is plotted as point 'D'. If we now join CD with a solid line, we have the graph ABCD which represents the work done to raise 1 lb. of water at 32°F and 0 Btu/lb. to 600°F and 1333 Btu/lb. Theoretically, this is the amount of work we should also get out of 1 lb. of steam as it passes through a steam engine or turbine if the machine were 100% efficient.

We started this lesson by stating that we wanted to show the relationship between pressure, temperature and enthalpy for steam and water. This relationship can now be illustrated in figure 4 which combines figures 1, 2 and 3.

You will notice that the solid line from 32°F, to B_6 is the same as that shown in figure 2. The area to the left of this line represents the liquid phase of water.

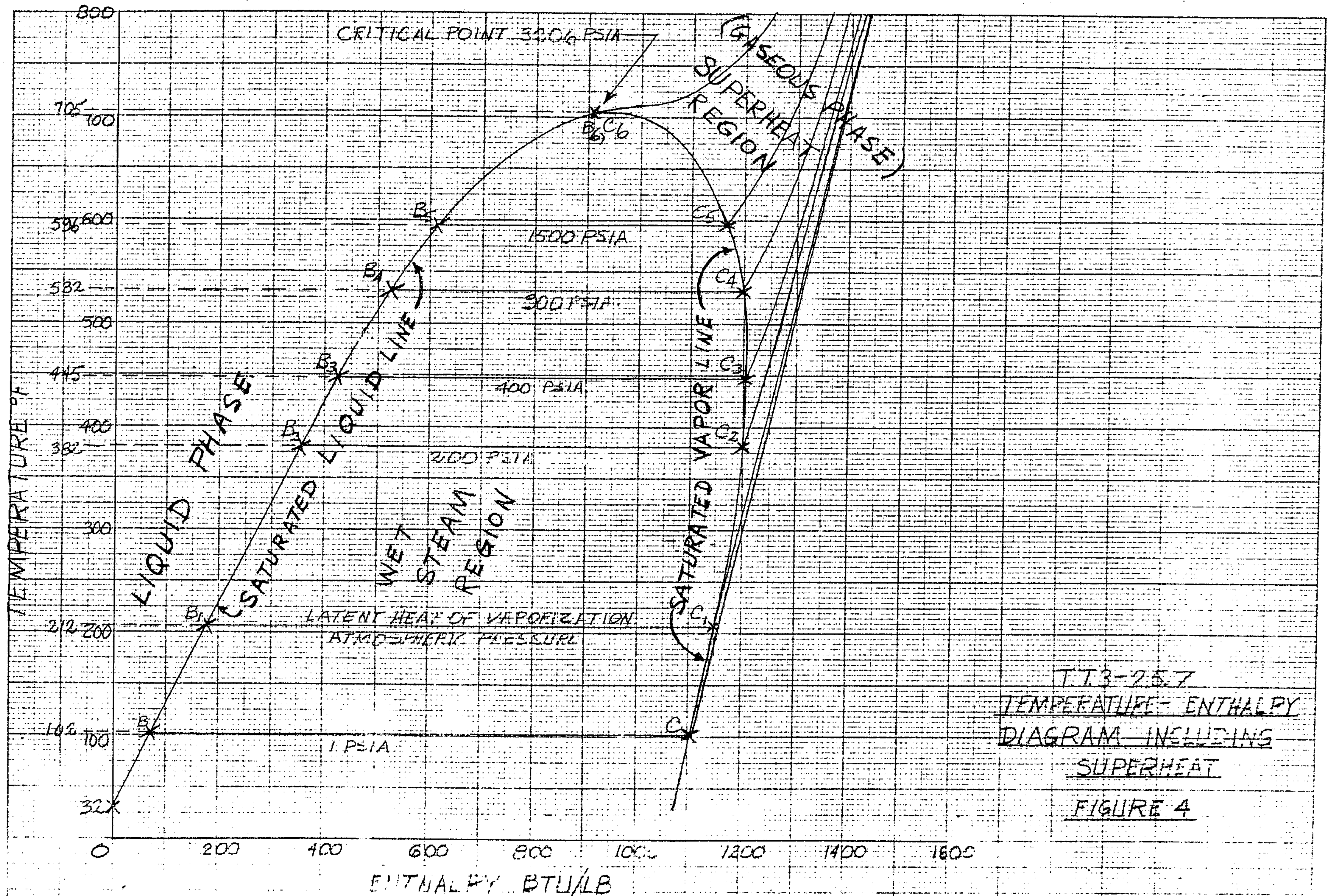
Referring back again to figure 2, all the points marked 'C' have also been plotted on figure 4, but they have been joined with



T.T.3-&.5.Z

TEMPERATURE-ENTHALPY DIAGRAM FOR SUPERHEAT

FIGURE 3



TT3-25.7
TEMPERATURE- ENTHALPY DIAGRAM INCLUDING SUPERHEAT

FIGURE 4

a solid line and this line combined with line 32°F,B_6 forms a horseshoe-shaped curve. The whole area under this horseshoe-shaped curve represents the wet steam region where you would find droplets of water in steam. Any point along line 32°F,B_6 represents saturated liquid; any point along line C_1C_6 represents saturated steam.

We have said that adding heat to saturated steam produces superheated steam, therefore, any point to the right of the horseshoe-shaped curve would represent superheated steam. Obtaining our information from steam tables, we can thus plot lines of superheated steam for the various pressures shown. Figure 4 shows the superheated region for temperatures up to 800°F. Modern conventional steam power plants generally operate with steam at 1000°F to 1100 °F.

Figure 4 represents only a skeleton of a normal temperature enthalpy diagram. But if one had access to a completed temperature-enthalpy diagram, then knowing two of either pressure, temperature or enthalpy of steam, one could,determine where on the diagram this condition would appear and how much work one could expect to obtain from the steam.

A more detailed diagram than the temperature-enthalpy diagram and one which is more commonly used for steam power plant work is the "Mollier Chart" which will be covered at the T.T.1 level.

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NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-7 - Steam and Water

A - Assignment

1. In what way does pressure on water affect:

   (a) the quantity of sensible heat required?

   (b) the quantity of latent heat of vaporization required?

   (c) the boiling point temperature?

2. Given the following data, plot the temperature-enthalpy diagram:

Pressure (PSIA)	1	14.7	200	400	900	1500		3206	
Temperature °F	102	212	382	445	532	596	800	705	800
hp Btu/lb.	70	180	355	424	527	611	-	910	-
hg Btu/lb.	1105	1150	1199	1204	1197	1168	-	910	-
h Btu/lb.	-	-	-	-	-	-	1362	-	1251

Label the liquid phase, saturated liquid line, wet steam region, saturated vapor line, superheat region.

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-8 - Steam Tables

0.0 INTRODUCTION

In this lesson we will discuss the arrangement of tables listing the properties of steam and water covered in the lesson on steam and water and some of the ways in which these tables are used in practice.

1.0 INFORMATION

1.1 Steam Tables

The properties of steam and water are arranged in tables called "steam tables". The ones most commonly used on this continent are "Thermodynamic Properties of Steam" by J.H. Keenan and F.G. Keys, published by John Willey & Sons, Inc., New York. However, these are too extensive to be reproduced here. Included in this lesson are tables 1 to 3 which are not as extensive as the Keenan & Keys tables and not quite as accurate but adequate for purposes of this course.

The first table has the properties arranged against temperature in degrees Fahrenheit for saturated water and saturated steam. In the first column are the values of steam and water temperature (in degrees F) against which, the other properties are listed.

The next two columns give the corresponding saturation pressure (in absolute figures); one gives values in psia, while the other one gives values in inches mercury ("Hg.) Then there are three columns giving specific volume (i.e. cubic feet per lb. of water) of saturated liquid v_f, of liquid and vapor mixture v_{fg} and of saturated vapor v_g respectively. Similarly there are three columns for enthalpy - one gives enthalpy of saturated water (above 32°F) h_f, the second one enthalpy required to change saturated water to saturated steam, which is really latent heat of vaporization, the third one gives the total enthalpy of saturated steam, h_g. The last set of three columns give the entropy of saturated water s_f, entropy change during evaporation s_{f_g} and entropy of saturated steam s_g. The term entropy has not been mentioned previously. It is a property of steam and water and will be covered in detail at the T.T.2 level. For the moment just remember that the information on entropy is included in steam tables.

In looking over table 1 notice that:

1. $v_g = v_f + v_{f_g}$

   $h_g = h_f + h_{f_g}$

   $s_g = s_f + s_{f_g}$

2. The values given in steam tables are for 1 lb. of water or steam only. This applies to table 1 as well as to tables 2 and 3.

Table 2 has the same properties listed in table 1 except that the pressure and temperature columns are interchanged thus making it easier to select values corresponding to given pressures.

Table 3 lists the properties of superheated steam against pressure and temperature. The first column lists the steam pressure in psia and corresponding saturation temperature. Across the top of the table is listed the temperature of superheated steam. Under each temperature and opposite each pressure are listed the specific volume (v) enthalpy (h) and entropy (s).

In any of the tables, the properties at values of pressure and temperature falling in between the listed values are found by interpolation.

1.2 <u>Sample Problem No. 1</u>

How much heat is required to warm 3200 lb. of water from 70°F to 180°F?

Difference in enthalpies (Table 1) is 147.9 - 38.0 = 109.9 BTU/lb.
or just take the difference in temperatures

180 - 70 = 110 BTU/lb.

Then

110 x 3200 = <u>352,000 BTU</u> is the total heat required.

1.3 Sample Problem No. 2

How much heat is needed to convert one poud of feed-water at 200°F into dry saturated steam at 135 psi gauge (150 psi abs)?

Enthalpy of feed water at 200°F (Table 1) is 168.0 BTU/lb.

Enthalpy of dry saturated steam at 150 psia (Table 2) is 1193.8 BTU/lb.

Difference in enthalpies

1193.8 - 168.0 = 1025.8 BTU/lb.

1.4 Sample Problem No. 3

How much heat would be needed to convert one pound of feedwater at 300°F into superheated steam at 700 psia and 900°F?

Enthalpy of the water is 269.6 BTU/lb.

Enthalpy of the steam (Table 3) is 1458.2 BTU/lb.

Heat needed

1458.2 - 269.6 = 1188.6 BTU/lb.

1.5 Quality of Steam

Steam exhausted from condensing turbines - like the NPD and the Douglas Point turbines - usually consists of a mixture of saturated steam and saturated water. This mixture, commonly termed "wet steam" must be measured according to its amount of water and steam content in order to determine its energy or enthalpy content. This is done by stating either percent moisture or percent quality. These terms are defined as follows:

$$y = \%\ \text{moisture} = \frac{\text{wt. of saturated water in mixture in lb} \times 100}{\text{total wt. of saturated water and steam}}$$

$$x = \%\ \text{quality} = \frac{\text{wt. of saturated steam in mixture in lb} \times 100}{\text{total wt. of saturated water and steam}}$$

Percent quality could just as well have been called per cent steam, but custom has fixed on the former term. Note that for any mixture

$$\%\ \text{quality} + \%\ \text{moisture} = 100, \text{ or } x + y = 100 \quad \ldots \quad (1)$$

Knowing the make up of the mixture by either of the foregoing percentages, it is possible to determine its volume and enthalpy with the aid of steam tables as follows:-

(a) when the quality is given

$$\text{Enthalpy of wet steam} = \frac{(100-x)}{100} h_f + \frac{x}{100} h_g$$

$$= h_f + \frac{x}{100}(h_g - h_f) = h_f + \frac{x}{100} h_{f_g} \text{ BTU/lb.} \quad \ldots \quad (2)$$

where h_f = enthalpy of saturated water

h_g = enthalpy of saturated steam

h_{f_g} = heat of vaporization

(b) when moisture is given

$$\text{Enthalpy of wet steam} = \frac{y}{100} h_f + \frac{(100-y)}{100} h_g$$

$$= h_g - \frac{y}{100}(h_g - h_f) = h_g - \frac{y}{100} h_{f_g} \text{ BTU/lb.} \quad \ldots \quad (3)$$

Similarly to find the specific volume,

$$\text{Specific volume of wet steam} = v_f + \frac{x}{100}(v_g - v_f) \text{ft}^3/\text{lb.} \quad \ldots \quad (4)$$

$$= v_g - \frac{y}{100}(v_g - v_f) \text{ft}^3/\text{lb.} \quad \ldots \quad (5)$$

where v_f = specific volume of saturated water

v_g = specific volume of saturated steam

1.6 Sample Problem No. 4

Steam having a temperature of 400°F is wet and has a quality of 80 per cent. Determine its enthalpy and specific volume.

From Table 1 at 400°F, h_f = 375.0 BTU/lb.

h_{f_g} = 826.2 BTU/lb., v_f = 0.01864 ft³/lb, v_g = 1.8632 ft³/lb.

$$\text{Enthalpy of wet steam } h = h_f + \frac{x}{100} h_{f_g} = 375.0 + \frac{80}{100} 826.2$$

$$= \underline{\underline{1.036.0 \text{ BTU/lb}}}.$$

Specific volume of wet steam $v = v_f + \frac{x}{100} (v_g - v_f)$

$= 0.0186 + \frac{80}{100} (1.8632 - 0.01864) = 1.4936 \ ft^3/lb.$

This can also be solved by using the moisture, $y = 100 - x$

$= 100 - 80 = 20\%$

1.7 Sample Problem No. 5

Steam exhausted from a condensing turbine is wet and has 5% moisture. If temperature in the condenser is 80° F, determine the following:

(a) Enthalpy of the steam
(b) Pressure in the condenser

$$h = h_g - \frac{y}{100} h_{f_g} = 1095.8 - \frac{5}{100} \times 1047.8 = \underline{\underline{1043.4 \ BTU/lb}}.$$

For saturated water and steam, pressure corresponding to 80° F is 0.5067 psi (Table 1), or approx. 1.0" Hg. abs.

1.8 Density and Specific Volume

The specific volume of steam is often used in calculations relating to the density of steam, that is, the weight (w), in pounds, of a cubic foot of steam. The density is reciprocal of the specific volume at the same pressure, that is,

$$w = \frac{1}{v}$$

In other words, the product of w and v is always 1. The value of w increases as the pressure increases, which is natural enough, as the steam becomes denser under increased pressure.

1.9 Sample Problem No. 6

Determine the pressure and density of dry saturated steam at 70° F.

From Table 1 at 70° F, p = 0.3628 psia,

$v_g = 868.9 \ ft^3/lb.$

$$w = \frac{1}{v} = \frac{1}{868.9} = 0.0011 \ lb/ft^3.$$

D. Dueck

STEAM TABLES

Absolute Pressure = atmospheric pressure − vacuum.
Barometer and vacuum columns may be corrected to mercury at 32°F. by subtracting, 0.00009 × (t − 32) × column height, where t is the column temperature in °F.
1 inch of mercury at 32°F. = 0.4912 lb./sq. in.

Example:
Barometer reads 30.17 inches at 70°F. Vacuum column reads 28.26 inches at 80°F. Abs. press. = (30.17 − 0.00009 × 38 × 30.17) − (28.26 − 0.00009 × 48 × 28.26) = 1.93 inches of mercury at 32°F.
Saturation temperature (from table) = 100°F.

