Saturation Temperature

The temperature at which a fluid changes from the liquid phase to the vapor phase, or conversely, from the vapor phase to the liquid phase is called the saturation temperature. A liquid at the saturation temperature is called a saturated liquid and a vapor at the saturation temperature is called a saturated vapor. It is important to recognize that the saturation temperature of the liquid (the temperature at which the liquid will vaporize) and the saturation temperature of the vapor (the temperature at which the vapor will condense) are the same for any given pressure.

For any given pressure, the saturation temperature is the maximum temperature the liquid can have and the minimum temperature the vapor can have. Any attempt to raise the temperature of a liquid above the saturation temperature will only result in vaporizing some part of the liquid. Similarly, any attempt to reduce the temperature of a vapor below the saturation temperature will only result in condensing some part of the vapor.

Superheated Vapor

A vapor at any temperature above the saturation temperature corresponding to its pressure is referred to as superheated vapor. Once a liquid has been completely vaporized, the temperature of the resulting vapor can be further increased by the addition of energy. When the temperature of a vapor has been so increased above the saturation temperature, the vapor is said to be superheated and the energy supplied to superheat the vapor is commonly referred to as superheat.

Before a vapor can be superheated, the vapor must be removed from contact with the vaporizing liquid. Also, before a superheated vapor can be condensed it must first be cooled to the saturation temperature corresponding to its pressure.

Subcooled Liquid

If, after condensation, the resulting liquid is cooled (constant pressure) so that its temperature is reduced below the saturation temperature, the liquid is said to be subcooled.

The Effect of Pressure on Saturation Temperature

The saturation temperature of a fluid depends on the pressure of a fluid. Increasing the pressure raises the saturation temperature, while reducing the pressure lowers the saturation temperature.

Condensation

Condensation of a vapor may be accomplished in several ways:

1. By extracting heat from the vapor
2. By increasing the pressure of the vapor.
3. By some combination of these two methods.

A good example of extracting heat from a vapor is in the Paraflow Steam Generator. Steam is fed to the high temperature generator through a steam modulating valve (refer to steam valve operation for further details). As the steam flows through the generator tube bundle, heat is given up to the colder lithium bromide/water solution located on the outside of the tubes. This causes the solution to heat up and the steam to condense.

The steam will be subcooled when it leaves the generator and will be further subcooled as it flows through the condensate drain cooler. This condensate will leave the condensate drain cooler at approximately 15 psig and 190 °F.

Steam Supply

Dry steam (no water droplets)or slightly superheated steam should be supplied to the unit to allow the heat content of the steam to be at a maximum. The steam temperature must not exceed 363°F as this may cause damage to system components.

The saturation pressure must not exceed 128 psig (142.7 psia). This pressure corresponds to a saturation temperature of 354 °F. Therefore, at this maximum allowed pressure the steam can have a maximum of 9 °F superheat.

On most installations, the inlet pressure will be rated for approximately 115 psig (129.7 psia) and will have a corresponding saturation temperature of 347°F.

Refer to steam tables at the end of this section for further relationships.

Steam Purity

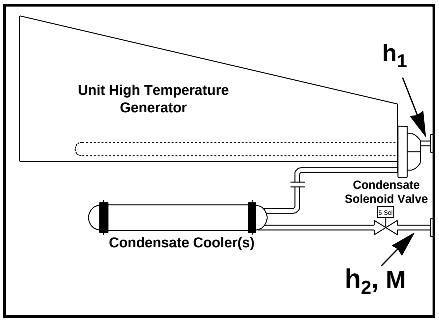
Boiler water treatment is an essential part of any maintenance program. If the water is not properly treated, certain chemicals may exceed tolerable limits and damage to the high temperature generator, condensate drain coolers, control devices and adjoining piping will occur. **It is the customers responsibility to test the condensate to make sure it is within certain limits**. These limits are listed in the maintenance portion of this section.

If the steam carries entrained air or other gases, this will have a tendency to reduce the steam temperature. Air will also reduce the heat transfer properties of a unit because it migrates to heat transfer surfaces causing an insulating effect.

Carbon dioxide in steam is probable the most destructive form of contaminant. CO_2 will dissolve in the condensate forming carbonic acid, which is extremely corrosive to pipes and other system components.

Heat Input Calculation

To determine the approximate heat input to the *Paraflow*™ unit the following equation should be used.



Input (Btu/hr) = (h_1 - h_2) X M

Where:

h_1 = enthalpy of steam entering the unit (Saturated Vapor)

Can be determined by reading the pressure at the Steam Inlet Pressure Indicator. Then refer to Steam Tables to find the enthalpy of the saturated vapor at this pressure. This value assumes that dry steam is entering the unit.

h_2 = enthalpy of condensate leaving the unit (subcooled liquid).

Determined by measuring the temperature leaving the condensate drain cooler. Next, refer to the steam tables at the end of this section and find the saturated liquid enthalpy corresponding to this temperature.

M = mass flow rate of steam (lbs/hr)

The mass flow rate will have to be measured using a flow meter located at the outlet flange of the condensate drain cooler (refer to start-up section for details).

Steam Tables

The saturated steam tables located at the end of this section lists saturated conditions in the range of 32°F to 500°F.

Pressures are listed in three units, In.Hg. Vacuum, mmHg Absolute, and psia.

Enthalpy of the saturated liquid, vapor and latent heat are also given. The latent heat value is simply the difference between the enthalpy of the saturated vapor and the saturated liquid.

Latent heat is the quantity of energy that must be removed to condense steam from a saturated vapor to a saturated liquid (at constant pressure). Any additional heat removed will subcool the liquid. The same energy is needed to vaporize steam from a saturated liquid to saturated vapor. Any additional heat added will only superheat the steam.

The specific volume (ft^3/lbm) is also listed for saturated liquid and vapor conditions.

Steam Quality

Steam quality is simply a mass percentage of saturated vapor to the total mass that is contained in a saturated steam sample. This percentage of vapor is referred to as the steam quality (X).

A quality of .80 means that 80% of the saturated steam is in the vapor phase while 20% is in the liquid phase.

The term **dry steam** that is often seen is equivalent to saturated steam with a quality of 1.0 (100% vapor).

It is important to note that as the quality decreases, the heat content of the steam also decreases. Therefore when dry steam is not supplied, heat transfer is not as great.

For example: Table S1 lists two enthalpy values; saturated liquid enthalpy and the saturated vapor enthalpy. As previously discussed, steam with a quality less than one (1.0) will have a certain percentage of liquid and vapor present in the steam. The saturated vapor enthalpy assumes dry steam, quality: X = 1. The saturated liquid enthalpy assumes pure water, quality: X = 0. The enthalpy of the saturated water is much less than the saturated steam. It follows that as the quality decreases, the enthalpy decreases from the saturated vapor value to the saturated liquid value. Since enthalpy is an indication of the heat in the steam, available heat is reduced if liquid water is contained in the steam.

Table S1 Saturated Steam Table Excerpt

Temp °F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp °F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
340		6098.7617	117.930	0.01787	3.7920	311.30	1190.80	879.50	340
345		6528.2363	126.235	0.01793	3.5690	316.55	1191.95	875.40	345
350		6957.2324	134.530	0.01799	3.3460	321.80	1193.10	871.30	350
360		7908.2731	152.920	0.01800	2.9610	332.35	1195.20	862.85	360

Steam Control Valves

The steam control valve is sized for each job based upon the available steam pressure, required steam pressure at the unit (115 psig) and the steam flow required at full load conditions. The valve and actuator will be supplied with the unit.

There are two types of steam valves presently used on York ParaFlow Units.

1. Honeywell Model 9137 Cage Valve

These valves have a carbon steel body, 150 lb. ANSI flange connections, teflon seat, maximum leakage across valve = .0001%, maximum fluid temperature = 363 °F, maximum shutoff pressure = 140 psi and a plain bonnet.

An electrically operated Actionator Motor (120VAC, 60 HZ): Honeywell Model 859136 is used to control the steam valve's position.

The valve comes in four sizes:

2.0" - Cv = 53
2.5" - Cv = 90
3.0" - Cv = 120
4.0" - Cv = 188

2. Leslie Model EBOYS-NX (n = valve size and x = Jordan Actuator)

These valves have a carbon steel body; plug and seat is 400 series stainless steel; 150 lb. ANSI flange connections; teflon seat; max leakage across valve = .0001% of rated Cv; maximum fluid temperature = 363°F; maximum shutoff pressure = 140 psi.

An electrically operated actuator motor (Jordan Electric, 120VAC, 50/60 HZ Model U843J2X1XX0) is used to control the steam valve's position.

Valve Flow Characteristics

Both control valves utilize an equal percentage flow characteristic. The flow characteristic is the relationship between the steam flow rate through the valve and the valve stem travel as it is varied from 0 to 100%. Two flow characteristics are shown in **Figure S1**.

Equal Percentage - Equal increments in valve stem travel will produce equal percentage changes in existing flow. **The change in flow rate is always proportional to the flow rate just before the change in position is made for a valve plug.**

For example: When the valve plug is near its seat and the flow is small, the change in flow rate will be small. If the flow rate is large to begin with, its change in flow rate will be large.

The equal percentage curve in **Figure S1** illustrates this behavior. **Table ST1** lists values for valve stem positions in 10% increments starting at 10%. Notice that for each 10% increase in valve stem travel a 50% increase in percent of maximum flow is observed (from its previous point).

Linear - The linear flow characteristic curve shows that the flow rate is directly proportional to the valve stem travel.

A 10% valve stem travel corresponds to 10% of maximum flow. A 60% stem travel corresponds to 60%, etc.

