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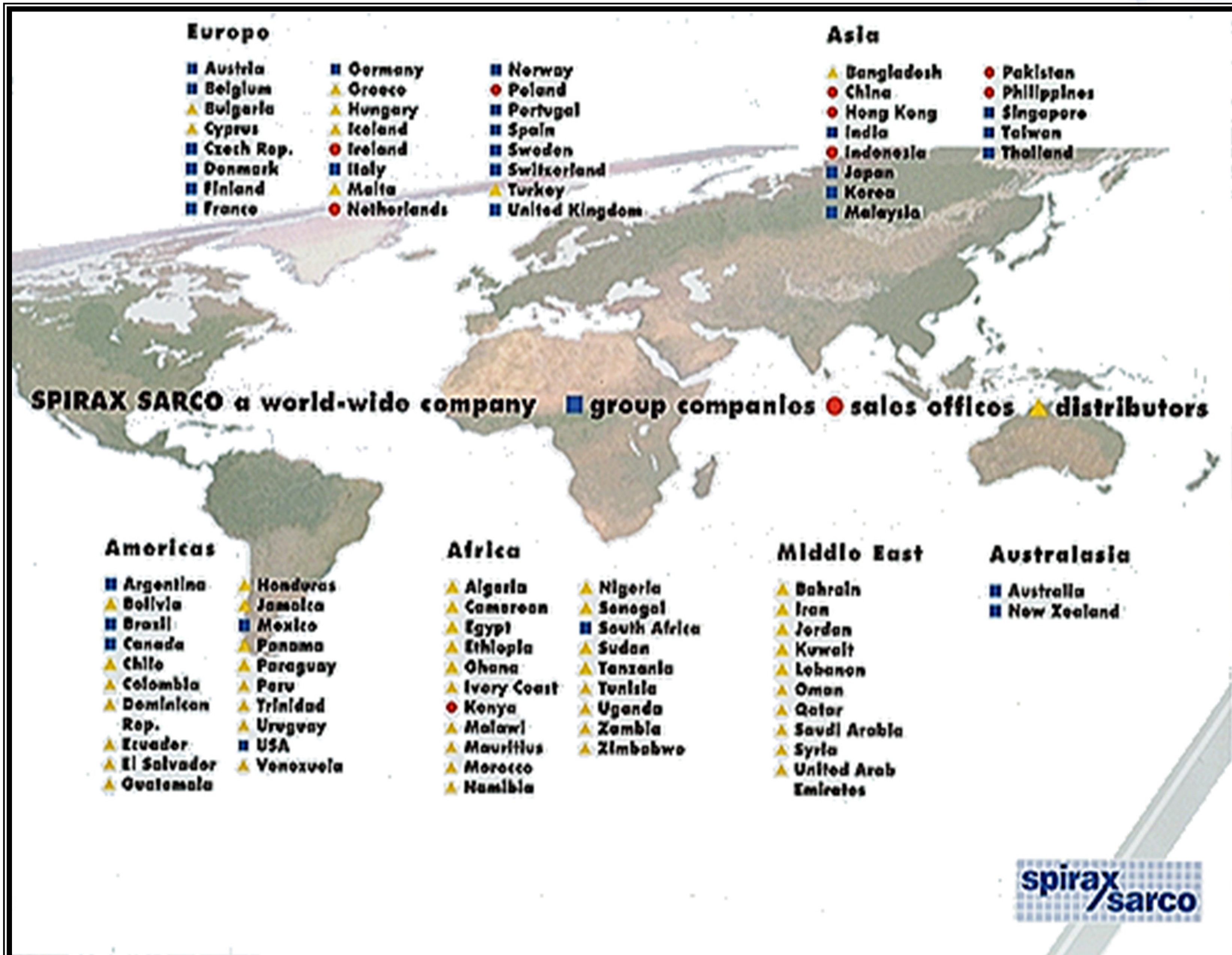
People remember less than 15% of what they hear, but nearly 90% of what they see. The second was that 72 hours after hearing something, the average adult remembers only eight percent of what he or she heard.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Ethiopia
Ghana
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Nigeria
Senegal
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Tunisia
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Australia
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Spirax Sarco Mission Statement

To be The World's Leading Provider of Steam System Solutions through the implementation of Knowledge, Service, and World Class Products to our Customers

Markets Served by Spirax Sarco

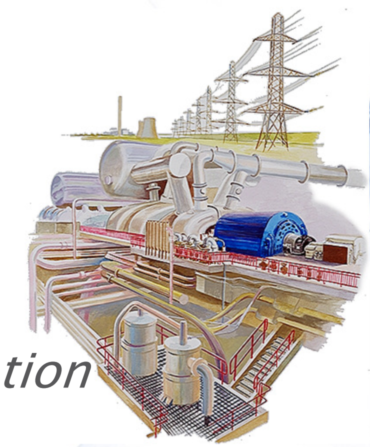
Tire & Automotive

Chemical / Petrochem

Brewery

Textile

Pharmaceutical



Power Generation

Goals to Achieve-Why are we doing this seminar?

Become a More Valuable Employee

Gain a Better Understanding of Steam

Decrease Total Life Cycle Costs for your client's or your own equipment

Identify and Correct Improper Piping Practices

Obtain lower cost for your client's or your own steam SYSTEM.

First for Steam Solutions

EXPERTISE | SOLUTIONS | SUSTAINABILITY

5X

Perceived Steam Issues

- *High Installation Costs*
- *Cost Savings with Decentralization*
- *High Maintenance*
- *Safety*
- *Poor Performance.*

What is a Modern Steam System?

- Correctly sized pipes (distribute at high pressure)
- Proper number of complete trap stations
- Proper Placement/Installation of traps
- Correct Installation of Steam Conditioning Equipment
- Installation of automatic air vents & vacuum breakers
- Properly installed and maintained boiler house
- Effective return of as much condensate as possible.

Generally, Steam is used for:

Power Generation (work)
Heat Transfer
Motion (work)

For our purposes, we will deal only with heat transfer

Why do we use Steam?

- *Highest Heat Transfer of all heating mediums*
- *Very High Rate of Heat Transfer*
- *Smaller Pipe Sizes-lower initial costs and lower installation costs*
- *Gives up it's energy without giving up it's temperature*
- *Clean and STERILE energy source*
- *Easy to control because of the pressure and temperature relationship*
- *Does Not Require pumps to achieve flow*
- *Very forgiving Medium when installed properly.*

Heat Transfer

Re-thinking HX equipment & hook-ups for improved efficiency and control…
while saving you money

Dave Cronin

District Manager & Field Sales Engineer

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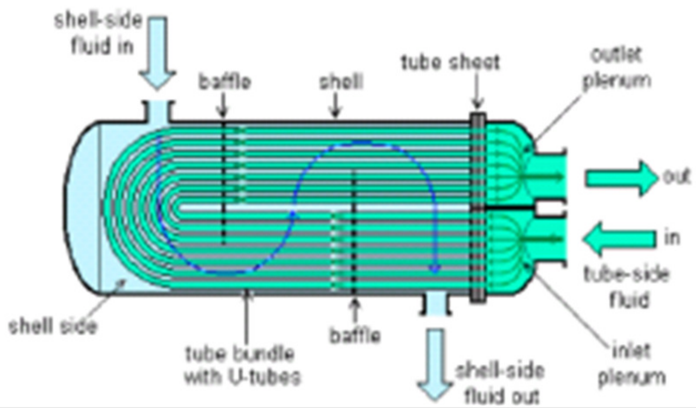
Syllabus

Steam-to-Water (or other fluid) Heat Transfer Syllabus:

1. Selection Issues during the design phase
2. Heat Exchanger Design
3. $Q = \mu A \times \Delta T$
4. Typical Design as currently installed
5. "Stalling" of the Heat Transfer Process
6. Closed Loop systems and how they improve overall performance of heat transfer
7. High Pressure steam versus Low Pressure Steam

U-tube heat exchanger



The Classic Quote from Henry Ford

“You can have any color for my Model T as long as it is ………..”

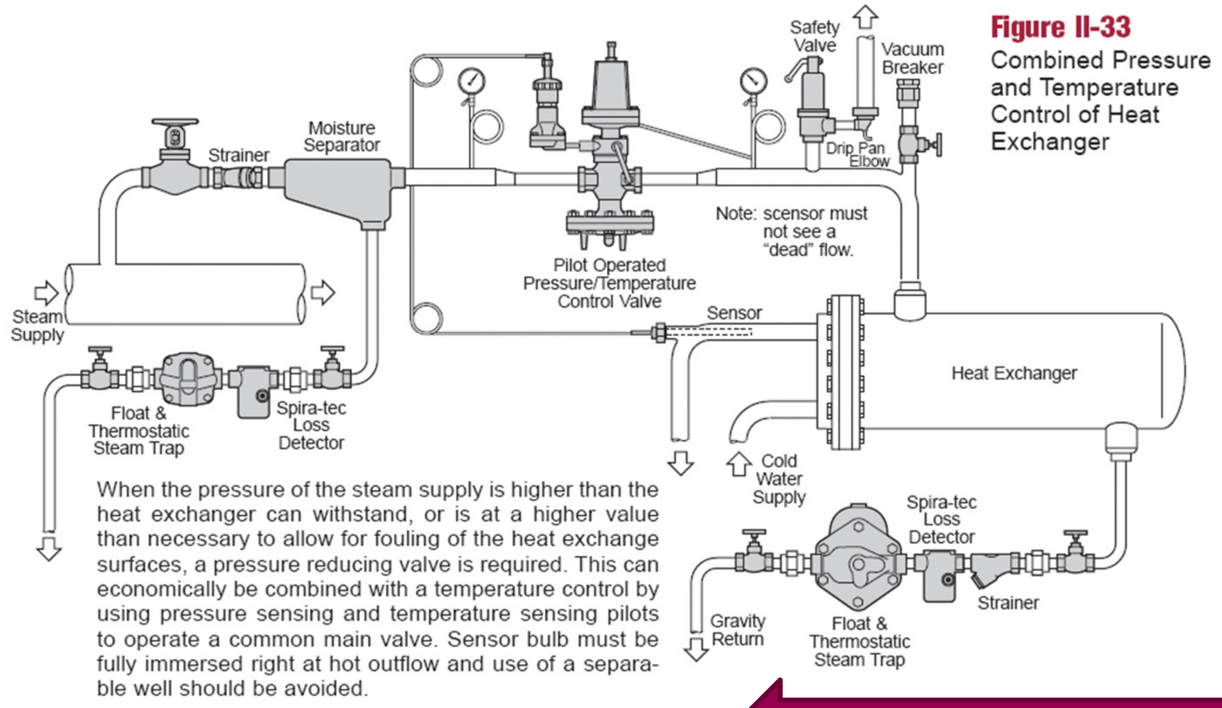
Heat Transfer Systems

"With all of the decisions that SHOULD be made when designing steam-to-water heat transfer systems, why would we rely on a single design and trust it to be the best solution"

Remember Einstein's definition of Insanity

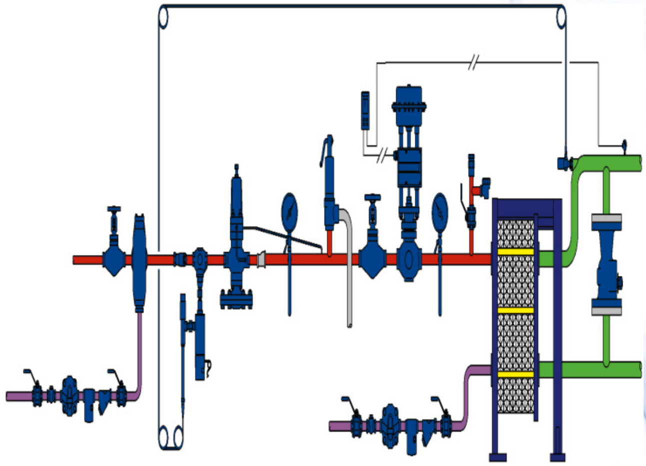
How Many of you do your own heat exchanger sizing?

Mr. Ford’s Idea



What about the flash losses
And running a vent?

Open Loop Issues



- Vacuum breakers introduce air !!!!
- Reverses Heat Transfer !!!!
- Wastes steam !!!!
- Increases duty cycles of heat transfer equipment !!!!
- Increases duty cycles of Control equipment !!!!
- Barriers heat transfer, reduces heating efficiency !!!!
- Reduces equipment capability to handle load changes !!!!
- Corrodes (oxygen pitting) Heat Transfer Equipment !!!!
- Generates Carbonic Acid !!!!
  - Erodes Heat Transfer Equipment !!!!
  - Corrodes/erodes Condensate System !!!!
  - Increases Chemical requirements !!!!.

Heat transfer theory

Heat always flows from source of higher energy to one of lesser

The greater the temperature difference the (the more rapid the energy flow)

Temperature is a relative measurement of “thermal pressure”, but it is not a unit of energy

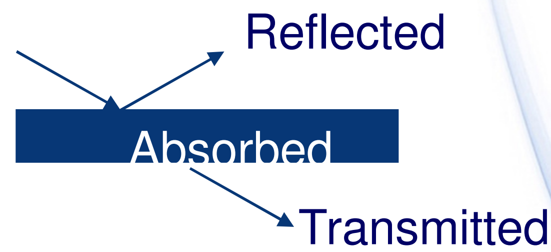
Heat lost by one medium is always equal to the amount of heat gained by the other medium, minus losses in transfer.

Every material has its own unique properties that influence its ability to move heat energy.

Three ways to transfer heat

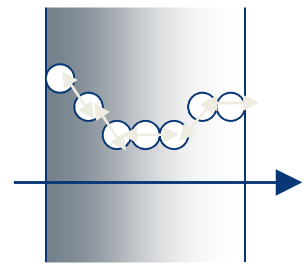
Radiation

- Electromagnetic waves
- When it reaches a body it has 3 options:



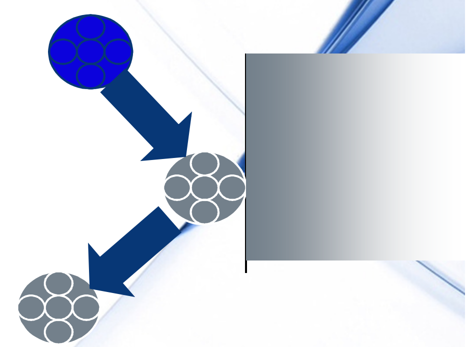
Conduction

- Molecular or atomic vibrations
- No material transport



Convection

- Energy is transferred by the motion and intermixing of small mass elements
- Natural convection is caused by density difference
- Forced convection is man-made i.e. pumping fluids



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Types of heat exchange

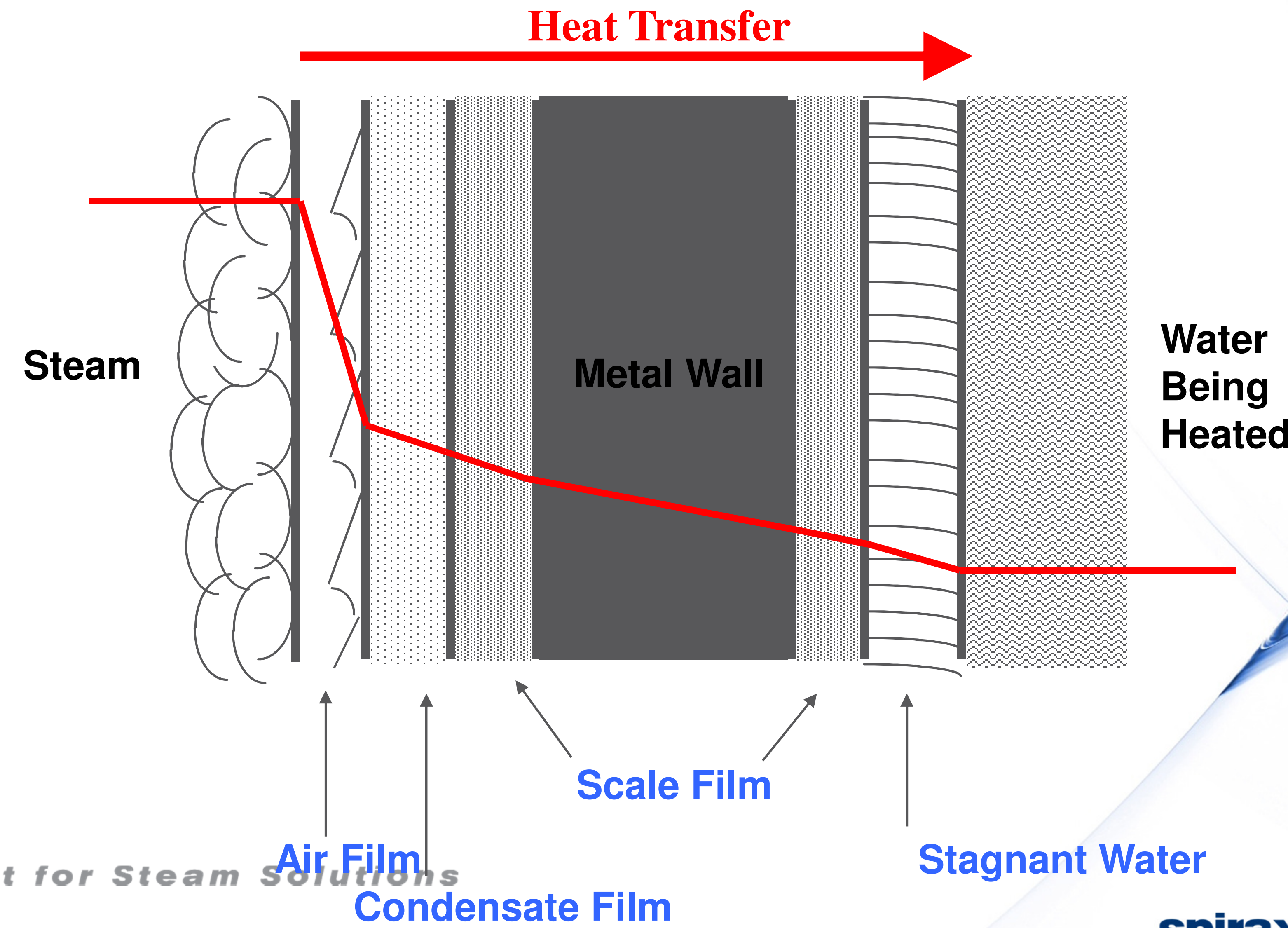
Direct

The heating medium is directly mixed (convection) with the substance being heated i.e. "Direct injection".

Indirect
(Heat Exchange Equipment)

Heat energy from the heating medium is passed to the substance being heated through a physical barrier (conduction).

Heat Transfer Q = "U" x A x DT



Calculation of Heat Transfer

$$Q = U \times A \times \Delta T$$

Where:

Q = heat transfer (BTU's)

U = overall heat transfer coefficient

(BTU/Hr/SqFt/F)

A = square feet of surface area (sqft)

T = log mean temperature difference

△ = (LMTD Steam to Product)

Heat Exchangers

Plate & Frame Design

Vertical or Horizontal Shell & Tube

Heat Exchangers

Helical-Coiled Tube Design

Plate & Shell Design

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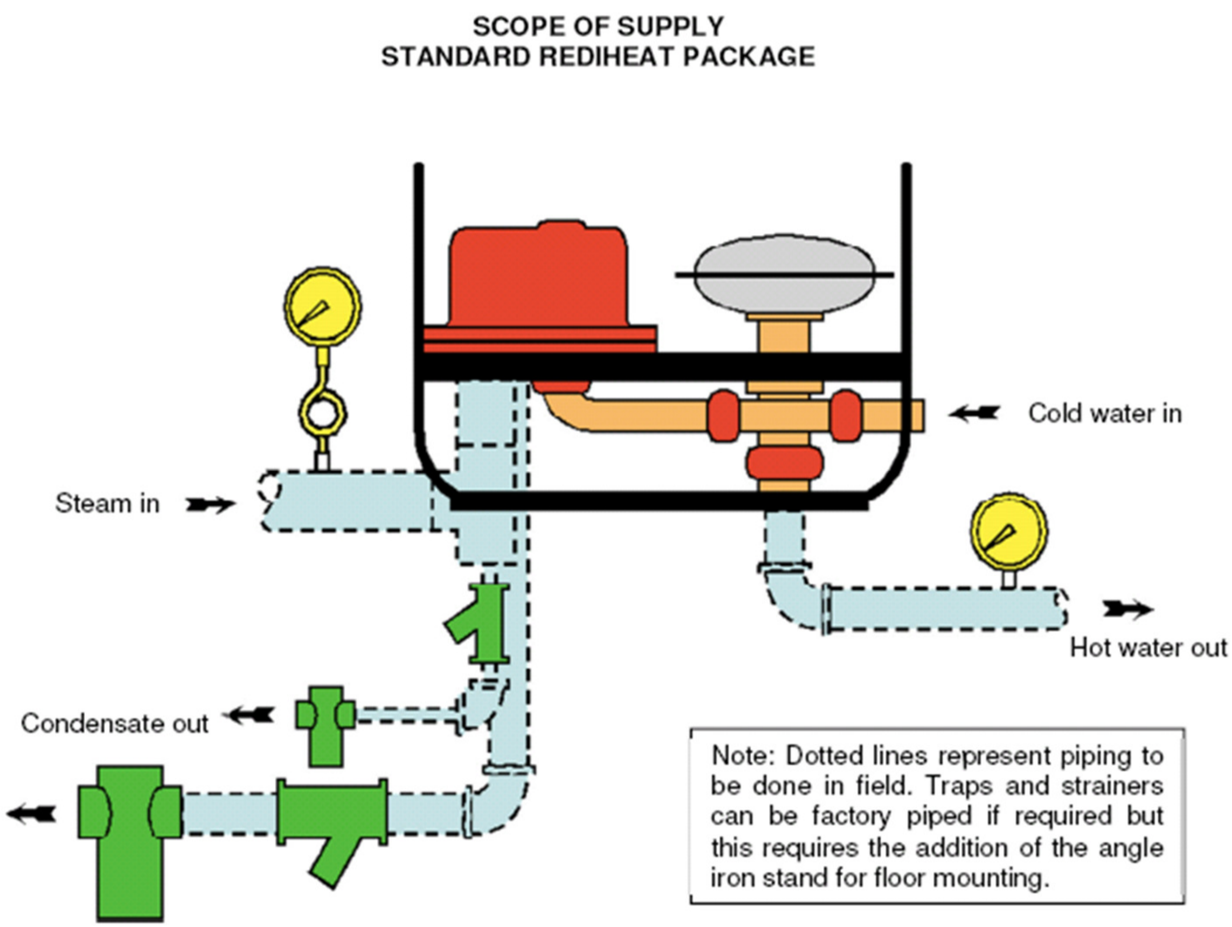
Feedforward Piping Flow Chart



Steam Supply Properties

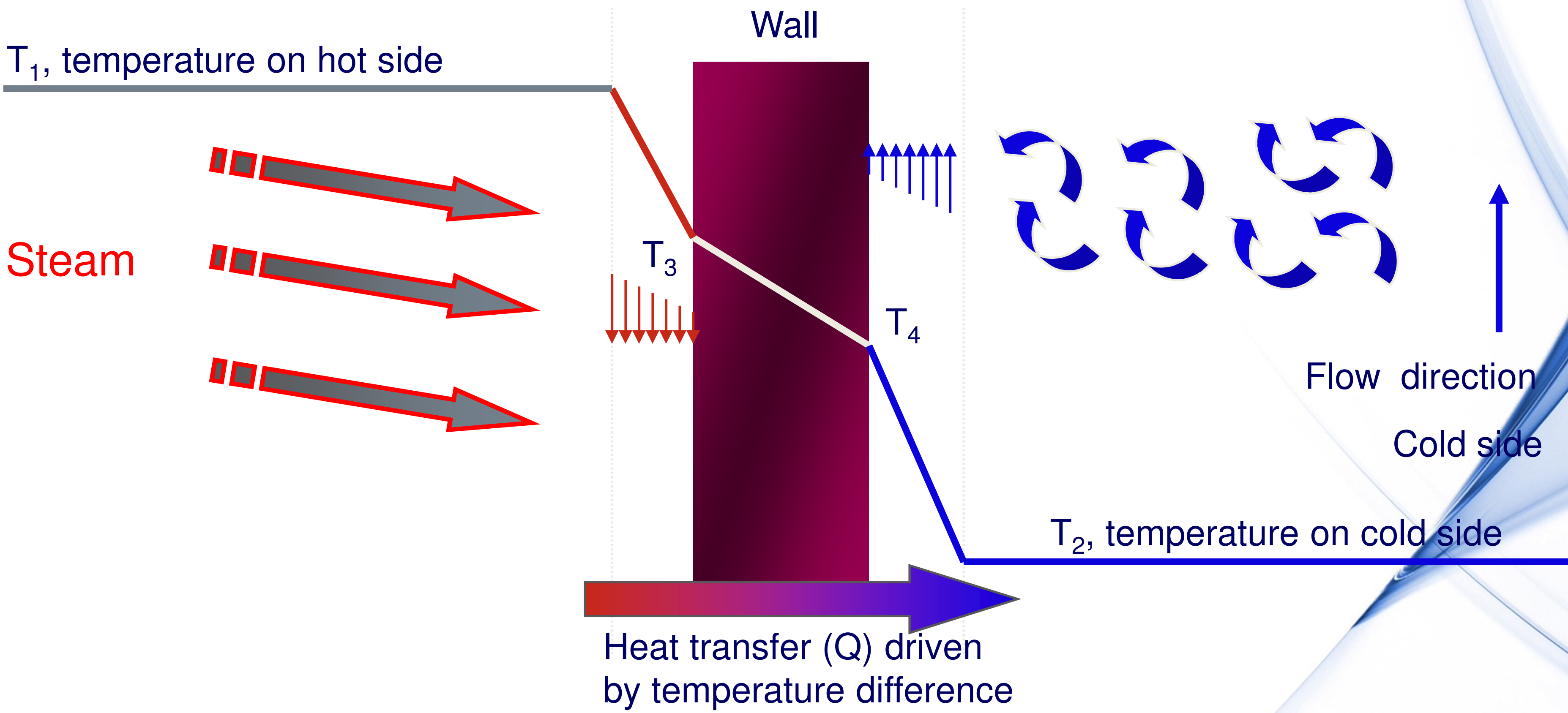
- LP steam carries more latent Btu's, increases efficiencies.
- LP steam is normally better quality, increasing efficiencies.
- LP steam REDUCES scaling (The lower the better)
- LP steam reduces the "fouling factor" calculation.

- LP steam typically requires PRV's to generate from HP.
- PRV's require more space and add to maintenance costs.
- LP steam requires large pipes.
- LP condensate is more difficult to drain from HX.

- HP steam requires no PRV's and pipe sizes are smaller.
- HP steam makes HX, conditioning, & control equipment smaller.
- Installation less expensive with HP steam.

We can combine the benefits from both systems!

Heat transferred in a heat exchanger



Factors that influence U in heat exchangers

Type of Fluid
Velocity
Ability to transfer heat through surface films, a combined function of:

- Density
- Viscosity
- Thermal conductivity
- Specific heat

Condition of the heat exchanger surface. Fouling can have a detrimental impact on heat transfer. Increased turbulence will:

- Reduce fouling tendencies (good)
- Increase heat transfer rates (good)
- Increase pressure loss (bad)

Heat Transfer Coefficients

Table 24: Heat Transmission Coefficients

In Btu per sq. ft. per hr. per °F.

Water	Cast Iron	Air or Gas	1.4
Water	Mild Steel	Air or Gas	2.0
Water	Copper	Air or Gas	2.25
Water	Cast Iron	Water	40 to 50
Water	Mild Steel	Water	60 to 70
Water	Copper	Water	62 to 80
Air	Cast Iron	Air	1.0
Air	Mild Steel	Air	1.4
Steam	Cast Iron	Air	2.0
Steam	Mild Steel	Air	2.5
Steam	Copper	Air	3.0
Steam	Cast Iron	Water	160
Steam	Mild Steel	Water	185
Steam	Copper	Water	205
Steam	Stainless Steel	Water	120

The above values are average coefficients for practically still fluids.

The coefficients are dependent on velocities of heating and heated media on type of heating surface, temperature difference and other circumstances. For special cases, see literature, and manufacturer's data.

Heat Exchangers & Fouling Factors

In order that heat exchangers shall have sufficient surface to maintain satisfactory performance in normal operation, with reasonable service time between cleanings, it is important in design to provide a fouling allowance.....

Products of corrosion, dirt, or other foreign materials which deposit on the heat transfer surface increases the overall thermal resistance and lower the overall heat transfer coefficient of the heat exchanger.

