Yankee Dryers
Safety, Steam & Condensate Systems

Presented by:
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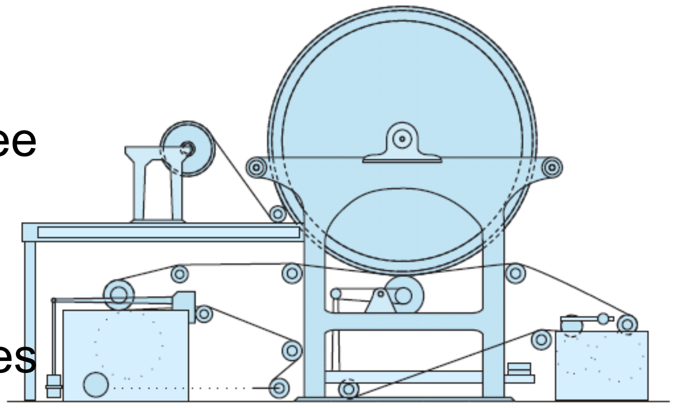
Objectives

- Increase the understanding of Yankee operational risks
- Purpose of a Yankee steam system
- Components of a Yankee steam system
- Control methods of a Yankee steam system

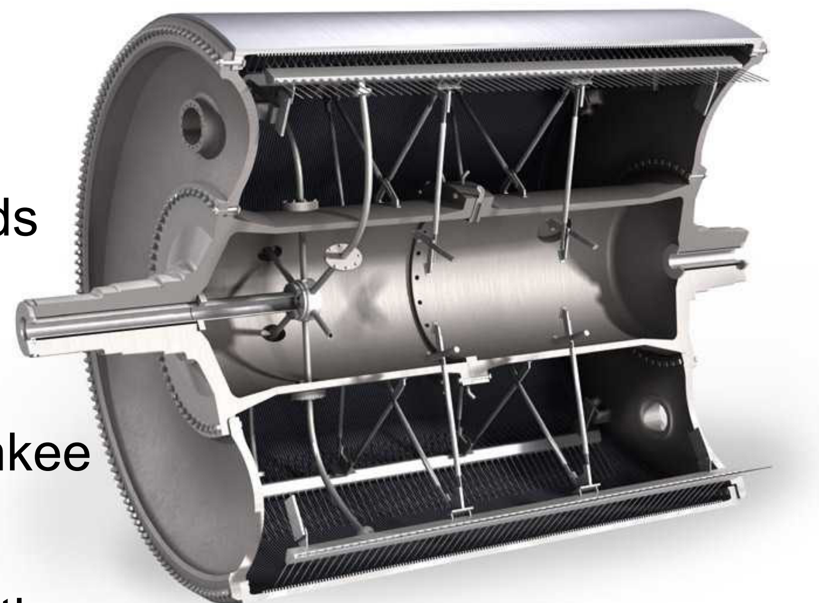
The Yankee Dryer Evolution

- 1820 the paper drying cylinder was first patented.
  Normally heated by charcoal fire.
- ~1850 the "Yankee paper making machine"
  Steam heated drying cylinders came into use.
- ~1900 Yankee diameters 2-3 m, steam pressures 0-200 kPa.
- ~1950 Yankee diameters 5 m.
- 1959 the internally ribbed Yankee
  dryer shell invented by Beloit.
- ~1960 Yankee diameters 5.5 m
  (18') and above, steam pressures
  up to 1100 kPa.



The Yankee Dryer Evolution

- ~1970 computer aided Yankee design (FEA).
- ~1980 - improved NDT and quality control.
- ~1990 - improved full face metallizing methods and breakthrough.
- ~2000 ENP against the Yankee. “high load Yankee dryers” 120-200 kN/m
- ~ 2003 Steel gains traction
- ~ 2020 Steel dominates the market



Yankee Safety Risks

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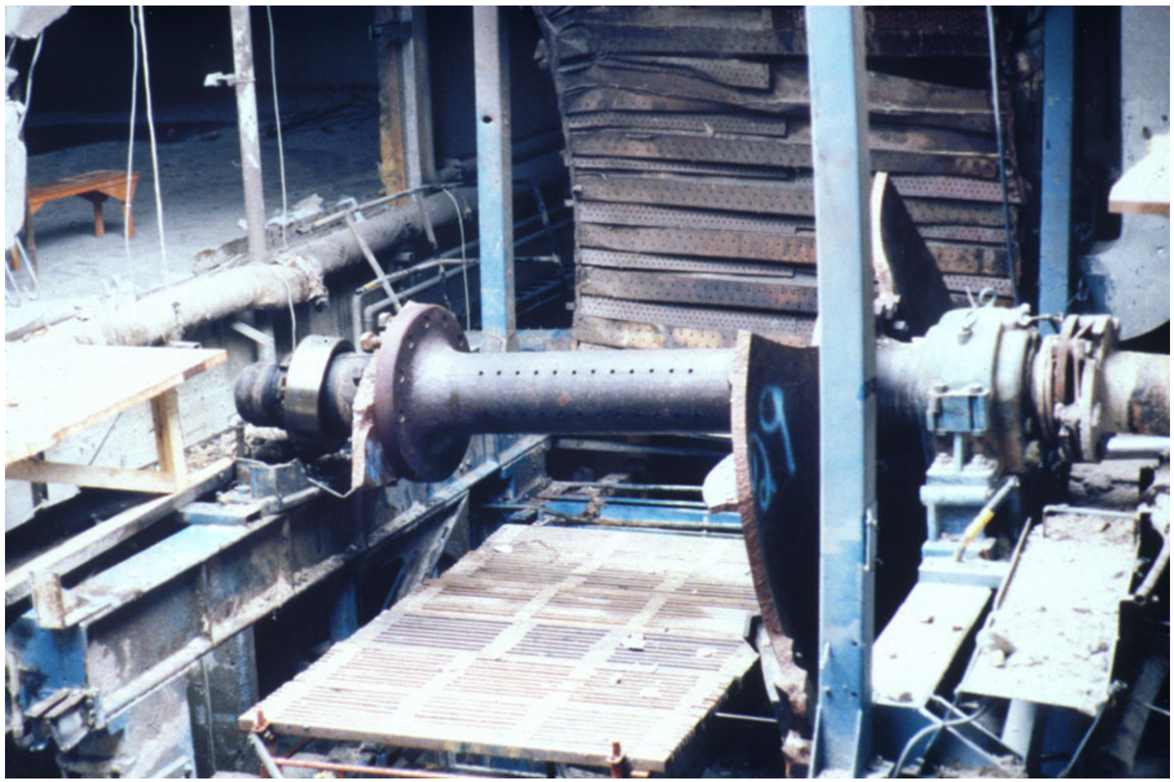
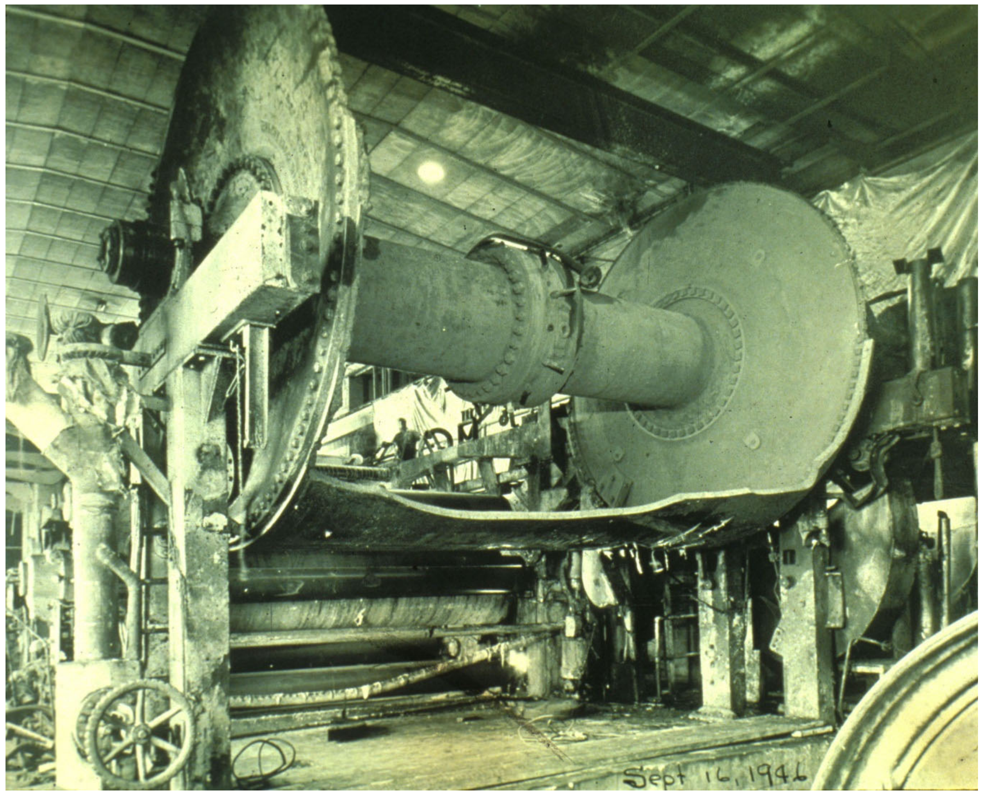