Piping Installation

All steam field piping should be installed in accordance with local, state and federal codes.

Piping should be adequately supported and braced independent of the *ParaFlow*™ chiller. The support system must account for the expansion and contraction of the steam piping, avoiding the

Table ST1- Equal Percentage Characteristic Data
Refer to Equal % Curve (Figure S1)

Initial Valve Stem Position (%)	Final Valve Stem Position(%)	Initial % of Max. Flow	Final % of Max. Flow	% Change in Flow
10	20	2.6	3.9	**50**
20	30	3.9	5.85	**50**
30	40	5.85	8.78	**50**
40	50	8.78	13.17	**50**
50	60	13.17	19.75	**50**
60	70	19.75	29.63	**50**
70	80	29.63	44.44	**50**
80	90	44.44	66.66	**50**
90	100	66.66	100	**50**

Typical Flow Characteristic Curves

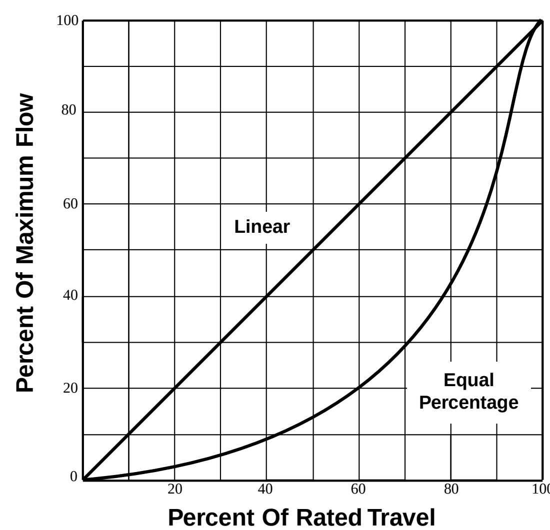
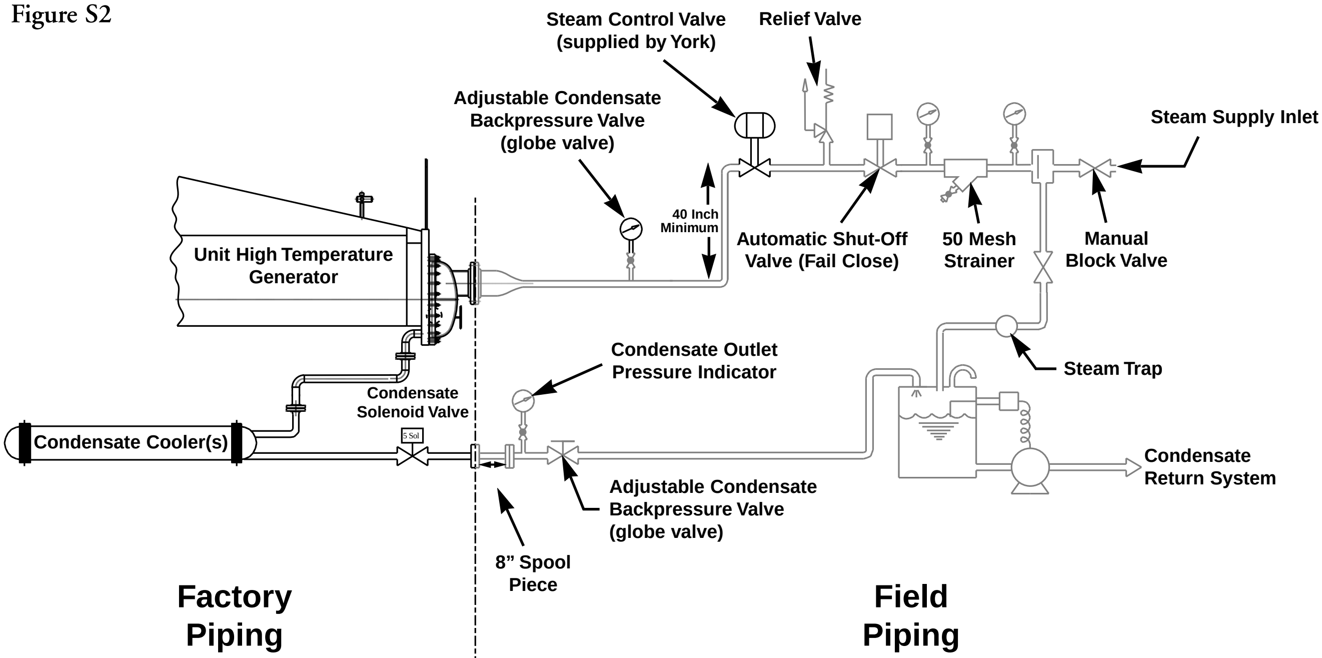


Figure S1

Figure S2



imposition of strain on chiller components.

All components shown in the above schematic must be installed for each unit present. Gray components and piping must be supplied by the customer.

The condensate return system may vary depending upon the design engineer’s preference.

Both steam supply and condensate pipes must be properly sized and pitched to prevent liquid hammering.

The factory installed steam control valve must be installed no further than 200 inches from the high temperature generator steam inlet flange in order to minimize the pressure drop from the valve exit to the generator inlet.

The vertical drop between the steam control valve outlet and the center line of the inlet flange should be no less than 40 inches. This will prevent condensate back flow.

Piping Design

The *ParaFlow*™ unit is nominally rated for dry steam with minimal superheat and a pressure of 115 psig at the York supplied steam control valve.

The inlet steam must not have a temperature greater than 363°F and cannot have a saturation pressure greater than 128 psig (354°F).

This allows for a maximum of 9°F superheat at an inlet pressure of 128 psig. Superheat should always be kept to a minimum.

The condensate system should be designed so that the pressure as read at the condensate outlet pressure indicator is no greater than 15 psig.

The drain cooler installed on the unit effectively eliminates the need for an additional condensate cooler or a steam trap.

Component Details

Manual Block Valve

This valve is installed to allow manual shut off of the steam supply to the *ParaFlow*™ Unit.

Condensate Separator

The condensate trap is installed in the steam supply line and is used to separate any saturated liquid present in the steam. This condensate will be piped back to the condensate tank. This will allow dry steam to enter the unit at all times.

Steam Strainer

The steam strainer is used to capture any impurities in the steam supply. These impurities may manifest in the form of dirt, rust or precipitates.

This strainer will prevent system components from getting plugged. Plugged components will reduce system capacity and increase maintenance costs.

A pressure gauge must be installed before and after the steam strainer. If the pressure drop as read from these two gauges increases to an unacceptable level, the strainer should be removed and cleaned.

Automatic Shut-Off Valve

This valve should shut-off 100% of the steam flow during either a cycling/safety shut down or a power failure.

The York supplied steam control valve will remain in what ever position it happened to be in at the time of a power failure. It is therefore necessary to have a valve that will completely shut-off steam flow to the unit during such a failure.

This steam valve should be bubble tight.

Pressure Relief Valve

A 150 psi pressure relief valve should be installed to protect the steam generator vessel. The vessel is rated for 150 psi.

Steam Control Valve (York Supplied)

The Steam Control Valve as found in the ship loose items, should be installed as shown in **Figure S2**.

This valve should be connected to the appropriate wiring harness and is used to control the amount of steam that enters the *ParaFlow*™ Unit.

It will modulate the steam flow from 20% to 100% depending on the leaving chilled water temperature.

The minimum value of 20% is set either in the field or at the factory (if a Factory Start-up Test is purchased) by setting a limit switch (Honeywell Valve) or Minimum Allowed Loading Setpoint (Leslie Valve). This is explained in detail in the Start-up portion of this section.

Steam Inlet Pressure Indicator

The pressure gauge (supplied by York) is installed to allow the operator to determine the inlet steam pressure to the unit.

8 Inch Flange Adapter

This adapter must be installed at the outlet condensate flange of the unit.

A flow meter will be installed at this location during start-up.

Condensate Outlet Pressure Indicator

The pressure immediately before the Back Pressure Valve (condensate back pressure) should be read at this location.

Condensate Back Pressure Valve

This valve is used to adjust the condensate back pressure during start-up. The condensate back pressure should be adjusted to 15 psig at full steam input.

A manual globe valve should be used for this purpose.

Drain Solenoid Valve

Factory installed device used to insure zero steam flow through the unit during shut down. This valve works in conjunction with the Automatic Shut-Off Valve.

Steam Start-Up Procedure

Before this start-up procedure is performed, the unit must be fully charged and cold purged (refer to purge section of this manual) before heat can be applied.

The unit must be connected to a large enough load to allow the unit to be fired at full load for an extended period of time without overheating the first stage generator. The generator temperature should be kept below 320°F at all times and is set to cut out at 330°F.

Note: If the chilled water temperature setpoint is increased while the unit is running, the Low Water Temperature Threshold will be the previous threshold and will last for a duration of 30 minutes.

PROGRAM KEY ACCESS

During this procedure it will be necessary to gain access to the **PROGRAM** key to allow various setpoints to be changed. Whenever a procedure requires access to the **PROGRAM** key, follow steps 1-8 below.

1. Press **ACCESS CODE** key.

2. ENTER VALID ACCESS CODE is displayed.

3. Using entry keys enter **1380.**

4. As each digit is entered, the characters **YORK** are displayed.

Note: If digits other than **YORK** are displayed, **YORK** is still displayed.

5. Press **ENTER** key.

Note: If digits other than **1380** were entered in step #4, **INVALID ACCESS CODE** is displayed when the **ENTER** key is pressed. If this occurs, enter the correct access code and proceed.

6.ACCESS TO PROGRAM KEY AUTHORIZED is displayed.