Heat Transfer Surface Fouling

Fouling can be caused by several mechanisms which in fact can happen at the same time (combined). The most important basic mechanisms are:

Crystallization or scaling (e.g. Mg- and Ca- bicarbonates)

Decomposition of organic products resulting in tar or cokes

Polymerization and or oxidation

Settlement of sludge, rust or dust particles

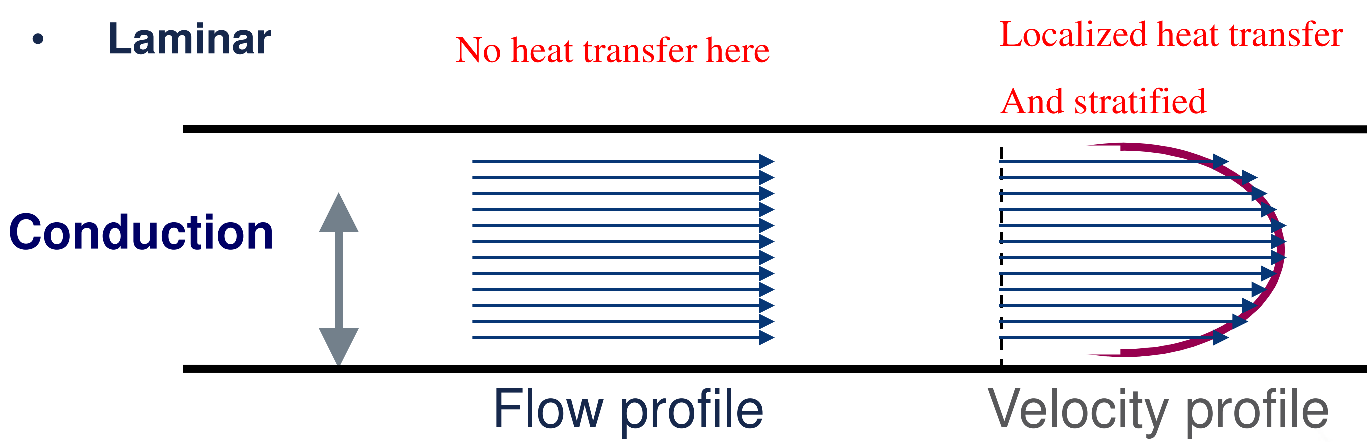
Biological deposits

Corrosion

Flow principles

Two types of flow

- Laminar



Orderly flow throughout the fluid

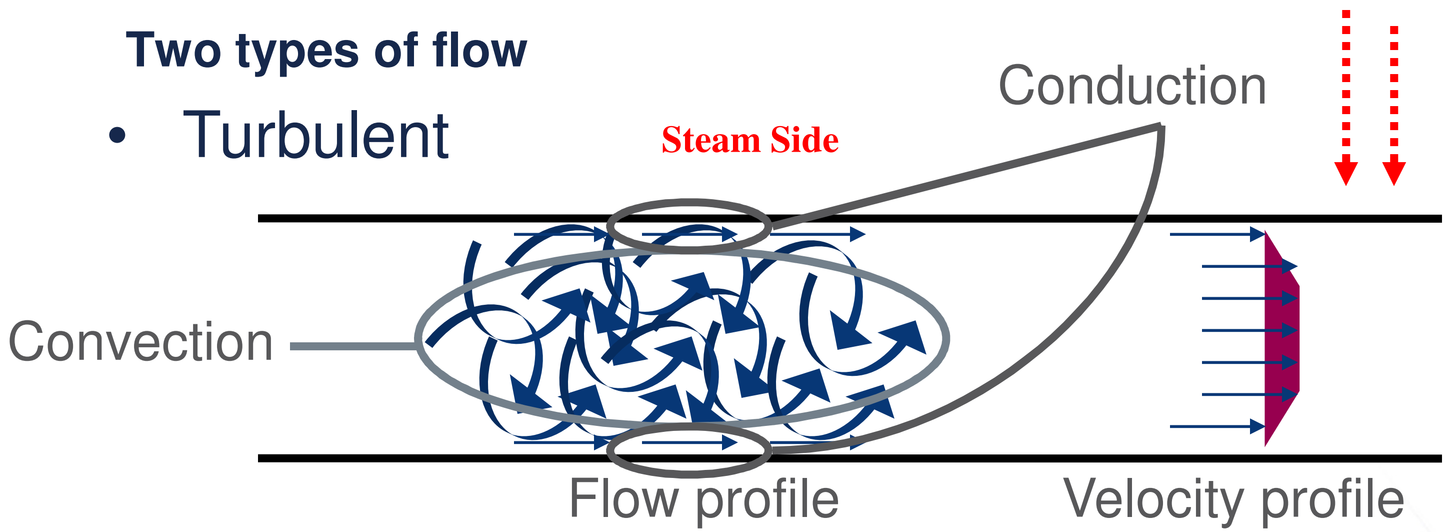
Parabolic flow profile

- Fluid at the wall moves slower due to the friction from the wall surface
- Example: viscous fluids or water at low velocity

Flow principles

Two types of flow

- Turbulent



No orderly flow

Random eddy motion mixes the fluid

Always a laminar film closest to the wall

Example: water at higher velocity

FOULING FACTORS FOR WATER

TYPICAL FOULING FACTORS

Temp of Heating Medium	*212-240F*	*240-400F*
Temp of Water	*<125F*	*> 125F*
Water Velocity	*≤3ft/sec*	*≥ 3ft/sec*

Fouling Factor/Type of Water		
Sea Water	*.0005*	*.001*
Distilled Water	*.0005*	*.0005*
Treated Boiler Feed Water	*.001*	*.001*
City or Well Water	*.001*	*.002*

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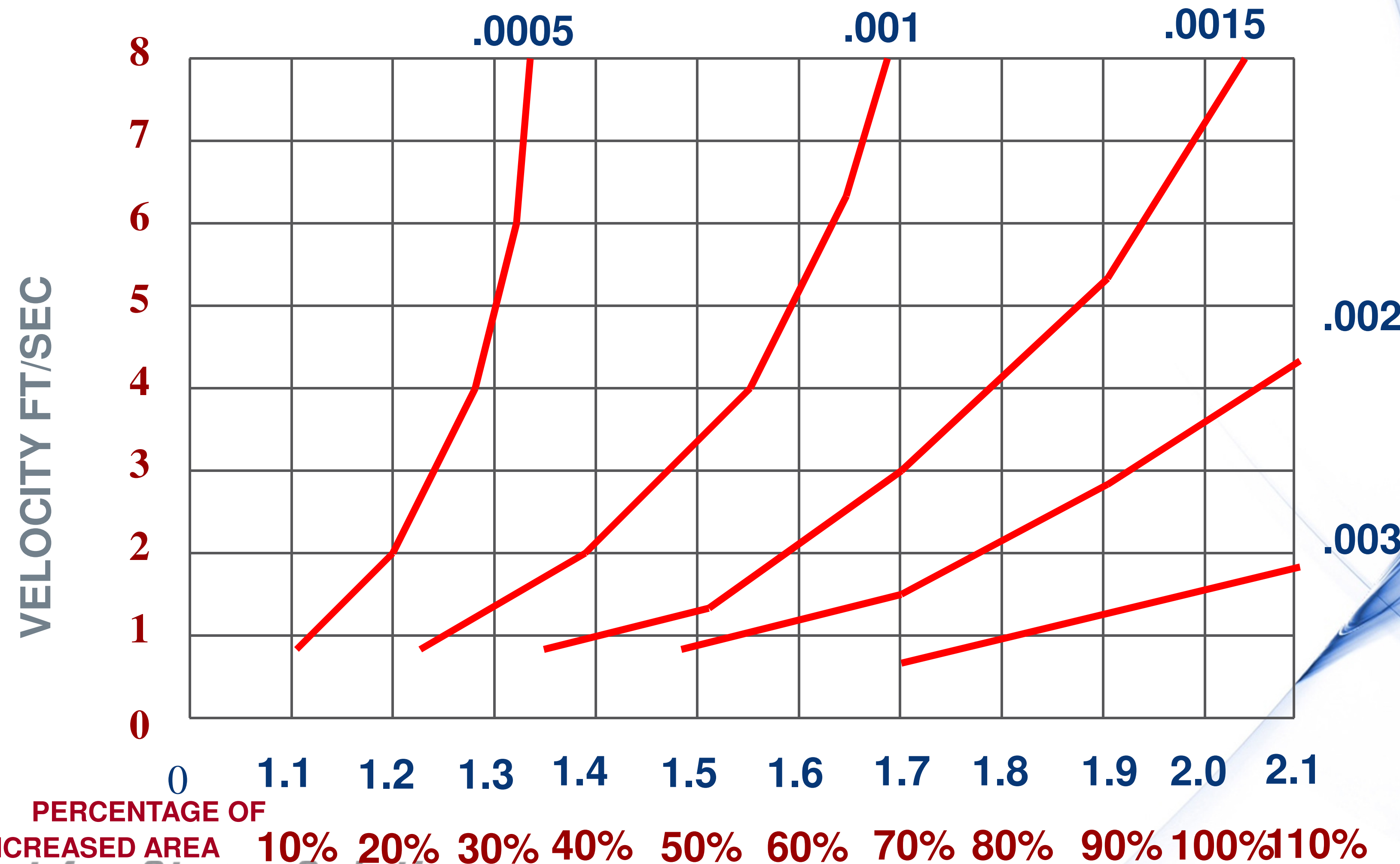
FOULING FACTORS AS INCREASE IN SURFACE AREA



Heat Exchanger Example

Heating City Water/Feed Water: 75 GPM of Water

Fouling Factor : .002

Inlet Temperature: 50°F

Outlet Temperature: 150°F

Steam Pressure Avail.: 15 PSIG Saturated (250°F)

HEAT ENERGY REQUIRED:

75Gal X 60min/hr X 8.34lbs/gal. X 100 BTU's /lb. = 3,753,000 BTU's/hr

STEAM FLOW REQUIRED AT 15 PSIG:

3,753,000 BTU's / 946 BTU's/ lb.(Latent Heat) = 3,967 lbs/hour

Heat Exchanger Example

HEAT EXCHANGER DATA:

Heat Transfer Coefficient: Steam to Copper to Water= ± 250

(200 is for Practically still fluids)

CALCULATE "REQUIRED" SURFACE AREA:

Q = U • A • (Steam Temp-Prod. Temp)

3,753,000 = 250 • A • (250 - 150)

150 Square Feet = A

FOULING FACTOR APPLIED (from chart) = X 1.92

SURFACE AREA USED= 288 Square Feet

Heat Exchanger Example New Installation

ACTUAL OPERATING CONDITIONS:

(With Fouling Factor on Start Up)

Q = U • A • (Steam Temp- Prod. Temp)

3,753,000 = 250 • 288 • (Steam Temp-150°F)

52 = (Steam Temp- 150°F)

202°F = Steam Temp. (5"Hg Vacuum) @

New Condition FULL LOAD

Note: Equipment was all sized and designed for 15 PSIG Steam in Shell

Equipment Drainage

High condensate back pressure and low exchanger steam pressure means there is ***insufficient pressure differential*** to remove the condensate from the equipment, through the trap and into the condensate return line.

In addition to this there is not enough pressure to return the condensate to the feed tank, de-aerator or to the process itself.

A cycle of stall and waterlogging begins.

Factors Leading to Stall

How close the equipment can be sized to the actual load- Fouling Factors

Large differential between the maximum design and actual running loads-Oversizing

Lifts or Pressurized Return Systems

Flash Recovery Systems

Operations changing either outlet temperatures or inlet flow conditions.

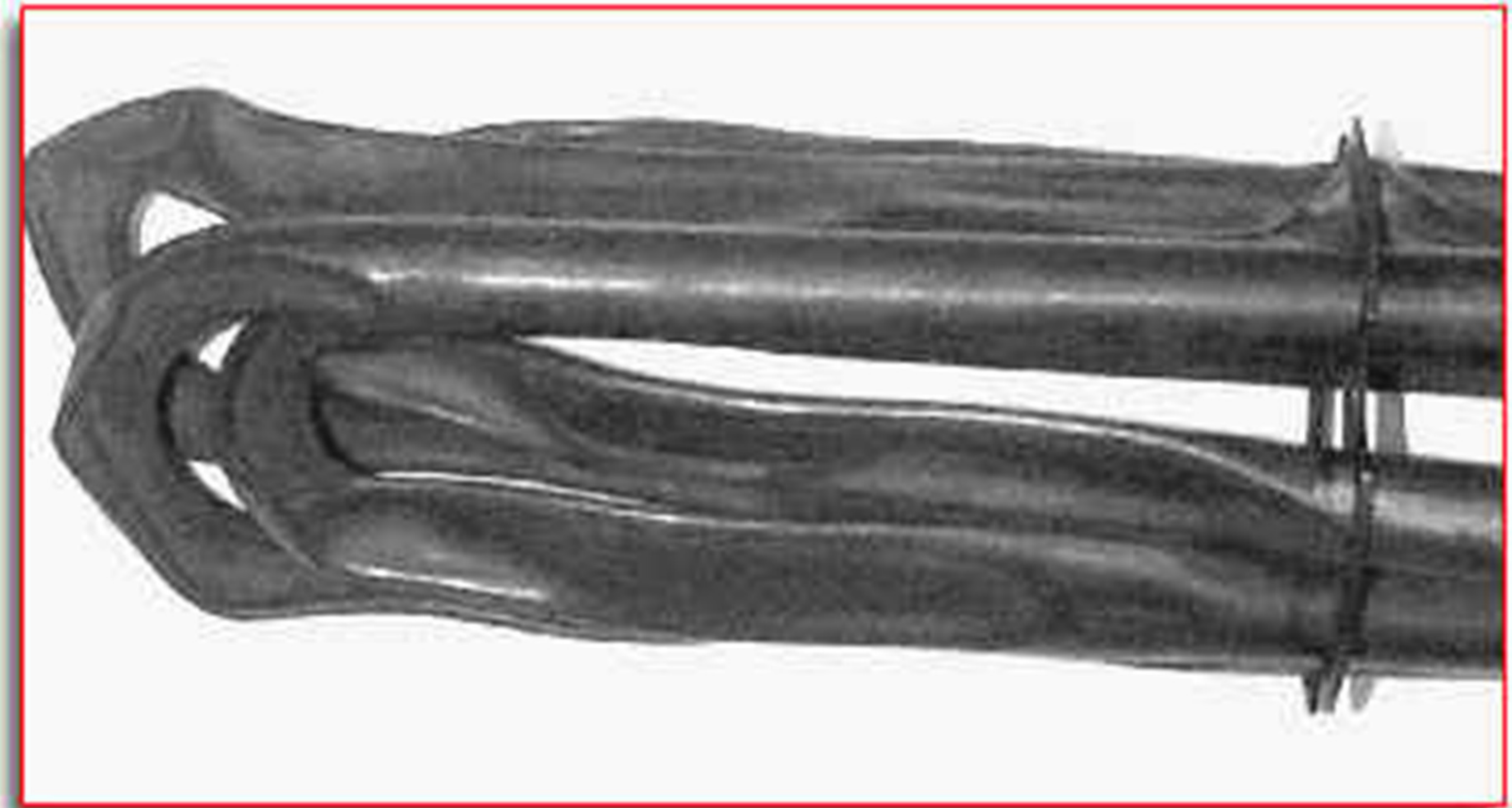
STALL Issues

What is Stall: The point at which the DIFFERENTIAL PRESSURE across the steam trap in insufficient in removing condensate.

Who Suffers: Calorifiers, Air Handlers, Process Tanks, Vessels, etc. that control the MASS of steam as a function of a product temperature

- Poor Control !!!!
- Slow response to load changes !!!!
- Noise !!!!
- Water Hammer !!!!
  - Leaking Gaskets !!!!
  - Damaged / Failed Equipment !!!!
  - Increased Maintenance !!!!
- Frozen, Ruined Air Handling Coils, Tube Bundles, and Vessels.

Water Hammer



Picture of Tubes Damaged by Water Hammer

Damage due to Thermal Cycling

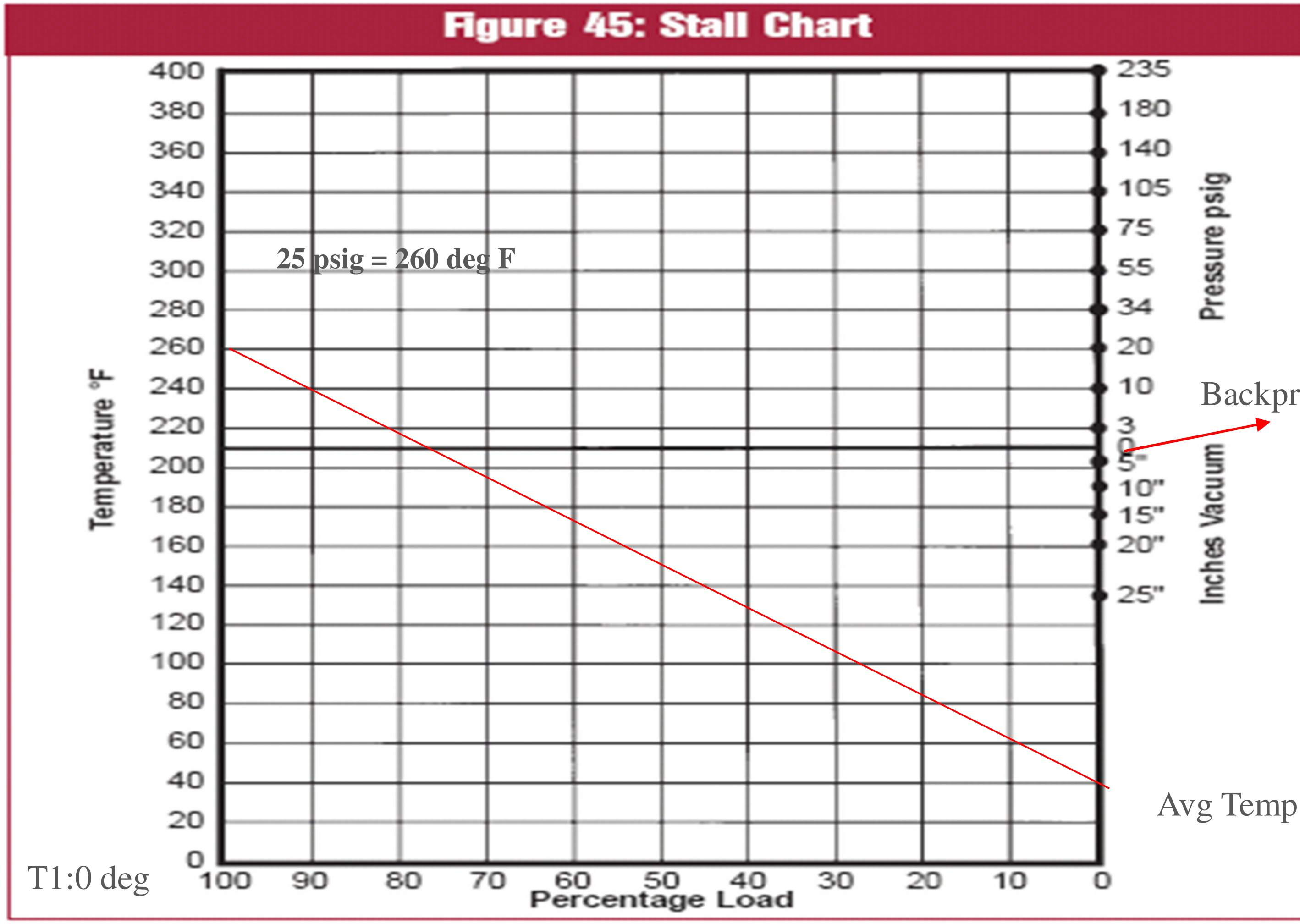
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plotting Maximum Steam Temperature versus air mean temperature



Backpressure = 0 PSIG

Avg Temp = 40 degF

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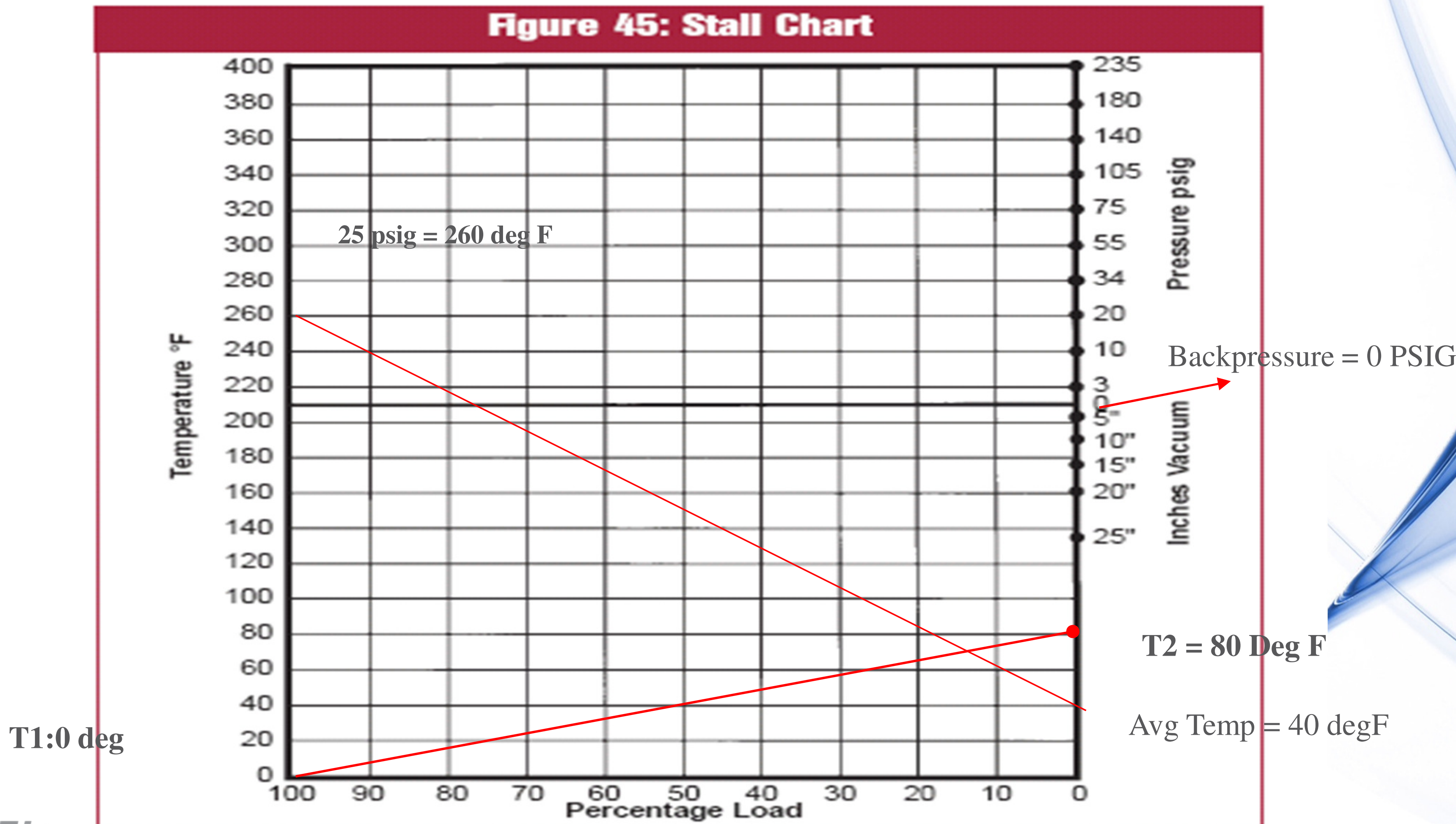
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plot Entering & Exiting Temperatures



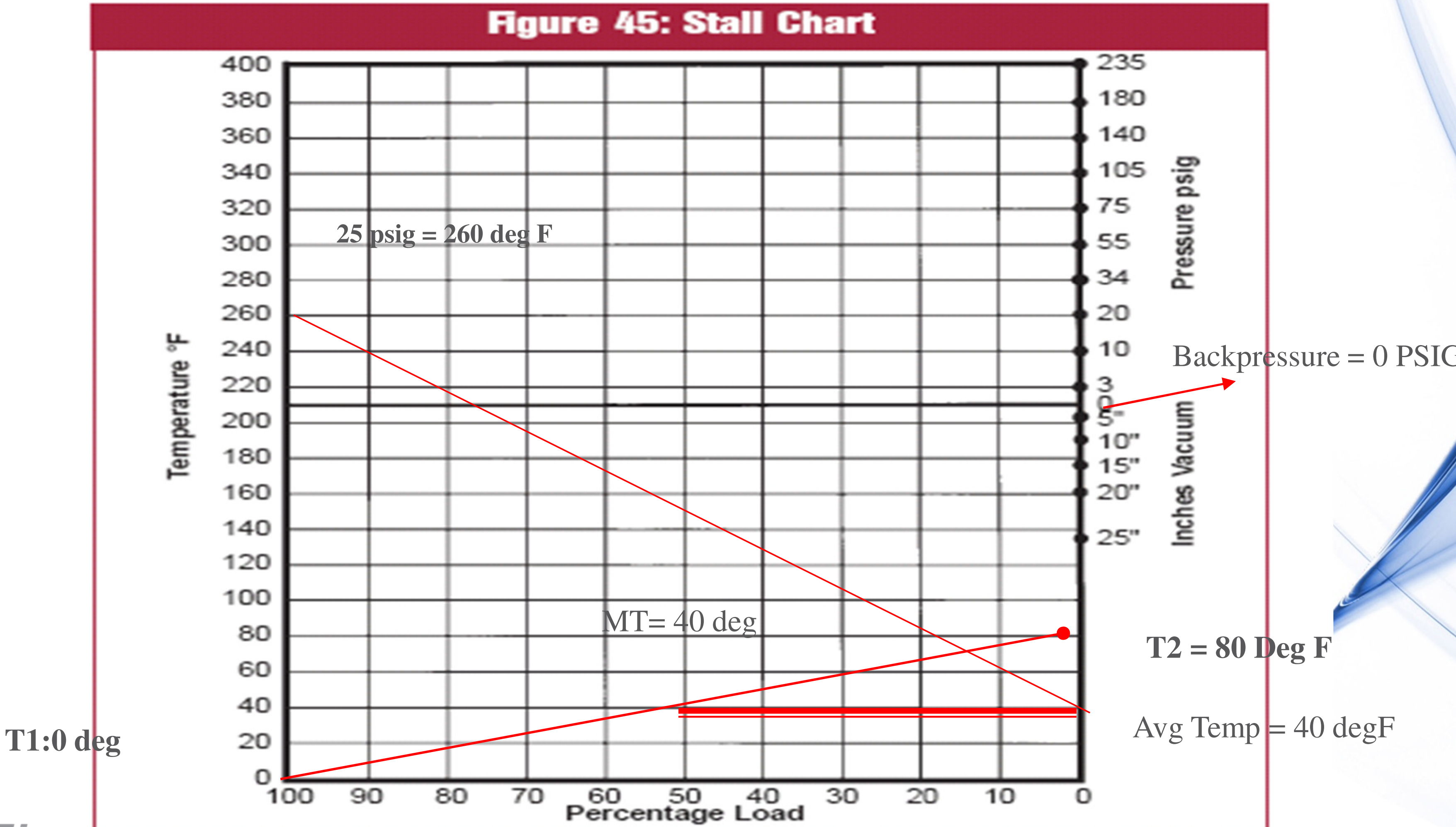
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plot Mean Average Temperature



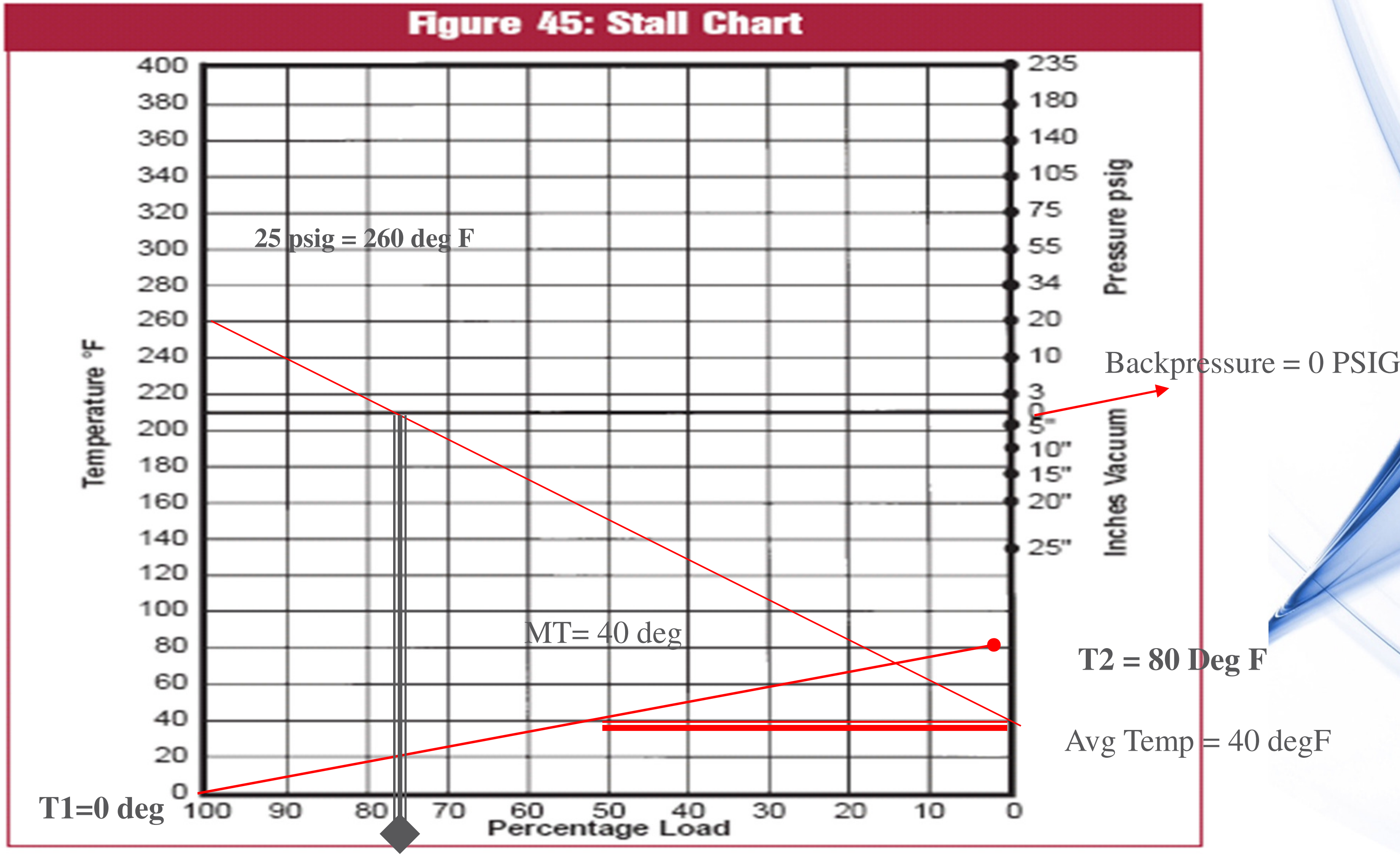
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Determining "Stall Point" as Percentage of Load