Table 1. Saturated Steam: Temperature Table

Temp. Fahr. t	Absolute Pressure Lb. per Sq. In. p	Absolute Pressure In. Hg. 32 F.	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	0.0886	0.1806	0.01602	3305.7	3305.7	0	1075.1	1075.1	0	2.1865	2.1865	32
34	0.0961	0.1957	0.01602	3060.4	3060.4	2.01	1074.0	1076.0	0.0041	2.1755	2.1796	34
36	0.1041	0.2120	0.01602	2836.6	2836.6	4.03	1072.9	1076.9	0.0082	2.1645	2.1727	36
38	0.1126	0.2292	0.01602	2632.2	2632.2	6.04	1071.7	1077.7	0.0122	2.1533	2.1655	38
40	0.1217	0.2478	0.01602	2445.1	2445.1	8.05	1070.5	1078.6	0.0162	2.1423	2.1585	40
42	0.1315	0.2677	0.01602	2271.8	2271.8	10.06	1069.3	1079.4	0.0203	2.1314	2.1517	42
44	0.1420	0.2891	0.01602	2112.2	2112.2	12.06	1068.2	1080.3	0.0242	2.1207	2.1449	44
46	0.1532	0.3119	0.01602	1965.5	1965.5	14.07	1067.1	1081.2	0.0282	2.1102	2.1384	46
48	0.1652	0.3364	0.01602	1829.9	1829.9	16.07	1065.9	1082.0	0.0322	2.0995	2.1317	48
50	0.1780	0.3624	0.01602	1704.9	1704.9	18.07	1064.8	1082.9	0.0361	2.0891	2.1252	50
52	0.1918	0.3905	0.01603	1588.4	1588.4	20.07	1063.6	1083.7	0.0400	2.0786	2.1186	52
54	0.2063	0.4200	0.01603	1482.4	1482.4	22.07	1062.5	1084.6	0.0439	2.0684	2.1123	54
56	0.2219	0.4518	0.01603	1383.5	1383.5	24.07	1061.4	1085.5	0.0478	2.0582	2.1060	56
58	0.2384	0.4854	0.01603	1292.7	1292.7	26.07	1060.2	1086.3	0.0517	2.0479	2.0996	58
60	0.2561	0.5214	0.01603	1208.1	1208.1	28.07	1059.1	1087.2	0.0555	2.0379	2.0934	60
62	0.2749	0.5597	0.01604	1129.7	1129.7	30.06	1057.9	1088.0	0.0594	2.0278	2.0872	62
64	0.2949	0.6004	0.01604	1057.1	1057.1	32.06	1056.8	1088.9	0.0632	2.0180	2.0812	64
66	0.3162	0.6438	0.01604	989.6	989.6	34.06	1055.7	1089.8	0.0670	2.0082	2.0752	66
68	0.3388	0.6898	0.01605	927.0	927.0	36.05	1054.5	1090.6	0.0708	1.9983	2.0691	68
70	0.3628	0.7387	0.01605	868.9	868.9	38.05	1053.4	1091.5	0.0745	1.9887	2.0632	70
72	0.3883	0.7906	0.01606	814.9	814.9	40.04	1052.3	1092.3	0.0783	1.9792	2.0575	72
74	0.4153	0.8456	0.01606	764.7	764.7	42.04	1051.2	1093.2	0.0820	1.9697	2.0517	74
76	0.4440	0.9040	0.01607	718.0	718.0	44.03	1050.1	1094.1	0.0858	1.9603	2.0461	76
78	0.4744	0.9659	0.01607	674.4	674.4	46.03	1048.9	1094.9	10.0895	9508	2.0403	78
80	0.5067	1.032	0.01607	633.7	633.7	48.02	1047.8	1095.8	0.0932	1.9415	2.0347	80
82	0.5409	1.101	0.01608	595.8	595.8	50.02	1046.6	1096.6	0.0969	1.9321	2.0290	82
84	0.5772	1.175	0.01608	560.4	560.4	52.01	1045.5	1097.5	0.1006	1.9230	2.0236	84
86	0.6153	1.253	0.01609	527.6	527.6	54.01	1044.4	1098.4	0.1042	1.9139	2.0181	86
88	0.6555	1.335	0.01609	497.0	497.0	56.00	1043.2	1099.2	0.1079	1.9047	2.0126	88
90	0.6980	1.421	0.01610	468.4	468.4	58.00	1042.1	1100.1	0.1115	1.8958	2.0073	90
92	0.7429	1.513	0.01611	441.7	441.7	59.99	1040.9	1100.9	0.1151	1.8867	2.0018	92
94	0.7902	1.609	0.01611	416.7	416.7	61.98	1039.8	1101.8	0.1187	1.8779	1.9966	94
96	0.8403	1.711	0.01612	393.2	393.2	63.98	1038.7	1102.7	0.1223	1.8692	1.9915	96
98	0.8930	1.818	0.01613	371.3	371.3	65.98	1037.5	1103.5	0.1259	1.8604	1.9863	98
100	0.9487	1.932	0.01613	350.8	350.8	67.97	1036.4	1104.4	0.1295	1.8517	1.9812	100
102	1.0072	2.051	0.01614	331.5	331.5	69.96	1035.2	1105.2	0.1330	1.8430	1.9760	102
104	1.0689	2.176	0.01614	313.5	313.5	71.96	1034.1	1106.1	0.1366	1.8345	1.9711	104
106	1.1338	2.308	0.01615	296.5	296.5	73.95	1033.0	1107.0	0.1401	1.8261	1.9662	106
108	1.2020	2.447	0.01616	280.7	280.7	75.94	1032.0	1107.9	0.1436	1.8179	1.9615	108
110	1.274	2.594	0.01617	265.7	265.7	77.94	1030.9	1108.8	0.1471	1.8096	1.9567	110
112	1.350	2.749	0.01617	251.6	251.6	79.93	1029.7	1109.6	0.1506	1.8012	1.9518	112
114	1.429	2.909	0.01618	238.5	238.5	81.93	1028.6	1110.5	0.1541	1.7930	1.9471	114
116	1.512	3.078	0.01619	226.2	226.2	83.92	1027.5	1111.4	0.1576	1.7848	1.9424	116
118	1.600	3.258	0.01620	214.5	214.5	85.92	1026.4	1112.3	0.1610	1.7767	1.9377	118
120	1.692	3.445	0.01620	203.45	203.47	87.91	1025.3	1113.2	0.1645	1.7687	1.9332	120
122	1.788	3.640	0.01621	193.16	193.18	89.91	1024.1	1114.0	0.1679	1.7606	1.9285	122
124	1.889	3.846	0.01622	183.44	183.46	91.90	1023.0	1114.9	0.1714	1.7526	1.9240	124
126	1.995	4.062	0.01623	174.26	174.28	93.90	1021.8	1115.7	0.1748	1.7446	1.9194	126
128	2.105	4.286	0.01624	165.70	165.72	95.90	1020.7	1116.6	0.1782	1.7368	1.9150	128
130	2.221	4.522	0.01625	157.55	157.57	97.89	1019.5	1117.4	0.1816	1.7289	1.9105	130
132	2.343	4.770	0.01626	149.83	149.85	99.89	1018.3	1118.2	0.1849	1.7210	1.9059	132
134	2.470	5.029	0.01626	142.59	142.61	101.89	1017.2	1119.1	0.1883	1.7134	1.9017	134
136	2.603	5.300	0.01627	135.73	135.75	103.88	1016.0	1119.9	0.1917	1.7056	1.8973	136
138	2.742	5.583	0.01628	129.26	129.28	105.88	1014.9	1120.8	0.1950	1.6980	1.8930	138
140	2.887	5.878	0.01629	123.16	123.18	107.88	1013.7	1121.6	0.1984	1.6904	1.8888	140
142	3.039	6.187	0.01630	117.37	117.39	109.88	1012.5	1122.4	0.2017	1.6828	1.8845	142
144	3.198	6.511	0.01631	111.88	111.90	111.88	1011.3	1123.2	0.2050	1.6752	1.8802	144
146	3.363	6.847	0.01632	106.72	106.74	113.88	1010.2	1124.1	0.2083	1.6678	1.8761	146
148	3.536	7.199	0.01633	101.82	101.84	115.87	1009.0	1124.9	0.2116	1.6604	1.8720	148

TABLE 1. SATURATED STEAM: TEMPERATURE TABLE—*Continued*

Temp. Fahr. t	Absolute Pressure Lb. per Sq. In. p	Absolute Pressure In. Hg. 32 F.	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
150	3.716	7.566	0.01634	97.18	97.20	117.87	1007.8	1125.7	0.2149	1.6530	1.8679	150
152	3.904	7.948	0.01635	92.79	92.81	119.87	1006.7	1126.6	0.2181	1.6458	1.8639	152
154	4.100	8.348	0.01636	88.62	88.64	121.87	1005.5	1127.4	0.2214	1.6384	1.8598	154
156	4.305	8.765	0.01637	84.66	84.68	123.87	1004.4	1128.3	0.2247	1.6313	1.8560	156
158	4.518	9.199	0.01638	80.90	80.92	125.87	1003.2	1129.1	0.2279	1.6241	1.8520	158
160	4.739	9.649	0.01639	77.37	77.39	127.87	1002.0	1129.9	0.2311	1.6169	1.8480	160
162	4.970	10.12	0.01640	74.00	74.02	129.88	1000.8	1130.7	0.2343	1.6098	1.8441	162
164	5.210	10.61	0.01642	70.79	70.81	131.88	999.7	1131.6	0.2376	1.6029	1.8405	164
166	5.460	11.12	0.01643	67.76	67.78	133.88	998.5	1132.4	0.2408	1.5958	1.8366	166
168	5.720	11.65	0.01644	64.87	64.89	135.88	997.3	1133.2	0.2439	1.5888	1.8327	168
170	5.990	12.20	0.01645	62.12	62.14	137.89	996.1	1134.0	0.2471	1.5819	1.8290	170
172	6.272	12.77	0.01646	59.50	59.52	139.89	995.0	1134.9	0.2503	1.5751	1.8254	172
174	6.565	13.37	0.01647	57.01	57.03	141.89	993.8	1135.7	0.2535	1.5683	1.8218	174
176	6.869	13.99	0.01648	54.64	54.66	143.90	992.6	1136.5	0.2566	1.5615	1.8181	176
178	7.184	14.63	0.01650	52.39	52.41	145.90	991.4	1137.3	0.2598	1.5547	1.8145	178
180	7.510	15.29	0.01651	50.26	50.28	147.91	990.2	1138.1	0.2629	1.5479	1.8108	180
182	7.849	15.98	0.01652	48.22	48.24	149.92	989.0	1138.9	0.2661	1.5412	1.8073	182
184	8.201	16.70	0.01653	46.28	46.30	151.92	987.8	1139.7	0.2692	1.5346	1.8038	184
186	8.566	17.44	0.01654	44.43	44.45	153.93	986.6	1140.5	0.2723	1.5280	1.8003	186
188	8.944	18.21	0.01656	42.67	42.69	155.94	985.3	1141.3	0.2754	1.5213	1.7967	188
190	9.336	19.01	0.01657	40.99	41.01	157.95	984.1	1142.1	0.2785	1.5147	1.7932	190
192	9.744	19.84	0.01658	39.38	39.40	159.95	982.8	1142.8	0.2816	1.5081	1.7897	192
194	10.168	20.70	0.01659	37.84	37.86	161.96	981.5	1143.5	0.2847	1.5015	1.7862	194
196	10.605	21.59	0.01661	36.38	36.40	163.97	980.3	1144.3	0.2877	1.4951	1.7828	196
198	11.057	22.51	0.01662	34.98	35.00	165.98	979.0	1145.0	0.2908	1.4885	1.7793	198
200	11.525	23.46	0.01663	33.65	33.67	167.99	977.8	1145.8	0.2938	1.4822	1.7760	200
202	12.010	24.45	0.01665	32.37	32.39	170.01	976.6	1146.6	0.2969	1.4759	1.7728	202
204	12.512	25.47	0.01666	31.15	31.17	172.02	975.3	1147.3	0.2999	1.4695	1.7694	204
206	13.031	26.53	0.01667	29.99	30.01	174.03	974.1	1148.1	0.3029	1.4633	1.7662	206
208	13.568	27.62	0.01669	28.88	28.90	176.04	972.8	1148.8	0.3059	1.4570	1.7629	208
210	14.123	28.75	0.01670	27.81	27.83	178.06	971.5	1149.6	0.3090	1.4507	1.7597	210
212	14.696	29.92	0.01672	26.81	26.83	180.07	970.3	1150.4	0.3120	1.4446	1.7566	212
215	15.591		0.01674	25.35	25.37	183.10	968.3	1151.4	0.3165	1.4352	1.7517	215
220	17.188		0.01677	23.14	23.16	188.14	965.2	1153.3	0.3239	1.4201	1.7440	220
225	18.915		0.01681	21.15	21.17	193.18	961.9	1155.1	0.3313	1.4049	1.7362	225
230	20.78		0.01684	19.371	19.388	198.22	958.7	1156.9	0.3386	1.3900	1.7286	230
235	22.80		0.01688	17.761	17.778	203.28	955.3	1158.6	0.3459	1.3751	1.7210	235
240	24.97		0.01692	16.307	16.324	208.34	952.1	1160.4	0.3531	1.3607	1.7138	240
245	27.31		0.01696	15.010	15.027	213.41	948.7	1162.1	0.3604	1.3462	1.7066	245
250	29.82		0.01700	13.824	13.841	218.48	945.3	1163.8	0.3675	1.3320	1.6995	250
255	32.53		0.01704	12.735	12.752	223.56	942.0	1165.6	0.3747	1.3181	1.6928	255
260	35.43		0.01708	11.754	11.771	228.65	938.6	1167.3	0.3817	1.3042	1.6859	260
265	38.54		0.01713	10.861	10.878	233.74	935.3	1169.0	0.3888	1.2906	1.6794	265
270	41.85		0.01717	10.053	10.070	238.84	931.8	1170.6	0.3958	1.2770	1.6728	270
275	45.40		0.01721	9.313	9.330	243.94	928.2	1172.1	0.4027	1.2634	1.6661	275
280	49.20		0.01726	8.634	8.651	249.06	924.6	1173.7	0.4096	1.2500	1.6596	280
285	53.25		0.01731	8.015	8.032	254.18	921.0	1175.2	0.4165	1.2368	1.6533	285
290	57.55		0.01735	7.448	7.465	259.31	917.4	1176.7	0.4234	1.2237	1.6471	290
295	62.18		0.01740	6.931	6.948	264.45	913.7	1178.2	0.4302	1.2107	1.6409	295
300	67.01		0.01745	6.454	6.471	269.60	910.1	1179.7	0.4370	1.1980	1.6350	300
305	72.18		0.01750	6.014	6.032	274.76	906.3	1181.1	0.4437	1.1852	1.6289	305
310	77.68		0.01755	5.610	5.628	279.92	902.6	1182.5	0.4505	1.1727	1.6232	310
315	83.50		0.01760	5.239	5.257	285.10	898.8	1183.9	0.4571	1.1587	1.6158	315
320	89.65		0.01765	4.897	4.915	290.29	895.0	1185.3	0.4637	1.1479	1.6116	320
325	96.16		0.01771	4.583	4.601	295.49	891.1	1186.6	0.4703	1.1356	1.6059	325
330	103.08		0.01776	4.292	4.310	300.69	887.1	1187.8	0.4769	1.1234	1.6003	330
335	110.31		0.01782	4.021	4.039	305.91	883.2	1189.1	0.4835	1.1114	1.5949	335
340	117.99		0.01788	3.771	3.789	311.14	879.2	1190.3	0.4900	1.0994	1.5894	340
345	126.10		0.01793	3.539	3.557	316.38	875.1	1191.5	0.4966	1.0875	1.5841	345
350	134.62		0.01799	3.324	3.342	321.64	871.0	1192.6	0.5030	1.0757	1.5787	350
355	143.58		0.01805	3.126	3.144	326.91	866.8	1193.7	0.5094	1.0640	1.5734	355
360	153.01		0.01811	2.940	2.958	332.19	862.5	1194.7	0.5159	1.0522	1.5681	360
365	162.93		0.01817	2.768	2.786	337.48	858.2	1195.7	0.5223	1.0406	1.5629	365
370	173.33		0.01823	2.607	2.625	342.79	853.8	1196.6	0.5286	1.0291	1.5577	370
375	184.23		0.01830	2.458	2.476	348.11	849.4	1197.5	0.5350	1.0176	1.5526	375
380	195.70		0.01836	2.318	2.336	353.45	844.9	1198.4	0.5413	1.0062	1.5475	380
385	207.71		0.01843	2.189	2.207	358.80	840.4	1199.2	0.5476	0.9949	1.5425	385