Note: Unless terminated by pressing the **ACCESS CODE** key again, the operator will have access to **PROGRAM** key for ten minutes. When 10 minutes have elapsed, access to program key will automatically be disabled and the operator must return to step 1 to gain access. Whenever **PROGRAM** mode is in effect, each key closure will re-initialize the ten minute timer. Automatic exiting of the program will occur only is no key has been pressed during the last ten minutes.

7. Press the **PROGRAM** key.

8. PROGRAM MODE SELECT SET POINT is displayed.

Step 1. Remove 8" Flange Adapter at outlet of condensate drain cooler (**Figure S2**) and install a suitable flow meter in its place. This meter will be used to determine the condensate flow at full load conditions. The meter should read in GPM or the units should be easily converted to GPM.

Note: This step is not necessary, if a factory start-up performance test was purchased by the customer.

Step 2. Make a general inspection tour of the equipment room to ensure that the installation is complete (i.e. piping, controls, wiring, etc.).

Step 3. The jumpers listed below should be in the following positions. These jumpers configure the unit for steam operation only. Refer to Figure 25 of Form 155.17-M2 -Two Stage Absorption Micro-Panel Service Manual to configure other system jumpers.

JP1 (Micro Board)- Removed

JP2 (I/O Expansion Board)

In - Honeywell Steam Valve Operation
Out - Leslie Steam Valve Operation

Step 4. Perform the Automatic Steam Valve Calibration Procedure for the **Honeywell** Steam Valve Only. The procedure is listed below.

Note: If a Leslie steam valve is used, proceed to step 5 on next page.

The Honeywell steam valve contains a 0-135Ω position feedback potentiometer. It indicates the position (0-100%) of the steam valve to the Micro Board. To assure the potentiometer indicates 100% when the steam valve is fully open and 0% when fully closed, calibration is necessary. The calibration procedure once initiated is automatic.

When should the calibration procedure be done?

a) On initial start-up.

b) Whenever the steam valve potentiometer, Micro Board or Micro Board "Real Time Clock" (RTC) IC U16 is replaced.

All calibrated values will be stored in the "RTC" Chip.

The automatic calibration procedure is initiated by the service technician. Once initiated, the Micro Computer Control Center automatically drives the steam valve to its fully loaded (100%) position. When the valve stops moving for 30 seconds, that position is stored as the 100% position. The steam valve is then driven to its fully closed (0%) position. Again when the valve stops moving for 30 seconds, this position is stored as the 0% position.

Note: If the feedback voltage to the I/O Expansion Board J6-2 from the potentiometer was 4.007 VDC to 4.643VDC (4.496 VDC nominal) at the 100% point, it is considered a pass (100%) calibration. Otherwise, it is considered a fail (100%) calibration. The pass range for the 0% calibration point is from 0.415VDC to 0.879VDC (0.488 VDC nominal). A fail indication for either the 0 or 100% point will require troubleshooting to determine the cause of the problem.

The two main problems that could lead to a calibration failure are listed below:

1. Potentiometer not positioned properly or is defective.

2. I/O expansion board problem.

Refer to Form 155.17-M2 -Two Stage Absorption Micro-Panel Service Manual for troubleshooting details.

Steam Valve Calibration Procedure

To perform the calibration procedure, gain access to the **PROGRAM** key as previously described then proceed to the calibration procedure.

Calibration Procedure

1. Press the **AUTO** service key.

AUTO-CAL STEAM VALVE POT-LOAD X.XXXV is displayed.

The steam valve is driven to its fully open (loaded) position while this message is displayed. As the steam valve is loading, the voltage feedback from the steam potentiometer is displayed. It will increment as the valve opens. When the valve stops moving for approximately 30 seconds, the voltage value at that time is logged as the 100% point and the valve is immediately driven to its closed (unloaded) position.

AUTO-CAL STEAM VALVE POT - UNLOAD X.XXXV is displayed.

The voltage feedback from the potentiometer will decrement as the valve unloads. When the valve stops moving for a period of 30 seconds, the voltage value is logged as the 0% point.

2. The pass/fail message is now displayed. If the auto-calibration was successful at both the 0% and 100% positions,

PASS LO = X.XXXV, PASS HI = X.XXXV is displayed.

The voltage value displayed is that which was logged as the fully closed and open points. If either the low or high points were not within the allowed voltage range, **FAIL** is substituted for **PASS**.

3. If either **PASS** or **FAIL** is displayed, press the **ENTER** key.

PROGRAM MODE SELECT SET-POINT is displayed.

If **PASS** is displayed for both the lo and hi positions, the calibration is complete. However, if **FAIL** is displayed for either one, the calibration was not successful and the technician must troubleshoot the problem. Once the problem is located and corrected, the calibration procedure must be repeated.

4. Press the **PROGRAM** key.

Step 5. For start-up, the micro-panel should be put in the **SERVICE** mode, and the **LOAD**, **UNLOAD** and **HOLD** keys should be used to manually modulate the steam valve.

To put the Micro-Panel in the Service Operating Mode gain access to the **PROGRAM** key and then press the **MODE** key.

a) Keep pressing the **ADVANCE DAY /SCROLL** key until the following message is displayed.

SERVICE OPERATING MODE SELECTED.

b) Press the **ENTER** key.

c) Press the **PROGRAM** key.

To verify that the Service Operating Mode has in fact been selected, press the **MODE** key and the following message should be displayed.

SERVICE MODE

The following set points must be set as follows to allow complete control of the LOAD, UNLOAD and HOLD keys.

"**Max. Allowed Loading**" - 100%
"**Pulldown Demand Limit**" - 0 min., start 100%, stop 100%

After gaining access to the **PROGRAM** key, change set points to the above settings as follows:

When all set-points have been changed, press the **PROGRAM** key to exit **PROGRAM** mode.

<u>**MAX. ALLOWED LOADING**</u>

1. To enter max. allowed loading, press and release the **LOAD** key. The following message is displayed.

MAX. ALLOWED LOADING, COOL=XXX%

2. Using the entry keys, enter 100% .

Note: If the cancel key is pressed, the default value of 100% appears.

3. Press **ENTER** key.

PROGRAM MODE SELECT SET POINT is displayed.

<u>**PULLDOWN DEMAND LIMIT**</u>

1. Press the **PULL DOWN DEMAND** key.

2. The following message is displayed.
SETP=XMIN;START=XXX%;STOP=XXX%

3. Input 0 Min,Start=100%;Stop=100%

4. Press the **ENTER** key.

Step 6. Start the unit by switching the start/run/start-reset switch on the micro-panel momentarily to the start position. If no faults are present, the steam valve will begin to open as described in the How It Works portion of this section.

Note: Unlike the direct-fired models where the solution and refrigerant pumps start immediately with the burner, the **pumps** on the steam units will **not start until** the generator pressure reaches **0.97 psia**.

Step 7. Use the **LOAD**, **UNLOAD** and **HOLD** keys to keep the steam input down while hot purging is being performed (refer to Purging section).

Continue to load unit until full load conditions can be achieved without the unit going off on high generator temperature or pressure over ride.

Step 8. Adjust the manual needle valve located upstream from the condensate shut-off valve until the desired condensate flow rate is read at the installed flow meter.

This flow rate is located on Form 155.19-F1 *Paraflow*™ Steam Fired Chiller Order Form (Section IV).

Step 9. Once the steam valve is in its fully open (loaded) position, and the inlet steam pressure is at its specified value (115-128 psi), adjust the condensate back pressure valve as shown in **Figure S3** until 15 lbs. of back pressure is read at the back pressure indicator.

Step 10. The 20% minimum flow point must now be set. Perform the setpoint procedures as listed below.

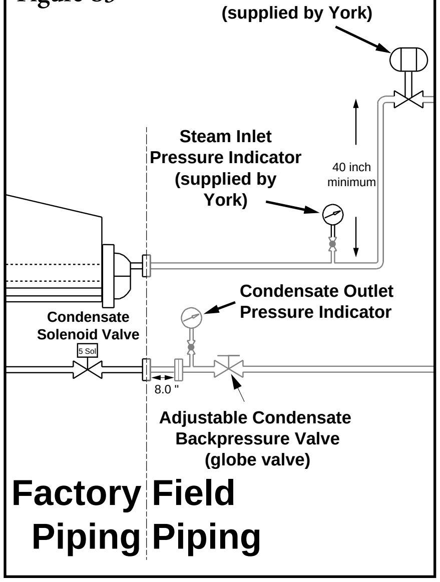
Determine the 20% steam flow rate point by multiplying the flow rate value used in step 8 by 0.2. (GPH max. X 0.2)

Honeywell Valves

a) Use the **UNLOAD**, **LOAD**, and **HOLD** keys until the (20%) flow rate is read at the installed flow meter.

b) Press the **DISPLAY DATA** key followed immediately by the **DISPLAY**

Figure S3



HOLD key. The steam valve's stem position corresponding to 20% steam flow rate will be displayed. Record this value.

(i.e. for 20% steam flow, the stem travel may be 58%)

c) Remove the two screws securing the actionator motor's end cover and remove the cover.

d) Unload the unit using the **UNLOAD** key. When the motor reaches its fully closed position note which cam breaks the counter clockwise limit switch.

e) Load the unit back to its previous 20% flow position and stop it there.

f) Adjust the appropriate cam until the limit switch opens.

g) Load the unit above this position and then unload it to see where the steam valve stops. Continue to **LOAD**, **UNLOAD** and adjust the cam until the desired stem travel is read at the 20% stem position.