Closed Loop HX Hook-up +

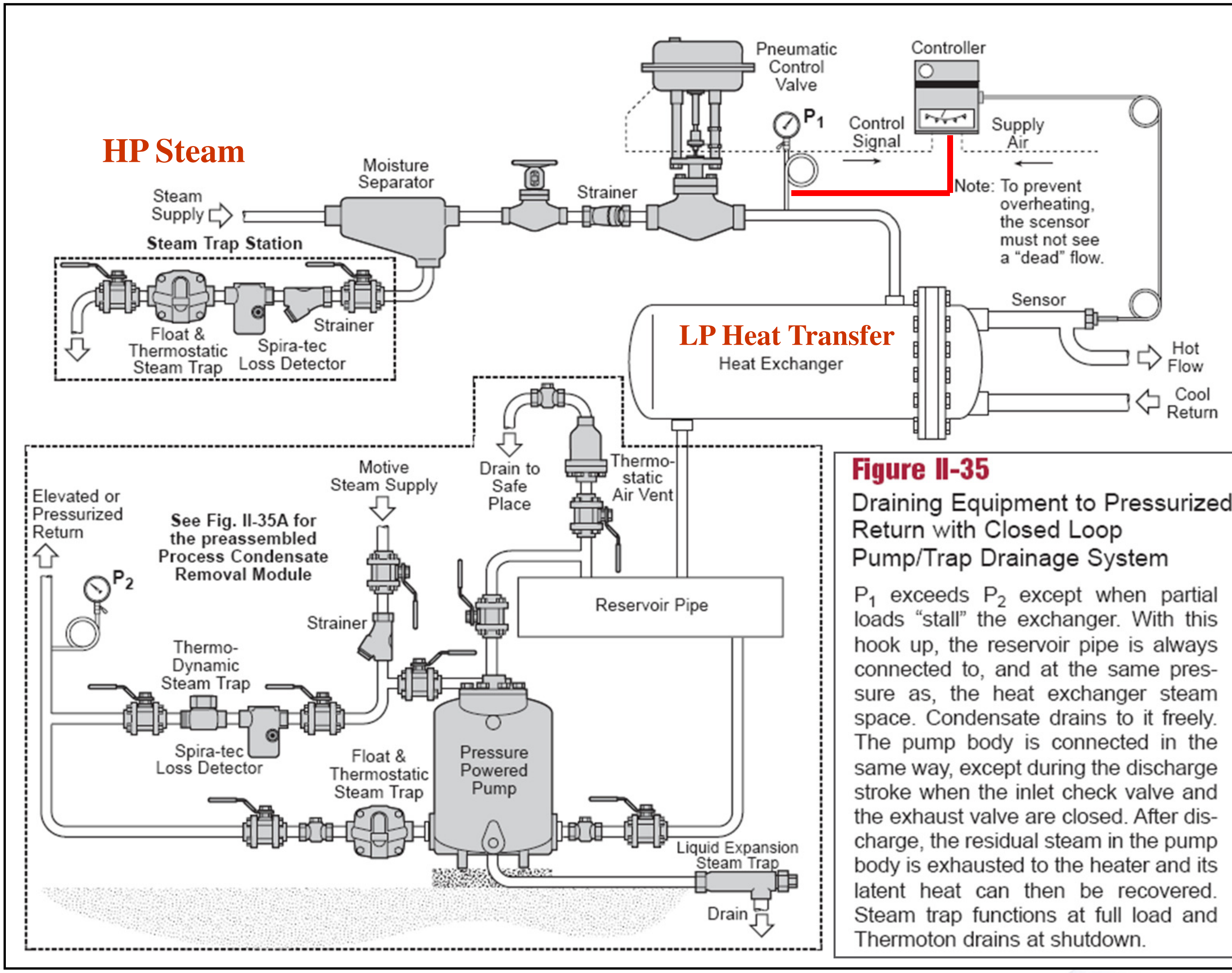


Figure II-35

Draining Equipment to Pressurized Return with Closed Loop Pump/Trap Drainage System

P_1 exceeds P_2 except when partial loads "stall" the exchanger. With this hook up, the reservoir pipe is always connected to, and at the same pressure as, the heat exchanger steam space. Condensate drains to it freely. The pump body is connected in the same way, except during the discharge stroke when the inlet check valve and the exhaust valve are closed. After discharge, the residual steam in the pump body is exhausted to the heater and its latent heat can then be recovered. Steam trap functions at full load and Thermoton drains at shutdown.

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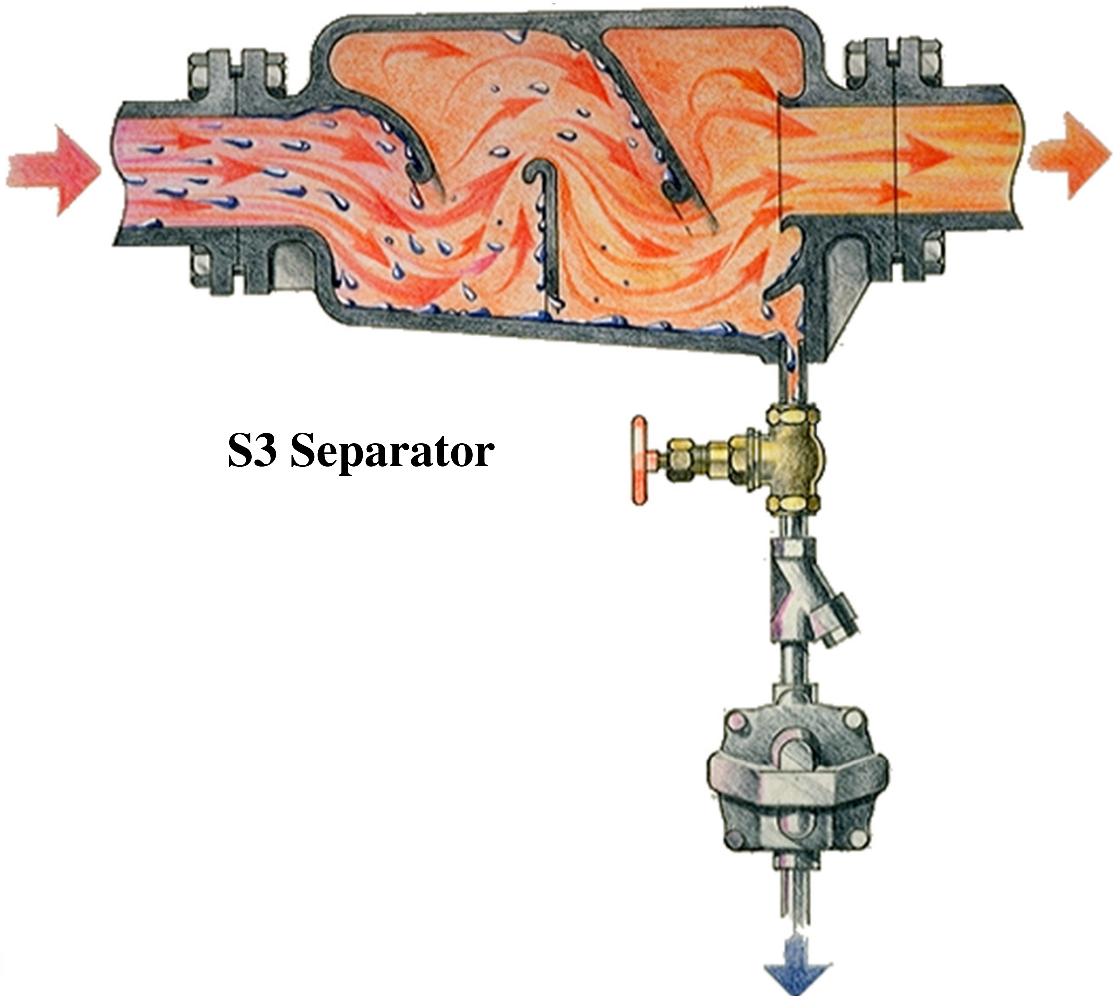
Steam Conditioning-Getting the biggest bang for your buck



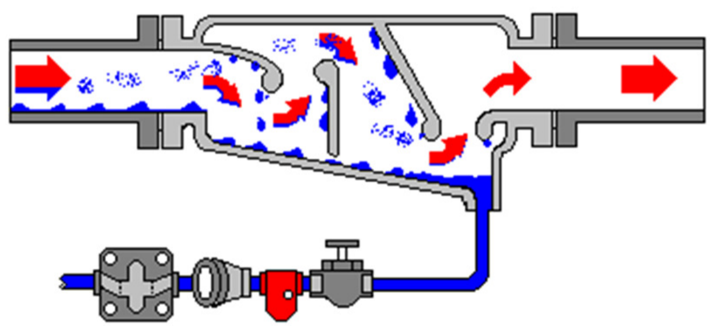
Steam Conditioning

Example: Process requires 5000 lb/hr (4,645,000 Btu's/hr)

30 psig 274ºF 929 Btu/lb (4,645,000 Btu's for 5,000 lb/hr)

@ 80% Dryness Fraction supplies 743 Btu/lb ∴ process now requires 6251 lb/hr **A 25% increase or 25% decrease in steam required!!!**

@ 90% Dryness Fraction supplies 836 Btu/lb ∴ process now requires 5556 lb/hr **A 11% Increase or 11% decrease in steam required!!!**



The heat transfer equation

Q = U x A x LMTD

Q = Total Heat Load (BTU's)

U = Overall Heat Transfer Coefficient (BTU's/hr/sqft/°F)

A = Square Feet of Surface Area

LMTD = Log Mean Temperature Difference (Steam to Product)

Steam vs. Water heating

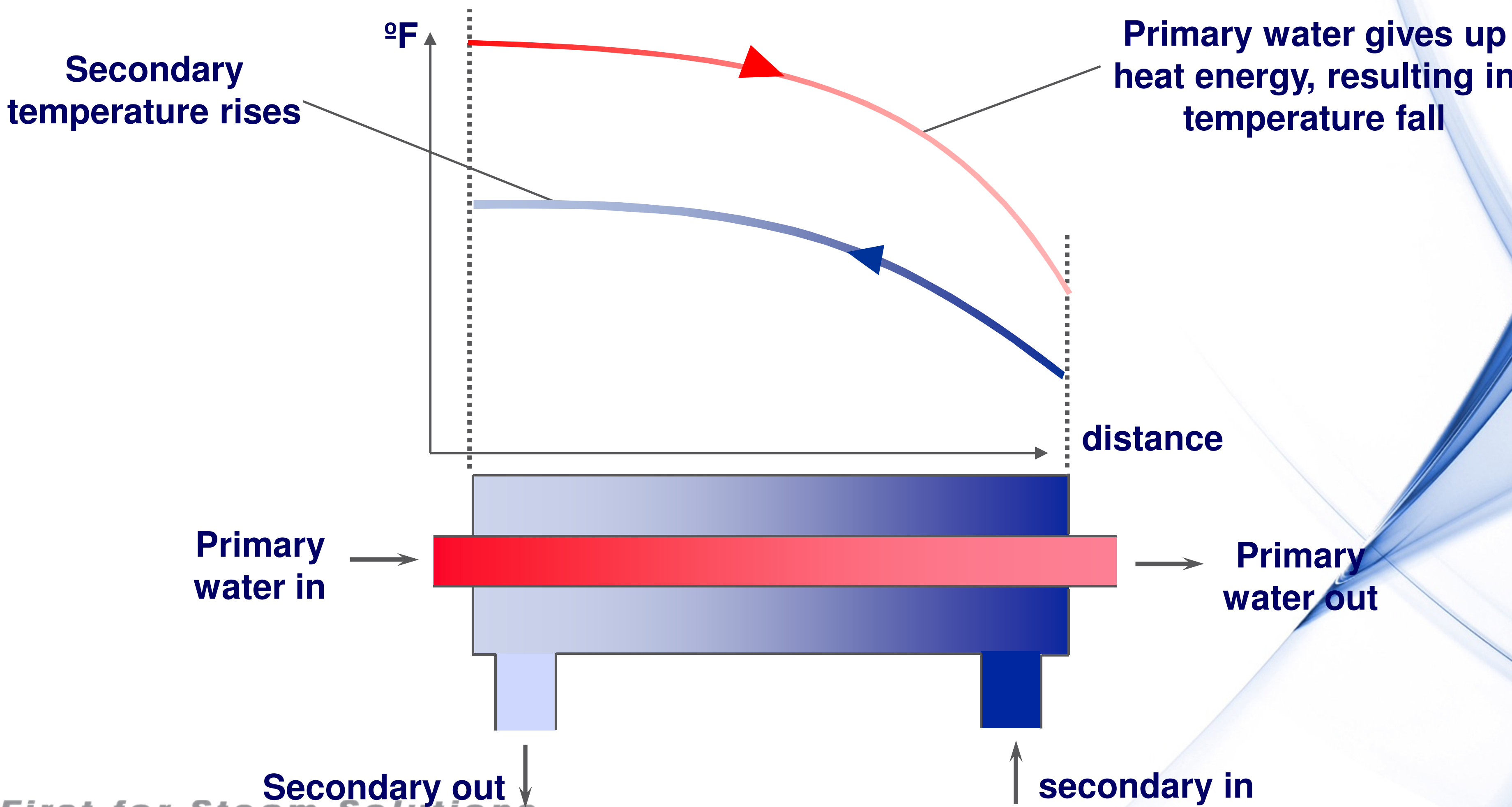
Water as a heating medium:

- Water does not change state
- As it gives up heat energy to the secondary medium its temperature drops
- For every 1 ºF drop in temperature, each 1 lb of water will give up approximately 1 BTU

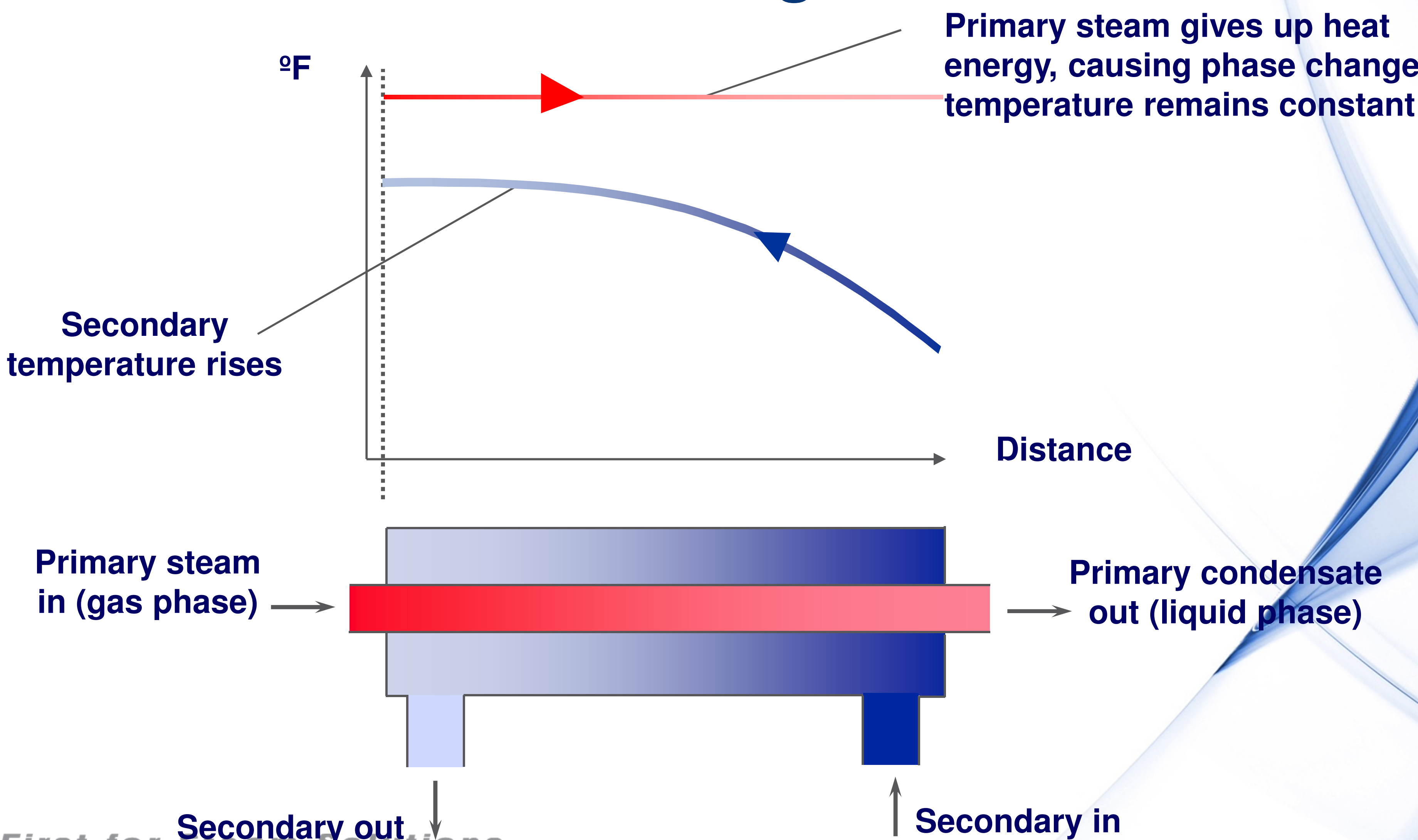
Steam as a heating medium:

- Steam changes state only as the Latent Heat energy passes to the secondary medium.
- As this latent heat is given up, the steam condenses, but ***the fluid (condensate) remains at the same temperature***
- At a pressure of 30 psi, each 1 lb of steam will give up approximately 929 BTU's

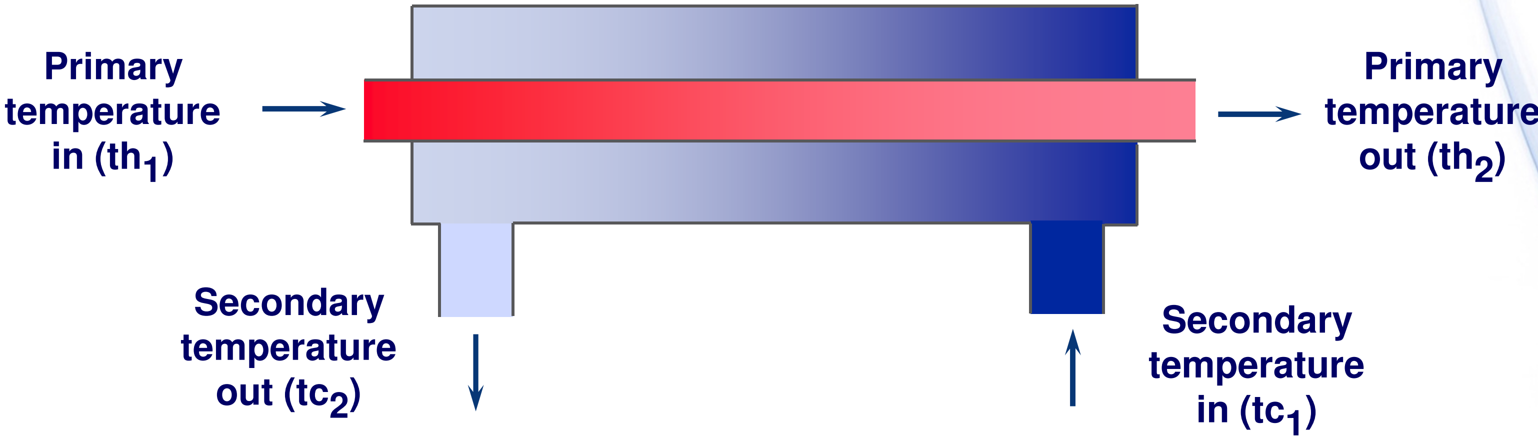
Water as a heating medium



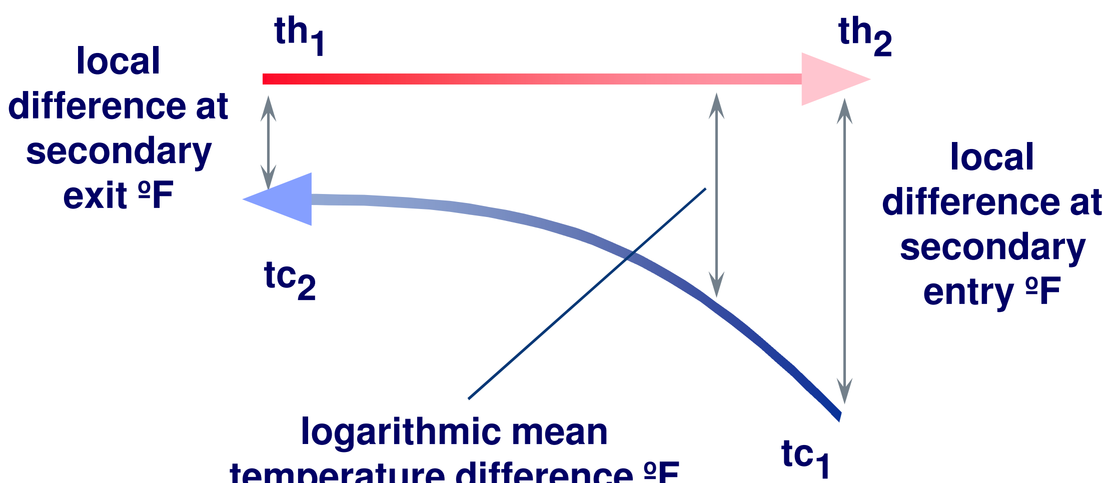
Steam as a heating medium



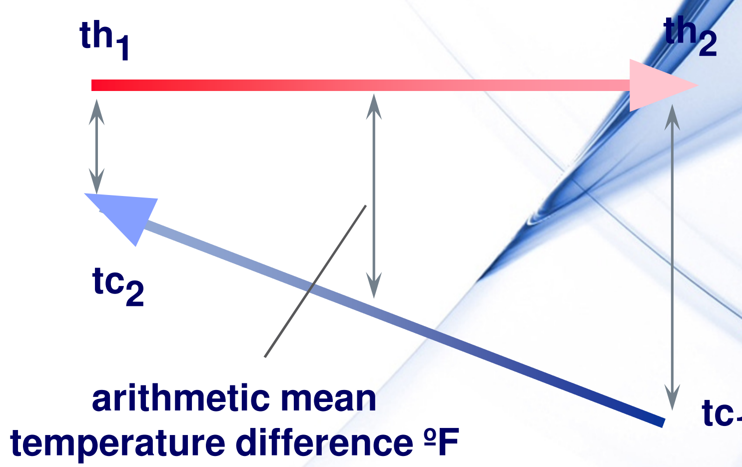
Mean temperature difference



Logarithmic Mean



Arithmetic Mean



Summary

- Industrial heat exchangers use indirect conduction to transfer heat
- Heat moves from hot to colder mediums
- Heat transfer rates are influenced by:
    - Surface area
    - Temperature Difference (Delta T)
    - Flow characteristics
    - Fouling and scaling
    - Thermal conductivity of metal
    - Film coefficient of fluid
- Steam contains and gives up more energy per unit mass than water (latent heat v sensible heat)
- The lower the pressure of steam, the more latent heat available for transfer
- Steam is a more efficient heat transfer medium than water

Heat exchange design sizing

More complex than just the evaluation of heat transfer and pressure drop,

1. **Rating problem**: when the heat exchanger type, size, surface geometry, flow rate, fluid conditions and fouling factors are specified.

2. **Sizing problem**: when flow rate, fluid conditions and allowable pressure drops are specified.

3. **The preliminary** decisions are:
   - Heat exchanger type and flow arrangements
   - Heat exchanger materials
   - Heat transfer surface area

Selection Issues

- Maximum design capacity
- Steam supply pressure
- Approach Temperature Required
- Materials of construction
- Space and access
- Pressure Drop across the secondary (water) side
- Controls and communication
- Steam Quality
- Steam Quantity
- Storage Vs. Instantaneous; i.e. Legionella Concerns
- Load TURNDOWN- think MASS FLOW
- Condensate handling and system issues
- Maintenance of ALL components.

Selection Issues

- Maximum design capacity
- Steam supply pressure
- Materials of construction
- Space and access
- Pressure drop across the secondary (water) side
- Controls and communication
- Steam Quality
- Steam Quantity
- Storage Vs. Instantaneous; i.e. Legionella Concerns
- Load TURNDOWN
- Condensate handling and system issues
- Maintenance of ALL components.

a. **<u>Systems That Use Hot Water Storage Tanks.</u>** If a facility uses hot water storage tanks, raise the water temperature of all domestic hot water storage tanks to a minimum of 140 degrees Fahrenheit (°F) to prevent growth of *Legionella*. A master thermostatic mixing valve assembly must be installed on the discharge side to reduce water temperature to 130°F before distribution, with a maximum decrement in water temperature of 10°F (120°F) at the tap. ***NOTE:*** *The facility needs to consider the presence and operational requirements of any anti-scald devices when determining if 120°F to 129°F at the tap is feasible. If at least 120°F is not feasible at the tap, consider the periodic (at least annually) evaluation of the water distribution system for Legionella or the implementation of preventive measures to inhibit Legionella growth (e.g., hyperchlorination) or Legionella transmission to patients (e.g., point-of-use filters).*

b. **<u>Systems That Use Instantaneous Hot Water Heaters</u>**

(1) If the facility has an instantaneous hot water heater that feeds instantly heated water directly into a circulating distribution system, then the water can be discharged into the circulating distribution system at 130°F without the need of a mixing valve. The maximum decrement in water temperature at the tap shall be 10°F (120°F). ***NOTE:*** *The facility needs to consider the presence and operational requirements of any anti-scald devices when determining if 120°F to 129°F at the tap is feasible. If at least 120°F is not feasible at the tap, consider the periodic (at least annually) evaluation of the water distribution system for Legionella or the implementation of preventive measures to inhibit Legionella growth (e.g., hyperchlorination) or Legionella transmission to patients (e.g., point-of-use filters).*

(2) If the facility has an instantaneous hot water heater that is configured to feed into a storage tank before the water enters the circulating distribution system, then raise the water temperature to a minimum of 140°F in the storage tank and distribute the hot water as described above (Att. A, subpar. 1a). It is encouraged that facilities that use instantaneous hot water heaters select systems that feed directly into circulating distribution systems to avoid the use of storage tanks and to conserve energy.