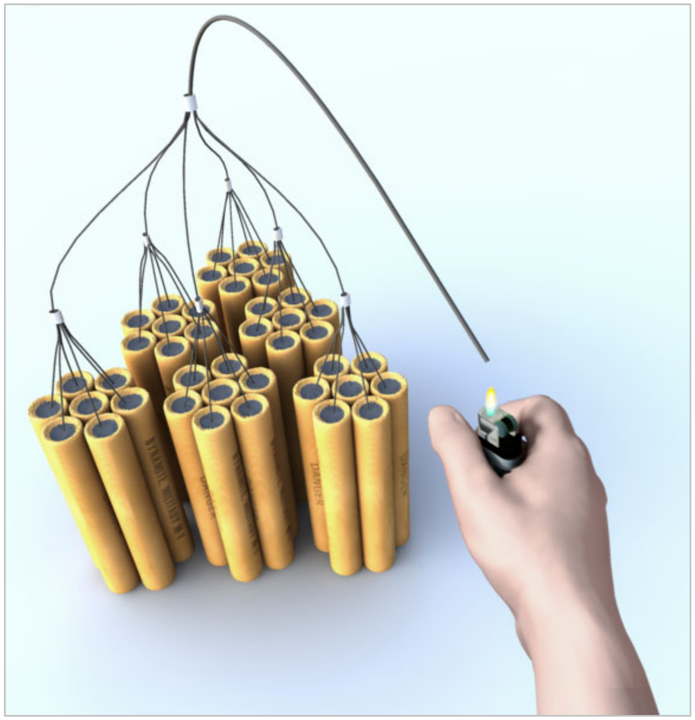
Yankee Safety Risks



Would you Light the Fuse ?

70 kg TNT

D.5500 x 4500 @ 600 kPa



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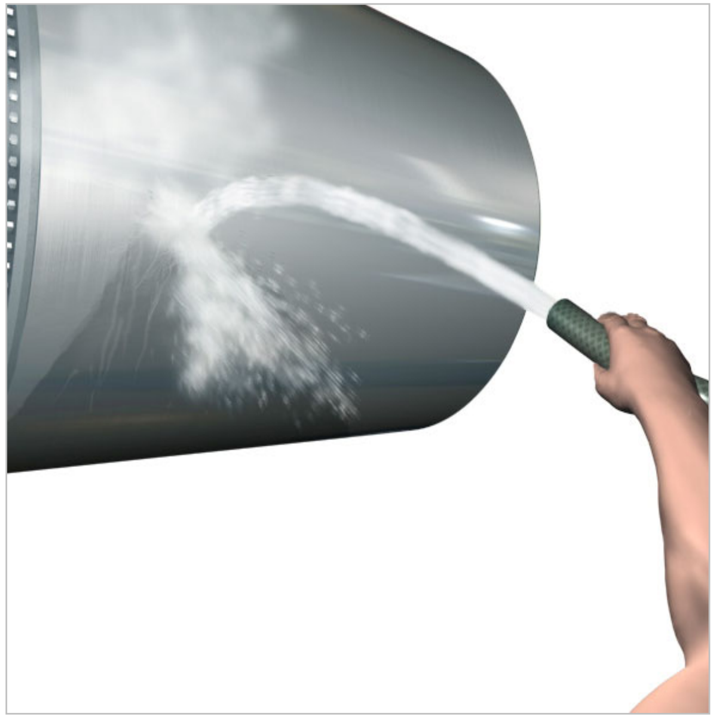
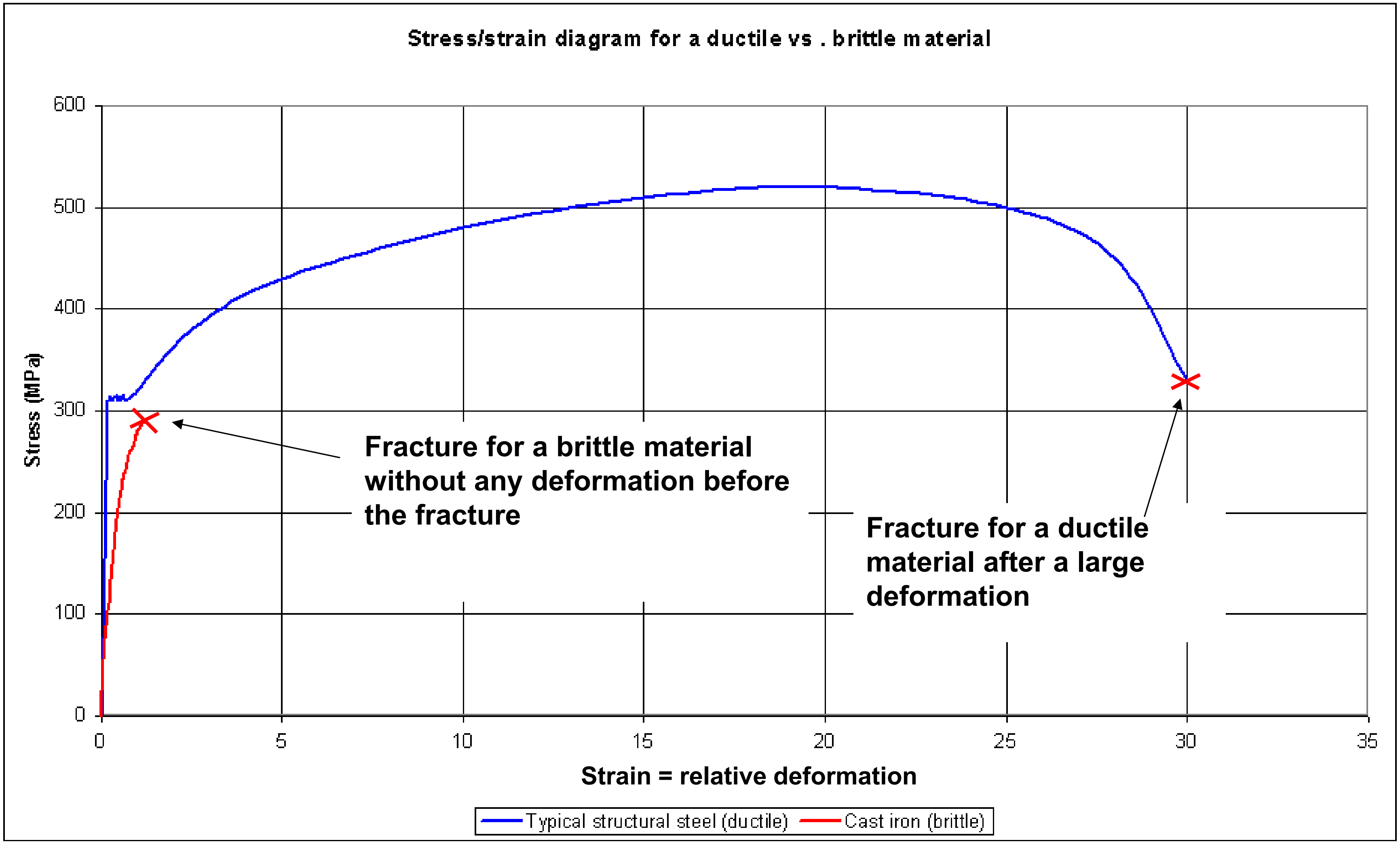