Leslie Valves

a) Use the **UNLOAD**, **LOAD**, and **HOLD** keys until the above (20%) flow rate is read at the installed flow meter.

b) Press the **DISPLAY DATA** key followed immediately by the **DISPLAY HOLD** key. The steam valve's stem position corresponding to 20% steam flow rate will be displayed. Record this value.

c) The 20% cut-out value will have to be set using the **MINIMUM ALLOWED LOADING** setpoint as described in the How it Works Section. This setpoint is adjustable from 5 - 60% of valve stem travel.

The **MINIMUM ALLOWED LOADING** setpoint should be set to whatever value was observed in step b.

Step 11. Remove flow meter and reinstall 8" flanged section.

Step 12. Make sure all piping is leak free after start-up and repair as necessary.

The start-up is now complete. If operational problems are encountered during or after start-up, it may be necessary to adjust any one of the steam valve setpoints.

Steam Valve Control

General

Early vintage units are equipped with **Honeywell Steam Valves**. Later vintage units that are equipped with eprom version A.01F.08 (or later) could use either **Honeywell** or **Leslie Steam Valves**.

The **Honeywell** valves are operated by 115VAC Pulse Width Modulated (PWM) signals from triacs located on the Relay Board.

The **Leslie** valves are operated from a 4-20ma signal from the I/O Expansion Board. Program jumper JP2, on the I/O Expansion Board, must be removed to enable the 4-20ma output control.

Operation

During unit run, the steam valve is modulated under program control to control the **Leaving Chilled Water Temperature** (**LCWT**) to the **Leaving Chilled water Temperature Setpoint**. It is modulated between 20% of unit capacity and 100% of unit capacity. The valve position that corresponds to 20% of unit capacity is determined by the procedure outlined in the start-up portion of this sectionl.

With **Honeywell** valves, a limit switch opens to prevent the valve from decreasing to less than 20% of unit capacity.

With **Leslie** valves, a programmable setpoint, **MINIMUM ALLOWED LOADING**, is programmed to a valve position between 5% to 60% that corresponds to 20% of design flow rate. The Leslie valve will not be allowed to close to a position less than the programmed value, however, the **UNLOAD** key can be used in **SERVICE** mode to manually drive the valve below this position.

In either case, the steam valve position is its physical position with respect to fully closed to fully open. Its position is 0% when fully closed and 100% when fully open.

With **Honeywell** valves, there is a position feedback potentiometer interfaced to the **I/O Expansion Board** that signals the valves position to the MICRO board. The 0% and 100% points are established with the "**STEAM VALVE POTENTIOMETER CALIBRATION**" (refer to Start-up portion of this section).

With **Leslie** valves, there is no position feedback potentiometer; the valve will be fully closed when the control output is 4ma and fully open when the output reaches 20 ma.

The program monitors:

A. The **error** between the **LCWT** and the **setpoint**.

B. The **rate of change** of the **LCWT** within each **Sample Period**.

While the unit is running, the duration of the run time is divided into a continuous series of Sample Periods. Each time the unit is started and enters "**SYSTEM RUN**" mode, the first Sample Period begins. When the first Sample Period ends, the next Sample Period begins, etc. This continues until the unit is shutdown.

Each time the unit is started (or the **AUTO** key is pressed in **Service** mode), the sample period is 1 minute in duration until the steam valve position is greater than or equal to 50% or the LCWT is within 5°F of the setpoint. After this, the duration of each sample period is determined by the setpoint **SAMPLE FACTOR**. This factor is programmable over the range of 0.5 to 16 minutes.

At the end of each sample period, the program responds with an output that contains a rate component and a proportion component. It will be in the form of a **LOAD, UNLOAD** or **HOLD** output, as appropriate, to the steam valve actuator. The actual output is determined by the magnitude of error between the **LCWT** and the **LCWT** setpoint (proportion), and the amount of change (Rate) and direction of change of the LCWT within the sample period. If the LCWT falls to 3°F below setpoint or <40°F, the unit shuts down and displays the following message.

DAY-TIME - LOW WATER TEMP - AUTO START

The **Rate** component of the output is applied in response to the LCWT's rate and direction of change (toward or away from setpoint) within the Sample Period. The amount of rate response is determined by the relationship of the rate of change (amount of LCWT change in the Sample Period) to the programmed **RATE LIMIT** setpoint. The closer the rate of change value is to the programmed **RATE LIMIT** setpoint, the greater the rate component in the output.

The actual **RATE LIMIT** value programmed will be a function of conditions at the job site; such as length of chilled water loop, number of chillers, multiple chiller configuration (series or parallel), primary/secondary chilled water loop, etc.

Short chilled water loops generally cause the **LCWT** rate of change to be greater. The greater the rate of change, the greater the tendency to overshoot or undershoot the setpoint. At unit commissioning, the service technician must evaluate the local conditions and refine the **RATE LIMIT** setpoint as required.

Typically, load and unload output requirements are balanced; the unit is required to load and unload at the same rate. However, in some applications, the unit will have a tendency to overshoot the LCWT setpoint and shutdown on "**DAY - TIME - LOW WATER TEMP - AUTOSTART**".

Short chilled water loops, series/parallel chillers, light load conditions and applications where loads are shed rapidly are typical causes of setpoint overshoot.

These applications require a greater unload output than would usually be allowed under the same conditions.

To accommodate these applications, setpoints **UNLOAD PULSE** (**Honeywell valves**) or **UNLOAD FACTOR** (**Leslie valves**) can be programmed to provide faster unloading.

Leslie valves have an additional setpoint, **DAC DIVIDE VALUE** that can be used to decrease the magnitude of the load and unload output that occurs at the end of the Sample Period when the LCWT is within 5°F of the setpoint. These smaller changes in output prevent large excursions of the LCWT when the unit operates continuously under light load conditions.

Programmable Values

Rate Limit

The **Rate Limit** is a field programmable setpoint that determines the control center's sensitivity/response to the rate of change of the **Leaving Chilled Water Temperature** (**LCWT**) within a **Sample Period**. The **Rate Of Change** is defined as the amount of change in the **LCWT** within one **Sample Period**. The rate of change is calculated over each sample period of unit operating time and at the end of the sample period, the rate of change is compared to the **RATE LIMIT** setpoint. The closer the rate of change is to the **RATE LIMIT** setpoint, the greater the effect rate of change has on the output that occurs at the end of the **Sample Period**.

If the rate of change equals or exceeds the **RATE LIMIT** setpoint, there would be a maximum rate response. Therefore, rate sensitivity increases as the programmed **RATE LIMIT** setpoint is decreased.

The **RATE LIMIT** setpoint is programmable over the range of 0.3 to 2.0°F in 0.1°F increments. The default value is 1.0 °F.

For example: if the **RATE LIMIT** setpoint is programmed for 1.0°F and the **LCWT** increased 0.9°F in the **SAMPLE PERIOD**, there would be a greater rate response than if the LCWT had increased 0.5°F in the same period.

In most applications, the default value (1.0°F) will provide proper operation. Programming a value less than 1.0 could tend to cause excessive steam valve movement (hunting) resulting in excessive steam pressure fluctuation in certain installations.

In detecting the rate of change, the Control Center anticipates where the **LCWT** is going and responds accordingly to prevent setpoint overshoot.

For example: if the LCWT is < 5°F above setpoint and decreasing, an **UNLOAD** output would occur at the end of the **SAMPLE PERIOD**, even though the **LCWT** is above setpoint.

The response to rate of change is somewhat different if the **LCWT** is > 5°F above the **LCWT** setpoint.

For example: if the **LCWT** decreases less than the **RATE LIMIT** setpoint within a Sample Period, there would be a **LOAD** output up to the maximum allowed. However, if the **LCWT** decreases greater than the **RATE LIMIT** setpoint within the Sample Period, there would be no **LOAD** output.

UNLOAD PULSE (Honeywell valves only)

The **UNLOAD PULSE** is a field programmable setpoint that determines the maximum allowed **PWM** pulse duration of the **UNLOAD** output for Honeywell Valves. The maximum allowed duration of the **UNLOAD** output is programmable over the range of 6 to 12 seconds, in 1 second increments. The default value is 6 seconds.

Since the maximum allowed **LOAD** pulse is a constant 6 seconds, programming this value to 6, would make the unit **LOAD** and **UNLOAD** at the same rate. In most applications, this will provide proper operation. However, if this value is programmed to "9", the maximum allowed **UNLOAD** pulse would be 9 seconds in duration, and this would cause the unit to unload at a faster rate. This can be helpful for applications where loads are shed rapidly.

UNLOAD FACTOR (Leslie valves only)

The **UNLOAD FACTOR** is a field programmable setpoint that can be used to make the unit unload at a faster rate.

The programmed value is the multiplier for the **UNLOAD** output that occurs at the end of a Sample Period, when the program calls for unloading the steam valve. It is programmable from 1.0 to 2.0 in 0.1 increments. The default value is 1.0.

If at the end of a **SAMPLE PERIOD**, the program determines that it is necessary to unload the steam valve, the decrease in the 4-20ma output that would normally occur, is multiplied by the programmed value.

For example: if the program determines that the output should decrease 2.0ma, and the UNLOAD FACTOR is 1.5, then the output would decrease 3.0ma (ie; 2.0 x 1.5 = 3.0). The greater the number programmed, the faster the steam valve will unload. This can be helpful for short water loops, continuous light load conditions and applications where loads are shed rapidly.

Note: The default value of 1.0 should provide proper operation in most installations.

SAMPLE FACTOR

The **SAMPLE FACTOR** is a field programmable setpoint that determines the duration of the Sample Periods that occur after the initial 1 minute criteria is satisfied.