Heat Exchanger – Hot Water Storage Tank

Design – Storage Tank typically with a "U" tube bundle or Helical coil

Strengths –
- Simple Design
- Low Initial Cost

Concerns –
- Floor Space Requirements
- Potential for Legionella

Heat exchange design sizing

Design Specifications

Process Requirements

a. Fluid compositions, and inlet flow conditions (flow rate, temperature and pressure)
b. Heat duty or required exit temperatures
c. Allowable presure drops

Operating and Maintenance Considerations

a. Fouling potential and method of cleaning
b. Failure due to corrosion, thermal stress, vibration or freezing
c. Repair of leaks
d. Part load operating characteristics

Size and Weight restrictions

a. Frontal area, length, or height
b. Possible weight restrictions

Design Selections

Heat Exchanger Materials

a. Fluid temperatures and pressures
b. Corrosive characteristics of fluid material combination

Heat Exchange Type

a. Design pressure and fluid temperatures
b. Corrosion, stress, vibration, and freezing considerations
c. Fouling potential and cleaning possibilities
d. First cost, operating and maintenance cost

Heat Transfer Surface Geometries

a. Thermal resistance ratio of fluids
b. Potential for use of enhanced surfaces
c. Fouling potential and cleaning possibilities
d. Unit cost of heat transfer surface

Typical Applications of Heat Exchangers

Domestic Water-Potable Water

Building Comfort Heat-Water/Glycol

Process Fluids

CIP-Clean In Place-Caustics

Blowdown Heat Recovery

Vent Condensers

Steam To Steam Generators

Types of Heat Exchangers

TUBE BUNDLE TYPE

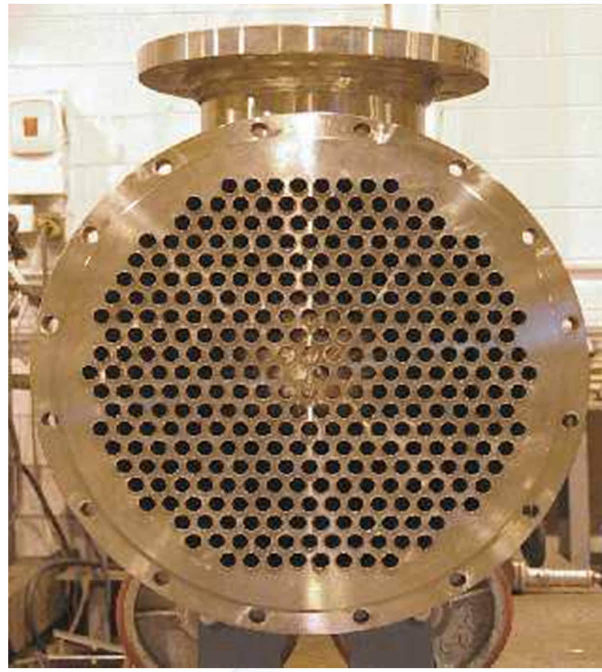
- U-Tube Bundle
- Helical Coil

Shell & Tube

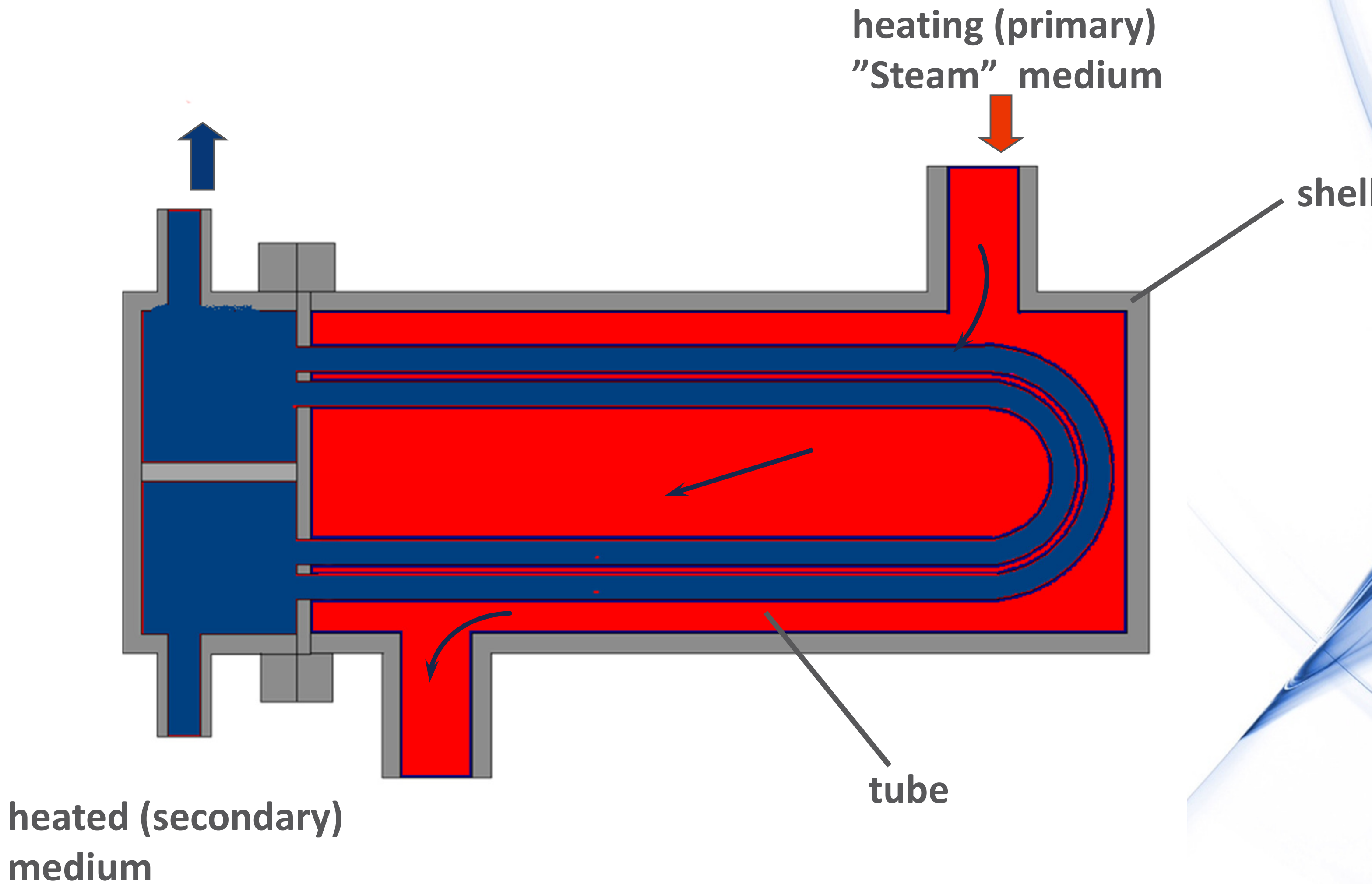
PLATE & FRAME

PLATE & SHELL

Shell & Tube



Typical Heat Exchanger-Shell & Tube Design



Heat Exchanger – Shell & Tube Concerns

Weight, size – overall footprint
Requires additional space to pull bundle
May require special rigging to change bundle
Large hold-up volume long response time
Subject to mechanical damage – Thermal Shock
Subject to scaling
10° F approach temperature
Common Proven Configuration
High pressure/temperature applications
Vertical or Horizontal Design
Low Initial Cost
Wide Choice of materials
Double Wall Tubes

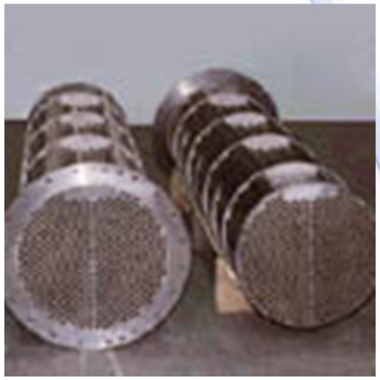
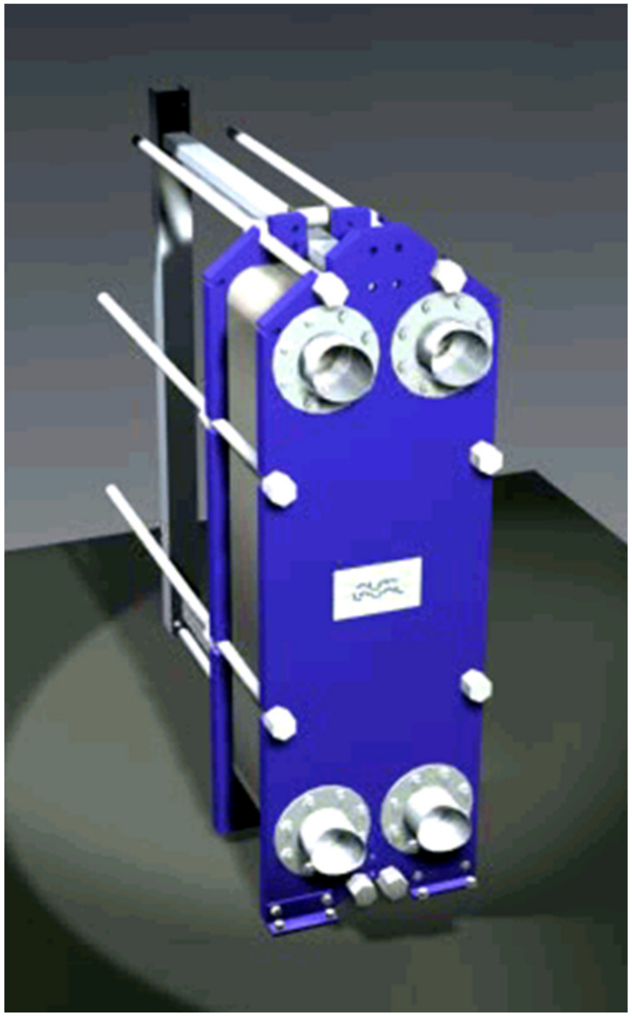
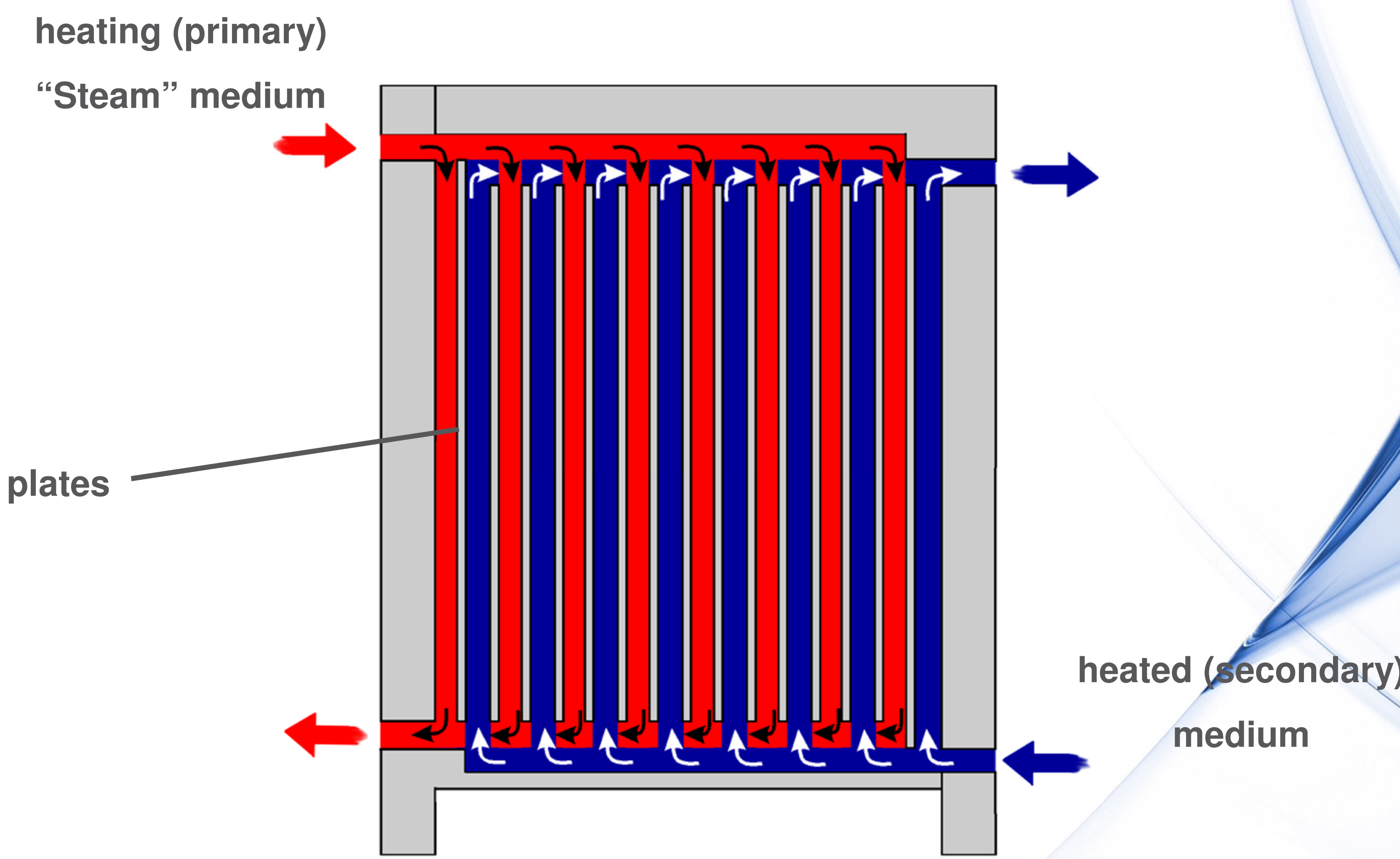


Plate & Frame Design



Heat Exchanger – Plate & Frame Design



Heat Exchanger – Plate & Frame Concerns

Expandable
Easily maintained
Minimum space required for servicing
Stainless steel plates
Low heat loss
Double wall-Available
2°F approach temperature
New higher pressure/temperature limits
Higher Pressure Drops
Higher heat transfer-velocities
Less sensitive to fouling-velocities
Reduced thermal fatigue-gaskets
Sensitive to Chlorides

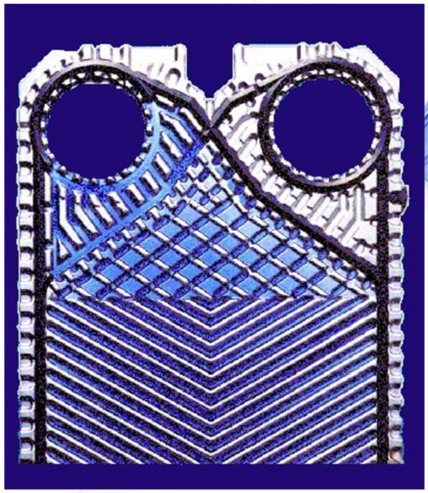


Plate & Shell

Design – Similar to Plate & Frame but substitute heavy duty shell for the frame.

Strengths – More robust design can handle higher temperatures and pressures.

Concerns –
- Design limits maintenance capabilities
- Cannot expand plate pack

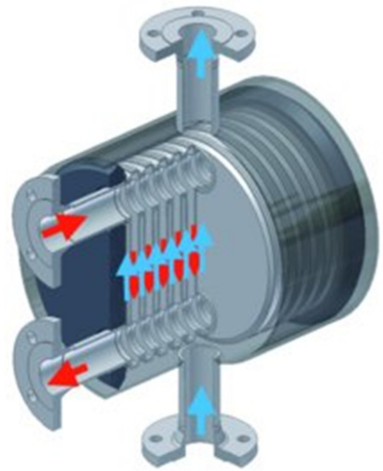


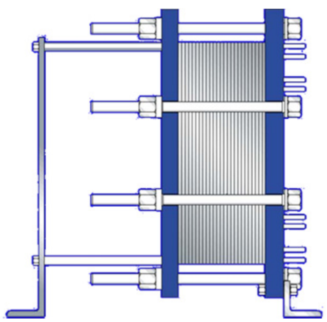
Plate & Frame vs Shell & Tube

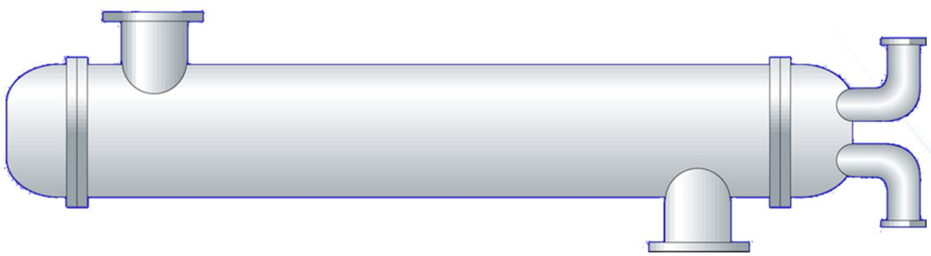
PHE requires less floor area

PHE weighs less

Easy installation

- For small heat exchangers pressure vessel certificates and regular inspection are unnecessary

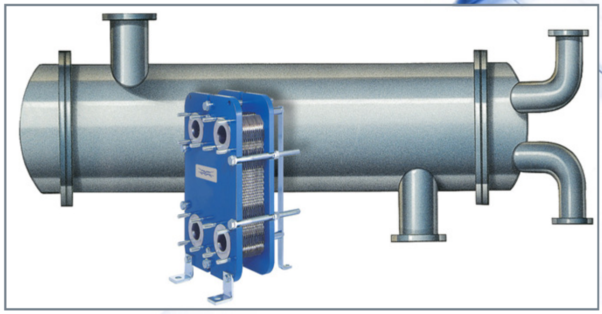




	PHE	S&T
Weight ratio	1	6
Space ratio	1	7
Hold-up volume ratio	1	6

Plate Frame versus Shell and Tube

- Economical to design the PHE with a lower condensation temperature to minimize flash steam
  and fouling
- Economical to sub cool the condensate within the PHE
- A PHE can operate in stall condition while maintaining an acceptable temperature control
- Versatile
- Cost efficient
- Compact Design 1/3 to ½ the size of S&T less weight and space
- Expandable Surface Area-adding additional plates
- High Thermal Efficiency- 3-5 times higher
- Short Response Time
- Resistant to fouling due to high turbulent Flow
- Closer Approach Temperatures



Domestic “Potable” Water Heating

Domestic water heating is adding heat energy to potable water. This hot water is utilized in our daily lives, including washing, cooking and cleaning. It is water heated from a source suitable for ingestion such as a municipal supply or well.

Note: May need double wall construction to meet state codes.

It <u>does not</u> include hot water utilized for space heating purposes or water used for process applications.

Domestic “Potable” Water Heaters

- For cooking
- For showers in institutional facilities
- For laundry washers
- For general cleaning (floors, walls, etc.)

Typical Hydronic Package Components

Circulation Pump

Suction Diffuser

Air Separator

Triple Duty Valves

Expansion Tank

Chemical Bypass Feeder

Make Up Water Assembly

CIP- Clean In Place

CIP is an attractive maintenance method, more convenient and simple. It is also a preferred cleaning method in the food and beverage industry also when especially corrosive liquids are being processed.

Typically, a CIP operation would be as follows:

1. The heat exchanger unit is turned off.
2. All fluids are drained from the unit.
3. The preselected cleaning solution is circulated through the unit in a bottom-to-top flow to totally flood the unit and prevent channeling.
4. When it is determined that the solution is no longer reacting with the substances inside the unit, the cleaning is complete.
5. The unit is drained of the cleaning solution and, if necessary, rinsed with water and put back online.

VENT CONDENSOR

In most cases, condensate receivers and deaerators, the flashing steam is vented and its energy content lost.

However, a heat exchanger can be placed in the vent to recover this energy, as long as there is a product that can be heated.

Typically, Shell & Tube design heat exchangers work the best in this application due to the free flow path characteristics inside the shell portion allowing for minimal pressure drops.

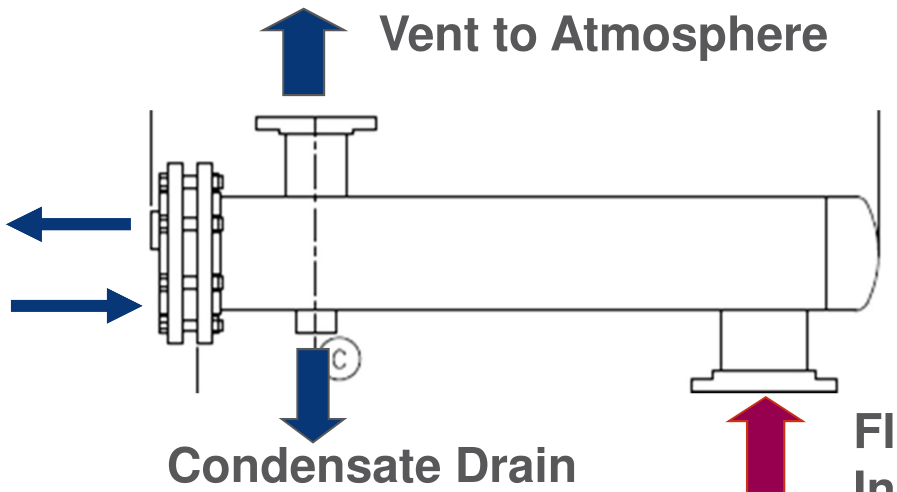


Table 12: Percent Flash

Steam Pressure psig	Atmosphere 0	Flash Tank Pressure 2	5	10	15	20	30	40	60	80	100
5	1.7	1.0	0								
10	2.9	2.2	1.4	0							
15	4.0	3.2	2.4	1.1	0						
20	4.9	4.2	3.4	2.1	1.1	0					
30	6.5	5.8	5.0	3.8	2.6	1.7	0				
40	7.8	7.1	6.4	5.1	4.0	3.1	1.3	0			
60	10.0	9.3	8.6	7.3	6.3	5.4	3.6	2.2	0		
80	11.7	11.1	10.3	9.0	8.1	7.1	5.5	4.0	1.9	0	
100	13.3	12.6	11.8	10.6	9.7	8.8	7.0	5.7	3.5	1.7	0
125	14.8	14.2	13.4	12.2	11.3	10.3	8.6	7.4	5.2	3.4	1.8
160	16.8	16.2	15.4	14.1	13.2	12.4	10.6	9.5	7.4	5.6	4.0
200	18.6	18.0	17.3	16.1	15.2	14.3	12.8	11.5	9.3	7.5	5.9
250	20.6	20.0	19.3	18.1	17.2	16.3	14.7	13.6	11.2	9.8	8.2
300	22.7	21.8	21.1	19.9	19.0	18.2	16.7	15.4	13.4	11.8	10.1
350	24.0	23.3	22.6	21.6	20.5	19.8	18.3	17.2	15.1	13.5	11.9
400	25.3	24.7	24.0	22.9	22.0	21.1	19.7	18.5	16.5	15.0	13.4

Percent flash for various initial steam pressures and flash tank pressures.

Boiler Blowdown & Heat Recovery

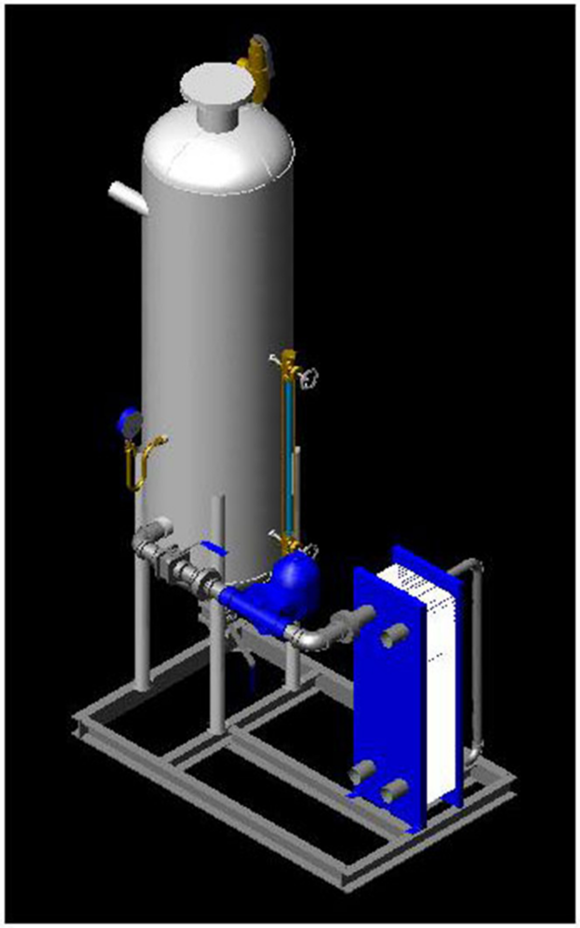
Blowdown refers to the removal of boiler water in order to maintain an acceptable level of Total Dissolved Solids (TDS)

Boilers require periodic blowdown in order to maintain effective operation, provide good equipment life, and reduce maintenance time and expense

The water that is blown down is replaced by make up water that has a much lower TDS level, which lowers the concentration in the boiler water

TDS = Total Dissolved Solids

Blowdown Heat Recovery



Standard:

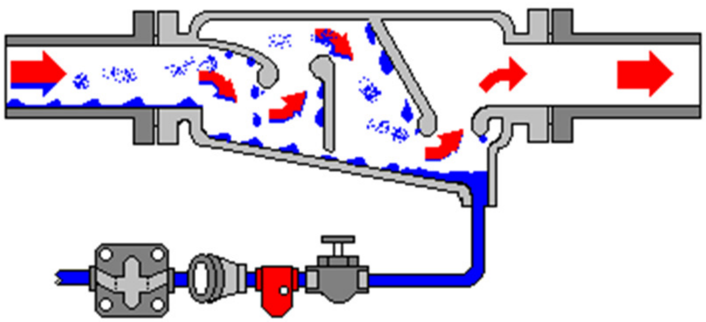
ASME flash vessel, P&T relief valve, pressure gauge, plate and frame HX, F&T Steam trap, skid mounted

Options:

Condensate cooler, inlet condensate manifold, vessel gauge glass

Sample cooler, temperature gauge

Steam Conditioning



Example:

Process requires 5000 lb/hr (4,645,000 Btu's)

30 psig 274 F 929 Btu/lb

@ 80% Dryness Fraction 743 Btu/lb

@ 90% Dryness Fraction 836 Btu/lb

Steam Separators improve Dryness Fraction

Removes liquids and solids down to 10 Microns, up to an efficiency of 99%

Heat Transfer Control Systems

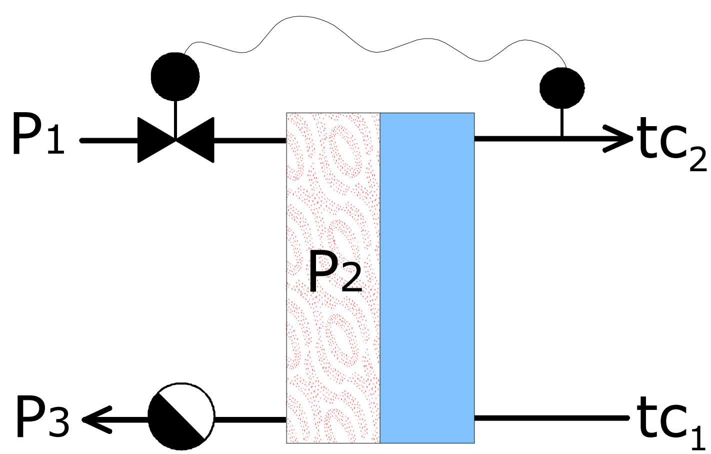
“A” Primary Steam Control-Steam Trap

“B “ Primary Steam Control- Pump/Trap

“C” Primary Pressure + Secondary Three Port Valve

“D” Primary Condensate Control-Two Port Valve

"A" Primary steam control + steam trap



Use when:

- P_2 will always be greater than P_3 under normal design operating conditions

Advantages:

Minimizes the condensation temperature.

Minimum scaling, maximize lifetime of gaskets and minimizes potential for flash steam

Simple design

Suitable for all types of heat exchanger

Responds adequately to load changes

Disadvantages:

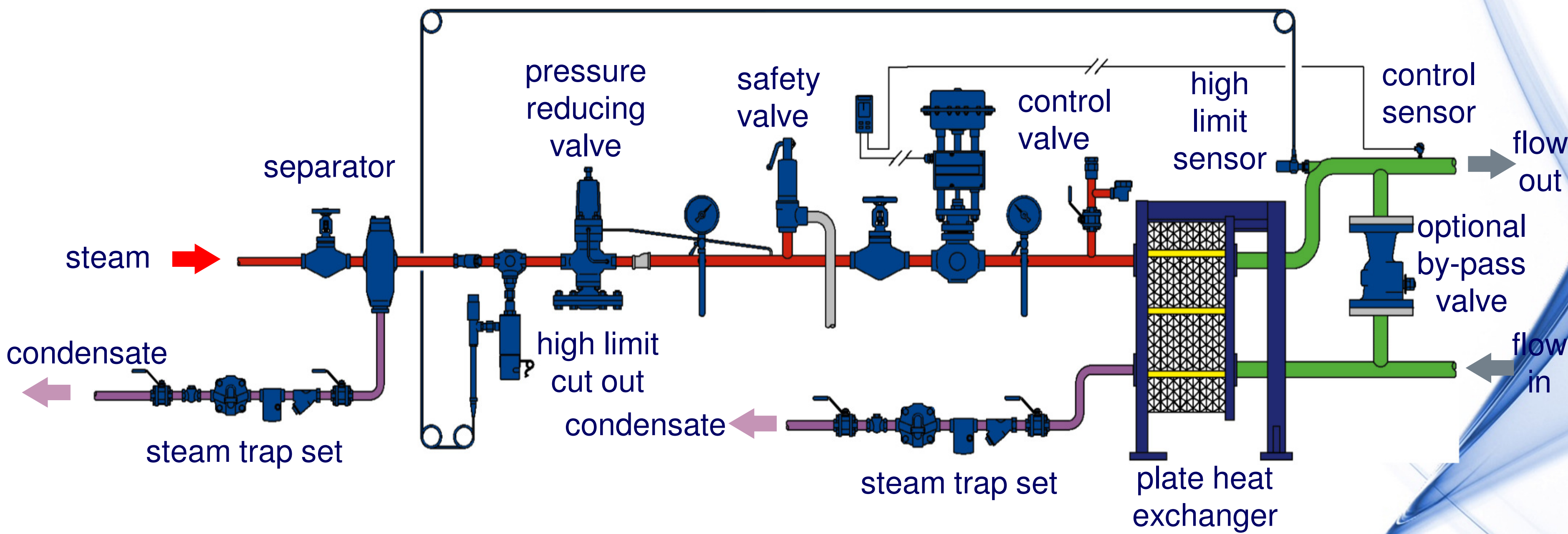
If the available steam temperature is close to secondary supply temp (tc2), there could be problems to achieve necessary pressure drop over the control valve

If secondary conditions or back pressure in the condensate system do alter, stall could occur

Introduction of potentially corrosive air into the steam system.

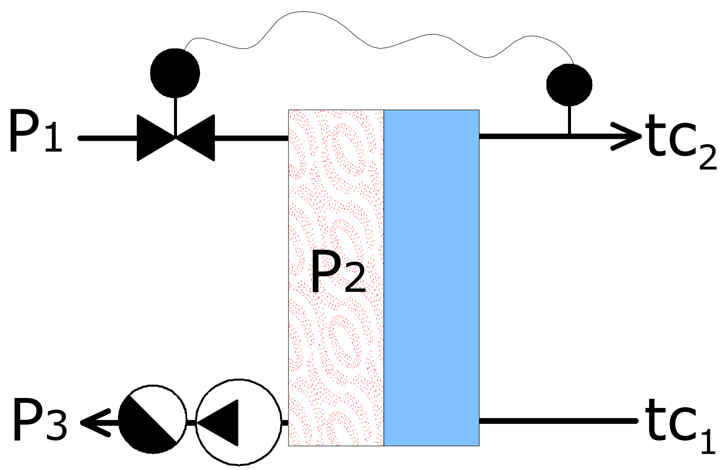
After what we have discussed, will this always occur?

“A” Primary steam control + steam trap



This is a typical “Open Loop” System where condensate is gravity drained to a pump Located BELOW the trap and with atmospheric pressure.