Material failure, different types of failure in metals

- Ductile material, as example Structural Steel
  - 1. When stress has reached yield strength, a plastic deformation (change of shape) occurs. This deformation comes from sliding between planes in lattice structure of the material.
  - 2. Failure when the material is strongly deformed.
- Brittle material, as an example Grey Cast Iron
  - 1. Fracture without change in form.
  - 2. Fracture in a plane between two atom layers in the grain structure.

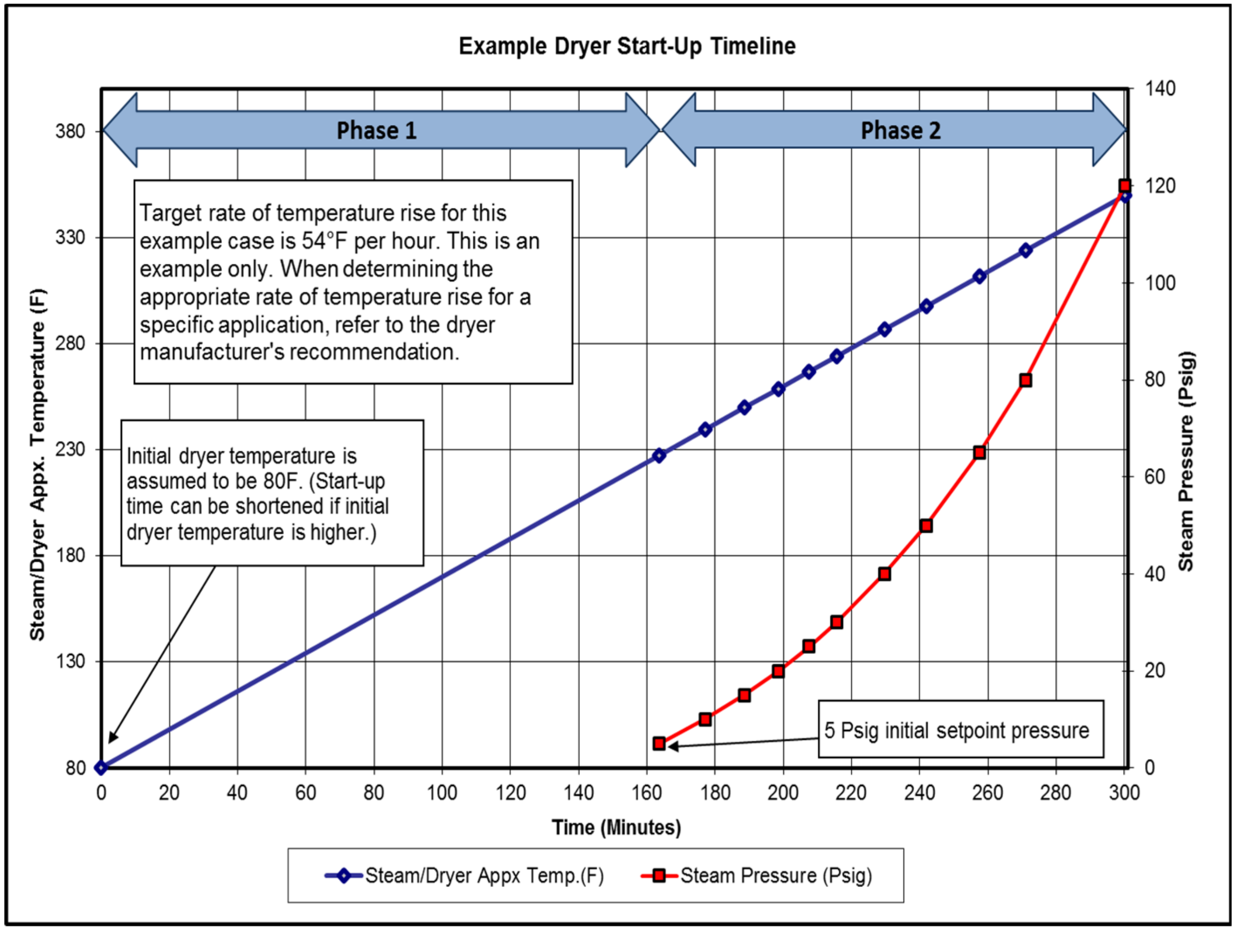


Stress/strain diagram for a ductile vs . brittle material
Stress (MPa)
600
500
400
300
200
100
0
0
5
10
15
20
25
30
35
Strain = relative deformation
Fracture for a brittle material without any deformation before the fracture
Fracture for a ductile material after a large deformation
Typical structural steel (ductile)
Cast iron (brittle)

Typical Warm-up Process

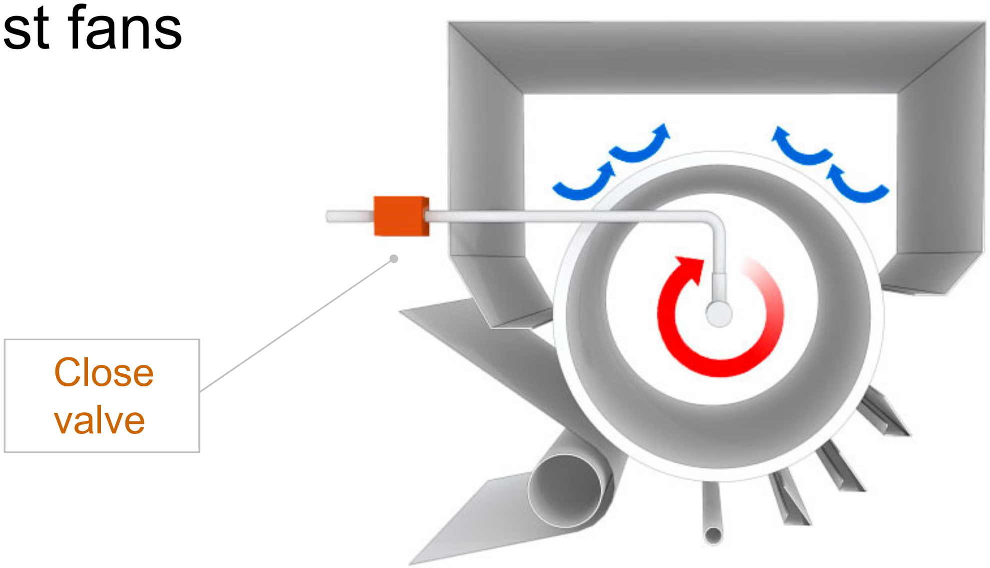
- Phase 1
  - Steam is bled into the Yankee dryer.
  - The Yankee dryer pressure control loop is not relied on.
  - With an appropriate bleed flow, the building of pressure in the Yankee dryer should be very slow.

- Phase 2
  - The Yankee pressure control loop is active.
  - The pressure setpoint for the Yankee dryer is incrementally increased until the Yankee is at the desired operating pressure.