Each time the unit is started, the duration of each Sample Period is 1 minute until the steam valve position is > 50% or the leaving chilled water temperature (LCWT) is within 5°F of the **LCWT** setpoint. After that, the duration of the Sample Periods will be whatever is programmed as the **SAMPLE FACTOR.**

This factor is programmable over the range of 0.5 to 16 minutes, in 0.1 minute increments. The default value is 4.0 minutes.

While the unit is running, the duration of the operating time is divided into a continuous series of Sample Periods.

When the unit enters System Run mode on start-up, the first Sample Period begins.

When the first sample period ends, the next one begins, etc. This continues until the unit is shutdown. The output is allowed to change only at the end of each Sample Period.

For example: if 2.0 is programmed, each time the unit is started, the Sample Periods will be 1 minute in duration until the steam valve reaches 50% position or the LCWT is within 5°F of the LCWT setpoint; the Sample Periods will be 2 minutes in duration thereafter. The default value of 4.0 should provide proper operation in most applications, however, applications with extremely short or long chilled water loops or with irregular load changes could require the Sample Period to be longer or shorter.

DAC DIVIDE VALUE (Leslie valves only)

The **DAC DIVIDE VALUE** is a field programmable setpoint that can be used to decrease the magnitude of the **LOAD** and **UNLOAD** outputs. It can be programmed for 1, 2, 4 or 8. The default value is 1. After the **LEAVING CHILLED WATER TEMP (LCWT)** gets within 5°F of the LCWT setpoint, if a change in the 4-20ma output is called for at the end of a Sample Period, that change will be divided by the programmed **DAC DIVIDE VALUE**.

For example, if the output is required to increase 2.5ma at the end of a **SAMPLE PERIOD**, and the programmed **DAC DIVIDE VALUE** is 4, the output would increase 0.6ma (2.5/4 = 0.6).

The default value 1 should provide proper operation in most applications, however, this value can be adjusted to provide smaller changes in the output when the unit operates under conditions such as continuous light load.

MINIMUM ALLOWED LOADING (Leslie valves only)

The **MINIMUM ALLOWED LOADING** setpoint is programmable from 5% to 60% in 1% increments. This value is typically set at 20% of unit capacity. Operating below this capacity could result in unstable operating conditions and possible loss of refrigerant in the refrigerant tank. This is caused by the unit absorbing more refrigerant than it is capable of boiling off in the generator.

During system operation the steam valve will not be allowed to unload below this programmed value, however, using the **LOAD/UNLOAD** keypad keys in **SERVICE** mode, will allow the service technician to unload below this position.

Steam Valve Control Setpoints

The following is a list of the various setpoints for each type of valve, followed by a description on how to change the setpoints.

Honeywell Valves

1. Rate Limit

2. Maximum Allowed Unload Pulse

3. Sample Factor

To change these set-point values, gain access to the **PROGRAM** key. Then refer to the specific procedure for each set point.

Rate Limit

The value entered as Rate Limit, determines the response to rate of change of the leaving chilled water temperature.

It is programmable from 0.3°F to 2.0°F in 0.1°F increments. **The default value is 1.0°F**.

Maximum Allowed Unload Pulse

The value entered as the maximum allowed unload pulse is the desired maximum allowed unload pulse duration.

This value is programmable from 6 to 12 seconds in one second increments. The default value is 6 seconds.

For Initial Start-up: It is recommended that the default values (Rate Limit = 1 and Unload Pulse = 6) be used initially. These values will provide proper operation for most applications. Local conditions such as chilled water loop length, number of chillers, multiple chiller configuration (series or parallel)and primary secondary water loops could require these values to be changed to refine the leaving chilled water temperature control.

To enter these values, proceed as follows:

1. Press **CHILLED WATER TEMPS key. RATE LIMIT = X.X: UNLOAD = XX** is displayed.

2. Using **ENTRY** keys, enter the desired rate limit value. Use leading zeroes where necessary (ie, 0.5). The curser will move under the first changeable digit of the unload pulse value. Use leading zeroes where necessary (ie, 06).

If the **CANCEL** key is pressed, default values of 1.0 (Rate Limit) and 6 (Unload Pulse) are displayed.

3. Press the **ENTER** key.

PROGRAM MODE, SELECT SET-POINT is displayed.

4. Press **PROGRAM** key to exit or continue to next setting using the **ADVANCE DAY/SCROLL** key. Step 1 of next setpoint procedure may be eliminated if entering from this point.

Sample Factor

1. Press **CHILLED WATER TEMPS key**. Press the **ADVANCE DAY/SCROLL** key until **SAMPLE FACTOR = XX.X** is displayed

2. Enter the desired value for **SAMPLE FACTOR.** Use leading zeroes when necessary (ie, 05.0).

3. Press the **ENTER** key. **PROGRAM MODE SELECT SETPOINT** is displayed.

4. Press **PROGRAM** key to exit.

Leslie Valves

1. Rate Limit

2. Unload Factor

3. Sample Factor

4. DAC Divide Value

5. Minimum Allowed Loading

To change these set-point values, gain access to the **PROGRAM** key. Then refer to the specific procedure for each set point.

Rate Limit

The value entered as Rate Limit, determines the response to rate of change of the leaving chilled water temperature.

It is programmable from 0.3°F to 2.0°F in 0.1°F increments. **The default value is 1.0°F**.

Unload Factor

For Initial Start-up: It is recommended that the default values (Rate Limit = 1.0 and Unload Factor = 1.0) be used initially. These values will provide proper operation for most applications. Local conditions such as chilled water loop length, number of chillers, multiple chiller configuration (series or parallel)and primary secondary water loops could require these values to be changed to refine the leaving chilled water temperature control.

To enter these values, proceed as follows:

1. Press **CHILLED WATER TEMPS key**. **RATE LIMIT = X.X: UNLOAD FACTOR = XX** is displayed.

2. Using **ENTRY** keys, enter the desired rate limit value. Use leading zeroes where necessary (ie, 0.5). The curser will move under the first changeable digit of the unload pulse value. Use leading zeroes where necessary (ie, 06).

If the **CANCEL** key is pressed, default values of 1.0 (Rate Limit) and 1.0 (Unload Factor) are displayed.

3. Press the **ENTER** key.

PROGRAM MODE, SELECT SET-POINT is displayed.

4. Press **PROGRAM** key to exit or continue to next setting using the **ADVANCE DAY/SCROLL** key. Step 1 of next setpoint procedure may be eliminated if entering from this point.

Sample Factor

1. Press **CHILLED WATER TEMPS key**. Press the **ADVANCE DAY/SCROLL** key until **SAMPLE FACTOR = XX.X** is displayed

2. Enter the desired value for **SAMPLE FACTOR.** Use leading zeroes when necessary (ie, 05.0).

3. Press the **ENTER** key. **PROGRAM MODE SELECT SETPOINT** is displayed.

4. Press **PROGRAM** key to exit or continue to next setting using the **ADVANCE DAY/SCROLL** key. Step 1 of next setpoint procedure may be eliminated if entering from this point.

DAC Divide Value

1. Press **CHILLED WATER TEMPS** key. Press **ADVANCE DAY/SCROLL** key until **DAC DIVIDE VALUE = X** is displayed.

2. Enter the desired value for the **DAC DIVIDE VALUE (1,2,4,8)**.

3. Press the **ENTER** key. **PROGRAM MODE SELECT SETPOINT** is displayed.

4. Press **PROGRAM** key to exit or continue to next setpoint.

Minimum Allowed Loading

1. Press **UNLOAD** key. **MIN ALLOWED LOADING = XX%** is displayed.

2. Enter the desired value. Use leading zeroes where necessary (ie, 05%).

3. Press the **ENTER** key. **PROGRAM MODE SELECT SETPOINT** is displayed.

4. Press **PROGRAM** key to exit.

Note: If the chilled water temperature setpoint is increased while the unit is running, the Low Water Temperature Threshold will be the previous threshold and will last for the duration of 30 minutes.

Steam Purity

Condensate Water (Chemical Components Allowance)	
P.H.	7.0 - 8.0 @ 77 °F
Total Carbonic Acid (HCO_3^-, H_2CO_3, CO_2)	Below 3ppm
Nickel (Ni)	Below 0.17 ppm
Copper (Cu)	Below 0.40 ppm

Boiler water treatment is an essential part of any maintenance program. If the water is not properly treated, certain chemicals may exceed tolerable limits and damage to the high temperature generator, condensate drain coolers, control devices and adjoining piping will occur. **It is the customers responsibility to test the condensate to make sure it is within certain limits**. These limits are listed in the table above.

If the steam carries entrained air or other gases, this will have a tendency to reduce the steam temperature. Air will also reduce the heat transfer properties of a unit because it migrates to heat transfer surfaces causing an insulating effect.

Carbon dioxide in steam is probably the most destructive form of contaminant. CO_2 will dissolve in the condensate forming carbonic acid, which is extremely corrosive to pipes and other system components.

Units and components damaged by poor steam (condensate) quality will not be covered under any of York's Warranties.

Condensate P.H. Testing

1. Take sample (with machine in operation) from the drain valve located at the condensate drain cooler.

2. Let sample cool in air to 77 °F.

3. Check P.H. immediately using appropriate test kit.

Note: PH content must be measured at the job site.

Procedure for Taking Condensate Samples for Lab Analysis

1. Take sample (with machine in operation) from the drain valve located at the condensate drain cooler.

2. Squeeze sample bottle to discharge any air trapped in the bottle. (Oxygen will cause erroneous results)

3. Securely fasten air tight cover.

4. If customer is using chemical additives to treat steam boiler, make note of chemical name and symbol and include with sample.