"B" Primary steam control + pump/trap



Advantages

Responses quickly to load changes

Will always work, under all conditions, within the operating limits of the equipment

Suitable for all types of heat exchanger

Minimises the condensation temperature and thus, scaling and flash steam

Easily commissioned

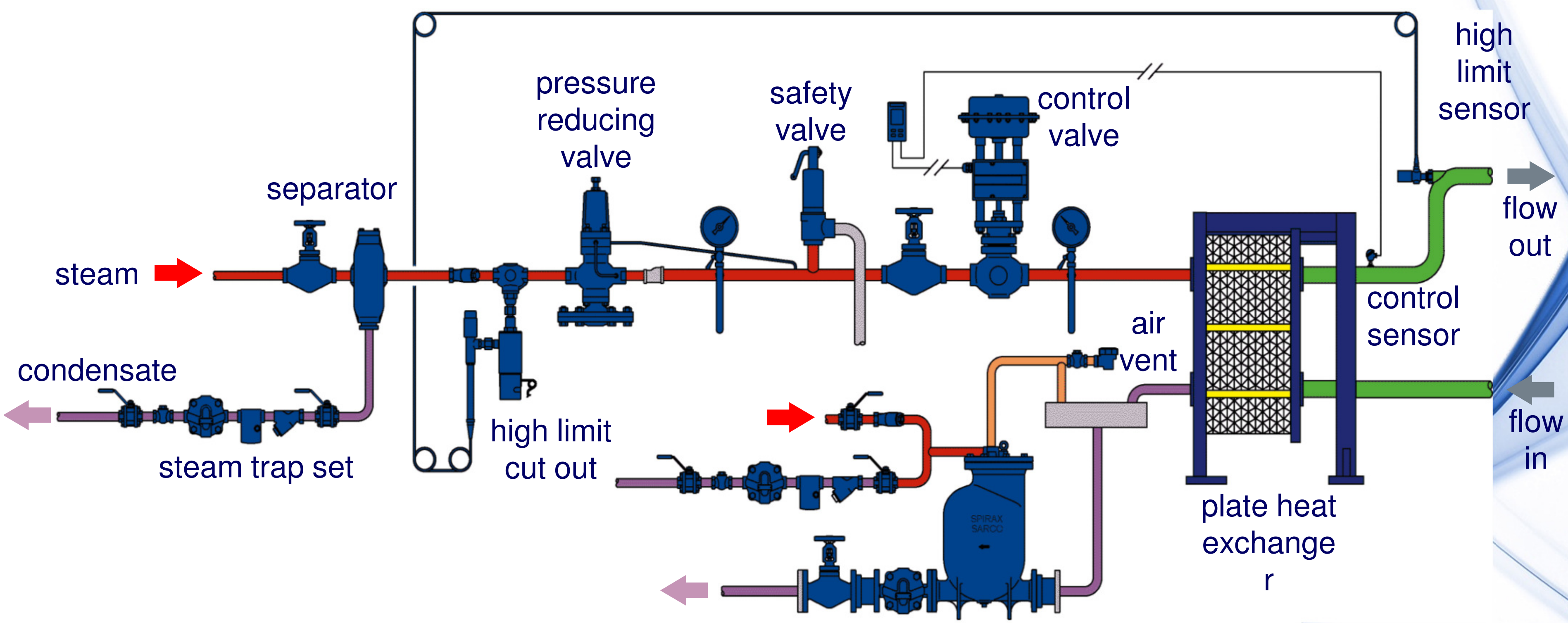
Disadvantages:

Expensive (pump) solution?

Use When:

- P3 is or can be greater than P2 under normal design operating conditions

"B" Primary steam control + pump/trap "Closed Loop System"



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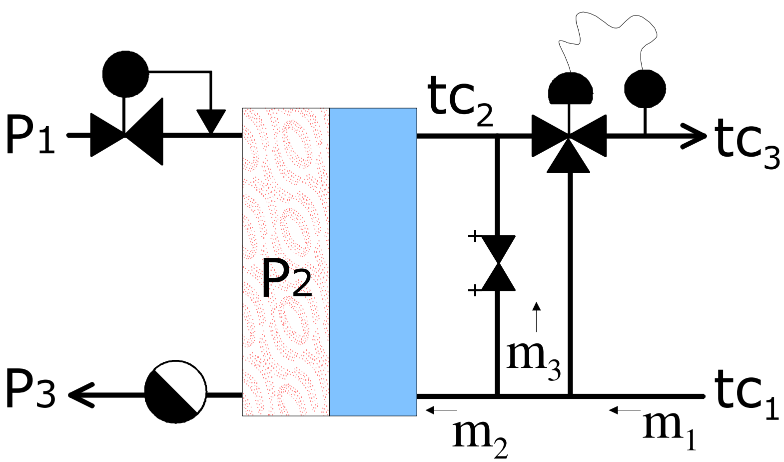
"C" Primary steam Pressure control + secondary three port control + steam trap



Advantages:

Allows closer matching of actual heat transfer area and design requirement.

Response quickly to secondary side load changes.

Inexpensive.

Disadvantages:

Maximum tc_2 value is limited by secondary fluid characteristics and/or system pressure.

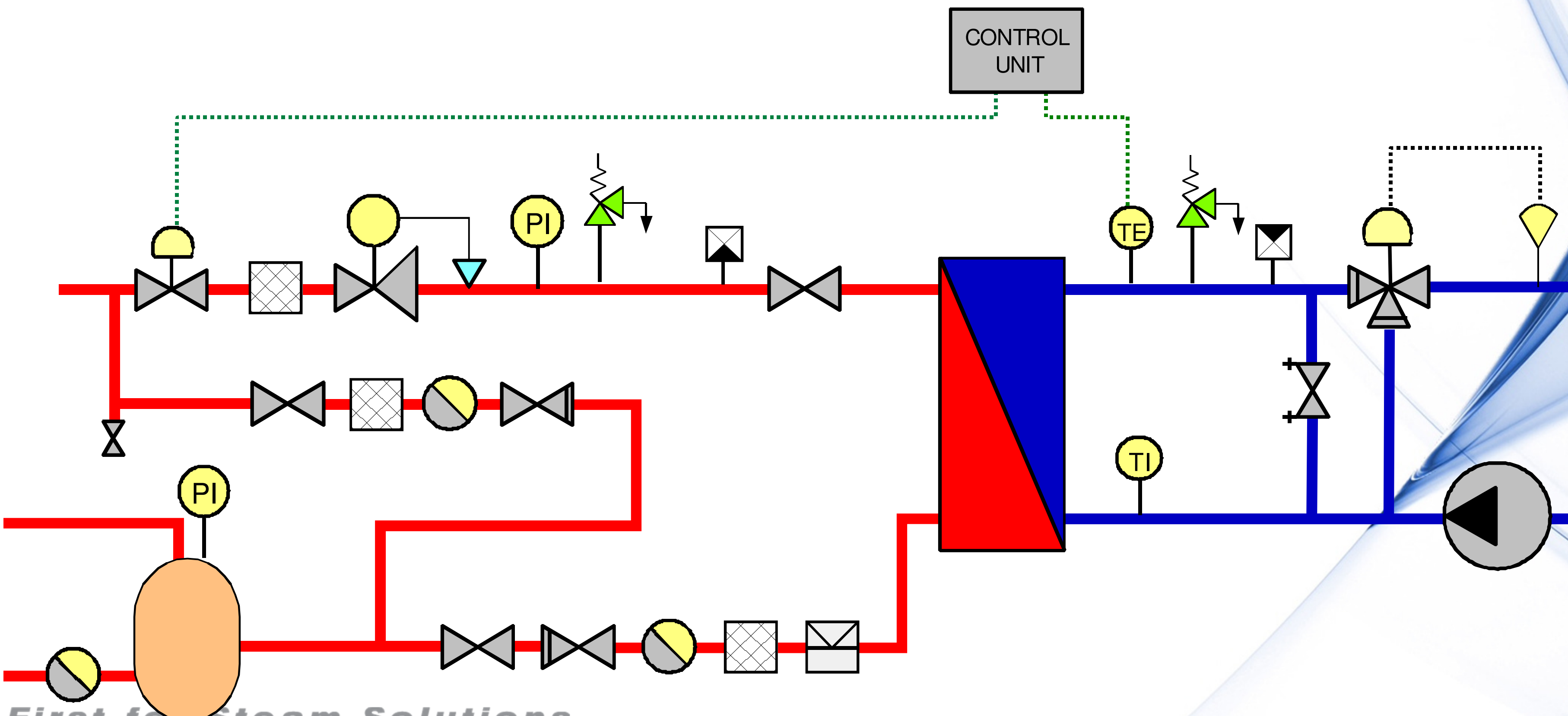
Risk of boiling!

High condensate temperature. Sub-cooler might be required. Risk of fouling / scaling.

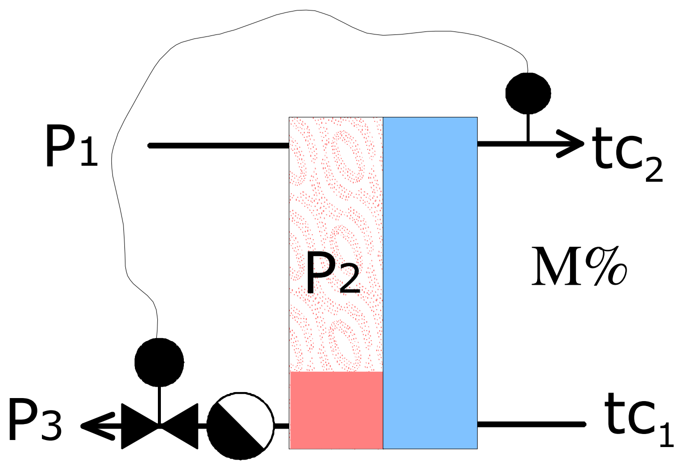
Use when:

- The primary steam pressure is low, typically less than 15 psig

"C" Primary pressure control + secondary three port control + steam trap



"D" Primary condensate control



Use when:

- The load changes slowly
- A sub-cooled condensate is desired

Advantages:

Full P_1 value always available at the steam trap.

No stall condition.

Reduced control valve size.

Condensate is sub-cooled with reduced flashing.

Condensing and sub-cooling is carried out in one (1) unit.

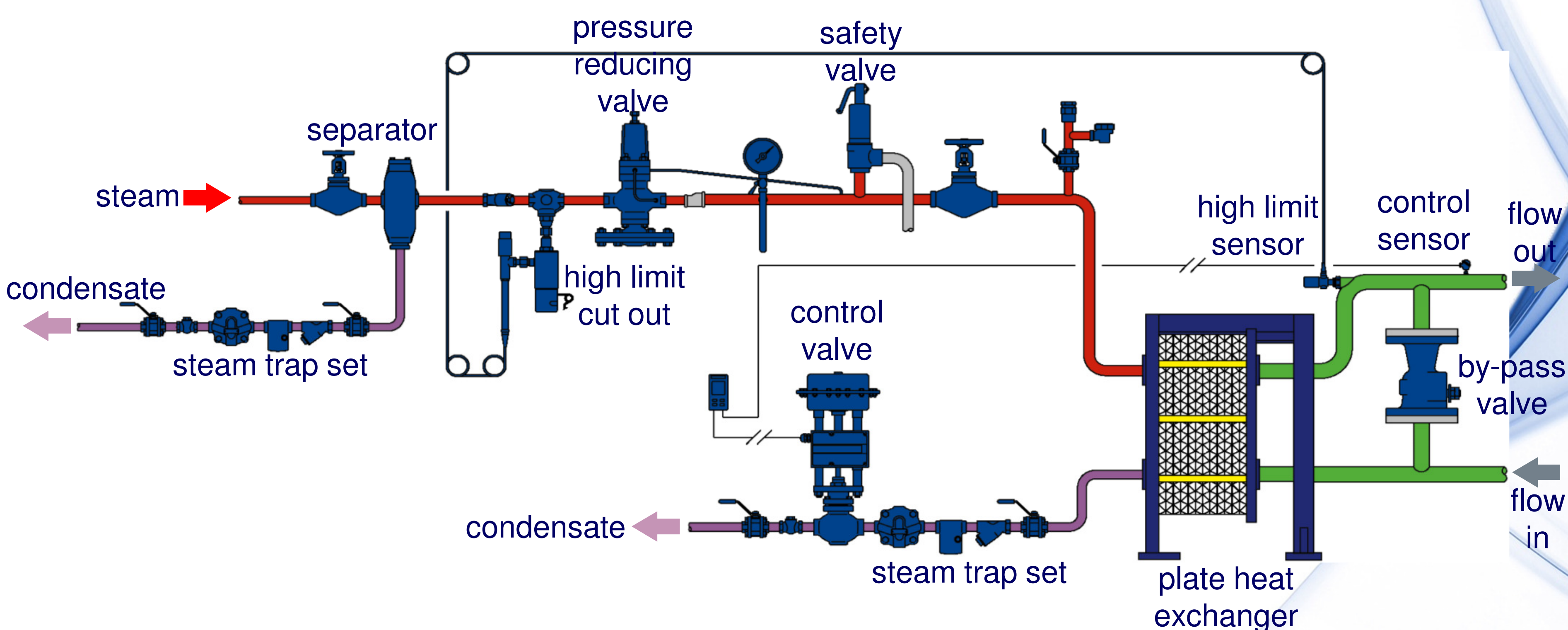
Disadvantages:

Poor/slow response to secondary load change.

Shell & tube (too large surface area) and brazed PHE's (thermal cycling) cannot be used.

Risk of boiling on the secondary side if the load is reduced quickly.

“D” Primary condensate control



Note Simplicity of Steam Inlet Control

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Typical Open Loop HX Hook-up, aka the "Ford" System

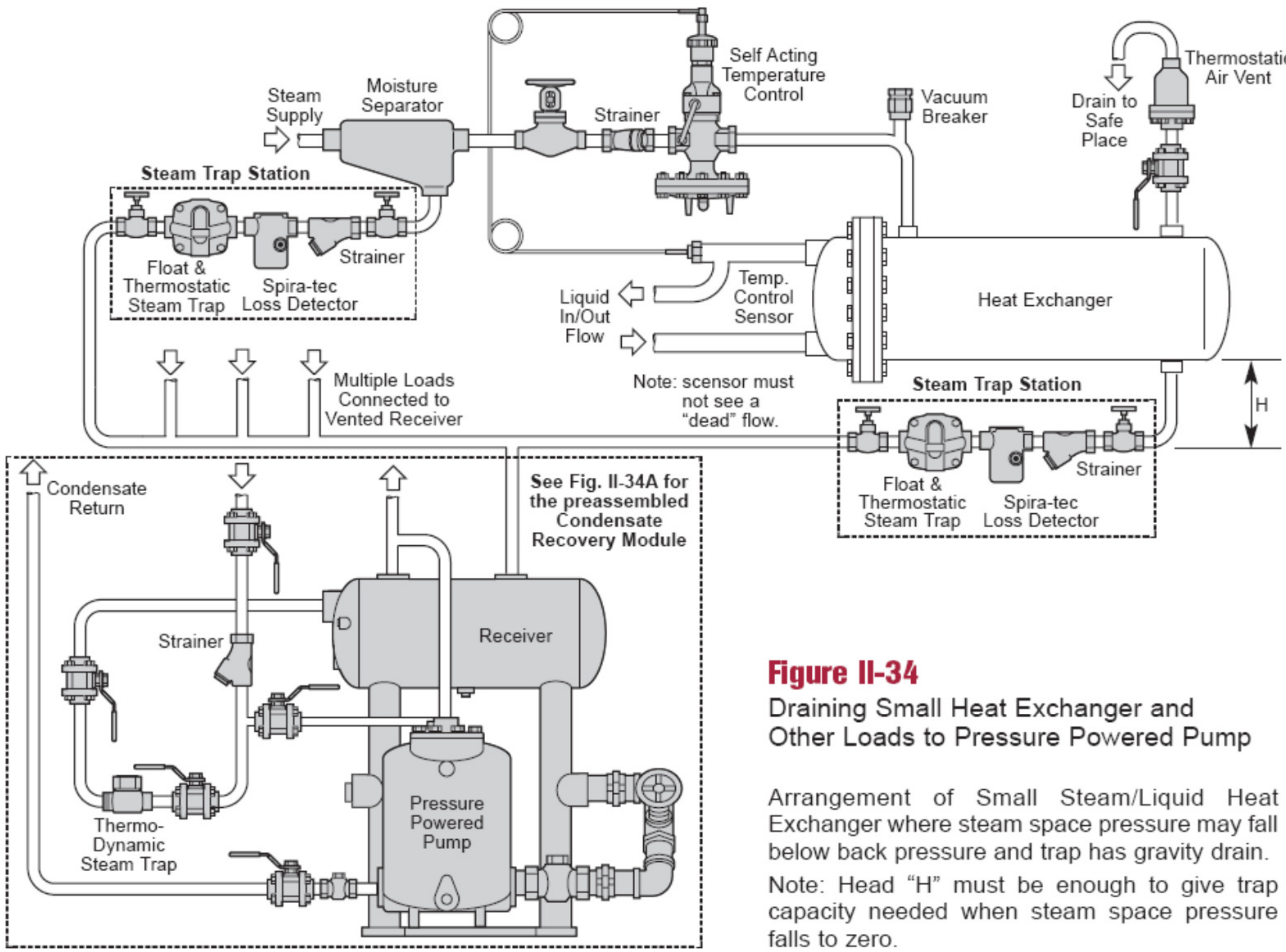


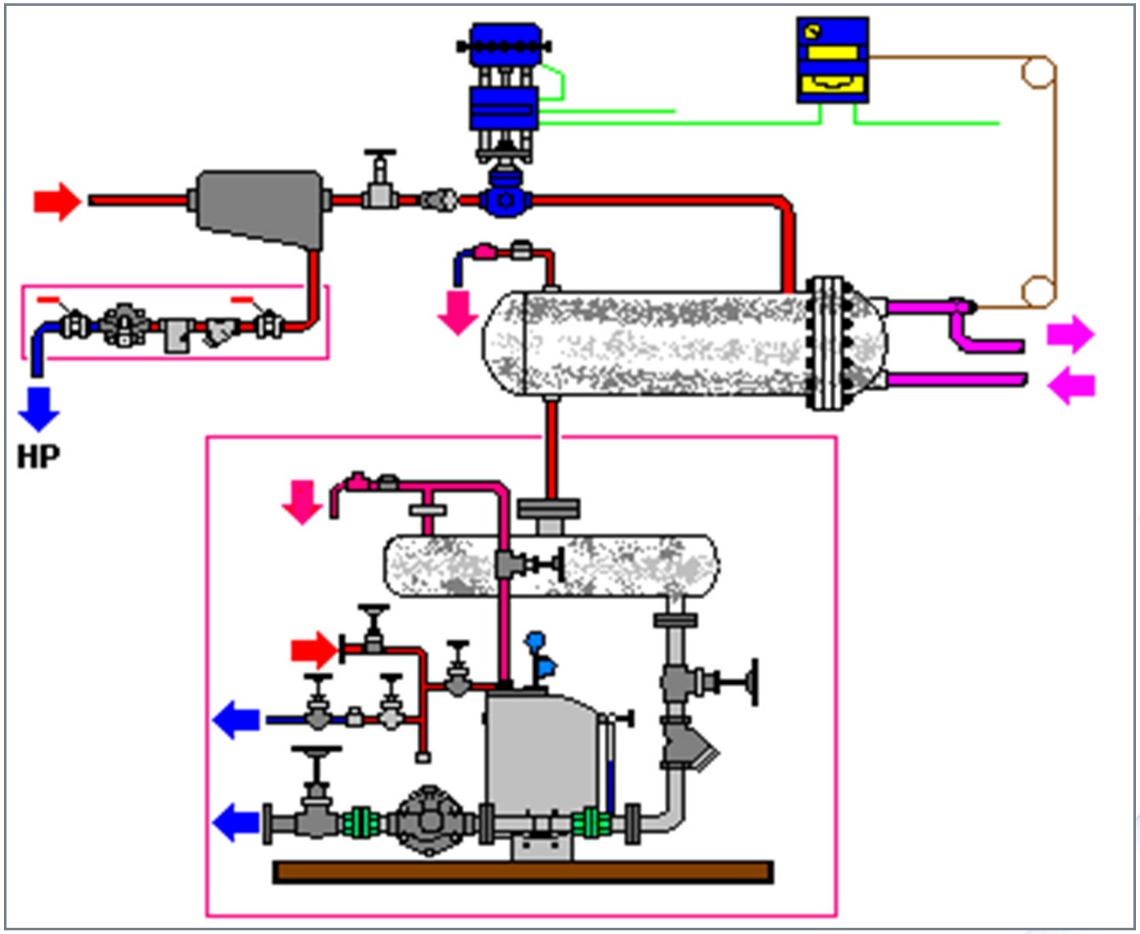
Figure II-34

Draining Small Heat Exchanger and Other Loads to Pressure Powered Pump

Arrangement of Small Steam/Liquid Heat Exchanger where steam space pressure may fall below back pressure and trap has gravity drain.

Note: Head "H" must be enough to give trap capacity needed when steam space pressure falls to zero.

Closed Systems-Equipment Drainage



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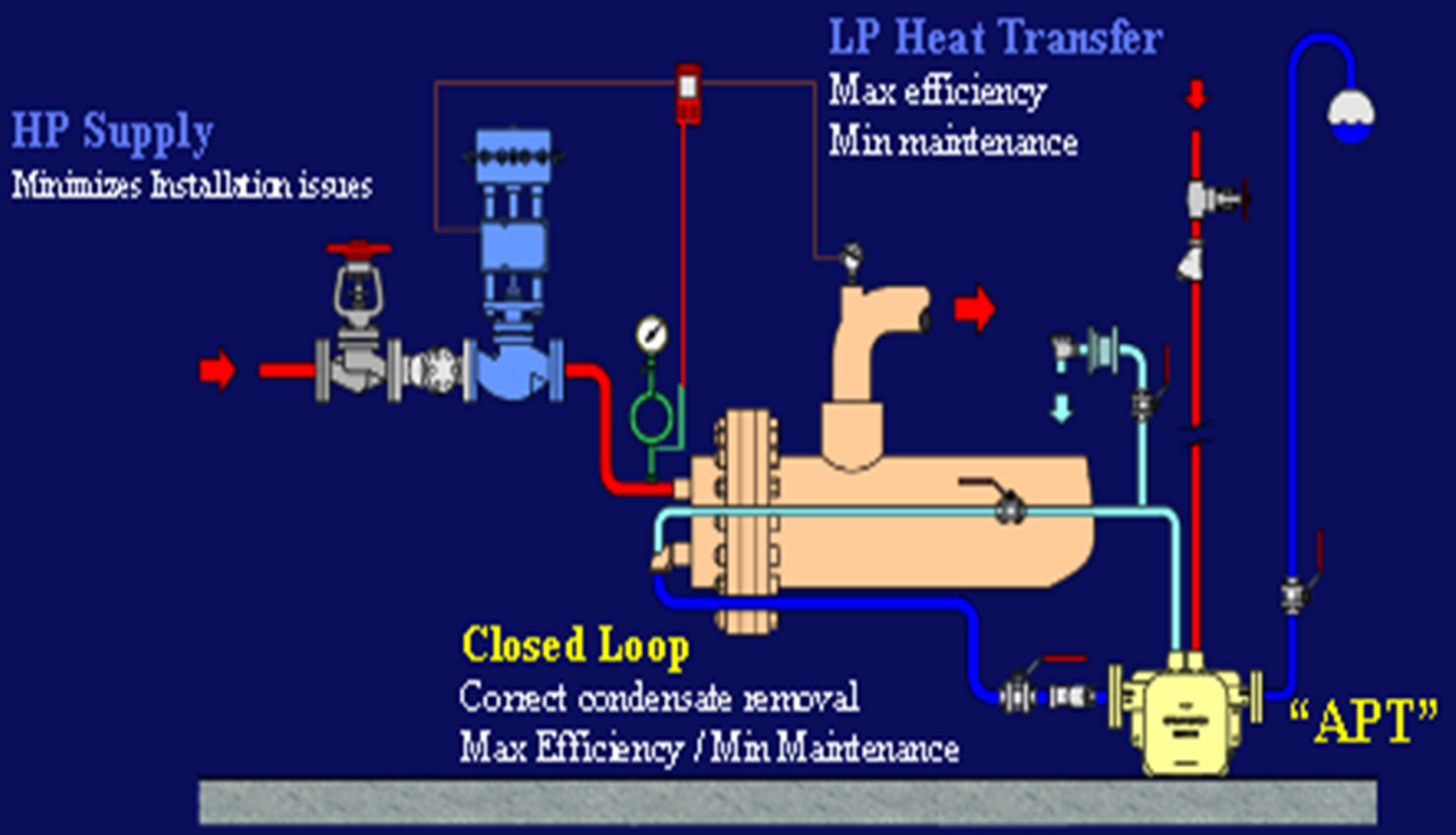
Summary – Heat Transfer



Heat Exchanger Example

This heat exchanger is now operating in a “vacuum” state, NO steam trap can remove condensate without a positive pressure differential.

Water logging conditions exist.

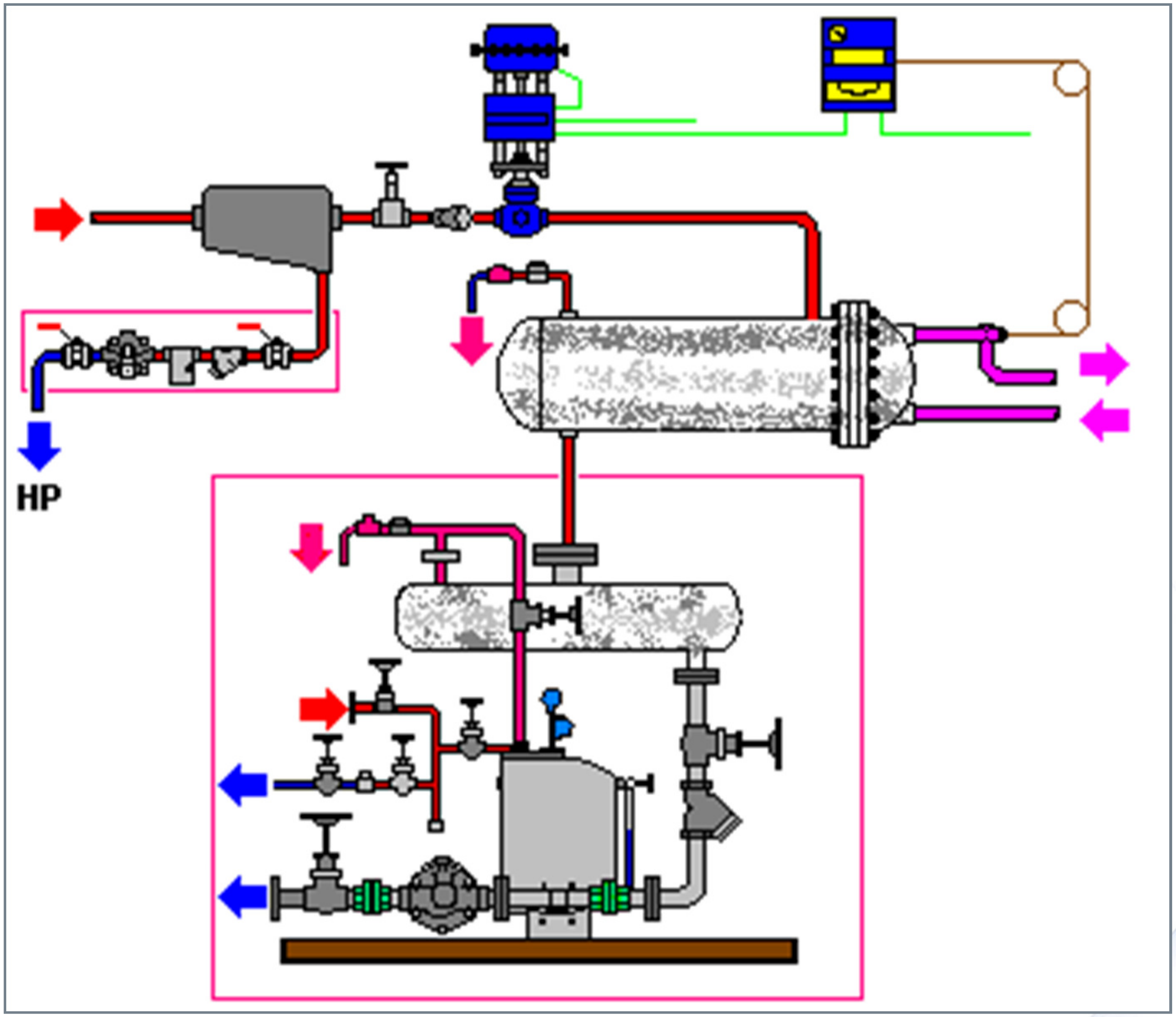
Product temperatures will drop due to flooding and subcooling of condensate.

Condensate drainage under these circumstances is virtually impossible.