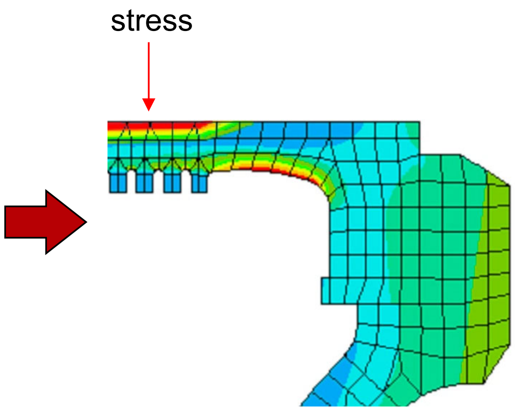
Shut-down

- Cooling whilst rotating at operating speed
  - Shut down the steam
  - If quicker cooling, draw room air over the Dryer by using hood exhaust fans



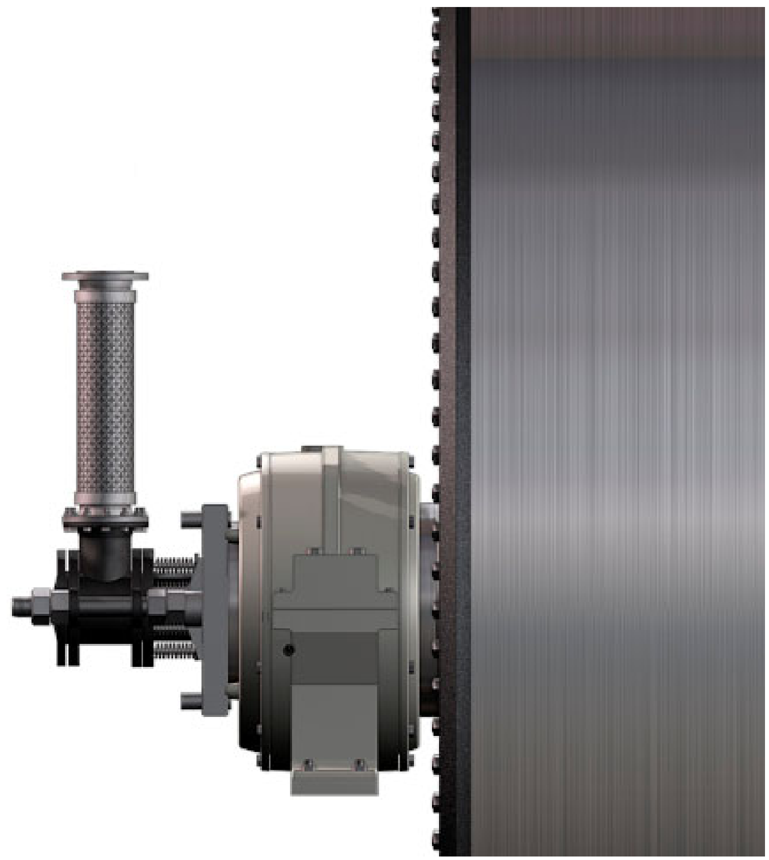
Shut-down

- Do not use saturated felts, can produce dangerous stresses in the Dryer

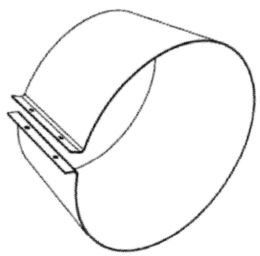


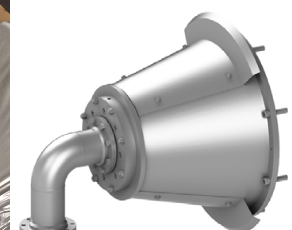
Yankee Safety Risks

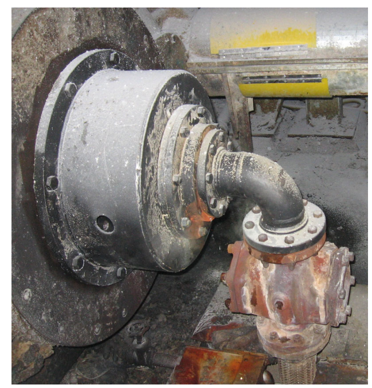
- Steam & condensate rotary joints
- Flexible hoses
- Uninsulated piping