5. Send sample to lab and check for above concentrations.

Steam Head Gasket Replacement

York has recently standardized on a new gasket material for all steam generator heads. Instead of the pre-cut gaskets with a separate part number for each unit, we are now using 1/4 inch **Gore-Tex® Joint Sealant**, which comes in fifty foot rolls. We have found through field testing that the new gasket compound is much more reliable than the previous gasket material, however, special application and bolt torquing procedures must be adhered to in order to attain that reliability.

Replacement Procedure

Caution: Bleed off any residual pressure and completely close and tag steam supply and condensate valves prior to attempting to remove steam head. Use proper lifting devices to secure and remove steam head to avoid personal injury and damage.

1. Completely remove all traces of the old gasket material from both the head and tube sheet. Clean all studs with a wire brush so that they are free of any residue and that the nuts can be run all the way on the stud by hand.

2. Remove the paper backing on the joint sealant and attach the joint sealant to the steam generator tube sheet near the 12 o'clock position just inside the bolt circle. Continue attaching the joint compound to the surface, working completely around until you are back at the starting point. Overlap the ends of the sealant by at least 1/2 inch.

3. Attach a strip of joint sealant across the pass baffle partition mating area, overlapping both of the ends across the joint sealant applied previously by 1/4 inch minimum.

4. Tap the overlapped areas down flush before attaching the head to the generator.

5. Apply a thin coat of **high temperature anti-seize compound** to the studs (Fel-Pro® C5-A, **York P/N 013-01690-000**).

6. Re-attach the head to the generator, taking care not to disturb the placement of the gasket material. Slide the head gently up against the tube sheet and install all nuts finger tight.

7. Using four (4) incremental steps, torque the nuts using a star (crisscross) pattern. In other words, first torque the nuts to 20 ft/lb, then 40 ft/lb, then 60 ft/lb and finally 80 ft/lb.

8. In a counter-clockwise direction (starting at the 12 o'clock position), recheck all studs/nuts and confirm they are at 80 ft.lbs. of torque.

9. After the unit has operated at design pressure and temperature, shut the unit down, reduce the pressure and re-torque all bolts to 80 ft/lb. The gasket should now be ready for normal use.

The type of **Gore-Tex® Joint Sealant** used in this application is one of many expanded PTFE compounds manufactured by W.L. Gore & Associates, Inc. DO NOT SUBSTITUTE.

The York part number for a 1/4 inch x 50 ft. roll of **Gore-Tex®Joint Sealant** is **028-12908-000**. One roll of joint sealant should be sufficient to do several generators. The actual length required per generator will depend on the size of the unit.

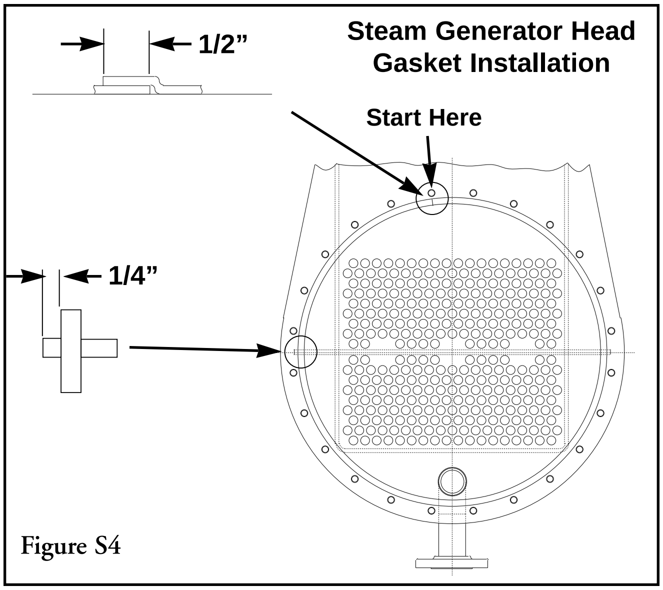


Figure S4

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
32	29.7417	4.5797	0.08856	0.01602	3304.60	0.00	1075.16	1075.16	32
33	29.7342	4.7702	0.09224	0.01602	3180.50	1.01	1075.60	1074.59	33
34	29.7265	4.9658	0.09602	0.01602	3061.70	2.01	1076.40	1074.39	34
35	29.7185	5.1690	0.09995	0.01602	2947.80	3.02	1076.48	1073.46	35
36	29.7102	5.3798	0.10403	0.01602	2838.70	4.02	1076.92	1072.90	36
37	29.7017	5.5957	0.10820	0.01602	2734.10	5.03	1077.36	1072.33	37
38	29.6928	5.8218	0.11257	0.01602	2633.80	6.03	1077.80	1071.77	38
39	29.6837	6.0529	0.11704	0.01602	2537.60	7.04	1078.24	1071.20	39
40	29.6742	6.2942	0.12171	0.01602	2445.40	8.04	1078.68	1070.64	40
41	29.6644	6.5431	0.12652	0.01602	2356.90	9.05	1079.11	1070.06	41
42	29.6543	6.7997	0.13148	0.01602	2272.00	10.05	1079.55	1069.50	42
43	29.6438	7.0664	0.13664	0.01602	2190.50	11.05	1079.99	1068.94	43
44	29.6329	7.3432	0.14199	0.01602	2112.30	12.06	1080.43	1068.37	44
45	29.6216	7.6303	0.14754	0.01602	2037.30	13.06	1080.87	1067.81	45
46	29.6100	7.9249	0.15324	0.01602	1965.20	14.06	1081.30	1067.24	46
47	29.5980	8.2297	0.15914	0.01602	1896.00	15.06	1081.74	1066.68	47
48	29.5856	8.5447	0.16523	0.01602	1829.50	16.07	1082.18	1066.11	48
49	29.5727	8.8723	0.17156	0.01602	1765.70	17.07	1082.62	1065.55	49
50	29.5594	9.2102	0.17809	0.01602	1704.30	18.07	1083.06	1064.99	50
51	29.5456	9.5607	0.18487	0.01602	1645.40	19.07	1083.49	1064.42	51
52	29.5314	9.9214	0.19185	0.01602	1588.70	20.07	1083.93	1063.86	52
53	29.5168	10.2922	0.19902	0.01603	1534.30	21.07	1084.37	1063.30	53
54	29.5017	10.6758	0.20643	0.01603	1481.90	22.07	1084.80	1062.73	54
55	29.4861	11.0720	0.21410	0.01603	1431.50	23.08	1085.24	1062.16	55
56	29.4700	11.4810	0.22200	0.01603	1383.10	24.08	1085.68	1061.60	56
57	29.4534	11.9026	0.23016	0.01603	1336.50	25.08	1086.12	1061.04	57
58	29.4362	12.3395	0.23861	0.01603	1291.70	26.08	1086.55	1060.47	58
59	29.4185	12.7891	0.24730	0.01603	1248.60	27.08	1086.99	1059.91	59
60	29.4002	13.2539	0.25629	0.01603	1207.10	28.08	1087.42	1059.34	60
61	29.3813	13.7340	0.26557	0.01604	1167.20	29.08	1087.86	1058.78	61
62	29.3619	14.2267	0.27510	0.01604	1128.70	30.08	1088.30	1058.22	62
63	29.3418	14.7373	0.28497	0.01604	1091.70	31.08	1088.73	1057.65	63
64	29.3211	15.2631	0.29514	0.01604	1056.10	32.08	1089.17	1057.09	64
65	29.2998	15.8041	0.30560	0.01604	1021.70	33.08	1089.60	1056.52	65
66	29.2778	16.3629	0.31640	0.01604	988.65	34.07	1090.04	1055.97	66
67	29.2551	16.9395	0.32755	0.01605	956.78	35.07	1090.47	1055.40	67
68	29.2317	17.5339	0.33905	0.01605	926.08	36.07	1090.91	1054.84	68
69	29.2076	18.1460	0.35088	0.01605	896.49	37.07	1091.34	1054.27	69