TABLE 1. SATURATED STEAM: TEMPERATURE TABLE—*Concluded*

Temp. Fahr. t	Abs. Press. Lb./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
390	220.29	0.01850	2.064	2.083	364.17	835.7	1199.9	0.5540	0.9835	1.5375	390
395	233.47	0.01857	1.9512	1.9698	369.56	831.0	1200.6	0.5602	0.9723	1.5325	395
400	247.26	0.01864	1.8446	1.8632	374.97	826.2	1201.2	0.5664	0.9610	1.5274	400
405	261.67	0.01871	1.7445	1.7632	380.40	821.4	1201.8	0.5727	0.9499	1.5226	405
410	276.72	0.01878	1.6508	1.6696	385.83	816.6	1202.4	0.5789	0.9390	1.5179	410
415	292.44	0.01886	1.5630	1.5819	391.30	811.7	1203.0	0.5851	0.9280	1.5131	415
420	308.82	0.01894	1.4806	1.4995	396.78	806.7	1203.5	0.5912	0.9170	1.5082	420
425	325.91	0.01902	1.4031	1.4221	402.28	801.6	1203.9	0.5974	0.9061	1.5035	425
430	343.71	0.01910	1.3303	1.3494	407.80	796.5	1204.3	0.6036	0.8953	1.4989	430
435	362.27	0.01918	1.2617	1.2809	413.35	791.2	1204.6	0.6097	0.8843	1.4940	435
440	381.59	0.01926	1.1973	1.2166	418.91	785.9	1204.8	0.6159	0.8735	1.4894	440
445	401.70	0.01934	1.1367	1.1560	424.49	780.4	1204.9	0.6220	0.8626	1.4846	445
450	422.61	0.01943	1.0796	1.0990	430.11	774.9	1205.0	0.6281	0.8518	1.4799	450
455	444.35	0.0195	1.0256	1.0451	435.74	769.3	1205.0	0.6342	0.8410	1.4752	455
460	466.97	0.0196	0.9745	0.9941	441.42	763.6	1205.0	0.6403	0.8303	1.4706	460
465	490.43	0.0197	0.9262	0.9459	447.10	757.8	1204.9	0.6463	0.8195	1.4658	465
470	514.70	0.0198	0.8808	0.9006	452.84	751.9	1204.7	0.6524	0.8088	1.4612	470
475	539.90	0.0199	0.8379	0.8578	458.59	745.9	1204.5	0.6585	0.7980	1.4565	475
480	566.12	0.0200	0.7972	0.8172	464.37	739.8	1204.2	0.6646	0.7873	1.4519	480
485	593.28	0.0201	0.7585	0.7786	470.18	733.6	1203.8	0.6706	0.7766	1.4472	485
490	621.44	0.0202	0.7219	0.7421	476.01	727.3	1203.3	0.6767	0.7658	1.4425	490
495	650.59	0.0203	0.6872	0.7075	481.90	720.8	1202.7	0.6827	0.7550	1.4377	495
500	680.80	0.0204	0.6544	0.6748	487.80	714.2	1202.0	0.6888	0.7442	1.4330	500
505	712.19	0.0206	0.6230	0.6436	493.8	707.5	1201.3	0.6949	0.7334	1.4283	505
510	744.55	0.0207	0.5932	0.6139	499.8	700.6	1200.4	0.7009	0.7225	1.4234	510
515	777.96	0.0208	0.5651	0.5859	505.8	693.6	1199.4	0.7070	0.7116	1.4186	515
520	812.68	0.0209	0.5382	0.5591	511.9	686.5	1198.4	0.7132	0.7007	1.4139	520
525	848.37	0.0210	0.5128	0.5338	518.0	679.2	1197.2	0.7192	0.6898	1.4090	525
530	885.20	0.0212	0.4885	0.5097	524.2	671.9	1196.1	0.7253	0.6789	1.4042	530
535	923.45	0.0213	0.4654	0.4867	530.4	664.4	1194.8	0.7314	0.6679	1.3993	535
540	962.80	0.0214	0.4433	0.4647	536.6	656.7	1193.3	0.7375	0.6569	1.3944	540
545	1003.6	0.0216	0.4222	0.4438	542.9	648.9	1191.8	0.7436	0.6459	1.3895	545
550	1045.6	0.0218	0.4021	0.4239	549.3	640.9	1190.2	0.7498	0.6347	1.3845	550
555	1088.8	0.0219	0.3830	0.4049	555.7	632.6	1188.3	0.7559	0.6234	1.3793	555
560	1133.4	0.0221	0.3648	0.3869	562.2	624.1	1186.3	0.7622	0.6120	1.3742	560
565	1179.3	0.0222	0.3472	0.3694	568.8	615.4	1184.2	0.7684	0.6006	1.3690	565
570	1226.7	0.0224	0.3304	0.3528	575.4	606.5	1181.9	0.7737	0.5890	1.3627	570
575	1275.7	0.0226	0.3143	0.3369	582.1	597.4	1179.5	0.7810	0.5774	1.3584	575
580	1326.1	0.0228	0.2989	0.3217	588.9	588.1	1177.0	0.7872	0.5656	1.3528	580
585	1378.1	0.0230	0.2840	0.3070	595.7	578.6	1174.3	0.7936	0.5538	1.3474	585
590	1431.5	0.0232	0.2699	0.2931	602.6	568.8	1171.4	0.8000	0.5419	1.3419	590
595	1486.5	0.0234	0.2563	0.2797	609.7	558.7	1168.4	0.8065	0.5297	1.3362	595
600	1543.2	0.0236	0.2432	0.2668	616.8	548.4	1165.2	0.8130	0.5175	1.3305	600
605	1601.5	0.0239	0.2306	0.2545	624.1	537.7	1161.8	0.8196	0.5050	1.3246	605
610	1661.6	0.0241	0.2185	0.2426	631.5	526.6	1158.1	0.8263	0.4923	1.3186	610
615	1723.4	0.0244	0.2068	0.2312	638.9	515.3	1154.2	0.8330	0.4795	1.3125	615
620	1787.0	0.0247	0.1955	0.2202	646.5	503.7	1150.2	0.8398	0.4665	1.3063	620
625	1852.4	0.0250	0.1845	0.2095	654.3	491.5	1145.8	0.8467	0.4531	1.2998	625
630	1919.8	0.0253	0.1740	0.1993	662.2	478.8	1141.0	0.8537	0.4394	1.2931	630
635	1989.0	0.0256	0.1638	0.1894	670.4	465.5	1135.9	0.8609	0.4252	1.2861	635
640	2060.3	0.0260	0.1539	0.1799	678.7	452.0	1130.7	0.8681	0.4110	1.2791	640
645	2133.5	0.0264	0.1441	0.1705	687.3	437.6	1124.9	0.8756	0.3961	1.2717	645
650	2208.8	0.0268	0.1348	0.1616	696.0	422.7	1118.7	0.8832	0.3809	1.2641	650
655	2286.4	0.0273	0.1256	0.1529	705.2	407.0	1112.2	0.8910	0.3651	1.2561	655
660	2366.2	0.0278	0.1167	0.1445	714.4	390.5	1104.9	0.8991	0.3488	1.2479	660
665	2448.0	0.0283	0.1079	0.1362	724.5	372.1	1096.6	0.9074	0.3308	1.2382	665
670	2532.4	0.0290	0.0991	0.1281	734.6	353.3	1087.9	0.9161	0.3127	1.2288	670
675	2619.2	0.0297	0.0904	0.1201	745.5	332.8	1078.3	0.9253	0.2933	1.2186	675
680	2708.4	0.0305	0.0810	0.1115	757.2	310.0	1067.2	0.9352	0.2720	1.2072	680
685	2800.4	0.0316	0.0716	0.1032	770.1	284.5	1054.6	0.9459	0.2485	1.1944	685
690	2895.0	0.0328	0.0617	0.0945	784.2	254.9	1039.1	0.9579	0.2217	1.1796	690
695	2992.7	0.0345	0.0511	0.0856	801.3	219.1	1020.4	0.9720	0.1897	1.1617	695
700	3094.1	0.0369	0.0389	0.0758	823.9	171.7	995.6	0.9904	0.1481	1.1385	700
705	3199.1	0.0440	0.0157	0.0597	870.2	77.6	947.8	1.0305	0.0661	1.0966	705
705.34*	3206.2	0.0541	0	0.0541	910.3	0	910.3	1.0645	0	1.0645	705.34*

* Critical temperature

Table 2. Saturated Steam: Pressure Table

Abs. Press. Lb./Sq. In. p	Temp. Fahr. t	Specific Volume Sat. Liquid v_f	Specific Volume Evap. v_{fg}	Specific Volume Sat. Vapor v_g	Enthalpy Sat. Liquid h_f	Enthalpy Evap. h_{fg}	Enthalpy Sat. Vapor h_g	Entropy Sat. Liquid s_f	Entropy Evap. s_{fg}	Entropy Sat. Vapor s_g	Abs. Press. Lb./Sq. In. p
0.0886	32.00	0.01602	3305.7	3305.7	0	1075.1	1075.1	0	2.1865	2.1865	0.0886
0.125	40.69	0.01602	2383.7	2383.7	8.74	1070.2	1078.9	0.0176	2.1388	2.1564	0.125
0.250	59.31	0.01603	1235.8	1235.8	27.38	1059.5	1086.9	0.0542	2.0414	2.0956	0.250
0.500	79.58	0.01607	641.71	641.73	47.60	1048.0	1095.6	0.0924	1.9434	2.0358	0.500
1	101.76	0.01614	333.77	333.79	69.72	1035.5	1105.2	0.1326	1.8443	1.9769	1
5	162.25	0.01641	73.584	73.600	130.13	1000.7	1130.8	0.2347	1.6090	1.8437	5
10	193.21	0.01659	38.445	38.462	161.17	982.1	1143.3	0.2834	1.5042	1.7876	10
14.696	212.00	0.01672	26.811	26.828	180.07	970.3	1150.4	0.3120	1.4446	1.7566	14.696
15	213.03	0.01672	26.303	26.320	181.11	969.6	1150.7	0.3135	1.4413	1.7548	15
20	227.96	0.01683	20.093	20.110	196.16	959.9	1156.1	0.3356	1.3959	1.7315	20
30	250.34	0.01700	13.746	13.763	218.83	945.2	1164.0	0.3680	1.3312	1.6992	30
40	267.24	0.01715	10.489	10.506	236.02	933.7	1169.7	0.3919	1.2844	1.6763	40
50	281.01	0.01727	8.505	8.522	250.09	923.9	1174.0	0.4110	1.2473	1.6583	50
60	292.71	0.01738	7.162	7.179	262.10	915.4	1177.5	0.4271	1.2166	1.6437	60
70	302.92	0.01748	6.193	6.210	272.61	907.9	1180.5	0.4409	1.1905	1.6314	70
80	312.03	0.01757	5.458	5.476	282.02	901.1	1183.1	0.4532	1.1677	1.6209	80
90	320.27	0.01766	4.880	4.898	290.57	894.8	1185.4	0.4641	1.1472	1.6113	90
100	327.83	0.01774	4.415	4.433	298.43	888.9	1187.3	0.4741	1.1287	1.6028	100
110	334.79	0.01782	4.032	4.050	305.69	883.3	1189.0	0.4832	1.1118	1.5950	110
120	341.26	0.01789	3.710	3.728	312.46	878.1	1190.6	0.4916	1.0963	1.5879	120
130	347.31	0.01796	3.437	3.455	318.81	873.2	1192.0	0.4995	1.0820	1.5815	130
140	353.03	0.01803	3.202	3.220	324.83	868.5	1193.3	0.5069	1.0686	1.5755	140
150	358.43	0.01809	2.998	3.016	330.53	863.9	1194.4	0.5138	1.0560	1.5698	150
160	363.55	0.01815	2.816	2.834	335.95	859.6	1195.5	0.5204	1.0442	1.5646	160
170	368.42	0.01821	2.656	2.674	341.11	855.2	1196.3	0.5266	1.0327	1.5593	170
180	373.08	0.01827	2.514	2.532	346.07	851.1	1197.2	0.5325	1.0220	1.5545	180
190	377.55	0.01833	2.386	2.404	350.83	847.2	1198.0	0.5382	1.0119	1.5501	190
200	381.82	0.01839	2.270	2.288	355.40	843.3	1198.7	0.5436	1.0021	1.5457	200
210	385.93	0.01844	2.165	2.183	359.80	839.6	1199.4	0.5488	0.9929	1.5417	210
220	389.89	0.01850	2.067	2.086	364.05	835.8	1199.9	0.5538	0.9838	1.5376	220
230	393.70	0.01855	1.9803	1.9989	368.16	832.2	1200.4	0.5585	0.9752	1.5337	230
240	397.40	0.01860	1.8990	1.9176	372.16	828.7	1200.9	0.5632	0.9669	1.5301	240
250	400.97	0.01866	1.8244	1.8431	376.04	825.4	1201.4	0.5677	0.9590	1.5267	250
260	404.43	0.01870	1.7555	1.7742	379.78	822.0	1201.8	0.5720	0.9513	1.5233	260
270	407.79	0.01875	1.6918	1.7101	383.43	818.8	1202.2	0.5761	0.9439	1.5200	270
280	411.06	0.01880	1.6316	1.6504	386.99	815.5	1202.5	0.5802	0.9365	1.5167	280
290	414.24	0.01885	1.5758	1.5947	390.47	812.4	1202.9	0.5841	0.9296	1.5137	290
300	417.33	0.01890	1.5237	1.5426	393.85	809.3	1203.2	0.5879	0.9228	1.5107	300
350	431.71	0.01912	1.3064	1.3255	409.70	794.7	1204.4	0.6057	0.8915	1.4972	350
400	444.58	0.0193	1.1416	1.1609	424.02	780.9	1204.9	0.6215	0.8635	1.4850	400
450	456.27	0.0195	1.0123	1.0318	437.18	767.8	1205.0	0.6357	0.8382	1.4739	450
500	467.00	0.0197	0.9077	0.9274	449.40	755.5	1204.9	0.6488	0.8153	1.4641	500
550	476.94	0.0199	0.8217	0.8416	460.83	743.6	1204.4	0.6609	0.7939	1.4548	550
600	486.21	0.0201	0.7494	0.7695	471.59	732.0	1203.6	0.6721	0.7739	1.4460	600
650	494.90	0.0203	0.6879	0.7082	481.73	721.0	1202.7	0.6826	0.7553	1.4379	650
700	503.09	0.0205	0.6347	0.6552	491.49	710.1	1201.6	0.6925	0.7376	1.4301	700
750	510.83	0.0207	0.5884	0.6091	500.8	699.4	1200.2	0.7019	0.7206	1.4225	750
800	518.20	0.0209	0.5476	0.5685	509.7	689.1	1198.8	0.7108	0.7047	1.4155	800
850	525.23	0.0210	0.5116	0.5326	518.3	678.9	1197.2	0.7194	0.6893	1.4087	850
900	531.94	0.0212	0.4794	0.5006	526.6	669.0	1195.6	0.7276	0.6746	1.4022	900
950	538.38	0.0214	0.4503	0.4717	534.6	659.2	1193.8	0.7355	0.6605	1.3960	950
1000	544.56	0.0216	0.4240	0.4456	542.4	649.5	1191.9	0.7431	0.6468	1.3899	1000
1050	550.52	0.0218	0.4001	0.4219	550.0	640.0	1190.0	0.7504	0.6335	1.3839	1050
1100	556.26	0.0219	0.3783	0.4002	557.4	630.4	1187.8	0.7575	0.6205	1.3780	1100
1150	561.81	0.0221	0.3583	0.3804	564.6	621.0	1185.6	0.7644	0.6079	1.3723	1150
1200	567.19	0.0223	0.3397	0.3620	571.7	611.5	1183.2	0.7712	0.5955	1.3667	1200
1250	572.39	0.0225	0.3228	0.3453	578.6	602.2	1180.8	0.7777	0.5835	1.3612	1250
1300	577.43	0.0227	0.3067	0.3294	585.4	592.9	1178.3	0.7840	0.5717	1.3557	1300
1350	582.32	0.0229	0.2918	0.3147	592.1	583.7	1175.8	0.7902	0.5602	1.3504	1350
1400	587.07	0.0231	0.2780	0.3011	598.6	574.6	1173.2	0.7963	0.5489	1.3452	1400
1450	591.70	0.0233	0.2652	0.2885	605.0	565.5	1170.5	0.8022	0.5379	1.3401	1450
1500	596.20	0.0235	0.2530	0.2765	611.4	556.3	1167.7	0.8081	0.5269	1.3350	1500
1550	600.59	0.0237	0.2416	0.2653	617.7	547.1	1164.8	0.8138	0.5160	1.3298	1550
1600	604.87	0.0239	0.2309	0.2548	623.9	538.0	1161.9	0.8195	0.5054	1.3249	1600
1650	609.05	0.0241	0.2207	0.2448	630.0	528.8	1158.8	0.8250	0.4948	1.3198	1650
1700	613.12	0.0243	0.2111	0.2354	636.1	519.6	1155.7	0.8304	0.4843	1.3147	1700
1750	617.11	0.0245	0.2020	0.2265	642.1	510.4	1152.5	0.8359	0.4740	1.3099	1750
1800	621.00	0.0247	0.1933	0.2180	648.0	501.3	1149.3	0.8412	0.4639	1.3051	1800
1850	624.82	0.0249	0.1850	0.2099	653.9	492.0	1145.9	0.8465	0.4537	1.3002	1850
1900	628.55	0.0252	0.1770	0.2022	659.9	482.5	1142.4	0.8517	0.4434	1.2951	1900
1950	632.20	0.0254	0.1695	0.1949	665.8	473.0	1138.8	0.8569	0.4332	1.2901	1950
2000	635.78	0.0257	0.1622	0.1879	671.7	463.5	1135.2	0.8620	0.4231	1.2851	2000
2100	642.73	0.0262	0.1486	0.1748	683.4	444.2	1127.6	0.8722	0.4029	1.2751	2100
2200	649.42	0.0267	0.1359	0.1626	695.0	424.4	1119.4	0.8823	0.3826	1.2649	2200
2300	655.87	0.0274	0.1240	0.1514	706.7	404.3	1111.0	0.8923	0.3624	1.2547	2300
2400	662.09	0.0280	0.1130	0.1410	718.5	382.9	1101.4	0.9025	0.3413	1.2438	2400
2500	668.10	0.0287	0.1026	0.1313	730.7	360.3	1091.0	0.9127	0.3195	1.2322	2500
2600	673.91	0.0295	0.0924	0.1219	743.1	337.0	1080.1	0.9232	0.2973	1.2205	2600
2700	679.54	0.0305	0.0818	0.1123	756.1	312.2	1068.3	0.9342	0.2740	1.2082	2700
2800	684.98	0.0316	0.0716	0.1032	770.0	284.6	1054.6	0.9458	0.2486	1.1944	2800
2900	690.26	0.0329	0.0612	0.0941	785.2	252.9	1038.1	0.9586	0.2199	1.1785	2900
3000	695.37	0.0346	0.0503	0.0849	802.6	216.7	1019.3	0.9731	0.1876	1.1607	3000
3100	700.29	0.0372	0.0380	0.0752	824.6	169.4	994.0	0.9916	0.1460	1.1376	3100
3200	705.04	0.0443	0.0153	0.0596	871.3	75.3	946.6	1.0311	0.0647	1.0958	3200
3206.2*	705.34	0.0541	0	0.0541	910.3	0	910.3	1.0645	0	1.0645	3206.2*