Rotary Joint with Safety Cover

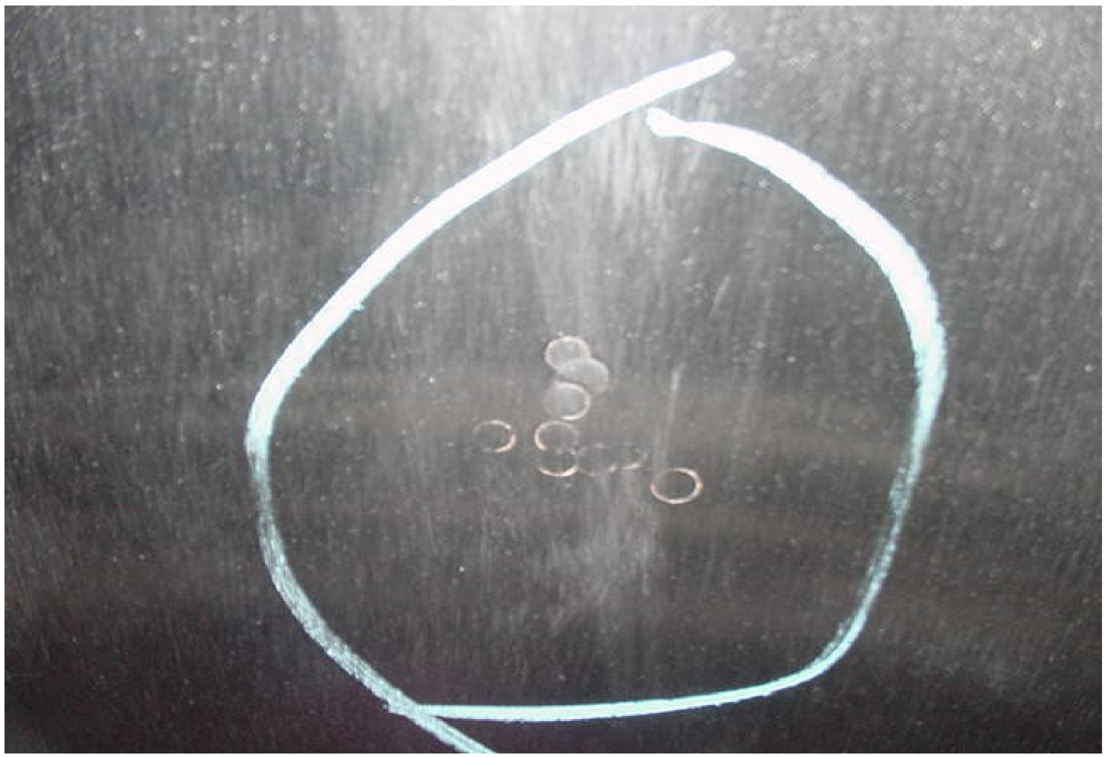


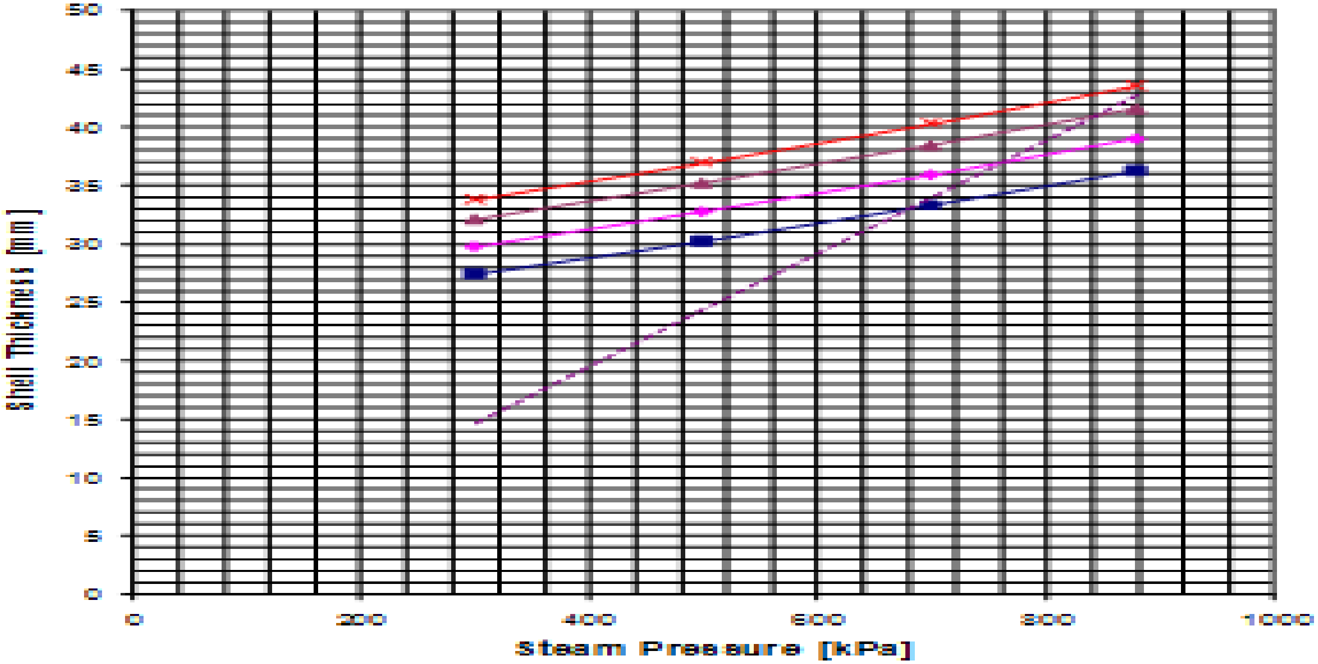
Through-shell steam leakage

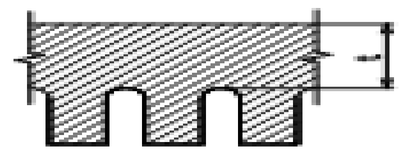
Yankee Cylinder Shell Plugging



Derate Curves

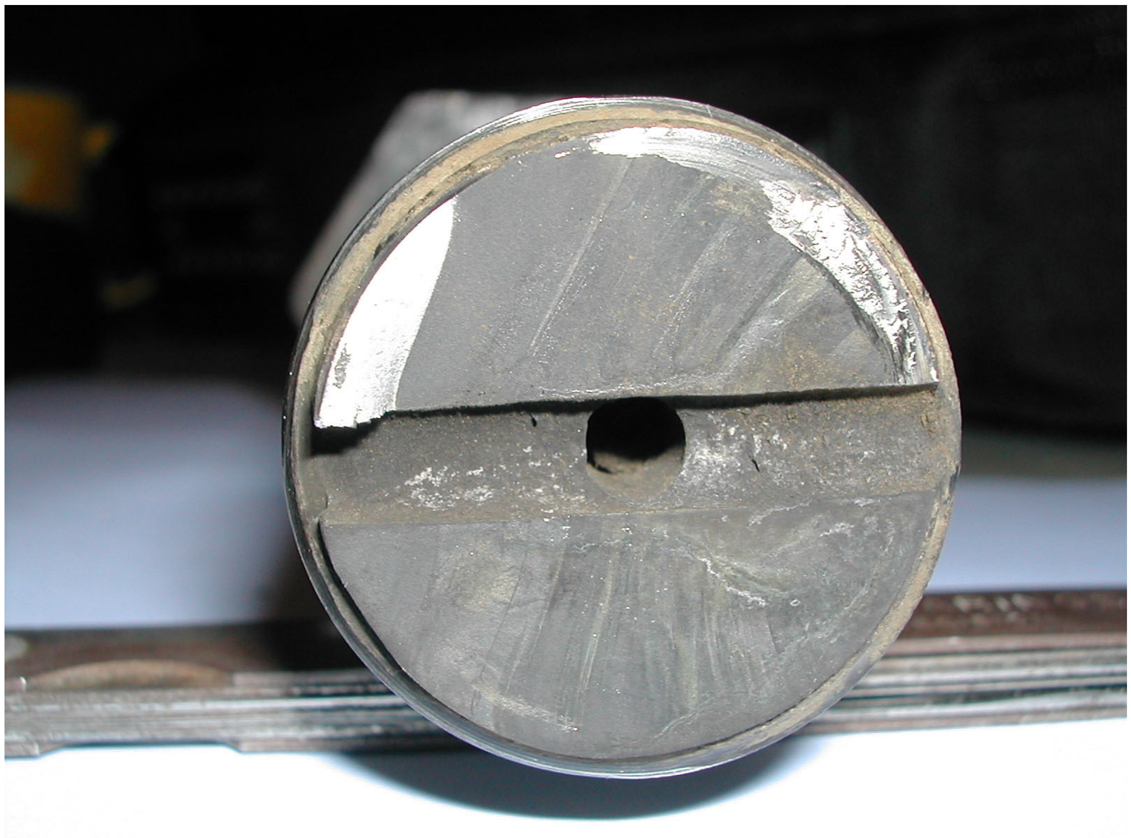
Example Only
Consider Each Cylinder as Unique





Head Crack

Yankee Safety Risks / Bolt failure



Inspection methods

- Ultrasonic testing
- Magnetic particle testing (Penetrant testing)
- Acoustic emission testing
- X-ray testing
- Hydrostatic testing
- OTR measurement
- IR measurement
- Visual inspection
- Dimensional checks

TAPPI

- Technical Association of the Pulp and Paper Industry
  - TAPPI is a non-profit, special interest organization, which promotes research and education, and serves as a technical information resource for its members.

YDSRC

- Yankee Dryer Safety and Reliability Committee.
  - YDSRC is a committee within TAPPI, which develops guidelines for YD inspections.
- Most YD inspections are developed from the TAPPI guidelines.

TAPPI Inspection Guidelines

Type	Methods	Location	Frequency
Routine	Mechanical lift	Relief Valves	Annual
Routine	Rebuild	Relief Valves	Annual
Routine	Operational	Interlocks/Safety Systems	Annual
Routine	Visual, Metric	Condensate system integrity, Run-out, Head Tilt	Annual
Routine	NDE	Ultrasonic bolts, MT	5 years
Statutory	Visual, Metric	Internal/External	As Required
Non-routine	As required	Incident based	As Required
Fitness for Service	NDE	Based on age/history	By manufacturer
Audit	Compliance based	Annual inspection, document review, drawing review, interviews	5 years

Documentation

- Appropriate approval documentation.
- Assembly drawings and design specifications
- Design specifications.
- Manufacturing protocols and operational protocols
- Nameplate photo, de-rate curves, and crown specification
- Shop Inspection Report and final dimensional details
- Manufacturers instruction documents.
  - Shell thickness.
  - Derating curve.
  - Bolt torque and bolt material specifications.
- U1-A ASME Certificate and Hydrostatic test certification
- Shop repair details by location
- Journal and shell run-outs, head tilts, hot and cold

Record keeping

- Shell thickness
- Grind reports
- Surface repairs
- Steam leaks
- Mechanical history , Damage reports
- Dryer inspections
- Alterations
- Metalizing Reports
- Safety relief valve testing and settings