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
70	29.1828	18.7759	0.36306	0.01605	867.97	38.07	1091.78	1053.71	70
71	29.1572	19.4262	0.37564	0.01605	840.47	39.07	1092.21	1053.14	71
72	29.1308	20.0968	0.38861	0.01606	813.97	40.07	1092.65	1052.58	72
73	29.1037	20.7851	0.40192	0.01606	788.40	41.07	1093.08	1052.01	73
74	29.0758	21.4938	0.41562	0.01606	763.75	42.06	1093.52	1051.46	74
75	29.0470	22.2253	0.42976	0.01606	739.97	43.06	1093.95	1050.89	75
76	29.0174	22.9772	0.44430	0.01606	717.03	44.06	1094.38	1050.32	76
77	28.9868	23.7544	0.45933	0.01607	694.90	45.06	1094.82	1049.76	77
78	28.9554	24.5520	0.47475	0.01607	673.54	46.06	1095.25	1049.19	78
79	28.9231	25.3724	0.49062	0.01607	652.93	47.06	1095.68	1048.62	79
80	28.8899	26.2157	0.50693	0.01607	633.03	48.05	1096.12	1048.07	80
81	28.8556	27.0869	0.52377	0.01608	613.82	49.05	1096.55	1047.50	81
82	28.8204	27.9810	0.54106	0.01608	595.27	50.50	1096.98	1046.48	82
83	28.7842	28.9005	0.55884	0.01608	577.36	51.05	1097.42	1046.37	83
84	28.7470	29.8454	0.57711	0.01608	560.06	52.05	1097.85	1045.80	84
85	28.7087	30.8182	0.59592	0.01609	543.35	53.05	1098.28	1045.23	85
86	28.6693	31.8190	0.61528	0.01609	527.21	54.04	1098.71	1044.67	86
87	28.6289	32.8452	0.63512	0.01609	511.62	55.04	1099.14	1044.10	87
88	28.5873	33.9018	0.65555	0.01610	496.54	56.04	1099.58	1043.54	88
89	28.5445	34.9890	0.67657	0.01610	481.98	57.04	1100.01	1042.97	89
90	28.5005	36.1066	0.69818	0.01610	467.90	58.04	1100.44	1042.40	90
91	28.4553	37.2547	0.72038	0.01610	454.28	59.03	1100.87	1041.84	91
92	28.4089	38.4333	0.74317	0.01611	441.12	60.03	1101.30	1041.27	92
93	28.3612	39.6449	0.76660	0.01611	428.40	61.03	1101.73	1040.70	93
94	28.3123	40.8869	0.79062	0.01611	416.09	62.03	1102.16	1040.13	94
95	28.2620	42.1646	0.81532	0.01612	404.19	63.03	1102.59	1039.56	95
96	28.2103	43.4778	0.84072	0.01612	392.67	64.02	1103.02	1039.00	96
97	28.1573	44.8240	0.86675	0.01612	381.53	65.02	1103.45	1038.43	97
98	28.1028	46.2083	0.89352	0.01612	370.75	66.02	1103.88	1037.86	98
99	28.0469	47.6282	0.92097	0.01613	360.32	67.02	1104.31	1037.29	99
100	27.9895	49.0862	0.94917	0.01613	350.22	68.02	1104.74	1036.72	100
101	27.9305	50.5848	0.97814	0.01614	340.44	69.01	1105.17	1036.16	101
102	27.8701	52.1190	1.00781	0.01614	330.98	70.01	1105.59	1035.58	102
103	27.8082	53.6912	1.03821	0.01614	321.82	71.01	1106.02	1035.01	103
104	27.7445	55.3092	1.06950	0.01614	312.95	72.01	1106.45	1034.44	104
105	27.6791	56.9704	1.10162	0.01615	304.36	73.01	1106.88	1033.87	105
106	27.6121	58.6723	1.13453	0.01615	296.04	74.01	1107.30	1033.29	106
107	27.5434	60.4173	1.16827	0.01616	287.98	75.00	1107.73	1032.73	107

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
108	27.4729	62.2080	1.20290	0.01616	280.16	76.00	1108.16	1032.16	108
109	27.4006	64.0444	1.23841	0.01616	272.60	77.00	1108.58	1031.58	109
110	27.3265	65.9266	1.27480	0.01617	265.26	78.00	1109.01	1031.01	110
111	27.2505	67.8570	1.31213	0.01617	258.16	79.00	1109.44	1030.44	111
112	27.1726	69.8357	1.35039	0.01617	251.27	80.00	1109.86	1029.86	112
113	27.0927	71.8652	1.38964	0.01618	244.59	80.99	1110.29	1029.30	113
114	27.0109	73.9429	1.42981	0.01618	238.12	81.99	1110.71	1028.72	114
115	26.9272	76.0689	1.47092	0.01618	231.84	82.99	1111.14	1028.15	115
116	26.8414	78.2483	1.51306	0.01619	225.75	83.99	1111.56	1027.57	116
117	26.7533	80.4861	1.55634	0.01619	219.85	84.99	1111.98	1026.99	117
118	26.6631	82.7772	1.60064	0.01620	214.12	85.99	1112.41	1026.42	118
119	26.5708	85.1216	1.64597	0.01620	208.56	86.98	1112.83	1025.85	119
120	26.4762	87.5245	1.69244	0.01620	203.18	87.98	1113.26	1025.28	120
121	26.3793	89.9858	1.74003	0.01621	197.95	88.98	1113.68	1024.70	121
122	26.2700	92.7621	1.79371	0.01621	192.87	89.98	1114.10	1024.12	122
123	26.1784	95.0887	1.83870	0.01622	187.95	90.98	1114.52	1023.54	123
124	26.0745	97.7278	1.88973	0.01622	183.17	91.98	1114.94	1022.96	124
125	25.9681	100.4304	1.94199	0.01622	178.53	92.98	1115.37	1022.39	125
126	25.8591	103.1991	1.99553	0.01623	174.02	93.98	1115.79	1021.81	126
127	25.7475	106.0337	2.05034	0.01623	169.65	94.97	1116.21	1021.24	127
128	25.6333	108.9345	2.10643	0.01624	165.40	95.97	1116.63	1020.66	128
129	25.5165	111.9012	2.16380	0.01624	161.28	96.97	1117.05	1020.08	129
130	25.3969	114.9391	2.22254	0.01625	157.27	97.97	1117.47	1019.50	130
131	25.2746	118.0456	2.28261	0.01625	153.39	98.97	1117.89	1018.92	131
132	25.1495	121.2231	2.34406	0.01626	149.60	99.97	1118.31	1018.34	132
133	25.0215	124.4744	2.40693	0.01626	145.93	100.97	1118.73	1017.76	133
134	24.8906	127.7993	2.47122	0.01626	142.36	101.97	1119.15	1017.18	134
135	24.7567	131.2004	2.53698	0.01627	138.89	102.97	1119.56	1016.59	135
136	24.6198	134.6777	2.60422	0.01627	135.52	103.97	1119.98	1016.01	136
137	24.4799	138.2312	2.67294	0.01628	132.24	104.97	1120.40	1015.43	137
138	24.3368	141.8660	2.74322	0.01628	129.06	105.97	1120.82	1014.85	138
139	24.1904	145.5846	2.81513	0.01629	125.96	106.97	1121.23	1014.26	139
140	24.0408	149.3845	2.88861	0.01629	122.96	107.96	1121.65	1013.69	140
141	23.8879	153.2682	2.96370	0.01630	120.03	108.96	1122.07	1013.11	141
142	23.7317	157.2357	3.04042	0.01630	117.18	109.96	1122.48	1012.52	142
143	23.5720	161.2922	3.11886	0.01631	114.42	110.96	1122.90	1011.94	143
144	23.4088	165.4375	3.19902	0.01631	111.72	111.96	1123.31	1011.35	144
145	23.2420	169.6743	3.28094	0.01632	109.11	112.96	1123.73	1010.77	145

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
146	23.0720	173.9924	3.36444	0.01632	106.56	113.96	1124.14	1010.18	146
147	22.8980	178.4120	3.44990	0.01633	104.08	114.96	1124.55	1009.59	147
148	22.7200	182.9333	3.53733	0.01633	101.67	115.96	1124.97	1009.01	148
149	22.5380	187.5561	3.62672	0.01634	99.32	116.96	1125.38	1008.42	149
150	22.3530	192.2552	3.71758	0.01634	97.04	117.96	1125.79	1007.83	150
151	22.1630	197.0813	3.81090	0.01635	94.82	118.96	1126.20	1007.24	151
152	21.9700	201.9835	3.90570	0.01635	92.65	119.96	1126.62	1006.66	152
153	21.7720	207.0128	4.00295	0.01636	90.54	120.97	1127.03	1006.06	153
154	21.5710	212.1183	4.10167	0.01636	88.49	121.97	1127.44	1005.47	154
155	21.3650	217.3507	4.20285	0.01637	86.50	122.97	1127.85	1004.88	155
156	21.1550	222.6848	4.30599	0.01637	84.55	123.97	1128.26	1004.29	156
157	20.9410	228.1205	4.41110	0.01638	82.66	124.97	1128.67	1003.70	157
158	20.7220	233.6832	4.51866	0.01638	80.81	125.97	1129.08	1003.11	158
159	20.4980	239.3728	4.62868	0.01639	79.02	126.97	1129.48	1002.51	159
160	20.2700	245.1641	4.74067	0.01639	77.27	127.97	1129.89	1001.92	160
161	20.0370	251.0824	4.85511	0.01640	75.56	128.97	1130.30	1001.33	161
162	19.8000	257.1023	4.97151	0.01640	73.90	129.97	1130.71	1000.74	162
163	19.5580	263.2492	5.09037	0.01641	72.28	130.98	1131.11	1000.13	163
164	19.3110	269.5230	5.21169	0.01642	70.71	131.98	1131.52	999.54	164
165	19.5390	263.7318	5.09971	0.01642	69.17	132.98	1131.92	998.94	165
166	18.8020	282.4518	5.46169	0.01643	67.67	133.98	1132.33	998.35	166
167	18.5400	289.1067	5.59037	0.01643	66.21	134.98	1132.73	997.75	167
168	18.2730	295.8886	5.72151	0.01644	64.79	135.98	1133.14	997.16	168
169	18.0010	302.7975	5.85511	0.01644	63.40	136.99	1133.54	996.55	169
170	17.7230	309.8588	5.99165	0.01645	62.05	137.99	1133.94	995.95	170
171	17.4390	317.0725	6.13114	0.01645	60.73	138.99	1134.35	995.36	171
172	17.1500	324.4132	6.27308	0.01646	59.44	139.99	1134.75	994.76	172
173	16.8560	331.8809	6.41749	0.01647	58.18	141.00	1135.15	994.15	173
174	16.5560	339.5010	6.56483	0.01647	56.96	142.00	1135.55	993.55	174
175	16.2510	347.2481	6.71464	0.01648	55.77	143.00	1135.95	992.95	175
176	15.9390	355.1730	6.86788	0.01648	54.60	144.00	1136.35	992.35	176
177	15.6210	363.2503	7.02407	0.01649	53.47	145.00	1136.75	991.75	177
178	15.2970	371.4800	7.18320	0.01650	52.36	146.01	1137.15	991.14	178
179	14.9670	379.8621	7.34528	0.01650	51.28	147.01	1137.55	990.54	179
180	14.6310	388.3967	7.51031	0.01651	50.22	148.01	1137.94	989.93	180
181	14.2890	397.0836	7.67829	0.01651	49.19	149.02	1138.34	989.32	181
182	13.9400	405.9483	7.84971	0.01652	48.19	150.02	1138.74	988.72	182
183	13.5850	414.9654	8.02407	0.01652	47.20	151.02	1139.14	988.12	183