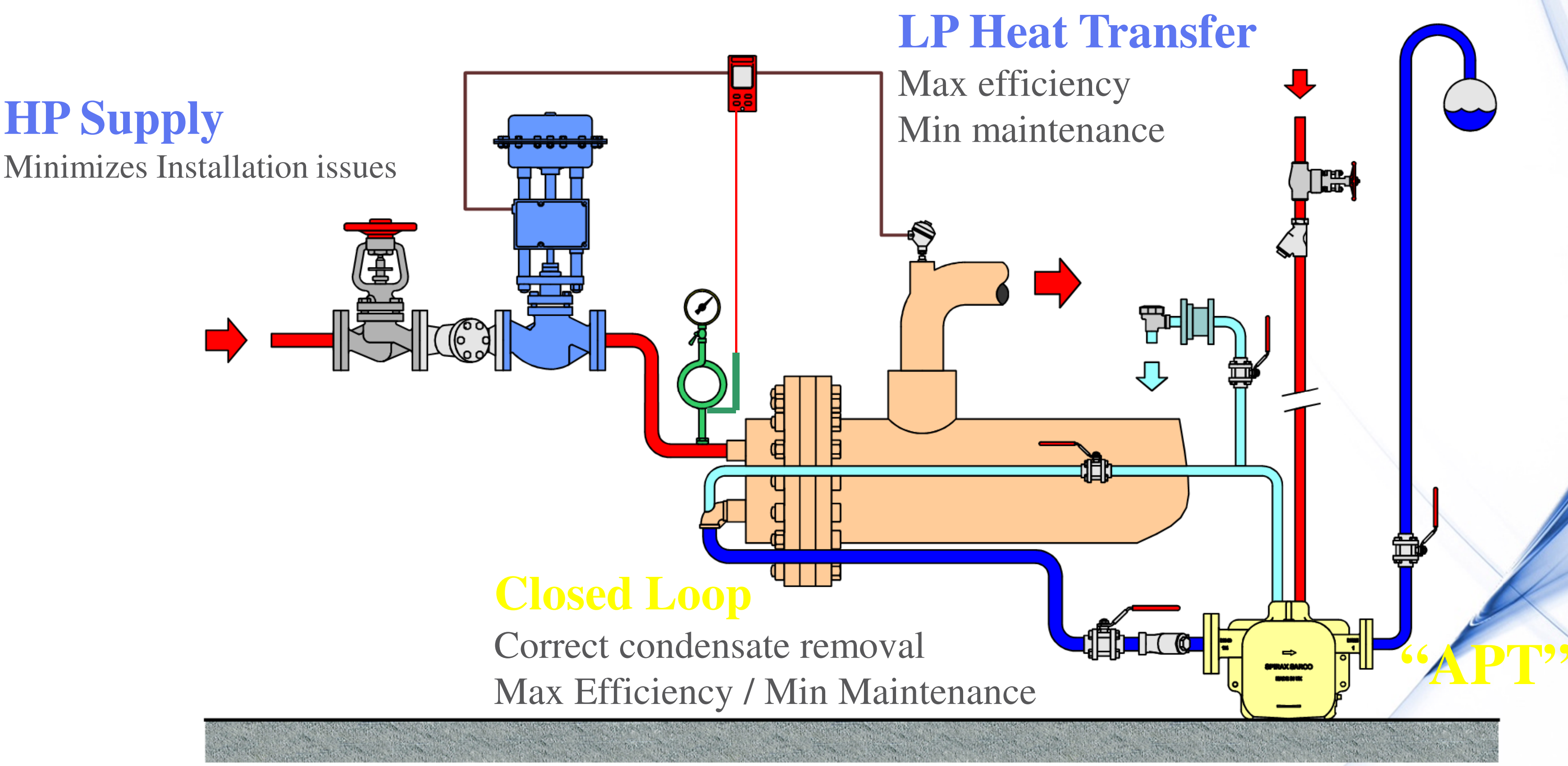
A vacuum breaker must be applied to the exchanger, this will only help if the condensate is allowed to drain by gravity, no lift. Introduction of air and non-condensible gases increase corrosion attack.

Continuous cycling of flooding and then filling the steam space with steam will cause the system to have greater temperature variations.

Closed Systems



Summary – Heat Transfer



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Steam Basics

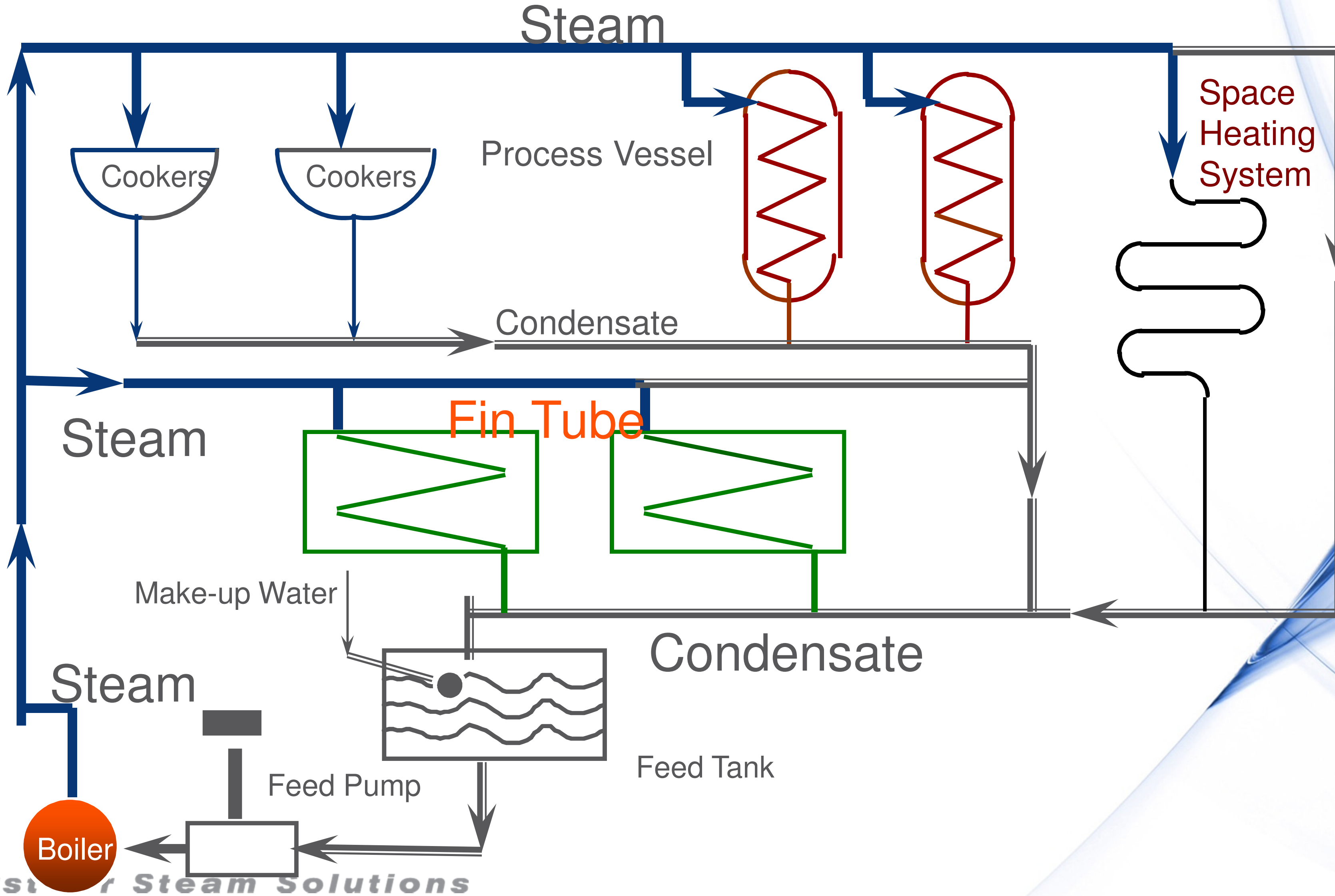
STEAM GENERATION - Boilers, Generators

STEAM DISTRIBUTION - High, Medium, Low Pressures

STEAM UTILIZATION AT THE PROCESS AREAS – Heat Exchangers, Coils, Jacketed Vessels, Etc.

CONDENSATE RECOVERY - Gravity or Pumped Returns

Typical Steam Circuit



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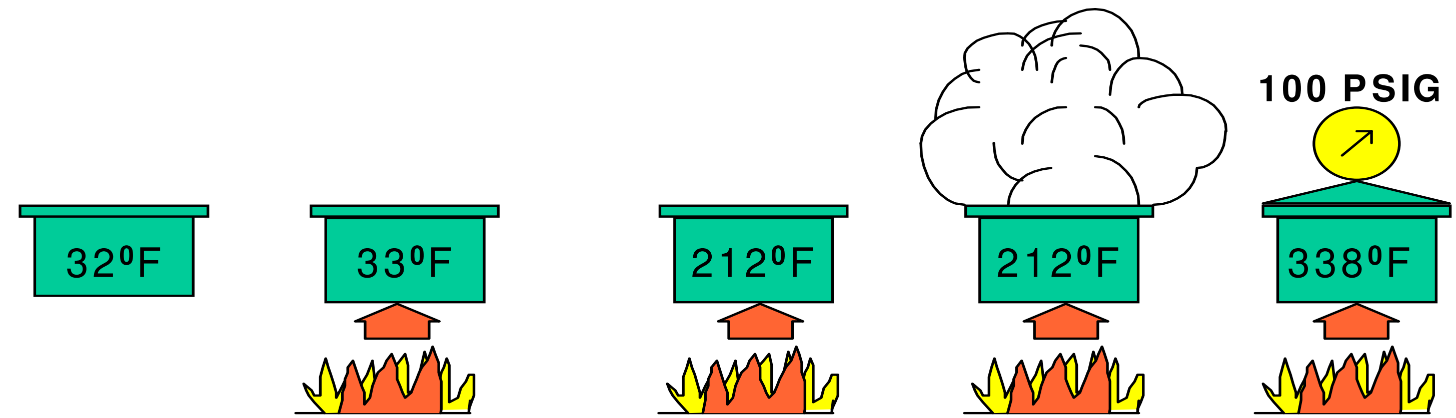
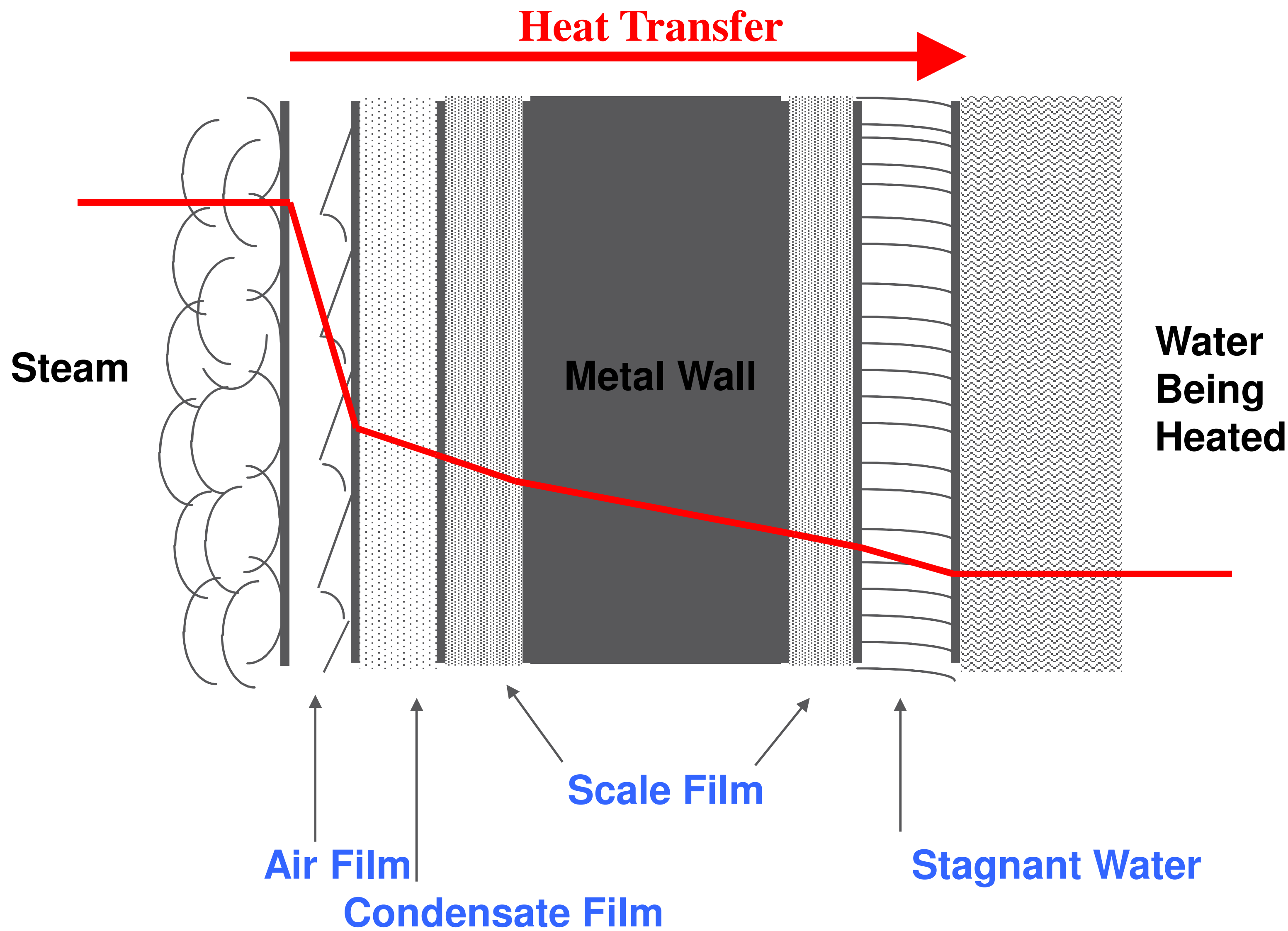
Steam Basics



0 BTU | 1 BTU | 180 BTU | 1150 BTU | 1189 BTU

GAUGE PRESSURE PSIG	TEMP °F	HEAT IN BTU /LB			SPECIFIC VOLUME CU. FT/LB
		SENSIBLE	LATENT	TOTAL	
0	32	0	0	0	0.016
0	33	1	0	1	0.016
0	212	180	0	180	0.017
0	212	180	970	1150	26.8
100	338	309	880	1189	3.89

Heat Transfer Q = "U" x A x DT



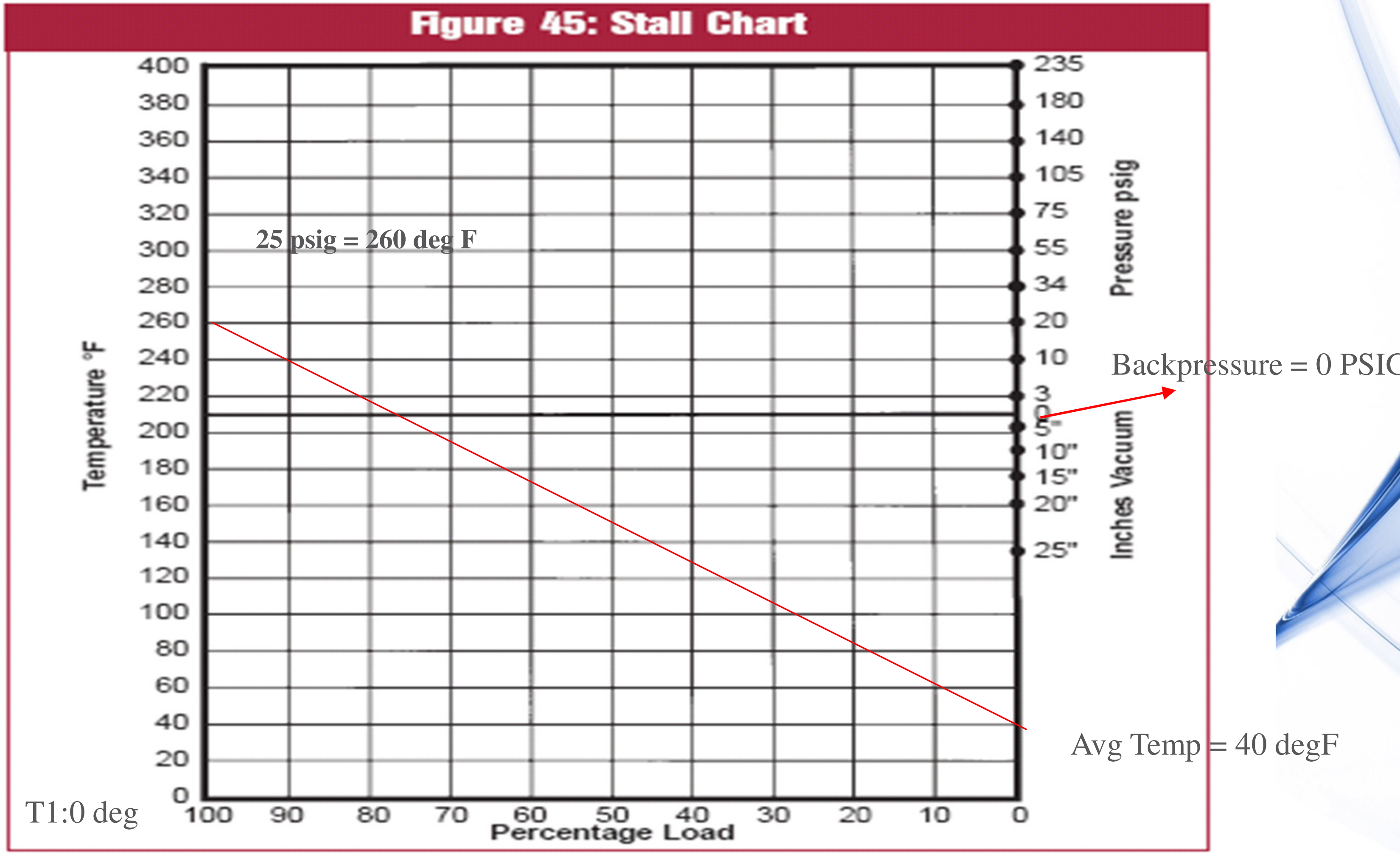
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plotting Maximum Steam Temperature versus air mean temperature



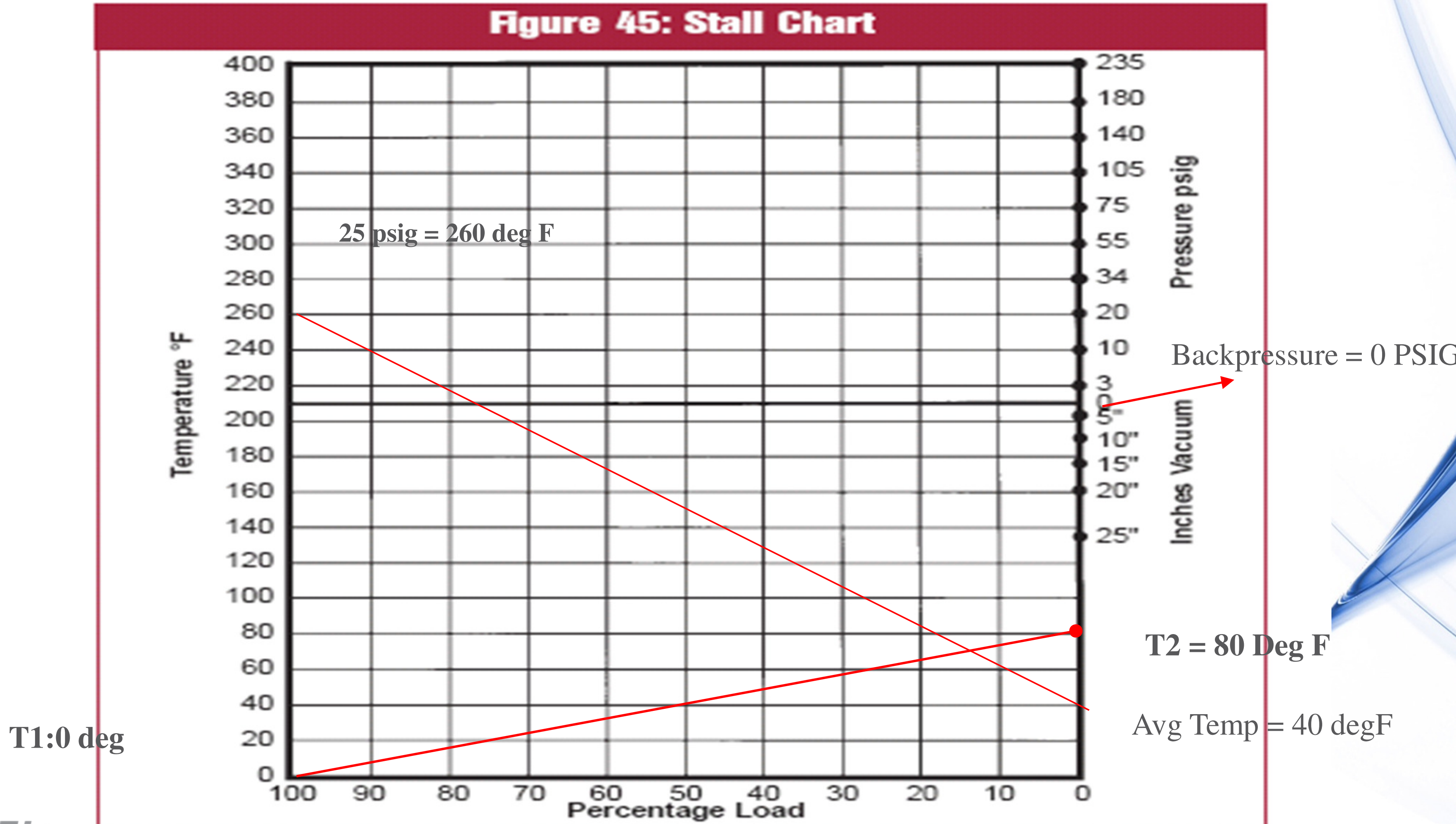
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plot Entering & Exiting Temperatures



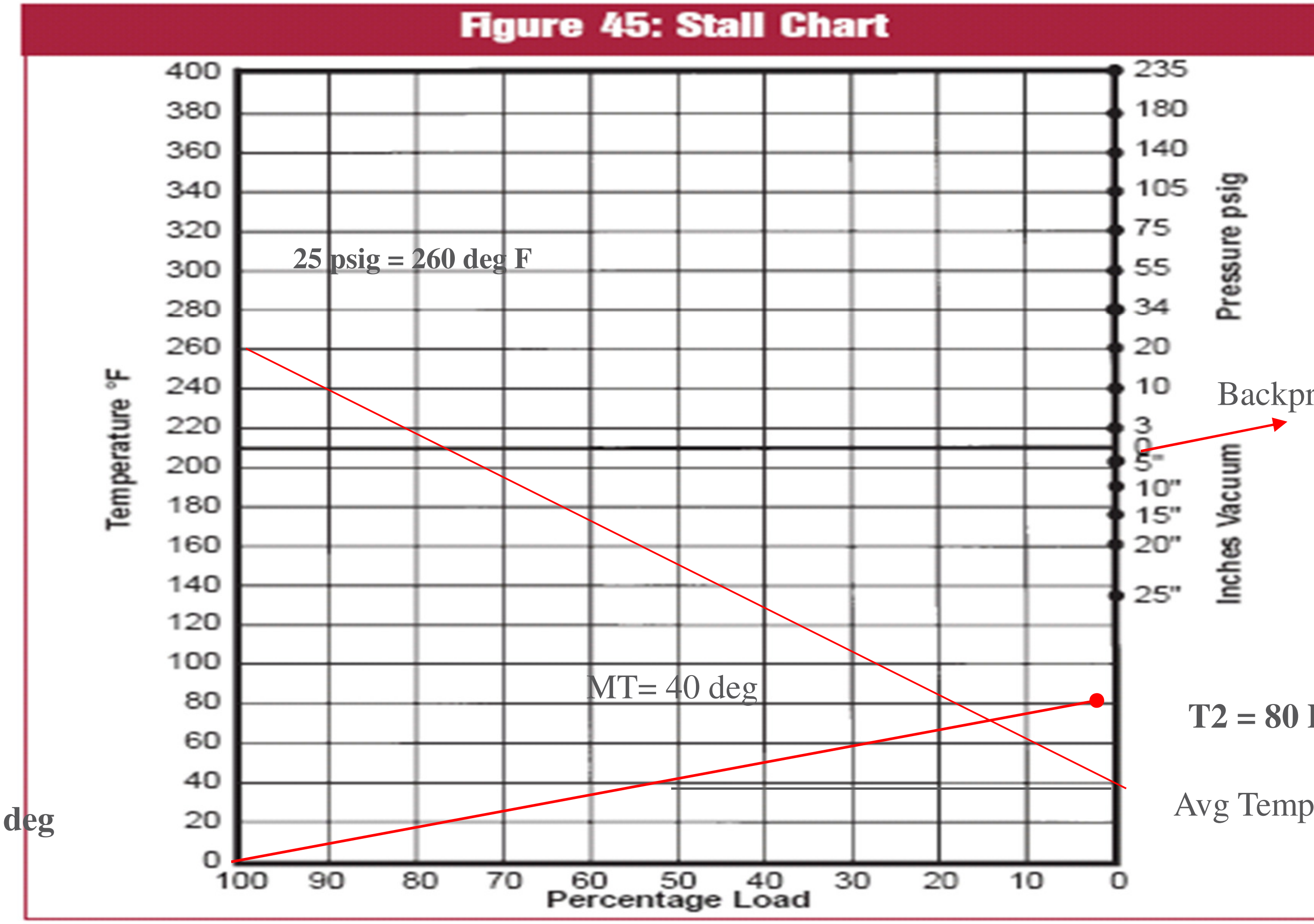
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Plot Mean Average Temperature



Backpressure = 0 PSIG

T2 = 80 Deg F

Avg Temp = 40 degF

T1:0 deg

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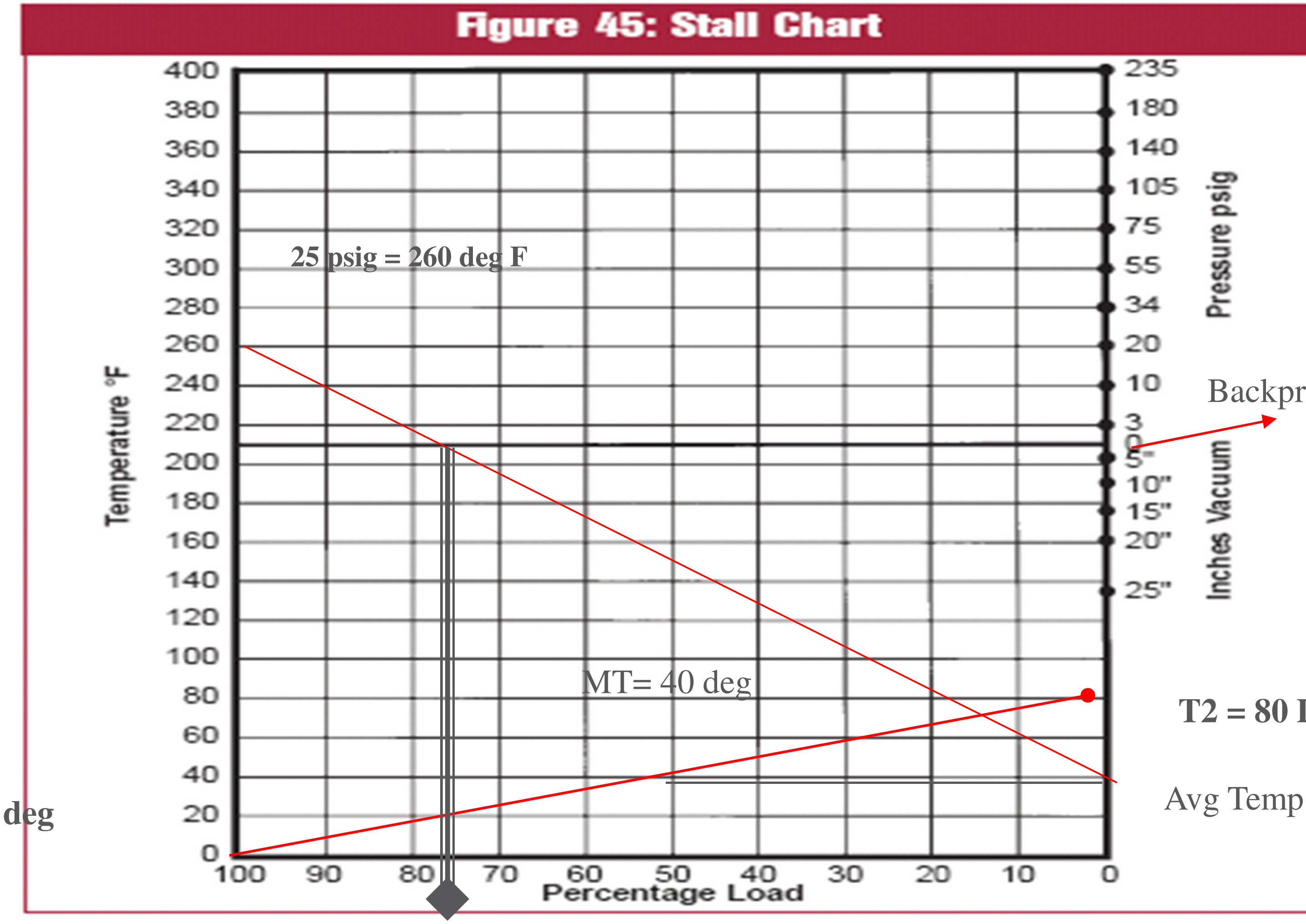
Stall Chart