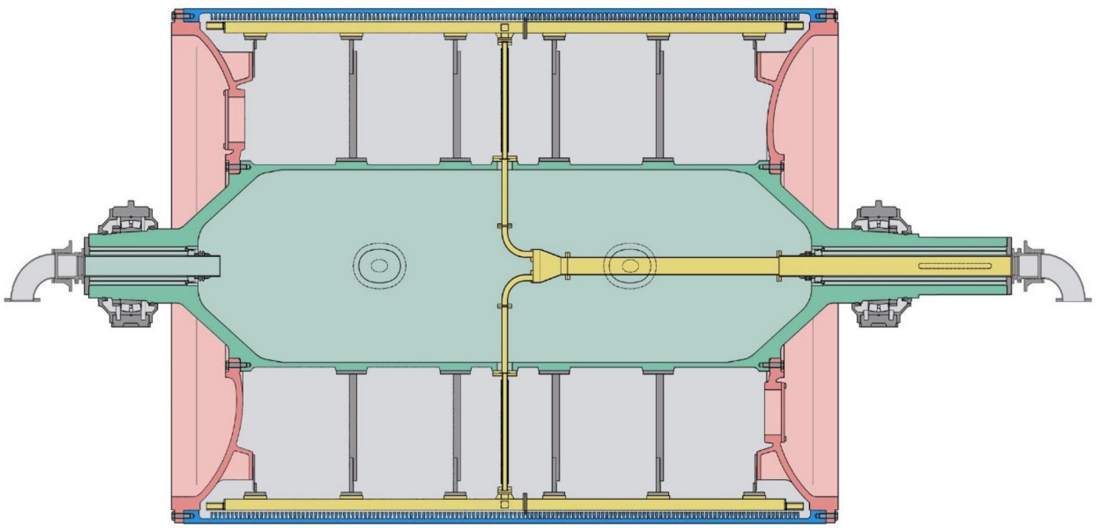
What is the Purpose of a Yankee Steam System?

- Supplies steam to the Yankee and maintains pressure
- Evacuates condensate from the Yankee and re-circulates blow-through steam.
- Returns condensate for reuse.
- Incorporates “failsafe” systems to protect people & equipment during operation.

Steam System Design Considerations

Yankee Dryer Steam System Design

- Each Yankee dryer and syphoning system is unique
- Each steam and condensate system must be tailor made
- Even replacement Yankees will behave differently



Yankee Dryer Steam System Design

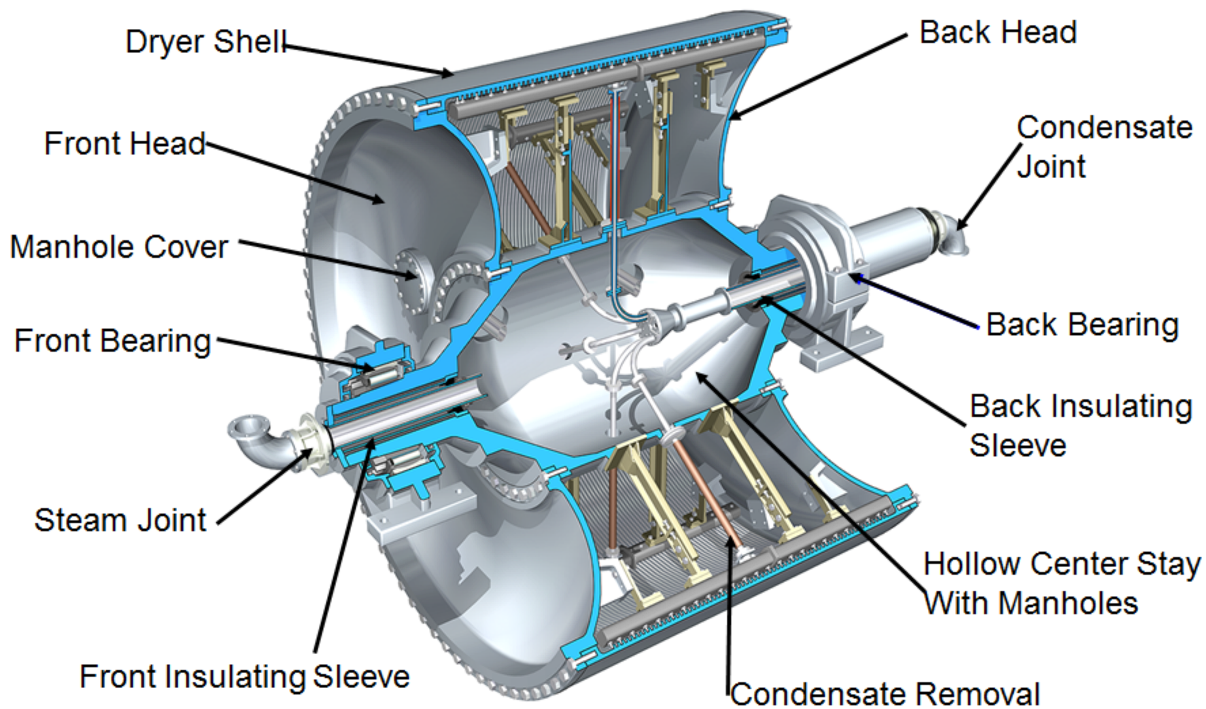
- Condensing load and syphon flow characteristics must be accurately established
- Determining condensing load
  - Yankee drying programs
  - Condensate rise tests useful on existing Yankee cylinder
- Methods for establishing the syphon flow characteristics:
  - Observed operating parameters
    - Existing Blow-through flow indication
    - Existing differential pressure
  - Syphon analysis
    - Allows syphon system to be modeled