Temp ˚F	Pressure			Specific Vol.(ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
184	13.2230	424.1603	8.20187	0.01653	46.25	152.03	1139.53	987.50	184
185	12.8540	433.5331	8.38310	0.01654	45.31	153.03	1139.92	986.89	185
186	12.4790	443.0582	8.56729	0.01654	44.40	154.04	1140.32	986.28	186
187	12.0970	452.7611	8.75491	0.01655	43.51	155.04	1140.71	985.67	187
188	11.7080	462.6419	8.94597	0.01656	42.64	156.04	1141.11	985.07	188
189	11.3110	472.7258	9.14096	0.01656	41.79	157.05	1141.50	984.45	189
190	10.9080	482.9621	9.33890	0.01657	40.96	158.05	1141.89	983.84	190
191	10.4970	493.4017	9.54077	0.01658	40.15	159.06	1142.28	983.22	191
192	10.0790	504.0190	9.74607	0.01658	39.35	160.06	1142.67	982.61	192
193	9.6530	514.8396	9.95530	0.01659	38.58	161.06	1143.06	982.00	193
194	9.2190	525.8633	10.16847	0.01659	37.82	162.07	1143.45	981.38	194
195	8.7780	537.0649	10.38507	0.01660	37.09	163.08	1143.84	980.76	195
196	8.3290	548.4696	10.60560	0.01661	36.37	164.08	1144.23	980.15	196
197	7.8720	560.0776	10.83006	0.01661	35.66	165.08	1144.62	979.54	197
198	7.4070	571.8887	11.05845	0.01662	34.97	166.09	1145.00	978.91	198
199	6.9350	583.8777	11.29028	0.01663	34.30	167.10	1145.39	978.29	199
200	6.4550	596.0699	11.52603	0.01663	33.64	168.10	1145.78	977.68	200
201	5.9650	608.5160	11.76670	0.01664	33.00	169.11	1146.16	977.05	201
202	5.4670	621.1654	12.01130	0.01665	32.37	170.11	1146.54	976.43	202
203	4.9610	634.0180	12.25982	0.01665	31.75	171.12	1146.93	975.81	203
204	4.4470	647.0738	12.51228	0.01666	31.15	172.12	1147.31	975.19	204
205	3.9220	660.4089	12.77014	0.01667	30.57	173.13	1147.69	974.56	205
206	3.3910	673.8965	13.03094	0.01667	29.99	174.14	1148.08	973.94	206
207	2.8480	687.6889	13.29764	0.01668	29.43	175.14	1148.46	973.32	207
208	2.2970	701.6845	13.56827	0.01669	28.88	176.15	1148.84	972.69	208
209	1.7370	715.9087	13.84332	0.01669	28.34	177.16	1149.22	972.06	209
210	1.1670	730.3869	14.12328	0.01670	27.82	178.17	1149.60	971.43	210
211	0.5890	745.0683	14.40717	0.01671	27.30	179.17	1149.98	970.81	211
212	0.0000	760.0291	14.69646	0.01671	26.80	180.16	1150.50	970.34	212
214		823.3561	15.92100	0.01673	25.83	182.17	1151.20	969.03	214
216		822.4252	15.90300	0.01674	24.90	184.18	1152.00	967.82	216
218		855.1092	16.53500	0.01676	24.00	186.20	1152.70	966.50	218
220		888.8791	17.18800	0.01677	23.15	188.22	1153.50	965.28	220
222		923.6834	17.86100	0.01679	22.33	190.24	1154.20	963.96	222
224		959.6771	18.55700	0.01680	21.55	192.26	1154.90	962.64	224
226		996.8086	19.27500	0.01682	20.80	194.28	1155.70	961.42	226
228		1035.0777	20.01500	0.01683	20.08	196.30	1156.40	960.10	228
230		1074.6398	20.78000	0.01685	19.39	198.32	1157.10	958.78	230

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
232		1115.4947	21.570	0.01686	18.7230	200.34	1157.90	957.56	232
234		1157.3839	22.380	0.01688	18.0870	202.37	1158.60	956.23	234
236		1200.8246	23.220	0.01689	17.4760	204.39	1159.30	954.91	236
238		1245.2996	24.080	0.01691	16.8900	206.42	1160.00	953.58	238
240		1291.3260	24.970	0.01692	16.3270	208.44	1160.70	952.26	240
242		1338.3868	25.880	0.01694	15.7860	210.47	1161.40	950.93	242
244		1386.9990	26.820	0.01695	15.2670	212.49	1162.10	949.61	244
246		1437.1626	27.790	0.01697	14.7670	214.52	1162.80	948.28	246
248		1488.8777	28.790	0.01699	14.2870	216.55	1163.50	946.95	248
250		1542.1443	29.820	0.01700	13.8260	218.59	1164.20	945.61	250
252		1596.9623	30.880	0.01702	13.3820	220.62	1164.90	944.28	252
254		1653.3317	31.970	0.01703	12.9550	222.65	1165.60	942.95	254
256		1711.2527	33.090	0.01705	12.5440	224.68	1166.20	941.52	256
258		1770.7250	34.240	0.01707	12.1490	226.72	1166.90	940.18	258
260		1831.7488	35.420	0.01708	11.7680	228.76	1167.60	938.84	260
262		1894.8413	36.640	0.01710	11.4020	230.79	1168.30	937.51	262
264		1959.4851	37.890	0.01712	11.0490	232.83	1168.90	936.07	264
266		2025.6805	39.170	0.01714	10.7090	234.87	1169.60	934.73	266
268		2093.9444	40.490	0.01715	10.3820	236.91	1170.20	933.29	268
270		2164.2769	41.850	0.01717	10.0660	238.95	1170.90	931.95	270
272		2236.1609	43.240	0.01719	9.7620	241.00	1171.60	930.60	272
274		2310.1135	44.670	0.01721	9.4690	243.04	1172.20	929.16	274
276		2385.6176	46.130	0.01722	9.1860	245.08	1172.80	927.72	276
278		2463.7074	47.640	0.01724	8.9130	247.13	1173.50	926.37	278
280		2543.3486	49.180	0.01726	8.6500	249.18	1174.10	924.92	280
282		2625.5756	50.770	0.01728	8.3970	251.23	1174.70	923.47	282
284		2709.8712	52.400	0.01730	8.1520	253.28	1175.40	922.12	284
286		2796.2355	54.070	0.01731	7.9150	255.33	1176.00	920.67	286
288		2884.6683	55.780	0.01733	7.6870	257.38	1176.60	919.22	288
290		2975.1697	57.530	0.01735	7.4670	259.44	1177.20	917.76	290
292		3068.2569	59.330	0.01737	7.2540	261.50	1177.80	916.30	292
294		3163.4127	61.170	0.01739	7.0480	263.55	1178.40	914.85	294
296		3261.1542	63.060	0.01741	6.8490	265.61	1179.00	913.39	296
298		3361.4815	65.000	0.01743	6.6570	267.67	1179.60	911.93	298
300		3463.8774	66.980	0.01745	6.4720	269.73	1180.20	910.47	300
310		4015.1604	77.640	0.01755	5.6320	280.06	1183.00	902.94	310
320		4633.6730	89.600	0.01765	4.9190	290.43	1185.80	895.37	320
330		5326.6553	103.000	0.01776	4.3120	300.84	1188.40	887.56	330

Temp ˚F	Pressure			Specific Vol. (ft3/lbm)		Enthalpy (Btu/Lbm)			Temp ˚F
	In Hg Vac.	mm Hg Abs.	PSIA	Liquid	Vapor	Liquid	Vapor	Latent Heat	
340		6098.7617	117.930	0.01787	3.7920	311.30	1190.80	879.50	340
345		6528.2363	126.235	0.01793	3.5690	316.55	1191.95	875.40	345
350		6957.2324	134.530	0.01799	3.3460	321.80	1193.10	871.30	350
360		7908.2731	152.920	0.01811	2.9610	332.35	1195.20	862.85	360
370		8958.6068	173.230	0.01823	2.2680	342.96	1197.20	854.24	370
380		10115.4736	195.600	0.01836	2.3390	353.62	1199.00	845.38	380
390		11387.6650	220.200	0.01850	2.0870	364.34	1200.60	836.26	390
400		12778.8012	247.100	0.01864	1.8661	375.12	1202.00	826.88	400
410		14299.2252	276.500	0.01878	1.6726	385.97	1203.10	817.13	410
420		15954.1084	308.500	0.01894	1.5024	396.89	1204.10	807.21	420
430		17753.7938	343.300	0.01909	1.3521	407.89	1204.80	796.91	430
440		19713.7961	381.200	0.01926	1.2192	418.98	1205.30	786.32	440
450		21828.9437	422.100	0.01943	1.1011	430.20	1205.60	775.40	450
460		24114.7511	466.300	0.01961	0.9961	441.40	1205.50	764.10	460
470		26586.7329	514.100	0.01980	0.9025	452.80	1205.20	752.40	470
480		29244.8891	565.500	0.02000	0.8187	464.30	1204.60	740.30	480
490		32099.5626	620.700	0.02021	0.7436	475.90	1203.70	727.80	490
500		35166.2680	680.000	0.02043	0.6761	487.70	1202.50	714.80	500