* Critical pressure

Table 3. Superheated Steam

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	Temperature—Degrees Fahrenheit 200°	250°	300°	350°	400°	450°	500°	600°	700°	800°	900°	1000°	1100°	1200°
	Sh			98.24	148.24	198.24	248.24	298.24	348.24	398.24	498.24	598.24	698.24	798.24	898.24	998.24	1098.24
1	v	0.0161	333.79	392.5	422.5	452.1	482.1	511.7	541.8	571.3	630.9	690.6	750.2	809.8	869.4	929.1	988.7
(101.76)	h	69.72	1105.2	1149.2	1171.9	1194.4	1217.3	1240.2	1263.5	1286.7	1333.9	1382.1	1431.0	1480.8	1531.4	1583.0	1635.4
	s	0.1326	1.9769	2.0491	2.0822	2.1128	2.1420	2.1694	2.1957	2.2206	2.2673	2.3107	2.3512	2.3892	2.4251	2.4592	2.4918
	Sh			37.75	87.75	137.75	187.75	237.75	287.75	337.75	437.75	537.75	637.75	737.75	837.75	937.75	1037.75
5	v	0.0164	73.600	78.17	84.24	90.21	96.26	102.19	108.23	114.16	126.11	138.05	149.99	161.91	173.83	185.80	197.72
(162.25)	h	130.13	1130.8	1148.3	1171.1	1193.6	1216.6	1239.8	1263.0	1286.1	1333.5	1381.8	1430.8	1480.6	1531.3	1582.9	1635.3
	s	0.2347	1.8437	1.8710	1.9043	1.9349	1.9642	1.9920	2.0182	2.0429	2.0898	2.1333	2.1738	2.2118	2.2478	2.2820	2.3146
	Sh			6.79	56.79	106.79	156.79	206.79	256.79	306.79	406.79	506.79	606.79	706.79	806.79	906.79	1006.79
10	v	0.0166	38.462	38.88	41.96	44.98	48.02	51.01	54.04	57.02	63.01	68.99	74.96	80.92	86.89	92.88	98.85
(193.21)	h	161.17	1143.3	1146.7	1170.2	1192.8	1216.0	1239.3	1262.5	1285.8	1333.3	1381.6	1430.6	1480.5	1531.2	1582.8	1635.2
	s	0.2834	1.7876	1.7928	1.8271	1.8579	1.8875	1.9154	1.9416	1.9665	2.0135	2.0570	2.0975	2.1356	2.1716	2.2058	2.2384
	Sh				38.00	88.00	138.00	188.00	238.00	288.00	388.00	488.00	588.00	688.00	788.00	888.00	988.00
14.696	v	0.0167	26.828		28.44	30.52	32.61	34.65	36.73	38.75	42.83	46.91	50.97	55.03	59.09	63.19	67.25
(212.00)	h	180.07	1150.4		1169.2	1192.0	1215.4	1238.9	1262.1	1285.4	1333.0	1381.4	1430.5	1480.4	1531.1	1582.7	1635.1
	s	0.3120	1.7566		1.7838	1.8148	1.8446	1.8727	1.8989	1.9238	1.9709	2.0145	2.0551	2.0932	2.1292	2.1634	2.1960
	Sh				36.97	86.97	136.97	186.97	236.97	286.97	386.97	486.97	586.97	686.97	786.97	886.97	986.97
15	v	0.0167	26.320		27.86	29.90	31.94	33.95	35.98	37.97	41.98	45.97	49.95	53.93	57.91	61.91	65.89
(213.03)	h	181.11	1150.7		1169.2	1192.0	1215.4	1238.9	1262.1	1285.4	1333.0	1381.4	1430.5	1480.4	1531.1	1582.7	1635.1
	s	0.3135	1.7548		1.7816	1.8126	1.8424	1.8705	1.8967	1.9216	1.9687	2.0123	2.0529	2.0910	2.1270	2.1612	2.1938
	Sh				22.04	72.04	122.04	172.04	222.04	272.04	372.04	472.04	572.04	672.04	772.04	872.04	972.04
20	v	0.0168	20.110		20.81	22.36	23.91	25.43	26.95	28.45	31.46	34.46	37.44	40.43	43.42	46.43	49.41
(227.96)	h	196.16	1156.1		1168.0	1191.1	1214.8	1238.4	1261.6	1285.0	1332.7	1381.2	1430.3	1480.2	1531.0	1582.6	1635.1
	s	0.3356	1.7315		1.7485	1.7799	1.8101	1.8384	1.8646	1.8896	1.9368	1.9805	2.0211	2.0592	2.0952	2.1294	2.1620
	Sh				9.93	59.93	109.93	159.93	209.93	259.93	359.93	459.93	559.93	659.93	759.93	859.93	959.93
25	v	0.0169	16.321		16.58	17.84	19.08	20.30	21.53	22.73	25.15	27.55	29.94	32.33	34.73	37.14	39.52
(240.07)	h	208.41	1160.4		1166.3	1190.2	1214.1	1237.9	1261.1	1284.6	1332.4	1381.0	1430.1	1480.0	1530.9	1582.5	1635.0
	s	0.3532	1.7137		1.7221	1.7570	1.7875	1.8160	1.8422	1.8673	1.9146	1.9584	1.9990	2.0371	2.0732	2.1074	2.1400
	Sh					49.66	99.66	149.66	199.66	249.66	349.66	449.66	549.66	649.66	749.66	849.66	949.66
30	v	0.0170	13.763			14.82	15.87	16.89	17.91	18.92	20.94	22.94	24.94	26.93	28.93	30.94	32.93
(250.34)	h	218.83	1164.0			1189.2	1213.4	1237.4	1260.6	1284.2	1332.1	1380.8	1429.9	1479.9	1530.8	1582.4	1634.9
	s	0.3680	1.6992			1.7335	1.7643	1.7930	1.8192	1.8444	1.8918	1.9357	1.9768	2.0145	2.0506	2.0848	2.1174
	Sh					40.72	90.72	140.72	190.72	240.72	340.72	440.72	540.72	640.72	740.72	840.72	940.72
35	v	0.0171	11.907			12.66	13.57	14.45	15.33	16.30	17.94	19.66	21.36	23.08	24.79	26.52	28.22
(259.28)	h	227.92	1167.0			1188.2	1212.7	1236.9	1260.1	1283.8	1331.9	1380.6	1429.8	1479.8	1530.7	1582.3	1634.8
	s	0.3807	1.6869			1.7156	1.7468	1.7758	1.8020	1.8274	1.8750	1.9189	1.9596	1.9978	2.0339	2.0681	2.1007
	Sh					32.76	82.76	132.76	182.76	232.76	332.76	432.76	532.76	632.76	732.76	832.76	932.76
40	v	0.0172	10.506			11.04	11.84	12.62	13.40	14.16	15.68	17.19	18.69	20.18	21.68	23.20	24.60
(267.24)	h	236.02	1169.7			1187.1	1211.9	1236.4	1259.6	1283.4	1331.6	1380.4	1429.6	1479.6	1530.6	1582.2	1634.8
	s	0.3919	1.6763			1.6997	1.7313	1.7606	1.7868	1.8123	1.8600	1.9040	1.9447	1.9829	2.0191	2.0533	2.0860
	Sh					25.55	75.55	125.55	175.55	225.55	325.55	425.55	525.55	625.55	725.55	825.55	925.55
45	v	0.0172	9.408			9.785	10.50	11.20	11.89	12.57	13.93	15.27	16.60	17.94	19.27	20.62	21.95
(274.45)	h	243.38	1172.0			1185.9	1211.1	1235.8	1259.1	1283.0	1331.3	1380.1	1429.4	1479.4	1530.5	1582.1	1634.7
	s	0.4019	1.6668			1.6854	1.7175	1.7471	1.7734	1.7990	1.8468	1.8908	1.9315	1.9697	2.0059	2.0401	2.0728
	Sh					18.99	68.99	118.99	168.99	218.99	318.99	418.99	518.99	618.99	718.99	818.99	918.99
50	v	0.0173	8.522			8.777	9.430	10.06	10.69	11.30	12.53	13.74	14.93	16.14	17.34	18.55	19.75
(281.01)	h	250.09	1174.0			1184.6	1210.3	1235.2	1258.6	1282.6	1331.0	1379.9	1429.3	1479.3	1530.4	1582.0	1634.6
	s	0.4110	1.6583			1.6724	1.7051	1.7349	1.7618	1.7870	1.8349	1.8790	1.9198	1.9580	1.9942	2.0284	2.0611
	Sh					12.93	62.93	112.93	162.93	212.93	312.93	412.93	512.93	612.93	712.93	812.93	912.93
55	v	0.0173	7.792			7.950	8.553	9.130	9.703	10.26	11.38	12.48	13.57	14.67	15.76	16.86	17.94
(287.07)	h	256.30	1175.8			1183.2	1209.4	1234.6	1258.2	1282.2	1330.7	1379.7	1429.1	1479.2	1530.3	1581.9	1634.5
	s	0.4193	1.6506			1.6604	1.6938	1.7240	1.7507	1.7764	1.8244	1.8685	1.9093	1.9475	1.9837	2.0179	2.0512
	Sh					7.29	57.29	107.29	157.29	207.29	307.29	407.29	507.29	607.29	707.29	807.29	907.29
60	v	0.0174	7.179			7.260	7.821	8.353	8.882	9.398	10.42	11.44	12.44	13.44	14.44	15.45	16.45
(292.71)	h	262.10	1177.5			1181.8	1208.5	1234.0	1257.7	1281.8	1330.4	1379.5	1428.9	1479.0	1530.2	1581.8	1634.4
	s	0.4271	1.6437			1.6494	1.6834	1.7139	1.7407	1.7665	1.8146	1.8588	1.8996	1.9378	1.9741	2.0083	2.0410
	Sh					2.03	52.03	102.03	152.03	202.03	302.03	402.03	502.03	602.03	702.03	802.03	902.03
65	v	0.0174	6.654			6.674	7.202	7.696	8.187	8.665	9.614	10.55	11.48	12.40	13.33	14.26	15.19
(297.97)	h	267.61	1179.1			1180.4	1207.6	1233.4	1257.2	1281.4	1330.1	1379.3	1428.8	1478.9	1530.1	1581.7	1634.4
	s	0.4342	1.6374			1.6391	1.6738	1.7047	1.7316	1.7575	1.8057	1.8500	1.8909	1.9291	1.9654	1.9996	2.0323
	Sh						47.08	97.08	147.08	197.08	297.08	397.08	497.08	597.08	697.08	797.08	897.08
70	v	0.0175	6.210				6.671	7.182	7.592	8.036	8.920	9.791	10.65	11.51	12.37	13.24	14.10
(302.92)	h	272.61	1180.5				1206.7	1232.8	1256.7	1281.0	1329.9	1379.0	1428.6	1478.7	1530.0	1581.6	1634.3
	s	0.4409	1.6314				1.6647	1.6960	1.7230	1.7490	1.7974	1.8416	1.8826	1.9208	1.9572	1.9914	2.0241
	Sh						42.40	92.40	142.40	192.40	292.40	392.40	492.40	592.40	692.40	792.40	892.40
75	v	0.0175	5.820				6.210	6.644	7.076	7.492	8.319	9.133	9.938	10.74	11.54	12.36	13.16
(307.60)	h	277.44	1181.9				1205.8	1232.2	1256.2	1280.6	1329.6	1378.8	1428.4	1478.6	1529.8	1581.5	1634.2
	s	0.4472	1.6260				1.6563	1.6879	1.7150	1.7411	1.7896	1.8339	1.8749	1.9132	1.9495	1.9837	2.0164

Sh – superheat, deg. F.
v – specific volume, cu. ft. per lb.
h – enthalpy, B.t.u. per lb.
s – entropy, B.t.u. per deg. F. per lb.

TABLE 3. SUPERHEATED STEAM—*Continued*

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	TEMPERATURE 340°	360°	DEGREES FAHRENHEIT 380°	400°	420°	450°	500°	600°	700°	800°	900°	1000°	1100°	1200°
	Sh			27.97	47.97	67.97	87.97	107.97	137.97	187.97	287.97	387.97	487.97	587.97	687.97	787.97	887.97
80	v	0.0176	5.476	5.720	5.889	6.055	6.217	6.384	6.623	7.015	7.793	8.558	9.313	10.07	10.82	11.58	12.33
(312.03)	h	282.02	1183.1	1200.0	1211.0	1221.2	1231.5	1240.3	1255.7	1280.2	1329.3	1378.5	1428.2	1478.4	1529.7	1581.4	1634.1
	s	0.4532	1.6209	1.6424	1.6560	1.6683	1.6804	1.6905	1.7077	1.7339	1.7825	1.8268	1.8679	1.9062	1.9426	1.9768	2.0095
	Sh			23.75	43.75	63.75	83.75	103.75	133.75	183.75	283.75	383.75	483.75	583.75	683.75	783.75	883.75
85	v	0.0176	5.169	5.368	5.528	5.685	5.839	5.995	6.226	6.594	7.329	8.050	8.762	9.472	10.18	10.90	11.61
(316.25)	h	286.40	1184.3	1198.5	1210.0	1220.5	1230.7	1239.7	1255.1	1279.7	1329.0	1378.3	1428.0	1478.2	1529.6	1581.3	1634.0
	s	0.4587	1.6150	1.6339	1.6481	1.6608	1.6728	1.6831	1.7003	1.7266	1.7754	1.8198	1.8609	1.8992	1.9357	1.9699	2.0026
	Sh			19.73	39.73	59.73	79.73	99.73	129.73	179.73	279.73	379.73	479.73	579.73	679.73	770.73	879.73
90	v	0.0177	4.898	5.055	5.208	5.357	5.504	5.653	5.869	6.220	6.916	7.599	8.272	8.943	9.626	10.29	10.96
(320.27)	h	290.57	1185.4	1197.3	1209.0	1219.8	1230.0	1239.1	1254.5	1279.3	1328.7	1378.1	1427.9	1478.1	1529.5	1581.2	1634.0
	s	0.4641	1.6113	1.6264	1.6408	1.6538	1.6658	1.6763	1.6935	1.7200	1.7689	1.8134	1.8546	1.8929	1.9294	1.9636	1.9964
	Sh			15.87	35.87	55.87	75.87	95.87	125.87	175.87	275.87	375.87	475.87	375.87	675.87	775.87	875.87
95	v	0.0177	4.653	4.773	4.921	5.063	5.205	5.346	5.552	5.886	6.547	7.195	7.834	8.481	9.117	9.751	10.38
(324.13)	h	294.58	1186.4	1196.0	1208.0	1219.0	1229.3	1238.6	1254.0	1278.9	1328.4	1377.8	1427.7	1478.0	1529.4	1581.1	1633.9
	s	0.4692	1.6070	1.6191	1.6339	1.6472	1.6593	1.6700	1.6872	1.7138	1.7628	1.8073	1.8485	1.8869	1.9234	1.9576	1.9904
	Sh			12.17	32.17	52.17	72.17	92.17	122.17	172.17	272.17	372.17	472.17	572.17	672.17	772.17	872.17
100	v	0.0177	4.433	4.520	4.663	4.801	4.936	5.070	5.266	5.589	6.217	6.836	7.448	8.055	8.659	9.262	9.862
(327.83)	h	298.43	1187.3	1194.9	1207.0	1218.3	1228.4	1238.6	1253.7	1278.6	1327.9	1377.5	1427.5	1478.0	1529.2	1581.0	1633.7
	s	0.4741	1.6028	1.6124	1.6273	1.6409	1.6528	1.6645	1.6814	1.7080	1.7568	1.8015	1.8428	1.8814	1.9177	1.9520	1.9847
	Sh			8.62	28.62	48.62	68.62	88.62	118.62	168.62	263.62	368.62	468.62	568.62	668.62	768.62	868.62
105	v	0.0178	4.232	4.292	4.429	4.562	4.691	4.820	5.007	5.316	5.916	6.507	7.090	7.670	8.245	8.819	9.391
(331.38)	h	302.13	1188.2	1193.5	1205.9	1217.2	1227.6	1237.5	1252.9	1278.0	1327.6	1377.4	1427.3	1477.7	1529.2	1580.9	1633.7
	s	0.4787	1.5988	1.6055	1.6208	1.6344	1.6466	1.6580	1.6752	1.7020	1.7511	1.7960	1.8372	1.8757	1.9122	1.9464	1.9791
	Sh			5.21	25.21	45.21	65.21	85.21	115.21	165.21	265.21	365.21	465.21	565.21	665.21	765.21	865.21
110	v	0.0178	4.050	4.084	4.217	4.345	4.469	4.592	4.773	5.069	5.643	6.208	6.765	7.319	7.869	8.417	8.963
(334.79)	h	305.69	1189.0	1192.2	1204.9	1216.4	1226.9	1236.9	1252.4	1277.5	1327.4	1377.1	1427.1	1477.5	1529.1	1580.8	1633.6
	s	0.4832	1.5950	1.5990	1.6147	1.6286	1.6410	1.6525	1.6698	1.6966	1.7460	1.7908	1.8321	1.8706	1.9072	1.9414	1.9742
	Sh				21.92	41.92	61.92	81.92	111.92	161.92	261.92	361.92	461.92	561.92	661.92	761.92	861.92
115	v	0.0179	3.882		4.022	4.146	4.266	4.384	4.558	4.843	5.393	5.935	6.469	6.999	7.525	8.049	8.572
(338.08)	h	309.13	1189.8		1203.8	1215.6	1226.2	1236.3	1251.9	1277.1	1327.1	1376.9	1427.0	1477.4	1528.9	1580.7	1633.6
	s	0.4875	1.5915		1.6088	1.6230	1.6355	1.6471	1.6645	1.6915	1.7410	1.7859	1.8273	1.8658	1.9023	1.9366	1.9695
	Sh				18.74	38.74	58.74	78.74	108.74	158.74	258.74	358.74	458.74	558.74	658.74	758.74	858.74
120	v	0.0179	3.728		3.845	3.963	4.079	4.194	4.361	4.635	5.165	5.685	6.197	6.705	7.210	7.718	8.215
(341.26)	h	312.46	1190.6		1202.7	1214.7	1225.4	1235.7	1251.4	1276.7	1326.8	1376.7	1426.8	1477.2	1528.8	1580.6	1633.5
	s	0.4916	1.5879		1.6028	1.6173	1.6299	1.6417	1.6592	1.6863	1.7359	1.7809	1.8223	1.8608	1.8974	1.9317	1.9646
	Sh				15.66	35.66	55.66	75.66	105.66	155.66	255.66	355.66	455.66	555.66	655.66	755.66	855.66
125	v	0.0179	3.586		3.680	3.796	3.908	4.019	4.181	4.445	4.954	5.454	5.947	6.435	6.920	7.403	7.885
(344.34)	h	315.69	1191.3		1201.6	1213.7	1224.5	1235.0	1250.8	1276.3	1326.5	1376.4	1426.6	1477.1	1528.7	1580.5	1633.4
	s	0.4956	1.5846		1.5973	1.6119	1.6246	1.6367	1.6544	1.6817	1.7314	1.7764	1.8179	1.8565	1.8931	1.9274	1.9603
	Sh				12.69	32.69	52.69	72.69	102.69	152.69	252.69	352.69	452.69	552.69	652.69	752.69	852.69
130	v	0.0180	3.455		3.528	3.641	3.750	3.857	4.013	4.268	4.760	5.242	5.716	6.186	6.653	7.117	7.581
(347.31)	h	318.81	1192.0		1200.4	1212.7	1223.6	1234.3	1250.3	1275.8	1326.1	1376.1	1426.4	1476.9	1528.6	1580.4	1633.3
	s	0.4995	1.5815		1.5918	1.6066	1.6194	1.6317	1.6496	1.6760	1.7267	1.7718	1.8134	1.8520	1.8887	1.9230	1.9559
	Sh				9.79	29.79	49.79	69.79	99.79	149.79	249.79	349.79	449.79	549.79	649.79	749.79	849.79
135	v	0.0180	3.333		3.388	3.497	3.603	3.707	3.859	4.105	4.580	5.045	5.502	5.955	6.405	6.853	7.303
(350.21)	h	321.86	1192.7		1199.2	1211.7	1222.7	1233.6	1249.7	1275.4	1325.8	1375.9	1426.2	1476.8	1528.5	1580.3	1633.2
	s	0.5032	1.5784		1.5864	1.6015	1.6144	1.6269	1.6449	1.6724	1.7223	1.7674	1.8090	1.8476	1.8843	1.9186	1.9515
	Sh				6.97	26.97	46.97	66.97	96.97	146.97	246.97	346.97	446.97	546.97	646.97	746.97	846.97
140	v	0.0180	3.220		3.258	3.364	3.467	3.567	3.715	3.954	4.413	4.862	5.303	5.741	6.175	6.607	7.037
(353.03)	h	324.83	1193.3		1198.0	1210.6	1221.8	1232.9	1249.1	1275.0	1325.5	1375.7	1426.0	1476.6	1528.4	1580.2	1633.2
	s	0.5069	1.5755		1.5813	1.5965	1.6097	1.6225	1.6406	1.6683	1.7183	1.7635	1.8051	1.8437	1.8804	1.9147	1.9476
	Sh				4.24	24.24	44.24	64.24	94.24	144.24	244.24	344.24	444.24	544.24	644.24	744.24	844.24
145	v	0.0181	3.114		3.136	3.240	3.340	3.438	3.581	3.812	4.257	4.692	5.119	5.541	5.961	6.378	6.794
(355.76)	h	327.71	1193.9		1196.7	1209.5	1220.9	1232.2	1248.5	1274.5	1325.1	1375.4	1425.8	1476.5	1528.3	1580.1	1633.1
	s	0.5104	1.5726		1.5760	1.5914	1.6048	1.6178	1.6360	1.6638	1.7139	1.7592	1.8009	1.8396	1.8763	1.9106	1.9435
	Sh					21.57	41.57	61.57	91.57	141.57	241.57	341.57	441.57	541.57	641.57	741.57	841.57
150	v	0.0181	3.016			3.124	3.221	3.317	3.456	3.681	4.112	4.533	4.946	5.355	5.761	6.164	6.567
(358.43)	h	330.53	1194.4			1208.4	1220.0	1231.4	1248.0	1274.1	1324.9	1375.1	1425.6	1476.3	1528.1	1580.0	1633.0
	s	0.5138	1.5698			1.5865	1.6002	1.6133	1.6319	1.6598	1.7101	1.7553	1.7970	1.8357	1.8724	1.9068	1.9397
	Sh					18.98	38.98	58.98	88.98	138.98	238.98	338.98	438.98	538.98	638.98	738.98	838.98
155	v	0.0181	2.921			3.015	3.110	3.203	3.340	3.558	3.976	4.384	4.785	5.181	5.574	5.964	6.354
(361.02)	h	333.27	1195.0			1207.2	1219.1	1230.7	1247.5	1273.6	1324.5	1374.9	1425.4	1476.2	1528.0	1579.9	1632.9
	s	0.5172	1.5671			1.5818	1.5958	1.6091	1.6279	1.6558	1.7062	1.7516	1.7933	1.8321	1.8688	1.9032	1.9361
	Sh					16.45	36.45	56.45	86.45	136.45	236.45	336.45	436.45	536.45	636.45	736.45	836.45
160	v	0.0182	2.834			2.913	3.006	3.097	3.230	3.443	3.849	4.245	4.633	5.018	5.398	5.777	6.154
(363.55)	h	335.95	1195.5			1206.0	1218.3	1230.0	1246.9	1273.2	1324.1	1374.7	1425.2	1476.0	1527.9	1579.8	1632.8
	s	0.5204	1.5646			1.5772	1.5917	1.6052	1.6241	1.6622	1.7026	1.7482	1.7809	1.8287	1.8655	1.8999	1.9328