Yankee Dryer Simulation Program

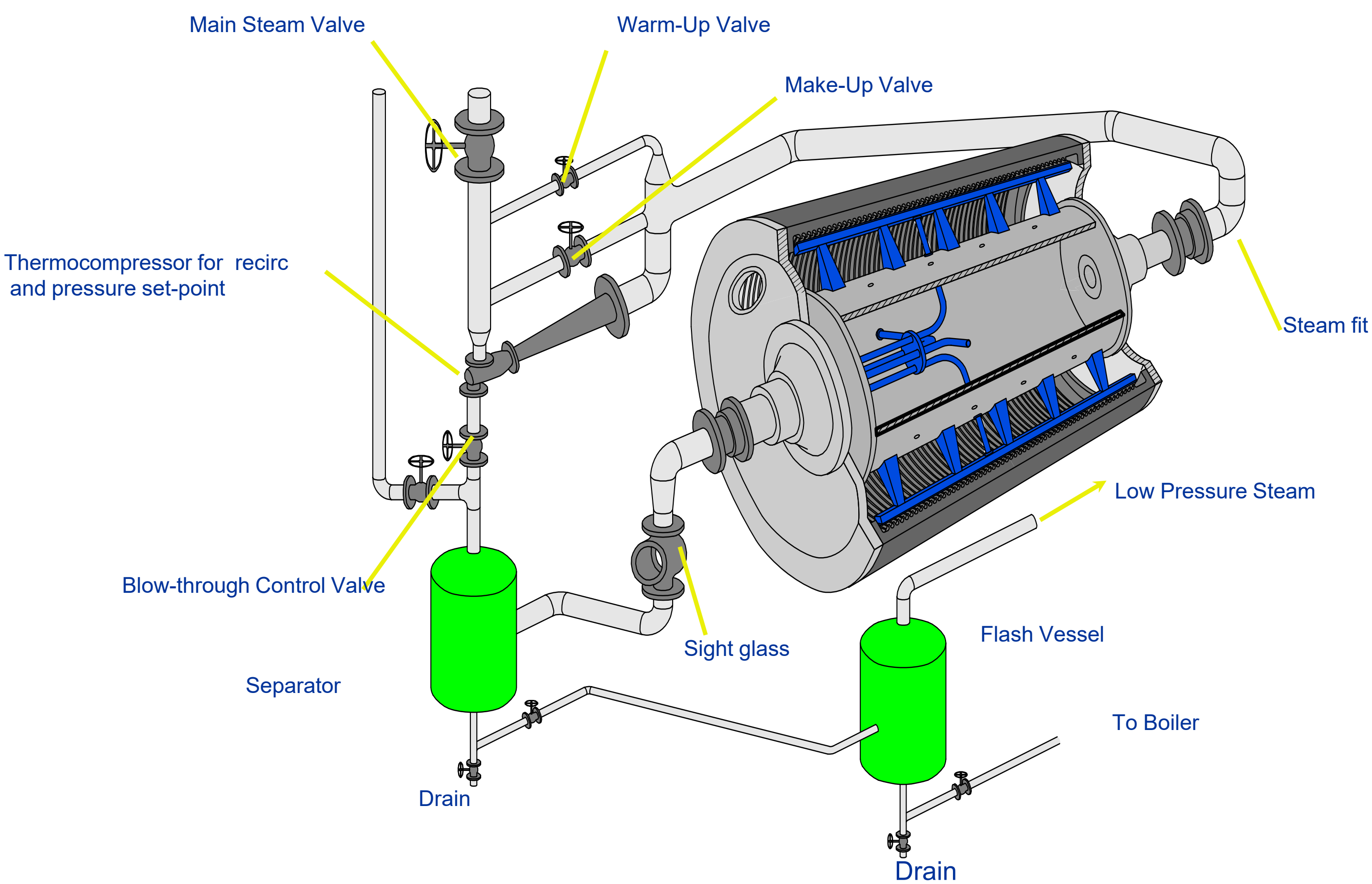
Production			**Calculations**		
Grade		Tissue			
Yankee Speed	ft / min	5,200.0	Production Off Yankee	lb / hr	14,126.3
Reel Speed	ft / min	4,335.0	BD Production Off Yankee	lb / hr	13,490.6
Percent Crepe	%	20.0	Production At Reel	tons / day	165.9
Reel Basis Weight	lb / 3,000 ft^2	10.40	Total Evaporation	lb / hr	18,184.4
Yankee Basis Weight	lb / 3,000 ft^2	8.67			
Sheet Width On Yankee	inches	188.00			
Sheet Width On Reel	inches	184.00			
Reel Moisture	% Moisture	4.5			
Reel Dryness	% Solids	95.5			
Cylinder					
Operating Pressure (gage)	psig	90	Percent Drying From Cylinder	%	49.0
Cylinder Diameter	feet	15	Cylinder Evaporation	lb / hr	8,916.8
Cylinder Maximum Rating	psig	125	Cylinder "Rw"	lb / hr / ft^2	12.08
Ribbed / Plain / Bars		Ribbed	Steam Temperature	deg. F	331
Root or Shell Thickness	inches	1.625	Evaporation Temperature	deg. F	205
Cast Iron Grade		50	Yankee Condensing Load	lb / hr	14,022.6
Plasma Coating On Yankee	no / yes	no	Cylinder "U" Calculated	btu / hr / ft^2 / F	102.9
			Cylinder "U" Expected	btu / hr / ft^2 / F	102.9
			Hc Calculated	btu / hr / ft^2 / F	275.0
			Cylinder Temp. Calculated	deg. F	213.8
Hood					
Hood temperature	deg. F	700	Percent Drying From Hood	%	51.0
Air velocity	ft / min	20,000	Hood Evaporation	lb / hr	9,267.6
Hood wrap angle	deg.	230	Hood "U" Calculated	btu / hr / ft^2 / F	42.61
Hood Effectiveness Adjustment		0.98			
Furnish			**Comments**		
Percent baled		100			
Percent Slush		0			
Sheet temperature in	deg. F	110			
Configuration					
Pre-Dryers Present	yes / no	no			
After Dryers Present	yes / no	no			
Pressing					
Press Code		13			
Nip 1	pli	600			
Nip 2	pli	800			
Dryness Ex-press Calculated	% solids	43.8			
Dryness Override	% solids				
Express Used In Calculation	% solids	43.8			
Misc.					
Spray Addition (liquid)	lb / hr	1,500			