100% load @ 0 deg F, 0% Load @ 80 deg F

25 PSIG to the coil @ Full Load

Atmospheric Condensate Return Pressure

Determining "Stall Point" as Percentage of Load



Backpressure = 0 PSIG

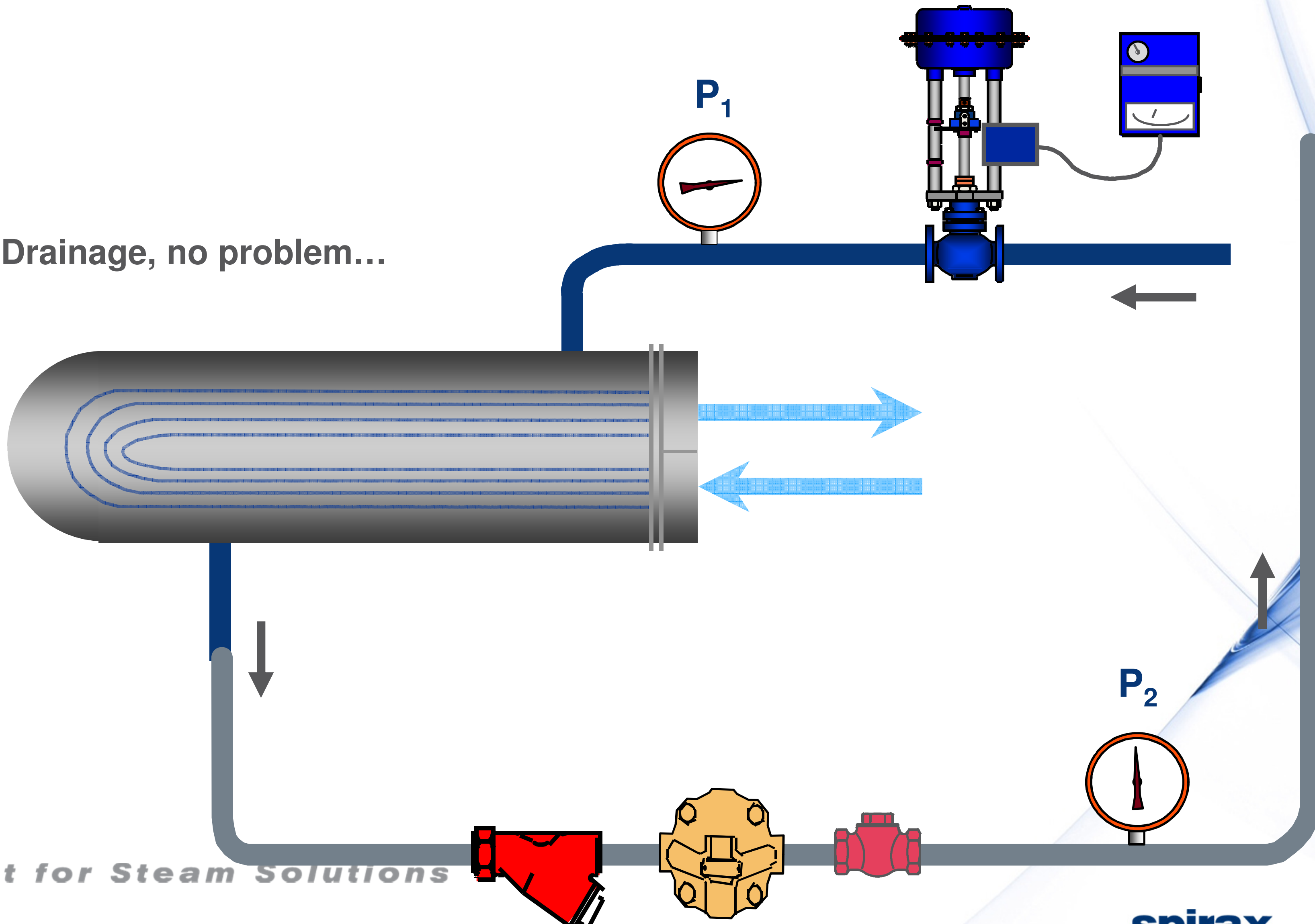
T2 = 80 Deg F

Avg Temp = 40 degF

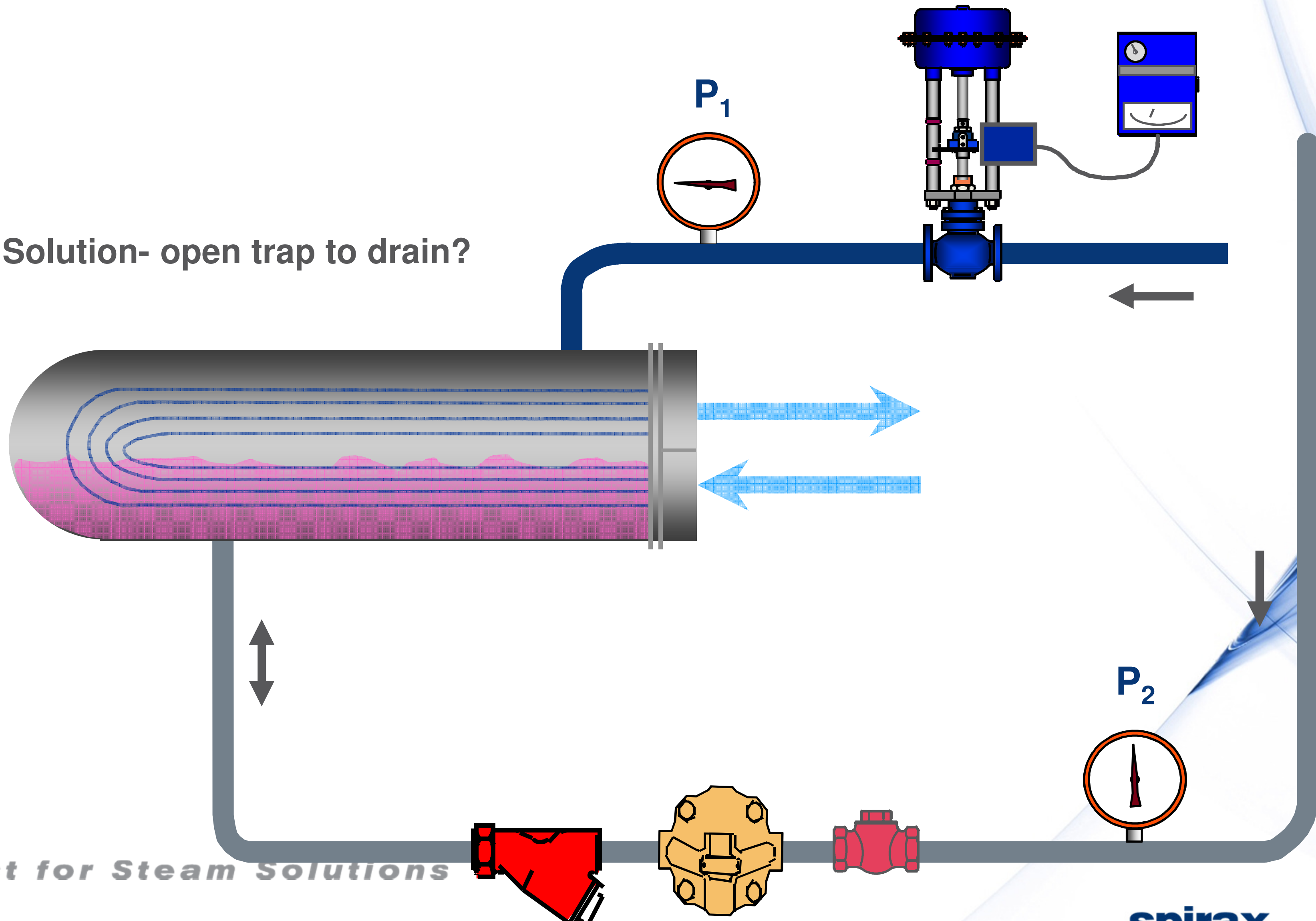
T1:0 deg

Heat Exchanger - Heavy Load

Drainage, no problem…



Heat Exchanger - Light Load (low pressure & vacuum??)



Closed Loop HX Hook-up

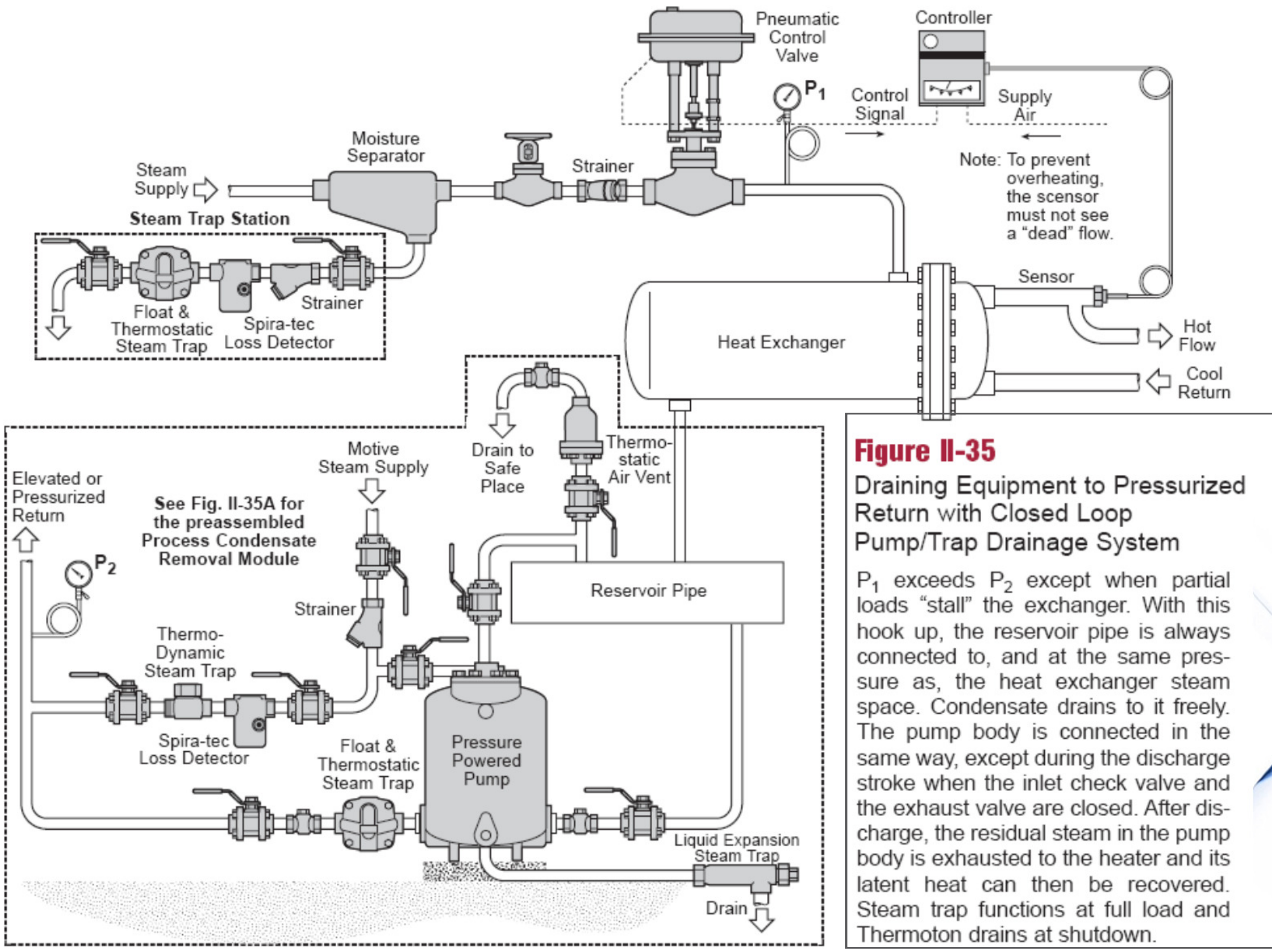


Figure II-35

Draining Equipment to Pressurized Return with Closed Loop Pump/Trap Drainage System

P_1 exceeds P_2 except when partial loads "stall" the exchanger. With this hook up, the reservoir pipe is always connected to, and at the same pressure as, the heat exchanger steam space. Condensate drains to it freely. The pump body is connected in the same way, except during the discharge stroke when the inlet check valve and the exhaust valve are closed. After discharge, the residual steam in the pump body is exhausted to the heater and its latent heat can then be recovered. Steam trap functions at full load and Thermoton drains at shutdown.

Closed Loop HX Hook-up +

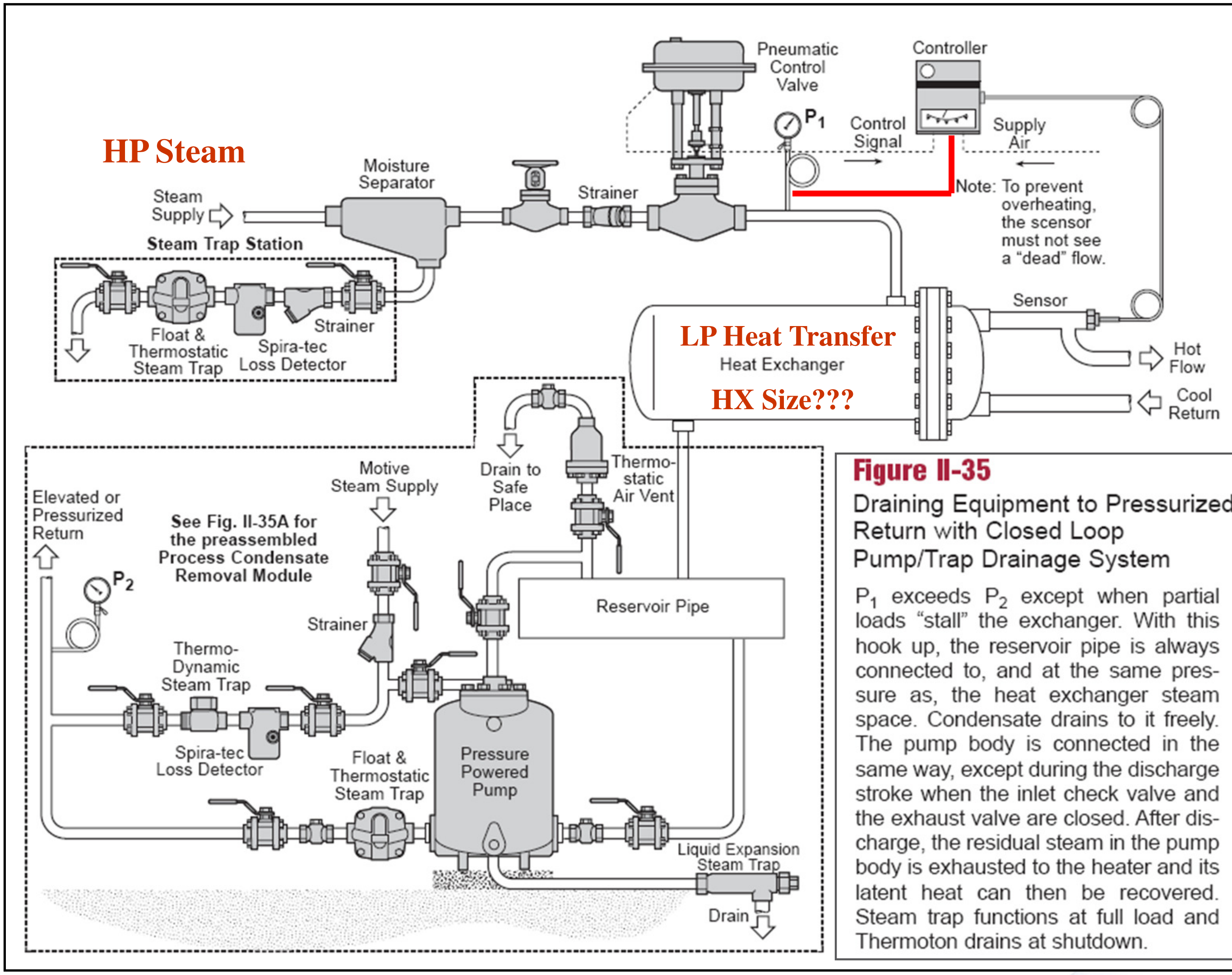


Figure II-35

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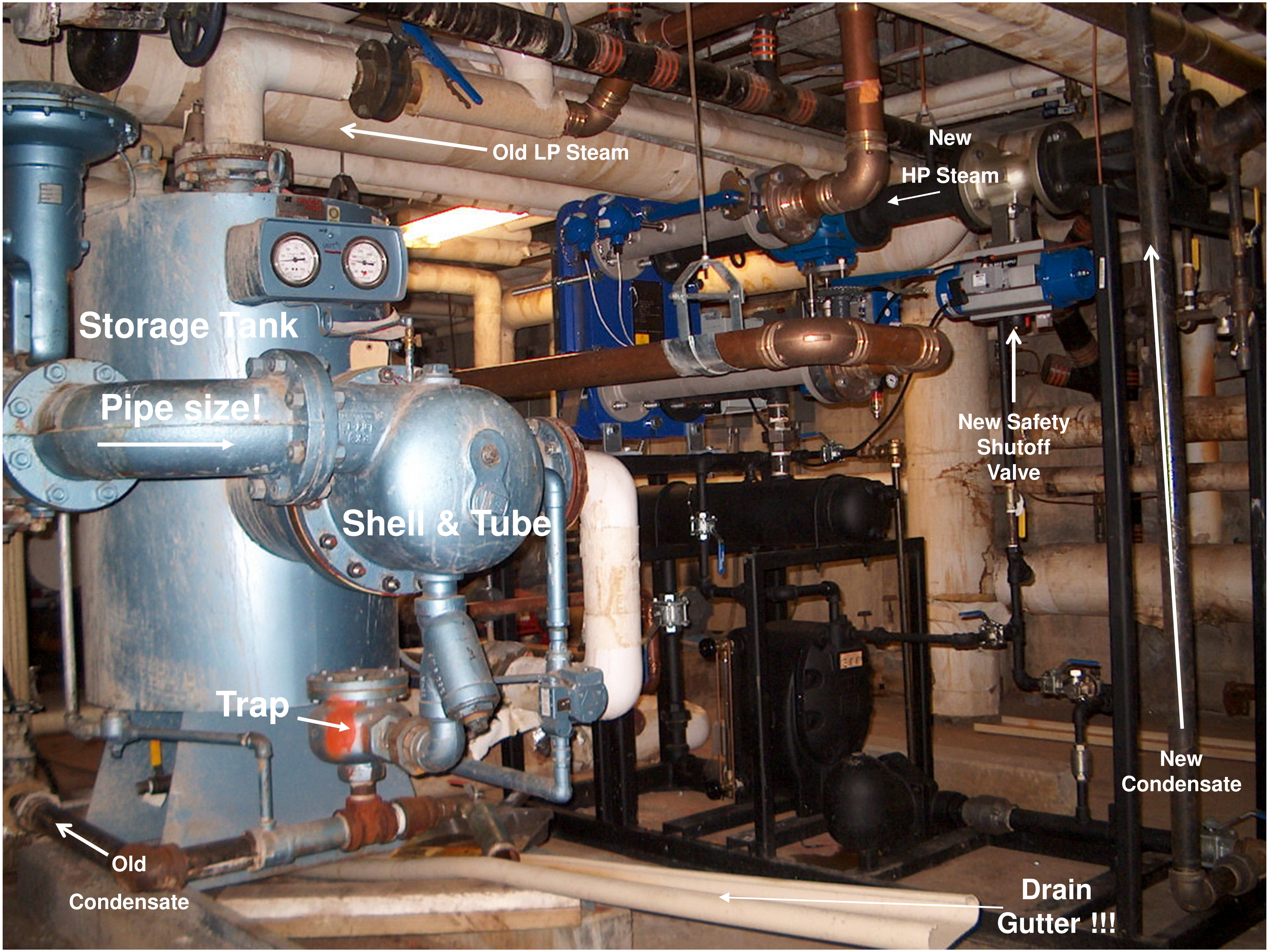
Plate & Frame HX Benefits

- Smaller Footprint
- Large Surface Area's for LP Transfer.
- NO Tube Withdrawal space req'd
- Easier to maintain
- Some Flexibility with capacity
- Stainless wetted parts as standard
- Higher efficiency
- Better control Accuracy
- More responsive


Old LP Steam
New
HP Steam
Storage Tank
Pipe size!
New Safety
Shutoff
Valve
Shell & Tube
Trap
New
Condensate
Old
Condensate
Drain
Gutter !!!

EASIHEAT UNITS

First for Steam Solutions

EXPERTISE | SOLUTIONS | SUSTAINABILITY

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EASIHEAT UNITS

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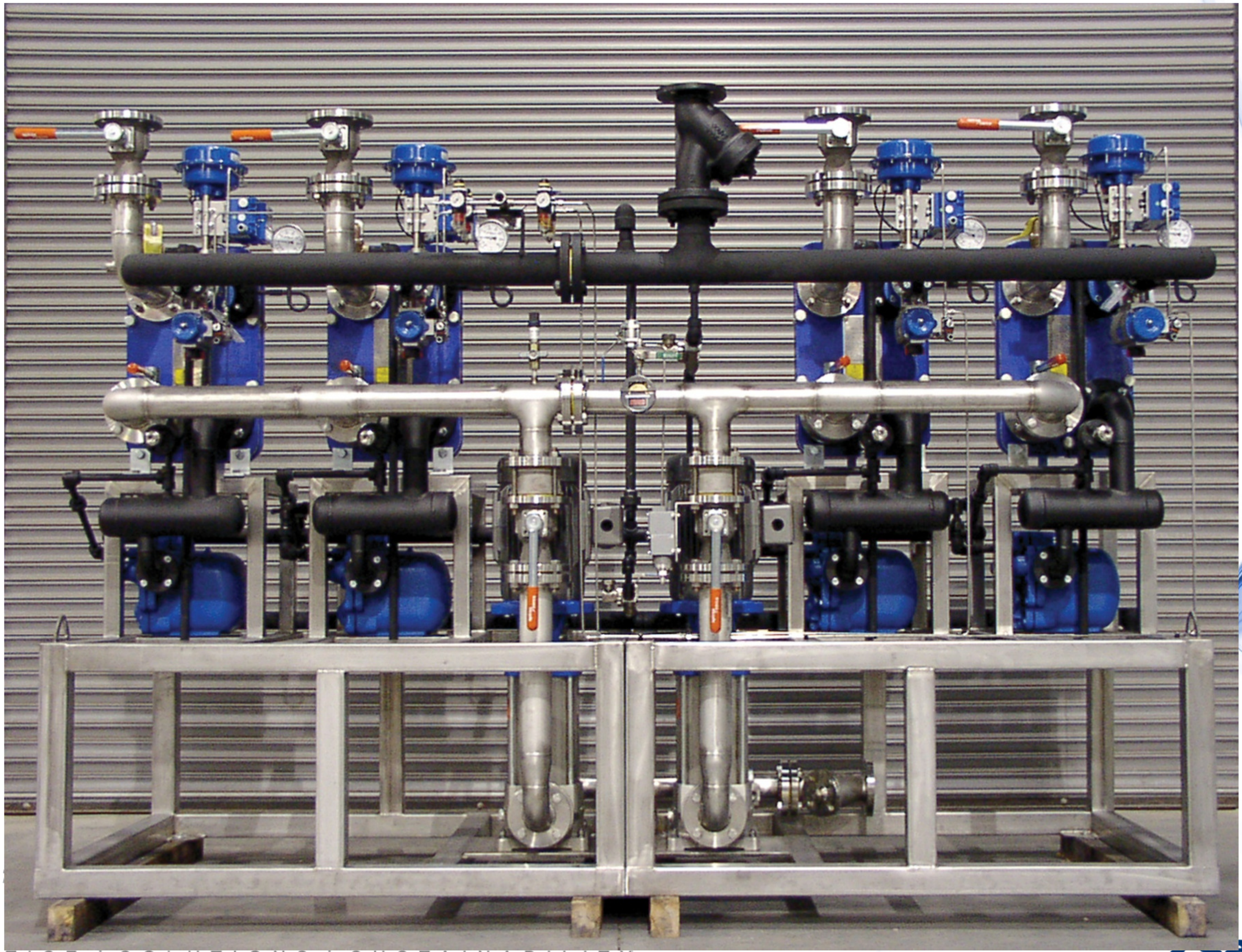
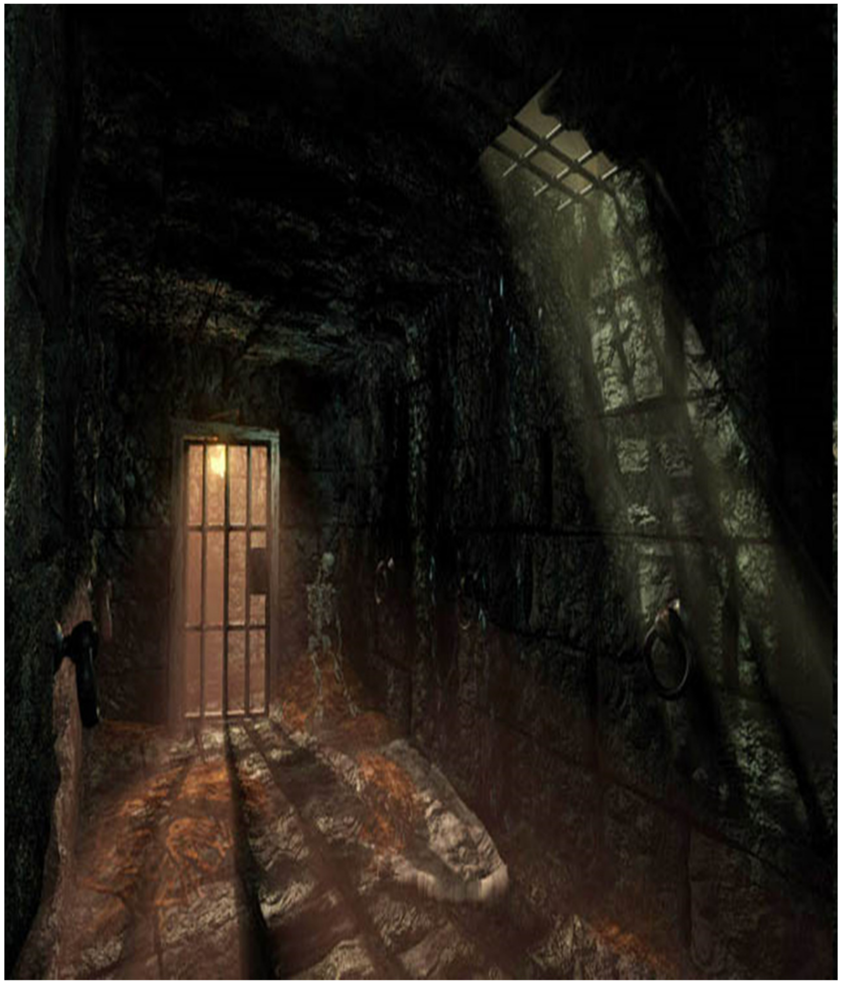
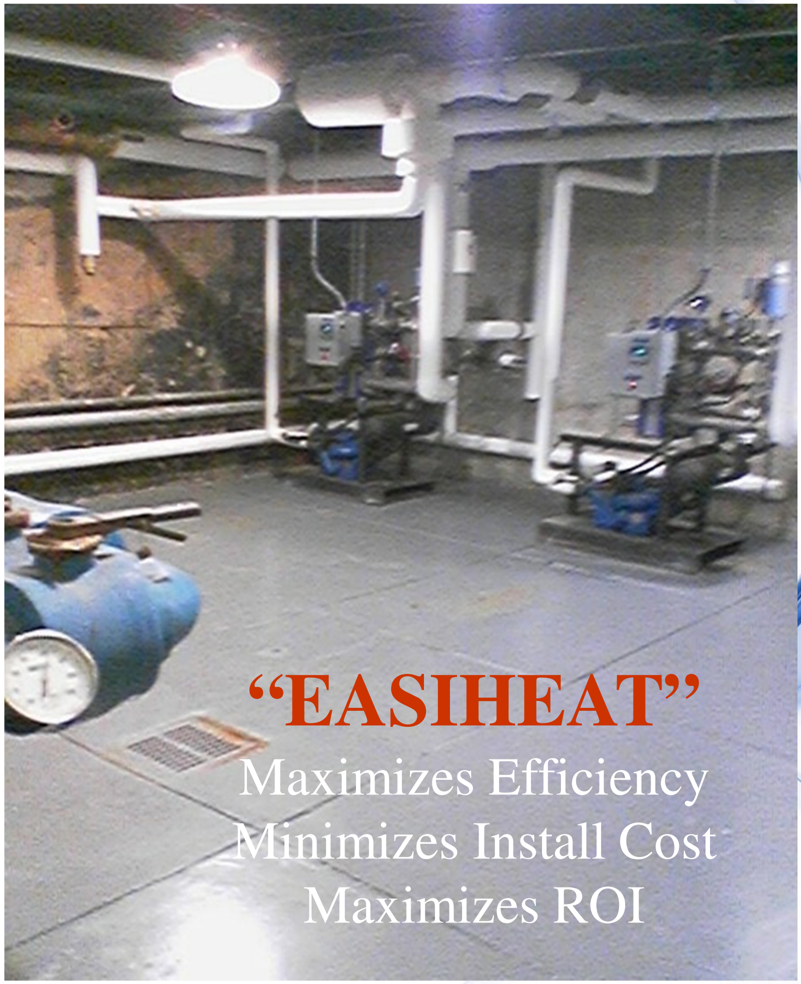
EASIHEAT UNITS



First

EASIHEAT UNITS





Thank You for Your Valuable Time and Attention…

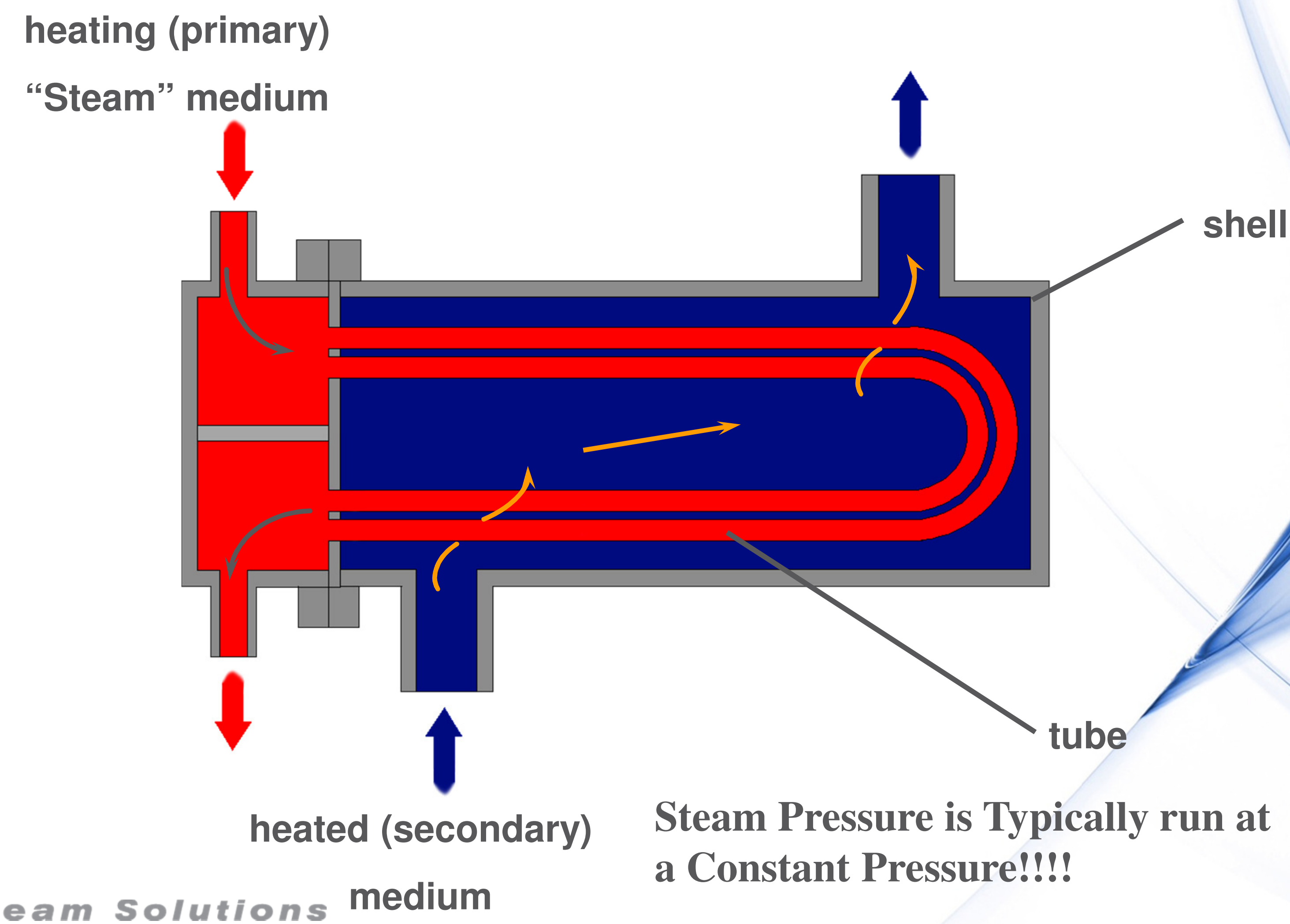
Questions?