Sh = superheat, deg. F.
v = specific volume, cu. ft. per lb.
h = enthalpy, B.t.u. per lb.
s = entropy, B.t.u. per deg. F. per lb.

TABLE 3. SUPERHEATED STEAM—*Continued*

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	400°	420°	440°	460°	480°	500°	550°	600°	700°	800°	900°	1000°	1100°	1200°
	Sh			33.99	53.99	73.99	93.99	113.99	133.99	183.99	233.99	333.99	433.99	533.99	633.99	733.99	833.99
165	v	0.0182	2.752	2.909	2.997	3.084	3.170	3.251	3.334	3.533	3.729	4.114	4.491	4.864	5.234	5.601	5.967
(366.01)	h	338.55	1195.9	1217.4	1229.3	1241.1	1251.8	1262.4	1272.8	1298.5	1323.8	1374.5	1425.0	1475.9	1527.8	1579.7	1632.7
	s	0.5236	1.5619	1.5874	1.6011	1.6144	1.6262	1.6376	1.6486	1.6747	1.6991	1.7448	1.7865	1.8254	1.8622	1.8966	1.9295
	Sh			31.58	51.58	71.58	91.58	111.58	131.58	181.58	231.58	331.58	431.58	531.58	631.58	731.58	831.58
170	v	0.0182	2.674	2.816	2.903	2.988	3.071	3.151	3.232	3.426	3.617	3.991	4.357	4.720	5.079	5.436	5.791
(368.42)	h	341.11	1196.3	1216.5	1228.4	1240.5	1251.3	1261.8	1272.3	1298.2	1323.5	1374.2	1424.9	1475.7	1527.6	1579.6	1632.7
	s	0.5266	1.5593	1.5832	1.5969	1.6105	1.6224	1.6337	1.6448	1.6711	1.6955	1.7412	1.7831	1.8219	1.8587	1.8931	1.9261
	Sh			29.23	49.23	69.23	89.23	109.23	129.23	179.23	229.23	329.23	429.23	529.23	629.23	729.23	829.23
175	v	0.0182	2.601	2.730	2.814	2.897	2.979	3.057	3.136	3.325	3.510	3.875	4.231	4.584	4.932	5.279	5.625
(370.77)	h	343.61	1196.7	1215.6	1227.6	1239.9	1250.8	1261.3	1271.9	1297.8	1323.2	1374.0	1424.7	1475.6	1527.5	1579.5	1632.6
	s	0.5296	1.5569	1.5793	1.5931	1.6069	1.6189	1.6302	1.6414	1.6677	1.6922	1.7380	1.7799	1.8185	1.8553	1.8897	1.9227
	Sh			26.92	46.92	66.92	86.92	106.92	126.92	176.92	226.92	326.92	426.92	526.92	626.92	726.92	826.92
180	v	0.0183	2.532	2.648	2.731	2.812	2.892	2.968	3.045	3.229	3.410	3.765	4.112	4.455	4.794	5.132	5.466
(373.08)	h	346.07	1197.2	1214.6	1226.8	1239.2	1250.2	1260.3	1271.5	1297.4	1322.8	1373.7	1424.5	1475.5	1527.4	1579.4	1632.[illegible]
	s	0.5325	1.5545	1.5751	1.5891	1.6030	1.6151	1.6265	1.6378	1.6641	1.6886	1.7345	1.7765	1.8154	1.8522	1.8866	1.919[illegible]
	Sh			24.66	44.66	64.66	84.66	104.66	124.66	174.66	224.66	324.66	424.66	524.66	624.66	724.66	824.66
185	v	0.0183	2.466	2.570	2.651	2.731	2.809	2.884	2.958	3.139	3.315	3.661	3.999	4.333	4.664	4.992	5.31[illegible]
(375.34)	h	348.47	1197.6	1213.7	1226.0	1238.4	1249.6	1260.3	1271.0	1297.4	1323.4	1373.4	1424.3	1475.3	1527.3	1579.3	1632.4
	s	0.5354	1.5522	1.5712	1.5853	1.5992	1.6115	1.6230	1.6343	1.6611	1.6853	1.7312	1.7733	1.8122	1.8491	1.8835	1.916[illegible]
	Sh			22.45	42.45	62.45	82.45	102.45	122.45	172.45	222.45	322.45	422.45	522.45	622.45	722.45	822.45
190	v	0.0183	2.404	2.496	2.576	2.654	2.731	2.804	2.877	3.053	3.225	3.563	3.893	4.218	4.540	4.860	5.179
(377.55)	h	350.83	1198.0	1212.7	1225.1	1237.7	1249.0	1259.8	1270.5	1296.6	1322.1	1373.1	1424.1	1475.2	1527.1	1579.2	1632.3
	s	0.5382	1.5501	1.5674	1.5817	1.5959	1.6083	1.6199	1.6312	1.6577	1.6823	1.7282	1.7703	1.8093	1.8461	1.8806	1.9134
	Sh			20.30	40.30	60.30	80.30	100.30	120.30	170.30	220.30	320.30	420.30	520.30	620.30	720.30	820.30
195	v	0.0184	2.344	2.426	2.505	2.581	2.656	2.728	2.799	2.972	3.140	3.470	3.791	4.109	4.423	4.735	5.046
(379.70)	h	353.18	1198.4	1211.7	1224.2	1237.0	1248.3	1259.3	1270.0	1296.2	1321.8	1372.9	1423.9	1475.0	1527.0	1579.1	1632.2
	s	0.5409	1.5479	1.5636	1.5780	1.5924	1.6048	1.6166	1.6279	1.6545	1.6792	1.7252	1.7673	1.8063	1.8432	1.8777	1.9167
	Sh			18.18	38.18	58.18	78.18	98.18	118.18	168.18	218.18	318.18	418.18	518.18	618.18	718.18	818.18
200	v	0.0184	2.288	2.360	2.437	2.512	2.585	2.656	2.726	2.895	3.058	3.381	3.697	4.005	4.311	4.616	4.919
(381.82)	h	355.40	1198.7	1210.8	1223.7	1236.3	1247.9	1258.7	1269.4	1295.6	1321.4	1372.5	1423.9	1474.9	1526.6	1579.0	1632.1
	s	0.5436	1.5457	1.5599	1.5748	1.5889	1.6017	1.6133	1.6245	1.6511	1.6761	1.7221	1.7646	1.8035	1.8402	1.8749	1.9079
	Sh			16.11	36.11	56.11	76.11	96.11	116.11	166.11	216.11	316.11	416.11	516.11	616.11	716.11	816.11
205	v	0.0184	2.235	2.297	2.373	2.446	2.518	2.587	2.656	2.821	2.982	3.297	3.604	3.906	4.205	4.502	4.798
(383.89)	h	357.61	1199.0	1209.7	1222.5	1235.4	1247.1	1258.2	1269.0	1295.4	1321.0	1372.4	1423.5	1474.7	1526.8	1578.9	1632.1
	s	0.5462	1.5436	1.5562	1.5709	1.5854	1.5983	1.6102	1.6216	1.6484	1.6731	1.7194	1.7616	1.8007	1.8377	1.8722	1.9052
	Sh			14.07	34.07	54.07	74.07	94.07	114.07	164.07	214.07	314.07	414.07	514.07	614.07	714.07	814.07
210	v	0.0184	2.183	2.237	2.311	2.384	2.454	2.522	2.589	2.751	2.909	3.216	3.516	3.812	4.104	4.395	4.683
(385.93)	h	359.80	1199.4	1208.8	1221.8	1234.7	1246.5	1257.7	1268.5	1295.0	1320.7	1372.1	1423.3	1474.6	1526.6	1578.8	1632.0
	s	0.5488	1.5417	1.5527	1.5676	1.5821	1.5951	1.6071	1.6185	1.6454	1.6702	1.7165	1.7588	1.7980	1.8349	1.8695	1.9025
	Sh			12.07	32.07	52.07	72.07	92.07	112.07	162.07	212.07	312.07	412.07	512.07	612.07	712.07	812.07
215	v	0.0185	2.134	2.179	2.252	2.324	2.393	2.460	2.526	2.685	2.839	3.140	3.433	3.722	4.008	4.292	4.574
(387.93)	h	301.95	1199.6	1207.8	1221.0	1234.0	1245.9	1257.2	1268.0	1294.6	1320.4	1371.9	1423.1	1474.4	1526.5	1578.7	1631.9
	s	0.5513	1.5395	1.5491	1.5643	1.5789	1.5920	1.6042	1.6156	1.6426	1.6675	1.7139	1.7562	1.7954	1.8324	1.8670	1.9000
	Sh			10.11	30.11	50.11	70.11	90.11	110.11	160.11	210.11	310.11	410.11	510.11	610.11	710.11	810.11
220	v	0.0185	2.086	2.124	2.196	2.267	2.335	2.400	2.465	2.621	2.772	3.067	3.354	3.637	3.916	4.193	4.469
(389.89)	h	364.05	1199.9	1206.8	1220.1	1233.2	1245.2	1256.7	1267.5	1294.1	1320.0	1371.6	1422.9	1474.2	1526.4	1578.6	1631.8
	s	0.5538	1.5376	1.5457	1.5610	1.5757	1.5889	1.6013	1.6127	1.6397	1.6647	1.7112	1.7536	1.7928	1.8298	1.8644	1.8974
	Sh			8.19	28.19	48.19	68.19	88.19	108.19	158.19	208.19	308.19	408.19	508.19	608.19	708.19	808.19
225	v	0.0185	2.042	2.072	2.142	2.212	2.279	2.344	2.407	2.560	2.708	2.997	3.278	3.555	3.828	4.100	4.369
(391.81)	h	366.11	1200.2	1205.8	1219.2	1232.3	1244.5	1256.2	1267.1	1293.7	1319.6	1371.4	1422.7	1474.1	1526.3	1578.5	1631.7
	s	0.5562	1.5358	1.5423	1.5577	1.5724	1.5858	1.5984	1.6099	1.6369	1.6619	1.7086	1.7510	1.7902	1.8272	1.8618	1.8948
	Sh			6.30	26.30	46.30	66.30	86.30	106.30	156.30	206.30	306.30	406.30	506.30	606.30	706.30	806.30
230	v	0.0186	1.9989	2.021	2.091	2.160	2.226	2.289	2.352	2.502	2.647	2.930	3.205	3.477	3.744	4.010	4.274
(393.70)	h	368.16	1200.4	1204.9	1218.3	1231.6	1243.8	1255.6	1266.7	1293.3	1319.3	1371.1	1422.5	1474.0	1526.2	1578.4	1631.6
	s	0.5585	1.5337	1.5390	1.5544	1.5693	1.5827	1.5954	1.6071	1.6341	1.6592	1.7059	1.7484	1.7877	1.8247	1.8593	1.8923
	Sh			4.44	24.44	44.44	64.44	84.44	104.44	154.44	204.44	304.44	404.44	504.44	604.44	704.44	804.44
235	v	0.0186	1.9573	1.973	2.042	2.110	2.175	2.237	2.298	2.446	2.589	2.866	3.136	3.402	3.664	3.924	4.182
(395.56)	h	370.17	1200.7	1203.9	1217.5	1230.8	1243.2	1255.0	1266.2	1292.9	1319.0	1370.9	1422.3	1473.8	1526.0	1578.3	1631.6
	s	0.5609	1.5320	1.5357	1.5513	1.5662	1.5798	1.5925	1.6043	1.6314	1.6566	1.7034	1.7459	1.7852	1.8222	1.8568	1.8899
	Sh				22.60	42.60	62.60	82.60	102.60	152.60	202.60	302.60	402.60	502.60	602.60	702.60	802.60
240	v	0.0186	1.9176		1.995	2.062	2.126	2.187	2.247	2.392	2.532	2.805	3.069	3.330	3.586	3.841	4.095
(397.40)	h	372.16	1200.9		1216.6	1230.0	1242.5	1254.4	1265.7	1292.5	1318.6	1370.5	1422.1	1473.6	1525.9	1578.2	1631.5
	s	0.5632	1.5301		1.5482	1.5633	1.5770	1.5898	1.6017	1.6289	1.6541	1.7000	1.7435	1.7828	1.8199	1.8545	1.8876
	Sh				20.80	40.80	60.80	80.80	100.80	150.80	200.80	300.80	400.80	500.80	600.80	700.80	800.80
245	v	0.0186	1.8797		1.950	2.015	2.078	2.139	2.198	2.341	2.479	2.746	3.006	3.261	3.513	3.762	4.011
(399.20)	h	374.11	1201.1		1215.6	1229.1	1241.8	1253.8	1265.2	1292.0	1318.3	1370.3	1421.9	1473.5	1525.8	1578.1	1631.4
	s	0.5654	1.5283		1.5450	1.5602	1.5742	1.5871	1.5991	1.6263	1.6517	1.6985	1.7411	1.7805	1.8176	1.8522	1.8853

Sh = superheat, deg. F.
v = specific volume, cu. ft. per lb.
h = enthalpy, B.t.u. per lb.
s = entropy, B.t.u. per deg. F. per lb.