Heat Exchangers

First for Steam Solutions

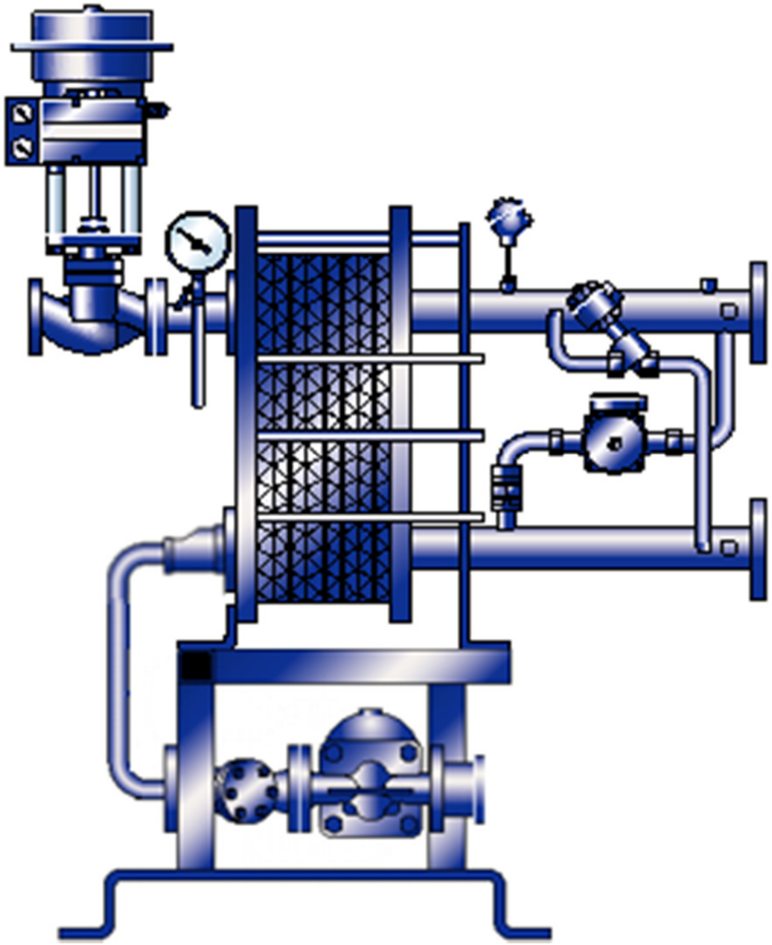
EXPERTISE | SOLUTIONS | SUSTAINABILITY

Heat Exchanger – Shell & Tube Design
“ Re-boiler”



Steam Pressure is Typically run at a Constant Pressure!!!!

Typical Domestic Water Heater Unit



'DHW' configuration secondary pipe work arrangement.

Flow in to, and flow out from the heat exchanger.

Re-circulation loop, with re-circulation pump running all the time.

Cold water injection circuit

'ST' Float & Thermostatic steam trap set

Hydronic Systems

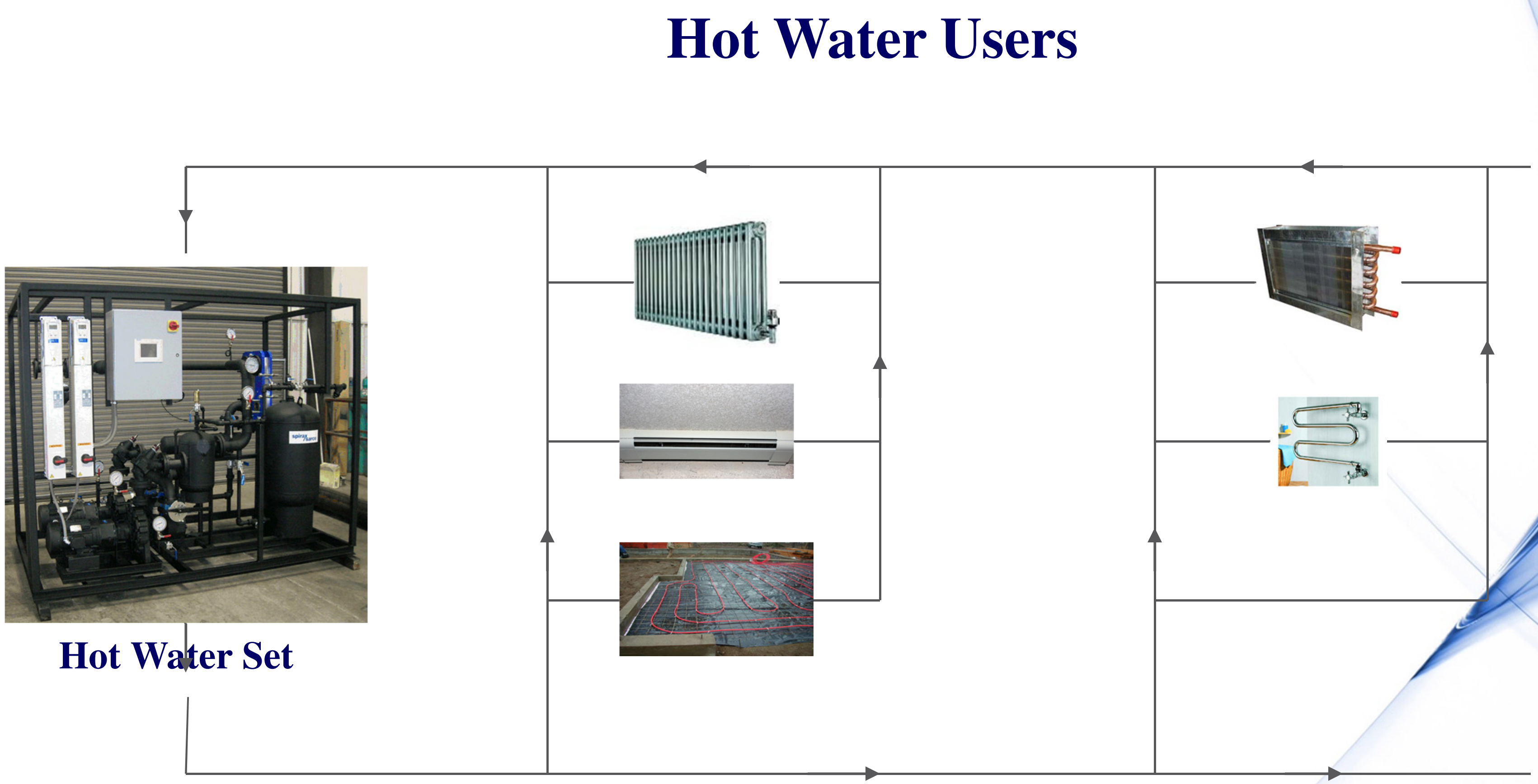
The hydronic system is a closed loop system in which Steam is used to heat water (or other media) through the use of heat transfer equipment. Specific use is for comfort space heating.

Since it is a liquid closed loop system, testing and chemical treatment is necessary to prevent the fouling and scaling of the pipe and/or heat transfer equipment.

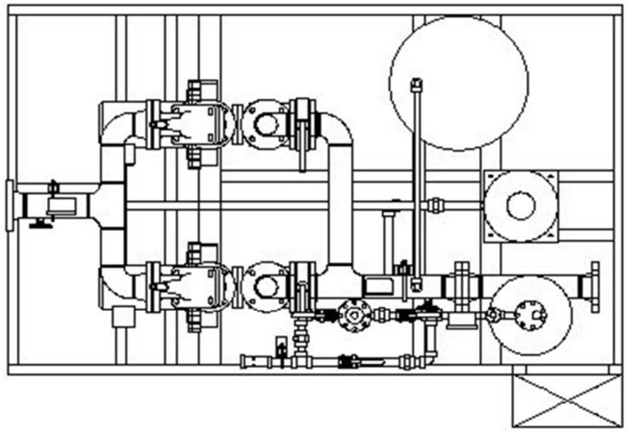
Balancing devices are used to fine-tune the system.

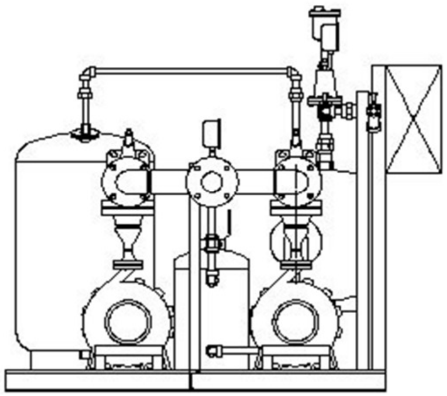
Variable frequency drives can be incorporated to improve the energy efficiency of the system.

What makes up this system?

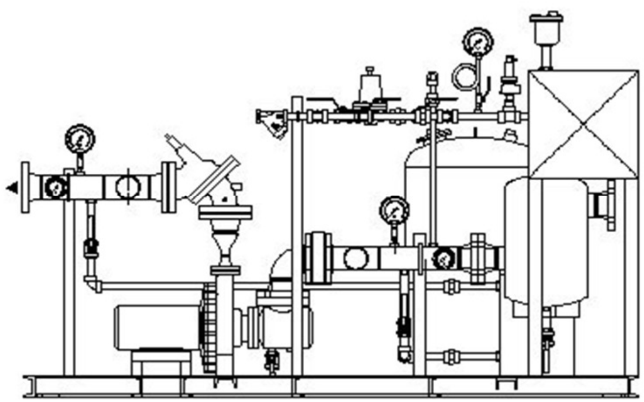


Typical Package Layout

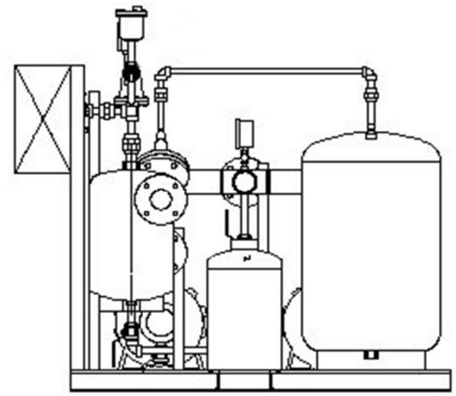




ELEVATION: LEFT



ELEVATION: FRONT



ELEVATION: RIGHT

Heat Recovery Savings

Blowdown has an economic impact because the water that is removed has been heated and chemically treated and the energy used to heat this water comes from the fuel burned in the boiler

Low Pressure Flash Steam Usage; Send TOTAL heat from flash steam to DA or other usable LP source

Send left over sensible heat through a Heat Exchanger to preheat make- up water.

STACK ECONOMIZER

WHAT IS A BOILER STACK ECONOMIZER?

A boiler stack economizer is a heat exchanger that reduces the overall losses of heat energy from the steam generation process.

It aids in reducing fuel costs as well as fewer emissions

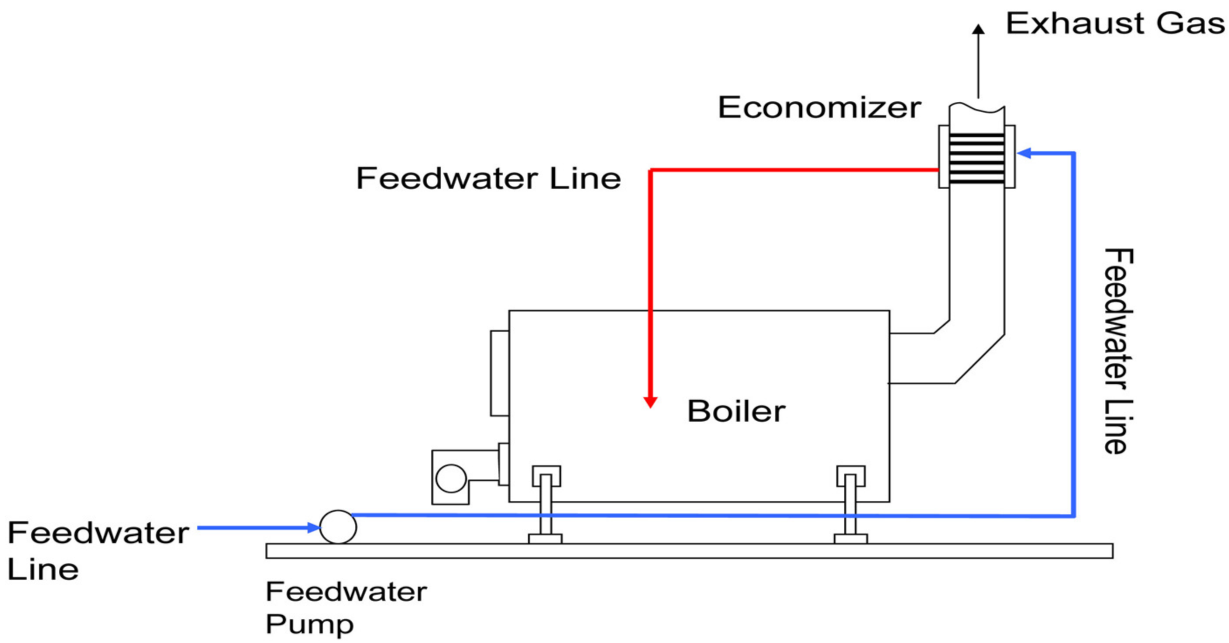
Increases boiler efficiency.

Boiler stack economizers recover the "waste heat" from the boiler's hot stack gas then transfers this waste heat to the boiler's feed-water

The boiler feed-water is now at a higher temperature the boiler does not need to provide as much additional heating to produce the steam requirements of a facility or process, thereby using less fuel and reducing the fuel expenses.

BOILER STACK ECONOMIZER

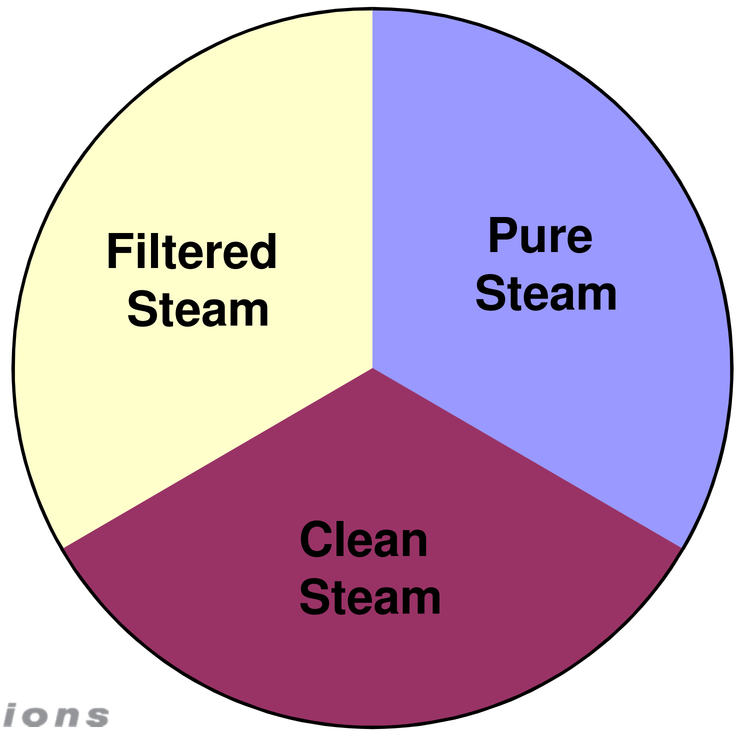
Feedwater Economizer



What is Clean Steam?

When we refer to “Clean Steam” what we often mean is Cleaner Steam than plant steam.

This is typically split in to 3 different categories…



Types of Steam

Plant Steam - Steam raised in a conventional boiler with typical water treatment, standard boiler chemicals FDA approved used. Piping is standard carbon steel or even black pipe, components can be cast iron. All condensate is recovered.

Filtered Steam - Steam raised in a conventional boiler and filtered to remove solid particles, standard boiler chemicals FDA approved used. Piping is standard carbon steel or black iron up to the Filter Station, then changes to 316 Stainless Steel. All condensate is recovered.

Types of Steam

Clean Steam - Steam raised in a non-fired steam to steam generator, produced from distilled or de-ionized water, or from a reverse osmosis system.
All materials, components and piping are 316 L Stainless Steel. Rarely is condensate recovered, typically sent to a kill tank then to water treatment.

Pure Steam - Steam raised in a multiple-effect still from distilled or de-ionized pyrogen-free water, normally defined uncondensed water for injection-WFI. All materials, components and piping are 316 L Stainless Steel. Condensate is sent to kill tank and then on to water treatment.

Sizing / Design considerations for Clean Steam Generators

Plant Steam pressure available

Clean Steam Generation pressure

Generation Rate #/hr

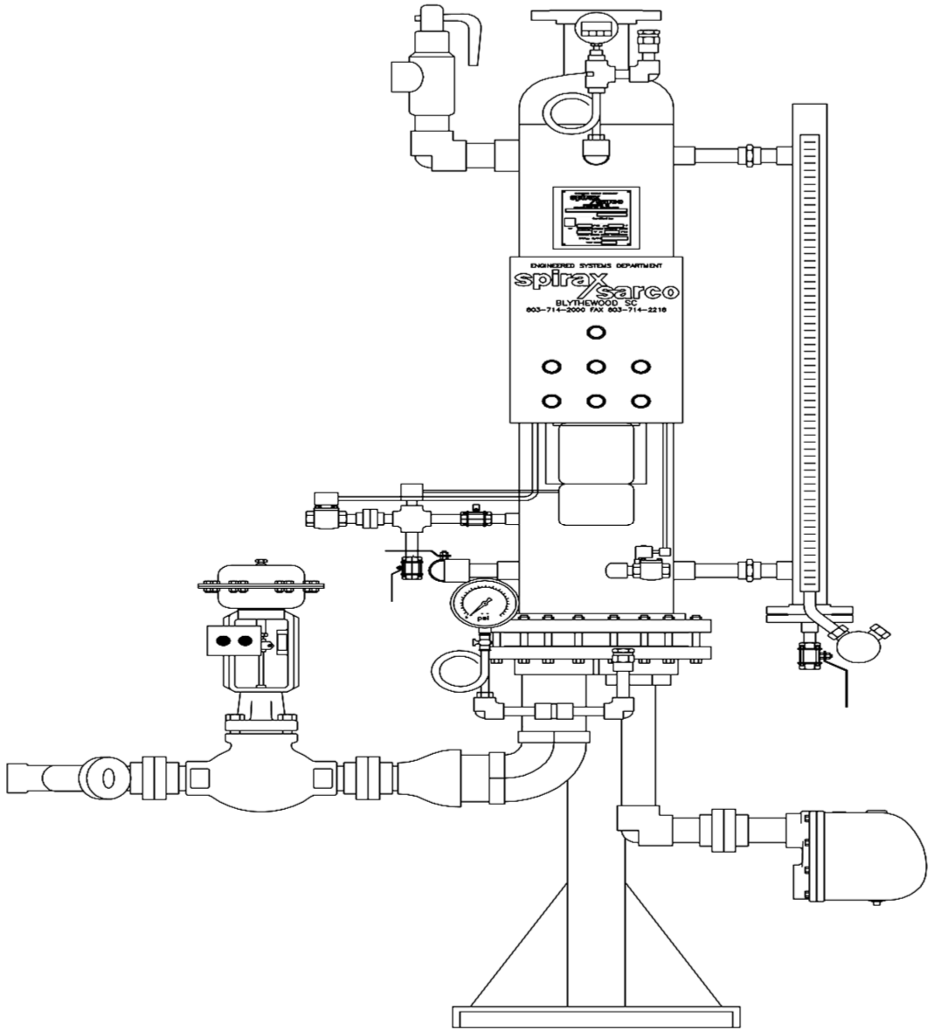
Type of Clean Steam

- Clean or Pure(WFI)

Feedwater quality – RO/DI water

Typically Stainless Steel 316 materials or contruction

Typical Clean Steam Generator



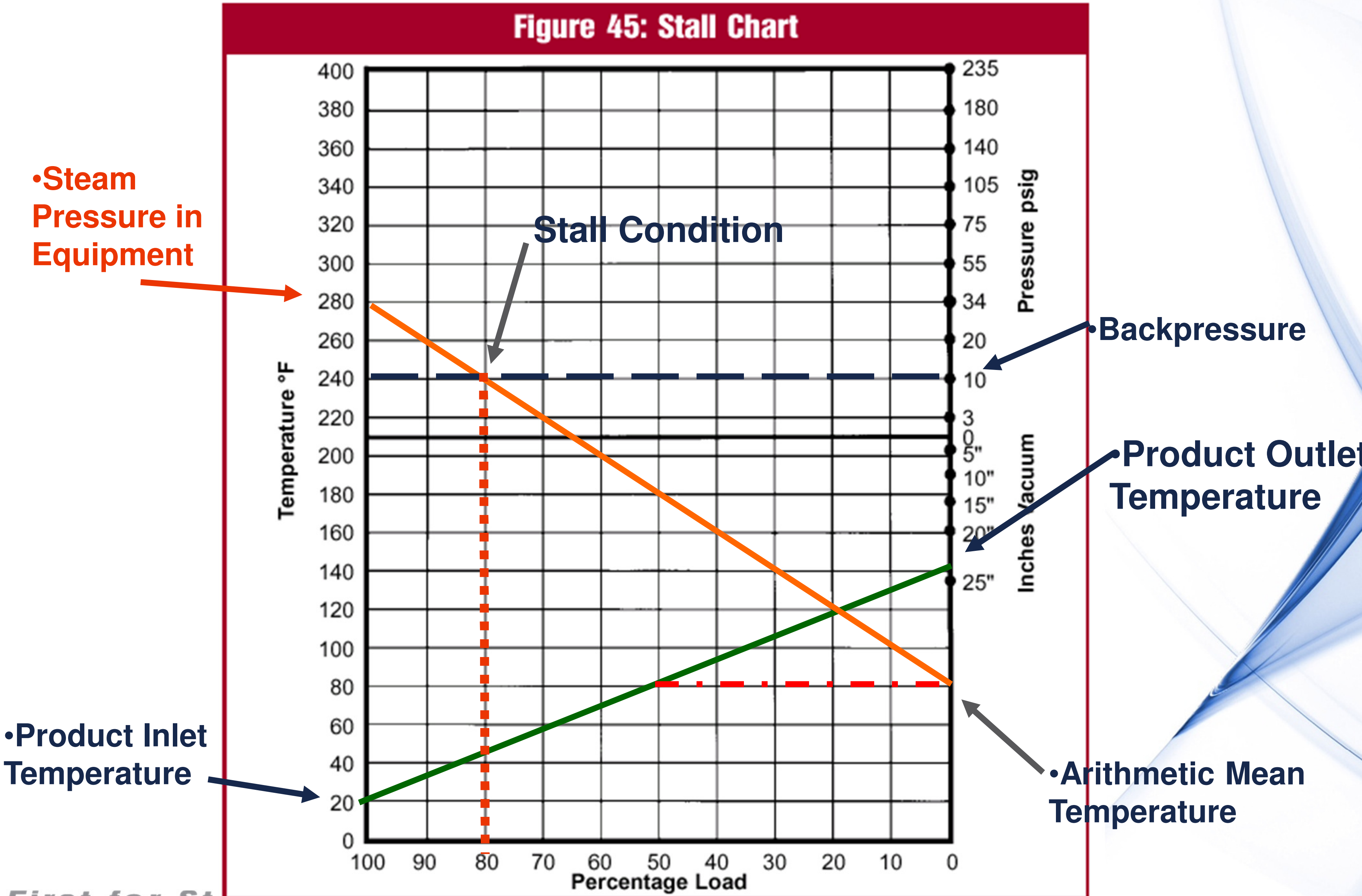


Figure 45: Stall Chart
•Steam Pressure in Equipment
Stall Condition
•Backpressure
•Product Outlet Temperature
•Product Inlet Temperature
•Arithmetic Mean Temperature
Temperature °F
400
380
360
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
Pressure psig
235
180
140
105
75
55
34
20
10
3
0
Inches Vacuum
5"
10"
15"
20"
25"
100 90 80 70 60 50 40 30 20 10 0
Percentage Load

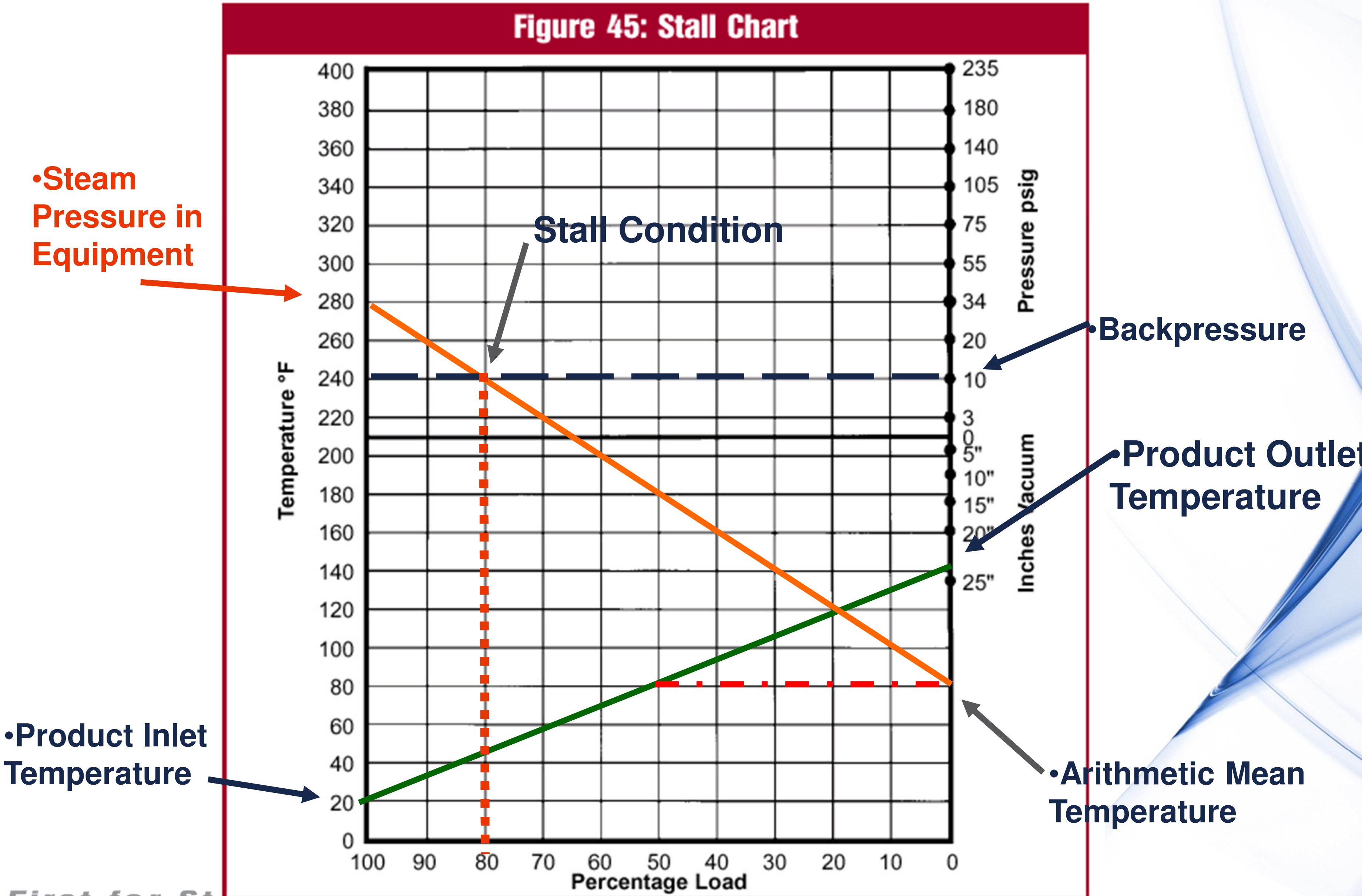


Figure 45: Stall Chart

THANK YOU for your time and attention!!!