TABLE 3. SUPERHEATED STEAM—*Continued*

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	Temperature—Degrees Fahrenheit 420°	440°	460°	480°	500°	520°	550°	600°	700°	800°	900°	1000°	1100°	1200°
	Sh			19.03	39.03	59.03	79.03	99.03	119.03	149.03	199.03	299.03	399.03	499.03	599.03	699.03	799.03
250	v	0.0187	1.8431	1.9065	1.9711	2.0334	2.0932	2.1515	2.2085	2.2920	2.4272	2.6897	2.9444	3.1949	3.4416	3.6867	3.9299
(400.97)	h	376.04	1201.4	1214.8	1228.3	1241.0	1253.2	1264.7	1274.5	1291.6	1317.9	1370.0	1421.7	1473.3	1525.6	1578.0	1631.3
	s	0.5677	1.5267	1.5419	1.5573	1.5713	1.5844	1.5965	1.6066	1.6238	1.6492	1.6961	1.7388	1.7782	1.8153	1.8500	1.8831
	Sh			17.29	37.29	57.29	77.29	97.29	117.29	147.29	197.29	297.29	397.29	497.29	597.29	697.29	797.29
255	v	0.0187	1.8079	1.8686	1.9286	1.9899	2.0489	2.1065	2.1626	2.2447	2.3776	2.6354	2.8855	3.1313	3.3733	3.6138	3.8524
(402.71)	h	377.91	1201.6	1213.7	1227.5	1240.3	1252.6	1264.2	1274.2	1291.2	1317.5	1369.8	1421.5	1473.2	1525.5	1577.9	1631.2
	s	0.5698	1.5249	1.5388	1.5543	1.5684	1.5816	1.5938	1.6041	1.6212	1.6466	1.6937	1.7364	1.7759	1.8130	1.8477	1.8808
	Sh			15.57	35.57	55.57	75.57	95.57	115.57	145.57	195.57	295.57	395.57	495.57	595.57	695.57	795.57
260	v	0.0187	1.7742	1.8246	1.8876	1.9482	2.0063	2.0631	2.1185	2.1991	2.3290	2.5833	2.8289	3.0701	3.3077	3.5437	3.7778
(404.43)	h	379.78	1201.8	1212.8	1226.6	1239.5	1252.0	1263.6	1273.8	1290.8	1317.1	1369.5	1421.3	1473.0	1525.4	1577.8	1631.1
	s	0.5720	1.5233	1.5359	1.5514	1.5656	1.5790	1.5912	1.6017	1.6188	1.6442	1.6914	1.7342	1.7737	1.8109	1.8456	1.8787
	Sh			13.88	33.88	53.88	73.88	93.88	113.88	143.88	193.88	293.88	393.88	493.88	593.88	693.88	793.88
265	v	0.0187	1.7416	1.7858	1.8481	1.9080	1.9654	2.0213	2.0759	2.1554	2.2840	2.5331	2.7744	3.0114	3.2446	3.4761	3.7061
(406.12)	h	381.62	1202.0	1211.9	1225.7	1238.7	1251.2	1263.0	1273.4	1290.4	1316.8	1369.3	1421.1	1472.9	1525.3	1577.7	1631.1
	s	0.5741	1.5217	1.5330	1.5485	1.5628	1.5762	1.5886	1.5993	1.6164	1.6419	1.6892	1.7320	1.7715	1.8087	1.8434	1.8765
	Sh			12.21	32.21	52.21	72.21	92.21	112.21	142.21	192.21	292.21	392.21	492.21	592.21	692.21	792.21
270	v	0.0188	1.7101	1.7486	1.8101	1.8692	1.9259	1.9810	2.0350	2.1131	2.2399	2.4847	2.7219	2.9548	3.1838	3.4112	3.6370
(407.79)	h	383.43	1202.2	1211.0	1224.9	1238.0	1250.6	1262.5	1273.0	1290.0	1316.4	1369.0	1420.9	1472.7	1525.1	1577.6	1631.0
	s	0.5761	1.5200	1.5301	1.5457	1.5601	1.5736	1.5861	1.5969	1.6140	1.6395	1.6869	1.7298	1.7693	1.8065	1.8413	1.8744
	Sh			10.56	30.56	50.56	70.56	90.56	110.56	140.56	190.56	290.56	390.56	490.56	590.56	690.56	790.56
275	v	0.0188	1.6798	1.7127	1.7735	1.8318	1.8879	1.9422	1.9956	2.0725	2.1973	2.4382	2.6714	2.9002	3.1253	3.3486	3.5704
(409.44)	h	385.22	1202.3	1210.0	1224.1	1237.3	1250.0	1262.0	1272.6	1289.5	1316.1	1368.7	1420.7	1472.6	1525.0	1577.5	1630.9
	s	0.5782	1.5183	1.5271	1.5429	1.5574	1.5711	1.5837	1.5946	1.6116	1.6373	1.6847	1.7277	1.7673	1.8045	1.8393	1.8724
	Sh			8.94	28.94	48.94	68.94	88.94	108.94	138.94	188.94	288.94	388.94	488.94	588.94	688.94	788.94
280	v	0.0188	1.6504	1.6780	1.7381	1.7957	1.8512	1.9048	1.9575	2.0334	2.1562	2.3932	2.6226	2.8475	3.0688	3.2883	3.5062
(411.06)	h	386.99	1202.5	1209.0	1223.2	1236.5	1249.4	1261.5	1272.2	1289.1	1315.7	1368.5	1420.5	1472.4	1524.9	1577.4	1630.8
	s	0.5802	1.5167	1.5241	1.5401	1.5547	1.5686	1.5813	1.5923	1.6093	1.6350	1.6826	1.7256	1.7652	1.8024	1.8372	1.8703
	Sh			7.34	27.34	47.34	67.34	87.34	107.34	137.34	187.34	287.34	387.34	487.34	587.34	687.34	787.34
285	v	0.0188	1.6232	1.6446	1.7040	1.7610	1.8157	1.8687	1.9207	1.9955	2.1165	2.3499	2.5756	2.7968	3.0143	3.2300	3.4443
(412.66)	h	388.74	1202.7	1208.0	1222.3	1235.6	1248.7	1260.9	1271.8	1288.6	1315.4	1368.2	1420.3	1472.2	1524.7	1577.3	1630.7
	s	0.5822	1.5153	1.5214	1.5375	1.5521	1.5662	1.5790	1.5902	1.6071	1.6330	1.6806	1.7237	1.7633	1.8005	1.8353	1.8684
	Sh			5.76	25.76	45.76	65.76	85.76	105.76	135.76	185.76	285.76	385.76	485.76	585.76	685.76	785.76
290	v	0.0189	1.5947	1.6122	1.6710	1.7273	1.7815	1.8338	1.8853	1.9590	2.0783	2.3060	2.5302	2.7478	2.9616	3.1738	3.3844
(414.24)	h	390.47	1202.9	1207.0	1221.4	1234.8	1248.0	1260.4	1271.4	1288.2	1315.0	1367.9	1420.1	1472.1	1524.6	1577.2	1630.6
	s	0.5841	1.5137	1.5184	1.5346	1.5493	1.5635	1.5766	1.5879	1.6048	1.6307	1.6784	1.7215	1.7612	1.7984	1.8332	1.8663
	Sh			4.20	24.20	44.20	64.20	84.20	104.20	134.20	184.20	284.20	384.20	484.20	584.20	684.20	784.20
295	v	0.0189	1.5684	1.5800	1.6391	1.6948	1.7484	1.8001	1.8510	1.9236	2.0413	2.2677	2.4863	2.7004	2.9108	3.1195	3.3[illegible]
(415.80)	h	392.17	1203.0	1206.1	1220.5	1234.0	1247.4	1259.8	1271.0	1287.8	1314.7	1367.6	1419.9	1472.0	1524.5	1577.1	1630.[illegible]
	s	0.5861	1.5122	1.5157	1.5319	1.5467	1.5611	1.5742	1.5857	1.6026	1.6286	1.6763	1.7195	1.7593	1.7965	1.8313	1.864[illegible]
	Sh			2.67	22.67	42.67	62.67	82.67	102.67	132.67	182.67	282.67	382.67	482.67	582.67	682.67	782.6[illegible]
300	v	0.0189	1.5426	1.5506	1.6082	1.6634	1.7164	1.7677	1.8172	1.8896	2.0056	2.2286	2.4447	2.6547	2.8634	3.0670	3.270[illegible]
(417.33)	h	393.85	1203.2	1205.2	1219.5	1233.4	1246.6	1259.2	1270.5	1287.4	1314.4	1367.4	1419.7	1471.8	1524.4	1577.0	1630.[illegible]
	s	0.5879	1.5107	1.5130	1.5291	1.5443	1.5585	1.5718	1.5834	1.6004	1.6265	1.6742	1.7175	1.7572	1.7945	1.8294	1.862[illegible]
	Sh				19.65	39.65	59.65	79.65	99.65	129.65	179.65	279.65	379.65	479.65	579.65	679.65	779.6[illegible]
310	v	0.0189	1.4938		1.5495	1.6036	1.6555	1.7054	1.7546	1.8246	1.9375	2.1541	2.3631	2.5675	2.7682	2.9671	3.164[illegible]
(420.35)	h	397.16	1203.5		1217.8	1231.5	1245.3	1258.0	1269.6	1286.4	1313.5	1366.9	1419.3	1471.5	1524.1	1576.8	1630[illegible]
	s	0.5917	1.5079		1.5240	1.5391	1.5539	1.5673	1.5793	1.5962	1.6224	1.6705	1.7138	1.7536	1.7909	1.8258	1.859[illegible]
	Sh				16.71	36.71	56.71	76.71	96.71	126.71	176.71	276.71	376.71	476.71	576.71	676.71	776.7[illegible]
320	v	0.0190	1.4479		1.4943	1.5473	1.5982	1.6472	1.6954	1.7637	1.8737	2.0644	2.2874	2.4857	2.6804	2.8735	3.064[illegible]
(423.29)	h	400.40	1203.8		1216.0	1229.9	1244.0	1256.8	1268.6	1285.6	1312.8	1366.3	1418.9	1471.2	1523.8	1576.6	1630[illegible]
	s	0.5953	1.5052		1.5189	1.5342	1.5494	1.5629	1.5751	1.5922	1.6185	1.6667	1.7102	1.7501	1.7874	1.8224	1.855[illegible]
	Sh				13.84	33.84	53.84	73.84	93.84	123.84	173.84	273.84	373.84	473.84	573.84	673.84	773.[illegible]
330	v	0.0190	1.4048		1.4424	1.4944	1.5445	1.5925	1.6397	1.7064	1.8138	2.0189	2.2163	2.4090	2.5981	2.7855	2.97[illegible]
(426.16)	h	403.56	1204.0		1214.1	1228.2	1242.5	1255.5	1267.6	1284.7	1312.1	1365.8	1418.4	1470.8	1523.6	1576.4	1630[illegible]
	s	0.5988	1.5028		1.5136	1.5291	1.5445	1.5582	1.5707	1.5879	1.6144	1.6628	1.7063	1.7463	1.7837	1.8187	1.852[illegible]
	Sh				11.04	31.04	51.04	71.04	91.04	121.04	171.04	271.04	371.04	471.04	571.04	671.04	771.04
340	v	0.0191	1.3640		1.3935	1.4446	1.4936	1.5409	1.5872	1.6525	1.7573	1.9572	2.1498	2.3368	2.5206	2.7027	2.8[illegible]
(428.96)	h	406.65	1204.2		1212.2	1226.5	1241.0	1254.2	1266.6	1283.8	1311.4	1365.2	1418.0	1470.5	1523.3	1576.2	[illegible]
	s	0.6023	1.4997		1.5086	1.5243	1.5399	1.5538	1.5666	1.5839	1.6106	1.6591	1.7027	1.7428	1.7802	1.8152	1.848[illegible]
	Sh				8.29	28.29	48.29	68.29	88.29	118.29	168.29	268.29	368.29	468.29	568.29	668.29	768.[illegible]
350	v	0.0191	1.3255		1.3472	1.3976	1.4460	1.4923	1.5377	1.6016	1.7041	1.8991	2.0863	2.2687	2.4475	2.6246	[illegible]
(431.71)	h	409.70	1204.4		1210.3	1224.8	1239.5	1252.9	1265.5	1282.9	1310.6	1364.7	1417.6	1470.2	1523.0	1576.0	[illegible]
	s	0.6057	1.4972		1.5038	1.5197	1.5355	1.5496	1.5626	1.5801	1.6069	1.6556	1.6993	1.7395	1.7769	1.8120	[illegible]
	Sh				5.61	25.61	45.61	65.61	85.61	115.61	165.61	265.61	365.61	465.61	565.61	665.61	76[illegible]
360	v	0.0192	1.2889		1.3085	1.3532	1.4008	1.4463	1.4909	1.5536	1.6538	1.8441	2.0266	2.2044	2.3784	2.5506	2.72[illegible]
(434.39)	h	412.67	1204.5		1208.5	1223.1	1238.0	1251.5	1264.5	1282.0	1309.9	1364.1	1417.2	1469.9	1522.8	1575.8	[illegible]
	s	0.6090	1.4946		1.4991	1.5151	1.5311	1.5453	1.5587	1.5763	1.6033	1.6521	1.6960	1.7362	1.7737	1.8068	[illegible]

Sh = superheat, deg. F.
v = specific volume, cu. ft. per lb.
h = enthalpy, B.t.u. per lb.
s = entropy, B.t.u. per deg. F. per lb.

TABLE 3. SUPERHEATED STEAM—*Continued*

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	Temperature—Degrees Fahrenheit 460°	480°	500°	520°	540°	560°	580°	600°	700°	800°	900°	1000°	1100°	1200°
	Sh			22.99	42.99	62.99	82.99	102.99	122.99	142.99	162.99	262.99	362.99	462.99	562.99	662.99	762.99
370	v	0.0192	1.2545	1.3111	1.3579	1.4028	1.4466	1.4881	1.5286	1.5675	1.6063	1.7921	1.9703	2.1435	2.3131	2.4809	2.6471
(437.01)	h	415.58	1204.6	1221.4	1236.5	1250.2	1263.4	1275.2	1286.7	1298.3	1309.1	1363.6	1410.8	1469.6	1522.5	1575.6	[illegible]
	s	0.6122	1.4921	1.5106	1.5268	1.5412	1.5548	1.5667	1.5781	1.5894	1.5997	1.6488	1.6928	1.7331	1.7706	1.8058	[illegible]
	Sh			20.41	40.41	60.41	80.41	100.41	120.41	140.41	160.41	260.41	360.41	460.41	560.41	660.41	760.41
380	v	0.0193	1.2217	1.2711	1.3173	1.3614	1.4045	1.4452	1.4850	1.5232	1.5612	1.7428	1.9168	2.0859	2.2512	2.4148	[illegible]
(439.59)	h	418.45	1204.7	1219.8	1235.0	1248.8	1262.3	1274.2	1286.0	1297.5	1308.4	1363.0	1416.4	1469.2	1522.2	1575.4	[illegible]
	s	0.6154	1.4897	1.5063	1.5226	1.5371	1.5510	1.5630	1.5747	1.5859	1.5963	1.6455	1.6896	1.7299	1.7675	1.8027	[illegible]
	Sh			17.89	37.89	57.89	77.89	97.89	117.89	137.89	157.89	257.89	357.89	457.89	557.89	657.89	757.89
390	v	0.0193	1.1904	1.2332	1.2788	1.3222	1.3647	1.4046	1.4436	1.4812	1.5184	1.6961	1.8661	2.0311	2.1925	2.3521	2.5101
(442.11)	h	421.27	1204.8	1218.0	1233.4	1247.4	1261.2	1273.2	1285.1	1296.7	1307.7	1362.5	1416.0	1468.9	1522.0	1575.2	[illegible]
	s	0.6184	1.4872	1.5017	1.5183	1.5330	1.5472	1.5593	1.5711	1.5824	1.5929	1.6423	1.6865	1.7269	1.7646	1.7998	[illegible]
	Sh			15.42	35.42	55.42	75.42	95.42	115.42	135.42	155.42	255.42	355.42	455.42	555.42	655.42	755.42
400	v	0.0193	1.1609	1.1972	1.2422	1.2849	1.3269	1.3660	1.4042	1.4413	1.4777	1.6522	1.8179	1.9796	2.1367	2.2926	2.4474
(444.58)	h	424.02	1204.9	1216.5	1231.6	1245.9	1259.9	1272.4	1284.3	1295.8	1307.0	1362.1	1415.5	1468.6	1521.5	1574.8	1628.8
	s	0.6215	1.4850	1.4977	1.5140	1.5290	1.5434	1.5561	1.5678	1.5790	1.5897	1.6398	1.6835	1.7240	1.7615	1.7968	1.8304
	Sh			13.00	33.00	53.00	73.00	93.00	113.00	133.00	153.00	253.00	353.00	453.00	553.00	653.00	753.00
410	v	0.0194	1.1327	1.1628	1.2071	1.2494	1.2906	1.3291	1.3669	1.4038	1.4390	1.6095	1.7722	1.9297	2.0837	2.2350	2.3864
(447.00)	h	426.74	1205.0	1214.6	1230.2	1244.5	1258.8	1271.2	1283.5	1295.1	1306.2	1361.4	1415.1	1468.3	1521.4	1574.8	1628.6
	s	0.6244	1.4828	1.4933	1.5101	1.5252	1.5399	1.5524	1.5646	1.5759	1.5865	1.6362	1.6806	1.7212	1.7589	1.7943	1.8277
	Sh			10.62	30.62	50.62	70.62	90.62	110.62	130.62	150.62	250.62	350.62	450.62	550.62	650.62	750.62
420	v	0.0194	1.1058	1.1300	1.1738	1.2156	1.2561	1.2942	1.3312	1.3671	1.4021	1.5693	1.7285	1.8826	2.0332	2.1819	2.3290
(449.38)	h	429.42	1205.0	1213.0	1228.6	1243.1	1257.5	1270.2	1282.6	1294.3	1305.4	1360.8	1414.6	1468.0	1521.2	1574.6	1628.4
	s	0.6273	1.4805	1.4892	1.5060	1.5218	1.5361	1.5489	1.5612	1.5726	1.5832	1.6331	1.6776	1.7184	1.7561	1.7915	1.8249
	Sh			8.28	28.28	48.28	68.28	88.28	108.28	128.28	148.28	248.28	348.28	448.28	548.28	648.28	748.28
430	v	0.0195	1.0800	1.0986	1.1419	1.1834	1.2233	1.2607	1.2972	1.3326	1.3670	1.5309	1.6869	1.8377	1.9850	2.1305	2.2742
(451.72)	h	432.05	1205.0	1211.2	1227.0	1241.7	1256.3	1269.1	1281.8	1293.5	1304.6	1360.3	1414.2	1467.6	1520.9	1574.4	1628.2
	s	0.6302	1.4782	1.4850	1.5020	1.5175	1.5326	1.5455	1.5581	1.5695	1.5801	1.6303	1.6748	1.7156	1.7534	1.7888	1.8222
	Sh			5.99	25.99	45.99	65.99	85.99	105.99	125.99	145.99	245.99	345.99	445.99	545.99	645.99	745.99
440	v	0.0195	1.0554	1.0688	1.1116	1.1524	1.1918	1.2288	1.2648	1.2996	1.3334	1.4943	1.6472	1.7949	1.9390	2.0814	2.2220
(454.01)	h	434.03	1205.0	1209.6	1225.3	1240.2	1255.0	1268.0	1280.9	1292.6	1303.9	1359.7	1413.8	1467.3	1520.6	1574.1	1628.0
	s	0.6330	1.4762	1.4812	1.4981	1.5138	1.5291	1.5422	1.5550	1.5664	1.5772	1.6275	1.6722	1.7130	1.7508	1.7862	1.8197
	Sh			3.73	23.73	43.73	63.73	83.73	103.73	123.73	143.73	243.73	343.73	443.73	543.73	643.73	743.73
450	v	0.0195	1.0318	1.0401	1.0824	1.1230	1.1617	1.1982	1.2337	1.2681	1.3013	1.4593	1.6092	1.7539	1.8951	2.0345	2.1720
(456.27)	h	437.18	1205.0	1207.9	1223.7	1238.7	1253.8	1266.9	1280.0	1291.8	1303.1	1359.1	1413.4	1467.0	1520.3	1573.9	1627.8
	s	0.6357	1.4739	1.4771	1.4941	1.5099	1.5255	1.5387	1.5517	1.5633	1.5740	1.6245	1.6694	1.7103	1.7481	1.7836	1.8171
	Sh				21.52	41.52	61.52	81.52	101.52	121.52	141.52	241.52	341.52	441.52	541.52	641.52	741.52
460	v	0.0196	1.0092		1.0545	1.0946	1.1329	1.1690	1.2039	1.2379	1.2706	1.4258	1.5729	1.7147	1.8530	1.9896	2.1243
(458.48)	h	439.69	1205.0		1222.0	1237.2	1252.5	1265.8	1279.0	1291.0	1302.3	1358.6	1413.0	1466.6	1520.0	1573.7	1627.7
	s	0.6384	1.4719		1.4902	1.5062	1.5220	1.5354	1.5485	1.5602	1.5710	1.6217	1.6667	1.7076	1.7455	1.7811	1.8146
	Sh				19.34	39.34	59.34	79.34	99.34	119.34	139.34	239.34	339.34	430.34	539.34	639.34	739.34
470	v	0.0196	0.9875		1.0278	1.0676	1.1053	1.1410	1.1756	1.2091	1.2412	1.3937	1.5381	1.6772	1.8127	1.9466	2.0785
(460.66)	h	442.17	1205.0		1220.2	1235.7	1251.2	1264.7	1278.0	1290.0	1301.5	1358.0	1412.5	1466.3	1510.8	1573.5	1627.5
	s	0.6411	1.4699		1.4862	1.5025	1.5185	1.5321	1.5453	1.5570	1.5680	1.6189	1.6639	1.7050	1.7429	1.7785	1.8120
	Sh				17.20	37.20	57.20	77.20	97.20	117.20	137.20	237.20	337.20	437.20	537.20	637.20	737.20
480	v	0.0197	0.9668		1.0021	1.0416	1.0789	1.1141	1.1482	1.1812	1.2131	1.3630	1.5049	1.6413	1.7742	1.9054	2.0347
(462.80)	h	444.60	1205.0		1218.6	1234.2	1249.9	1263.5	1277.0	1289.1	1300.8	1357.5	1412.1	1466.0	1519.5	1573.3	1627.3
	s	0.6436	1.4679		1.4825	1.4989	1.5151	1.5288	1.5422	1.5539	1.5650	1.6161	1.6612	1.7023	1.7402	1.7758	1.8093
	Sh				15.09	35.09	55.09	75.09	95.09	115.09	135.09	235.09	335.09	435.09	535.09	635.09	735.09
490	v	0.0197	0.9466		0.9774	1.0166	1.0535	1.0884	1.1220	1.1548	1.1860	1.3335	1.4729	1.5067	1.7371	1.8659	1.9927
(464.91)	h	447.00	1204.9		1217.0	1232.7	1248.4	1262.3	1276.0	1288.3	1300.0	1356.9	1411.7	1465.6	1519.2	1573.1	1627.1
	s	0.6462	1.4659		1.4789	1.4954	1.5116	1.5256	1.5392	1.5511	1.5622	1.6135	1.6588	1.6999	1.7379	1.7736	1.8071
	Sh				13.00	33.00	53.00	73.00	93.00	113.00	133.00	233.00	333.00	433.00	533.00	633.00	733.00
500	v	0.0197	0.9274		0.9638	0.9926	1.0290	1.0636	1.0969	1.1292	1.1600	1.3061	1.4417	1.5735	1.7016	1.8280	1.9532
(467.00)	h	449.40	1204.9		1215.3	1231.4	1246.6	1261.1	1275.0	1287.3	1299.3	1356.3	1411.2	1465.1	1518.8	1572.9	1627.3
	s	0.6488	1.4641		1.4752	1.4922	1.5079	1.5225	1.5363	1.5482	1.5596	1.6110	1.6564	1.6975	1.7356	1.7714	1.8052
	Sh				10.95	30.95	50.95	70.95	90.95	110.95	130.95	230.95	330.95	430.95	530.95	630.95	730.95
510	v	0.0198	0.9090		0.9310	0.9695	1.0056	1.0397	1.0727	1.1046	1.1350	1.2780	1.4127	1.5418	1.6675	1.7915	1.9135
(469.05)	h	451.75	1204.8		1213.5	1229.6	1245.6	1259.9	1274.0	1286.6	1298.4	1355.7	1410.9	1465.0	1518.7	1572.6	1626.8
	s	0.6518	1.4621		1.4714	1.4888	1.5048	1.5192	1.5332	1.5454	1.5566	1.6082	1.6538	1.6951	1.7332	1.7689	1.8026
	Sh				8.93	28.93	48.93	68.93	88.93	108.93	128.93	228.93	328.93	428.93	528.93	628.93	728.93
520	v	0.0198	0.8912		0.9091	0.9472	0.9829	1.0169	1.0494	1.0810	1.1110	1.2519	1.3844	1.5113	1.6347	1.7565	1.8763
(471.07)	h	454.07	1204.7		1211.8	1228.1	1244.2	1258.6	1272.9	1285.6	1297.6	1355.1	1410.4	1464.6	1518.4	1572.4	1626.6
	s	0.6537	1.4601		1.4677	1.4849	1.5015	1.5160	1.5302	1.5425	1.5539	1.6057	1.6514	1.6928	1.7310	1.7668	1.8005
	Sh				6.95	26.95	46.95	66.95	86.95	106.95	126.95	226.95	326.95	426.95	526.95	626.95	726.95
530	v	0.0199	0.8741		0.8879	0.9258	0.9612	0.9948	1.0269	1.0582	1.0878	1.2267	1.3571	1.4818	1.6031	1.7228	1.8402
(473.05)	h	456.35	1204.6		1210.0	1226.5	1242.8	1257.3	1271.8	1284.8	1296.8	1354.6	1410.0	1464.3	1518.1	1572.2	1626.4
	s	0.6562	1.4584		1.4642	1.4816	1.4984	1.5130	1.5274	1.5400	1.5514	1.6035	1.6493	1.6908	1.7290	1.7648	1.7985

Sh = superheat, deg. F.
v = specific volume, cu. ft. per lb.
h = enthalpy, B.t.u. per lb.
s = entropy, B.t.u. per deg. F. per lb.

TABLE 3. SUPERHEATED STEAM—*Continued*

Abs. Press. Lb./Sq. In. (Sat. Temp.)		Sat. Water	Sat. Steam	Temperature—Degrees Fahrenheit 500°	520°	540°	560°	580°	600°	650°	700°	750°	800°	900°	1000°	1100°	1200°
	Sh			24.98	44.98	64.98	84.98	104.98	124.98	174.98	224.98	274.98	324.98	424.98	524.98	624.98	724.98
540	v	0.0199	0.8576	0.9051	0.9401	0.9736	1.0054	1.0363	1.0655	1.1356	1.2025	1.2671	1.3309	1.4535	1.5727	1.6903	1.8056
(475.02)	h	458.62	1204.5	1225.0	1241.4	1256.1	1270.7	1283.8	1296.0	1325.6	1354.0	1382.1	1409.6	1463.9	1517.8	1572.0	1626.2
	s	0.6585	1.4565	1.4781	1.4950	1.5098	1.5248	1.5370	1.5486	1.5759	1.6009	1.6246	1.6469	1.6884	1.7266	1.7625	1.7962
	Sh			23.06	43.06	63.06	83.06	103.06	123.06	173.06	223.06	273.06	323.06	423.06	523.06	623.06	723.06
550	v	0.0199	0.8416	0.8851	0.9198	0.9530	0.9846	1.0151	1.0441	1.1132	1.1791	1.2428	1.3055	1.4262	1.5434	1.6590	1.7724
(476.94)	h	460.83	1204.4	1223.4	1240.0	1254.8	1269.6	1282.9	1295.2	1324.9	1353.5	1381.6	1409.2	1463.6	1517.5	1571.7	1626.0
	s	0.6609	1.4548	1.4748	1.4919	1.5068	1.5215	1.5344	1.5461	1.5735	1.5987	1.6224	1.6447	1.6862	1.7244	1.7603	1.7940
	Sh			21.15	41.15	61.15	81.15	101.15	121.15	171.15	221.15	271.15	321.15	421.15	521.15	621.15	721.15
560	v	0.0200	0.8263	0.8658	0.9003	0.9332	0.9644	0.9947	1.0233	1.0917	1.1566	1.2193	1.2810	1.3998	1.5151	1.6289	1.7403
(478.85)	h	463.04	1204.3	1221.8	1238.5	1253.5	1268.5	1282.0	1294.4	1324.2	1352.9	1381.1	1408.7	1463.2	1517.2	1571.5	1625.8
	s	0.6632	1.4530	1.4714	1.4886	1.5038	1.5187	1.5318	1.5436	1.5711	1.5964	1.6202	1.6425	1.6841	1.7224	1.7584	1.7921
	Sh			19.27	39.27	59.27	79.27	99.27	119.27	169.27	219.27	269.27	319.27	419.27	519.27	619.27	719.27
570	v	0.0200	0.8114	0.8472	0.8814	0.9141	0.9450	0.9749	1.0033	1.0708	1.1348	1.1966	1.2575	1.3744	1.4879	1.5998	1.7093
(480.73)	h	465.22	1204.1	1220.2	1236.9	1252.2	1267.3	1281.0	1293.5	1323.5	1352.3	1380.6	1408.3	1462.9	1517.0	1571.3	1625.6
	s	0.6655	1.4512	1.4681	1.4853	1.5008	1.5156	1.5291	1.5410	1.5686	1.5940	1.6179	1.6403	1.6820	1.7204	1.7564	1.7901
	Sh			17.42	37.42	57.42	77.42	97.42	117.42	167.42	217.42	267.42	317.42	417.42	517.42	617.42	717.42
580	v	0.0201	0.7968	0.8291	0.8631	0.8956	0.9263	0.9558	0.9839	1.0506	1.1137	1.1747	1.2347	1.3498	1.4616	1.5714	1.6794
(482.58)	h	467.37	1204.0	1218.6	1235.5	1250.9	1266.1	1280.0	1292.6	1322.8	1351.6	1380.0	1407.8	1462.5	1516.7	1571.0	1625.4
	s	0.6677	1.4494	1.4648	1.4822	1.4978	1.5128	1.5264	1.5384	1.5662	1.5916	1.6156	1.6381	1.6799	1.7183	1.7543	1.7881
	Sh			15.59	35.59	55.59	75.59	95.59	115.59	165.59	215.59	265.59	315.59	415.59	515.59	615.59	715.59
590	v	0.0201	0.7831	0.8116	0.8455	0.8778	0.9082	0.9373	0.9653	1.0310	1.0934	1.1535	1.2128	1.3262	1.4360	1.5442	1.6506
(484.41)	h	469.50	1203.8	1217.0	1234.0	1249.6	1265.0	1278.9	1291.8	1322.1	1351.1	1379.5	1407.4	1462.2	1516.4	1570.8	1625.2
	s	0.6699	1.4477	1.4616	1.4791	1.4949	1.5101	1.5236	1.5359	1.5638	1.5894	1.6134	1.6360	1.6778	1.7162	1.7522	1.7861
	Sh			13.79	33.79	53.79	73.79	93.79	113.79	163.79	213.79	263.79	313.79	413.79	513.79	613.79	713.79
600	v	0.0201	0.7695	0.7945	0.8284	0.8605	0.8907	0.9194	0.9471	1.0123	1.0738	1.1332	1.1915	1.3032	1.4115	1.5179	1.6224
(486.21)	h	471.59	1203.6	1215.6	1232.5	1248.3	1263.7	1278.1	1290.9	1321.4	1350.5	1379.0	1407.0	1461.8	1516.0	1570.5	1625.0
	s	0.6721	1.4460	1.4586	1.4760	1.4920	1.5072	1.5212	1.5334	1.5615	1.5871	1.6112	1.6339	1.6757	1.7141	1.7502	1.7841
	Sh			12.01	32.01	52.01	72.01	92.01	112.01	162.01	212.01	262.01	312.01	412.01	512.01	612.01	712.01
610	v	0.0202	0.7565	0.7781	0.8120	0.8436	0.8736	0.9022	0.9296	0.9942	1.0548	1.1135	1.1708	1.2809	1.3878	1.4928	1.5964
(487.99)	h	473.67	1203.5	1213.8	1230.9	1246.9	1262.5	1276.8	1290.0	1320.6	1350.0	1378.5	1406.5	1461.5	1515.8	1570.3	1624.9
	s	0.6743	1.4444	1.4552	1.4728	1.4890	1.5044	1.5186	1.5309	1.5591	1.5850	1.6091	1.6318	1.6738	1.7123	1.7484	1.7823
	Sh			10.25	30.25	50.25	70.25	90.25	110.25	160.25	210.25	260.25	310.25	410.25	510.25	610.25	710.25
620	v	0.0202	0.7438	0.7622	0.7960	0.8275	0.8572	[illegible]	0.9127	0.9765	1.0364	1.0943	1.1505	1.2596	1.3648	1.4677	1.5707
(489.75)	h	475.72	1203.3	1212.2	1229.5	1245.5	1261.3	[illegible]	[illegible]	1310.9	1349.3	1377.9	1406.1	1461.2	1515.5	1570.1	1624.7
	s	0.6764	1.4427	1.4520	1.4698	1.4860	1.5016	1.5187	1.5284	1.5568	1.5827	1.6068	1.6296	1.6717	1.7102	1.7464	1.7803
	Sh			8.51	28.51	48.51	68.51	88.51	108.51	158.51	208.51	258.51	308.51	408.51	508.51	608.51	708.51
630	v	0.0202	0.7316	0.7466	0.7802	0.8117	0.8413	0.8694	0.8963	0.9595	1.0187	1.0757	1.1312	1.2387	1.3423	1.4445	1.5449
(491.49)	h	477.75	1203.1	1210.6	1227.8	1244.1	1260.1	1274.7	1288.3	1319.2	1348.7	1377.4	1405.7	1460.8	1515.2	1569.9	1624
	s	0.6785	1.4410	1.4488	1.4665	1.4830	1.4988	1.5130	1.5260	1.5545	1.5805	1.6047	1.6276	1.6697	1.7083	1.7445	[illegible]
	Sh			6.79	26.79	46.79	66.79	86.79	106.79	156.79	206.79	256.79	306.79	406.79	506.79	606.79	[illegible]
640	v	0.0203	0.7197	0.7317	0.7651	0.7963	0.8258	0.8537	0.8804	0.9429	1.0015	1.0578	1.1124	1.2187	1.3210	1.4213	[illegible]
(493.21)	h	479.79	1202.9	1209.0	1226.3	1242.7	1258.9	1273.6	1287.4	1318.5	1348.2	1376.8	1405.2	1460.5	1515.0	1569.7	1624.3
	s	0.6806	1.4394	1.4458	1.4686	1.4802	1.4962	1.5105	1.5236	1.5523	1.5785	1.6026	1.6256	1.6678	1.7065	1.7427	[illegible]
	Sh			5.10	25.10	45.10	65.10	85.10	105.10	155.10	205.10	255.10	305.10	405.10	505.10	605.10	[illegible]
650	v	0.0203	0.7082	0.7171	0.7504	0.7816	0.8107	0.8384	0.8648	0.9269	0.9846	1.0404	1.0944	1.1988	1.2999	1.3987	[illegible]
(494.90)	h	481.73	1202.7	1207.3	1224.8	1241.3	1257.6	1272.5	1286.5	1317.8	1347.6	1376.3	1404.7	1460.1	1514.7	1569.4	[illegible]
	s	0.6826	1.4379	1.4427	1.4607	1.4774	1.4935	1.5080	1.5213	1.5501	1.5764	1.6006	1.6236	1.6659	1.7046	1.7408	[illegible]
	Sh			3.42	23.42	43.42	63.42	83.42	103.42	153.42	203.42	253.42	303.42	403.42	503.42	603.42	[illegible]
660	v	0.0204	0.6969	0.7031	0.7361	0.7672	0.7962	0.8237	0.8499	0.9113	0.9686	1.0234	1.0769	1.1803	1.2797	[illegible]	[illegible]
(496.58)	h	483.77	1202.5	1205.7	1223.2	1240.0	1256.4	1271.4	1285.5	1317.1	1347.0	1375.8	1404.3	1459.7	1514.4	[illegible]	[illegible]
	s	0.6847	1.4363	1.4396	1.4576	1.4746	1.4908	1.5054	1.5188	1.5479	1.5742	1.5985	1.6216	1.6639	1.7027	[illegible]	[illegible]
	Sh			1.77	21.77	41.77	61.77	81.77	101.77	151.77	201.77	251.77	301.77	401.77	501.77	[illegible]	[illegible]
670	v	0.0204	0.6861	0.6892	0.7224	0.7531	0.7820	0.8093	0.8354	0.8963	0.9527	1.0072	1.0599	1.1617	1.2600	[illegible]	[illegible]
(498.23)	h	485.61	1202.3	1204.0	1221.7	1238.7	1255.1	1270.2	1284.5	1316.3	1346.3	1375.3	1403.9	1459.4	1514.1	[illegible]	[illegible]
	s	0.6867	1.4349	1.4367	1.4549	1.4721	1.4883	1.5030	1.5166	1.5459	1.5723	1.5968	1.6200	1.6624	1.7012	[illegible]	[illegible]
	Sh				20.13	40.13	60.13	80.13	100.13	150.13	200.13	250.13	300.13	400.13	500.13	600.13	[illegible]
680	v	0.0204	0.6757		0.7089	0.7397	0.7683	0.7954	0.8212	0.8814	0.9375	0.9912	1.0432	1.1440	1.2408	[illegible]	[illegible]
(499.87)	h	487.64	1202.1		1220.2	1237.3	1253.9	1269.1	1283.6	1315.6	1345.8	1374.7	1403.4	1459.0	1513.8	1568.7	[illegible]
	s	0.6886	1.4332		1.4519	1.4692	1.4856	1.5004	1.5142	1.5437	1.5703	1.5947	1.6179	1.6603	1.6992	1.7356	[illegible]
	Sh				18.51	38.51	58.51	78.51	98.51	148.51	198.51	248.51	298.51	398.51	498.51	598.51	698.51
690	v	0.0205	0.6652		0.6956	0.7263	0.7549	0.7818	0.8075	0.8675	0.9225	0.9758	1.0272	1.1267	1.2223	1.3162	[illegible]
(501.49)	h	489.56	1201.8		1218.5	1235.8	1252.5	1268.0	1282.7	1314.9	1345.1	1374.2	1402.8	1458.7	1513.6	1568.5	[illegible]
	s	0.6906	1.4316		1.4488	1.4663	1.4828	1.4978	1.5118	1.5415	1.5681	1.5927	1.6159	1.6586	1.6975	1.7339	[illegible]
	Sh				16.91	36.91	56.91	76.91	96.91	146.91	196.91	246.91	296.91	396.91	496.91	596.91	[illegible]
700	v	0.0205	0.6552		0.6830	0.7133	0.7419	0.7687	0.7941	0.8534	0.9084	0.9608	1.0117	1.1096	1.2043	1.2965	[illegible]
(503.09)	h	491.49	1201.6		1217.1	1234.7	1251.3	1266.8	1281.9	1314.3	1344.6	1373.7	1402.5	1458.2	[illegible]	1568.2	[illegible]
	s	0.6925	1.4301		1.4461	1.4638	1.4803	1.4953	1.5097	1.5396	1.5663	1.5908	1.6141	1.6567	1.6958	1.7321	[illegible]

Sh = superheat, deg. F.
v = specific volume, cu. ft. per lb.
h = enthalpy, B.t.u. per lb.
s = entropy, B.t.u. per deg. F. per lb

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

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-8 - Steam Tables

A - Assignment

1. (a) Define "quality" of wet steam.

   (b) Define "per cent" of moisture.

2. Determine enthalpy of superheated steam at 600 psia and 800°F.

3. Steam admitted to the NPD turbine is dry saturated and has a temperature of 450°F. Determine enthalpy and density of the steam.

4. Steam exhausted from the above turbine into the condenser has a moisture content of 11%. Calculate enthalpy of the steam if temperature in the condenser is 95°F.

NUCLEAR ELECTRIC G.S. TECHNICAL TRAINING COURSE

2 - Science Fundamentals - T.T.3

5 - Heat & Thermodynamics

-9 - Air and Steam

0.0 INTRODUCTION

In this lesson we will discuss the properties of a mixture of air and steam and define some of the terms which are frequently used, such as relative humidity and dew point.

1.0 INFORMATION

Pure dry air is a mixture of oxygen and nitrogen. It also contains negligible amounts of rare gases, such as argon. Air, as we find it all around us, however, contains moisture in varying amounts, and can be regarded as a mixture of air and steam.

How can we get steam at atmospheric pressure and low temperatures? The answer is that while the mixture is at atmospheric pressure, the water vapor is not. It is actually at extremely low pressure. And since we know from the previous lessons that the temperature at which water boils or vaporizes gets lower as pressure goes down, we can see that, at these extremely low pressures, water will exist in the form of steam even at ordinary temperatures say, 70°F.

1.1 Partial Pressures

These low pressures come about because if we mix any two gases in a given space, each acts pressure-wise as if the other did not exist. Each is under the pressure it would have, if it occupied the space by itself. Pressure of the mixture is the sum of the two partial pressures. The last statement is known as Dalton's Law, which is defined as follows:

"Dalton's Law": If two or more gases exist as a mixture in a closed vessel, the total pressure exerted by the mixture on the walls of the vessel will be equal to the sum of individual pressures exerted by the gases making up the mixture.

To see how this works, let us start with steam at 70°F. Its absolute pressure at that temperature is approximately 0.36 psia and density 0.0011 lb/ft^3. (see lesson on steam tables. Sample Problem No. 6). This means that 0.0011 lb. of dry saturated steam at 70°F would fill one cubic foot. Now if we add enough air to make one cubic foot of mixture, what do we have? Total pressure, we know will be atmospheric pressure, say 14.70 psia. Then the partial pressure of the air must be 14.70-0.36 or 14.34 psia.

We remember from the previous lessons that for any given pressure there is one temperature at which steam starts to vaporize or condense. This is known as saturation temperature. It depends entirely on the pressure being lower at lower pressures. Furthermore, steam at any given pressure and saturation temperature has a certain density.

For convenience, let us put down some of the figures (extracted from the steam tables given in lesson on steam tables) corresponding to the range of temperatures of moist air that are of practical interest to us.

Saturation Temperature	Corresponding Pressure	Spec. Vol. of dry sat. Steam	Density of dry sat. Steam
deg. F	psia	v, ft^3/lb.	$w = \frac{1}{v}$, lb/ft^3
40	0.12170	2444	0.0004
50	0.17811	1703.2	0.0006
60	0.2563	1206.7	0.0008
70	0.3631	867.9	0.0011
80	0.5069	633.1	0.0016
90	0.6982	468.0	0.0021

Now let us assume we have a cubic foot of moist air at 70°F and we find that it contains 0.0004 lb. of moisture. A glance at the table above shows that at 70°F a cubic foot will hold .0011 lb. of steam. Since we have less, the steam must be superheated, and the table tells us how much: 70 - 40, or 30°F.

1.2 Relative Humidity

We can see that our cubic foot holds less moisture than it could hold. The term "relative humidity" is a measure of this. Here we have 0.0004 lb. when we could have 0.0011. Ratio is $\frac{4}{11}$ = 0.36 or 36%.

This is relative humidity. Thus denoting relative humidity with the symbol ø (phi) it can be defined as follows:

$$\phi = \frac{\text{Actual vapor density}}{\text{Density, sat. vapor at mixture temperature.}}$$

1.3 Dewpoint

Now let us take our mixture, with 0.0004 lb. of moisture in a cubic foot, and cool it down. Referring to the table again, we see that if we cool it to 40°F, it will be holding all the moisture a cubic foot can hold at that temperature. It has 100% relative humidity. Such a mixture is called saturated. If we try to cool this mixture further, some of the steam will condense. Temperature at which this condensation starts, in this case, 40°F, is the dew point temperature.

As we can see, the dew point of any mixture of air and water vapor depends entirely on how much moisture is present. For example, a cubic foot containing 0.0006 lb. of water vapor has a dew point of 50°F.

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A - Assignment

1. Define "Dalton's Law".
2. Define "Relative Humidity".
3. Explain briefly the meaning of the term "Dew Point Temperature".
4. A cubic foot of a mixture of air and steam at 80°F contains 0.0008 lb. of moisture. How much is the steam superheated?

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-10 - Dew Point Hygrometer

0.0 INTRODUCTION

This lesson will describe the Dew Point Hygrometer and demonstrate how this instrument is used to measure relative humidity of the air.

1.0 INFORMATION

In the usual form of these instruments, (see Figure 1), means are provided for cooling and observing the temperature of the surface which is exposed to air. The temperature at which visible condensation occurs on the surface is considered the dew point of the air. With the dew point temperature known, the relative humidity and other properties of the air can be calculated or taken from tables and charts. A bright surface or metallic mirror is usually employed to improve the visibility of the dew deposit and various means are used to cool the mirror from the back, including evaporating ether or another refrigerant, or a stream of air passed through dry ice. Dew point temperatures, in some cases, are observed by means of thermometers in fluids in contact with the back of the mirror, but in modern instruments, thermocouples are used, and are soldered or welded to the mirror itself.

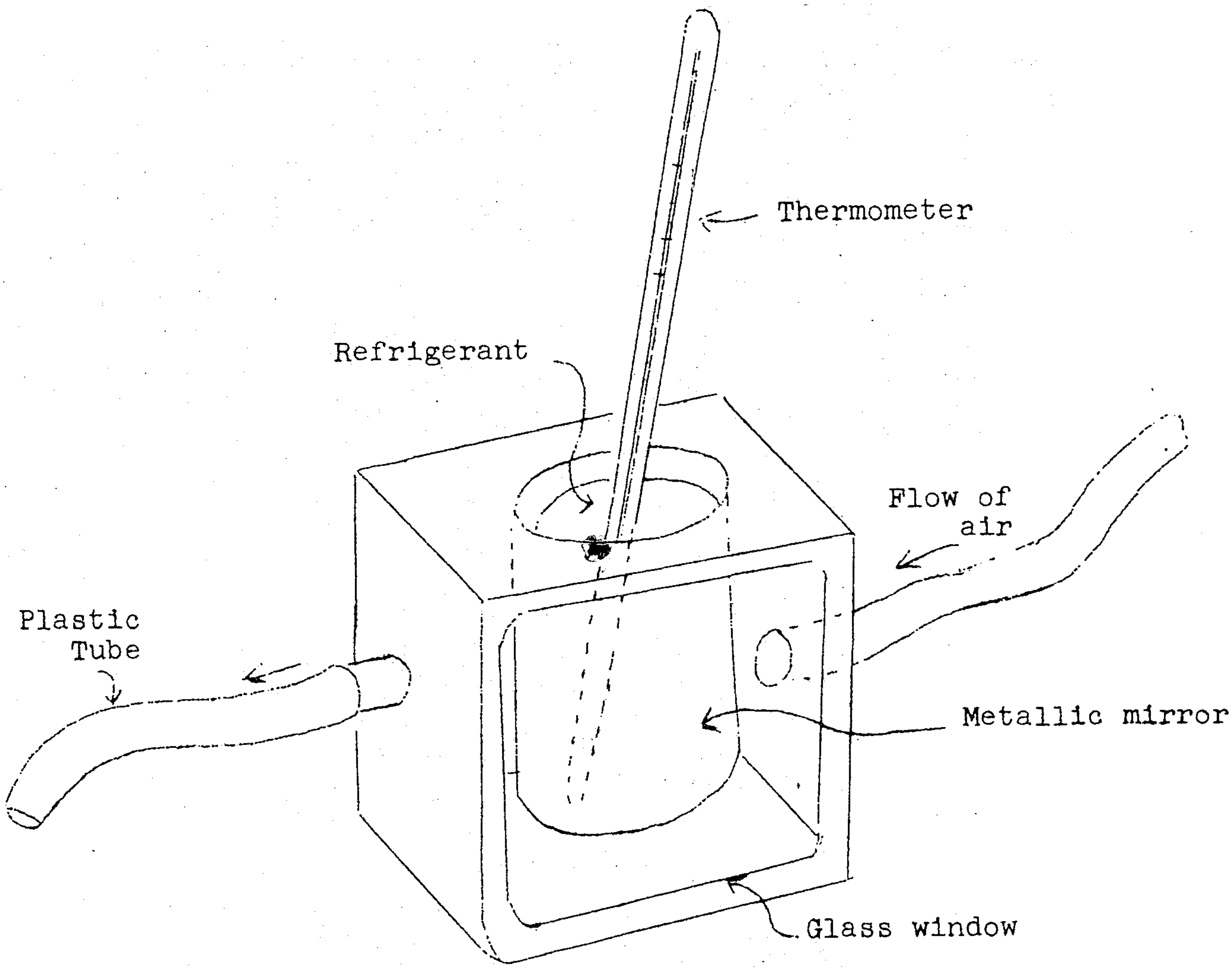

Fig. I

Sample Problem

A dew point hygrometer is used in the NPD Fan Room to measure the dew point of the air leaving the plant. What is the relative humidity of the air at 70°F if the dew point temperature is 50°F?

From the steam tables

at 50°F, $v = 1703.2\ ft^3/lb$, $w = \frac{1}{v} = 0.0006\ lb/ft^3$.

at 70°F, $v = 867.9\ ft^3/lb$. $w = \frac{1}{v} = 0.0011\ lb/ft^3$.

$$\varnothing = \frac{0.0006}{0.0011} = 0.545 = 54.5\%$$

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-10 - Dew Point Hygrometer

1. Describe briefly, the dew point hygrometer.
2. What is the relative humidity of the air at 75° F if the dew point temperature is 45° F?