Equipment Design Parameters

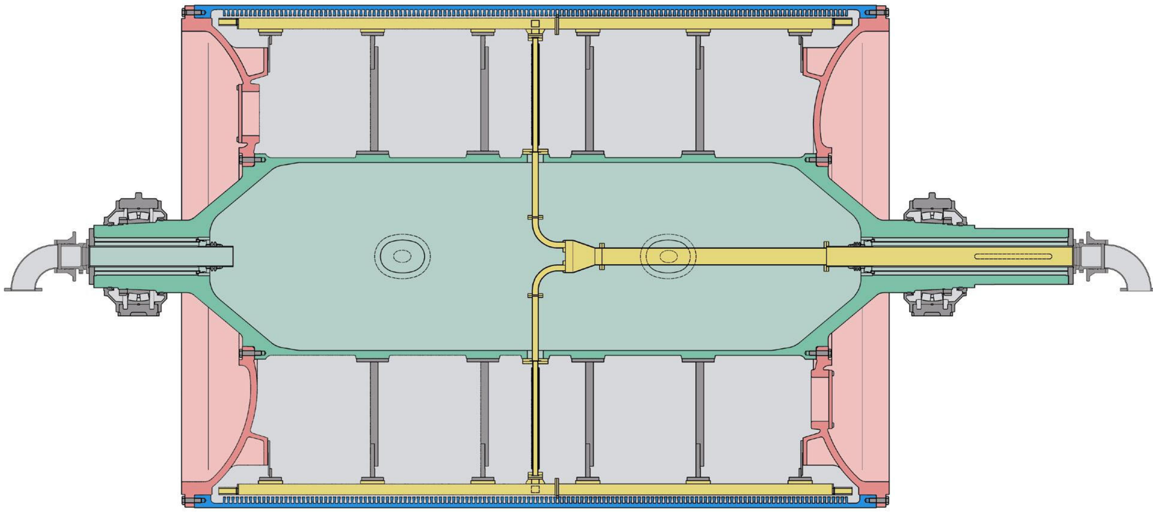
Components of a Yankee Dryer

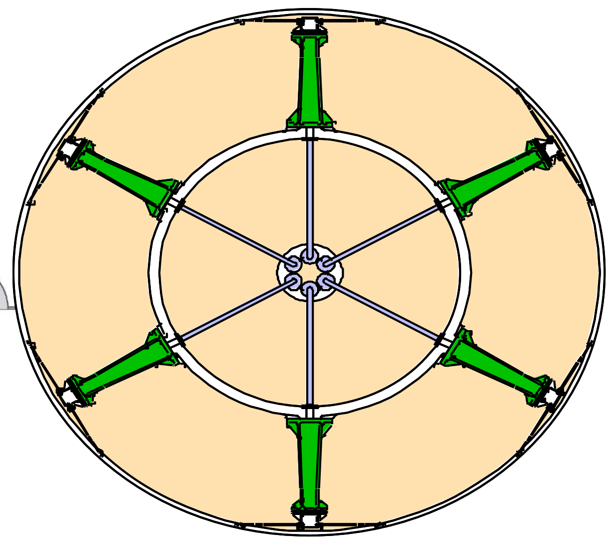


Typical Steam System

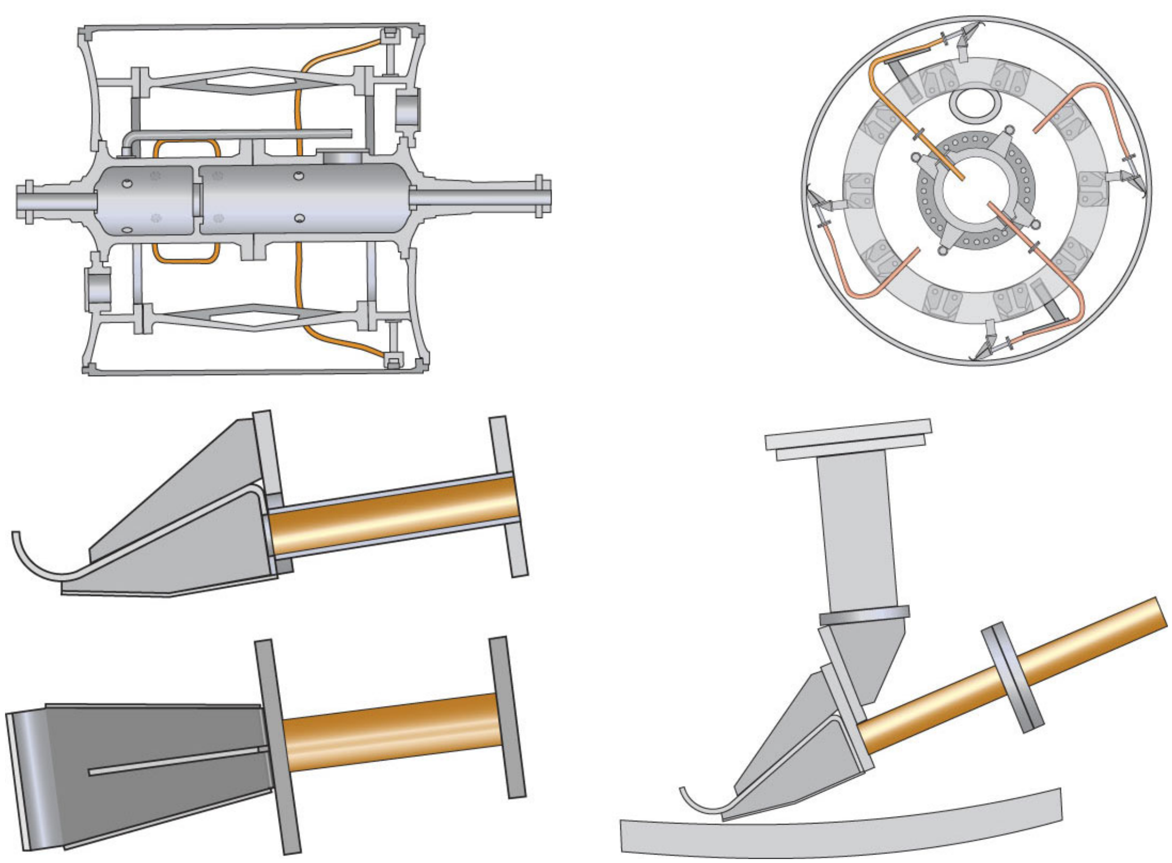


Yankee Syphons

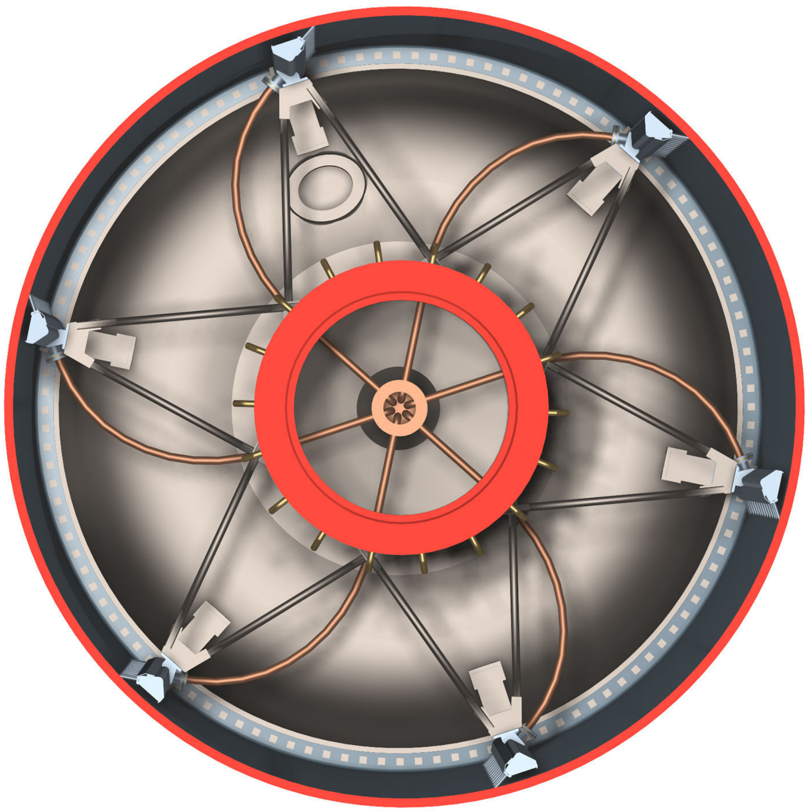




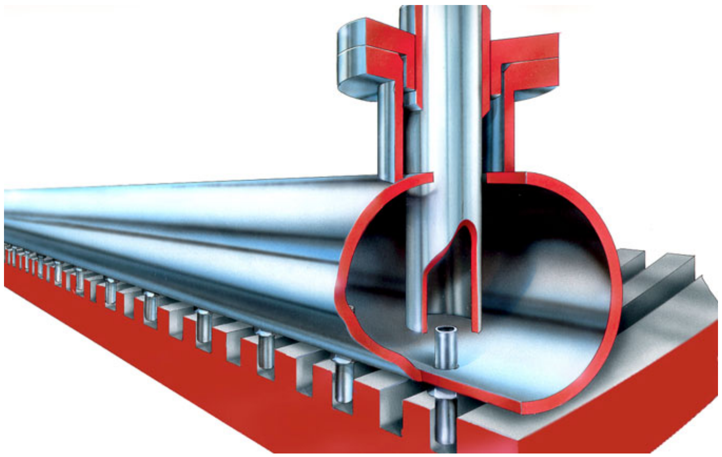
Condensate Removal with Scoops



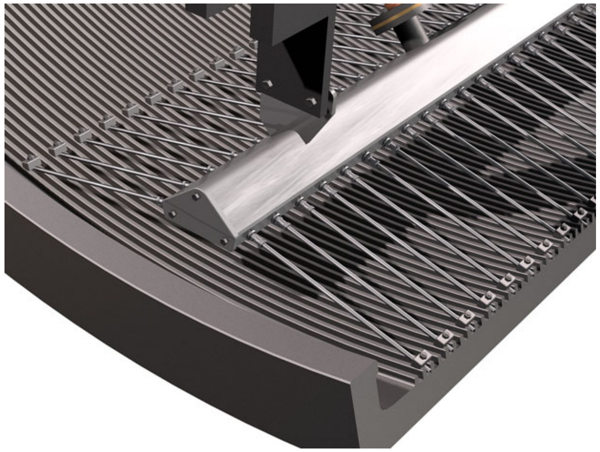
Yankee Dryer - Six Header System



Ribbed Yankees Have Soda Straws

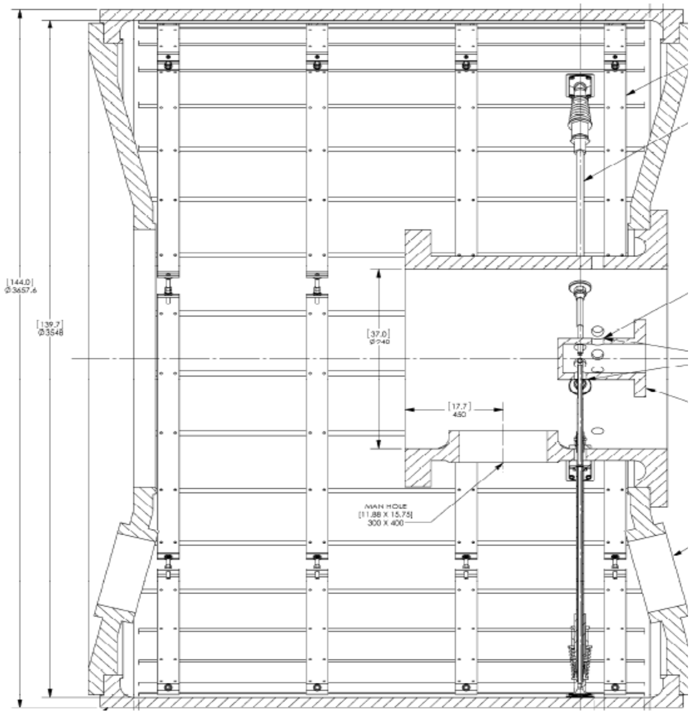


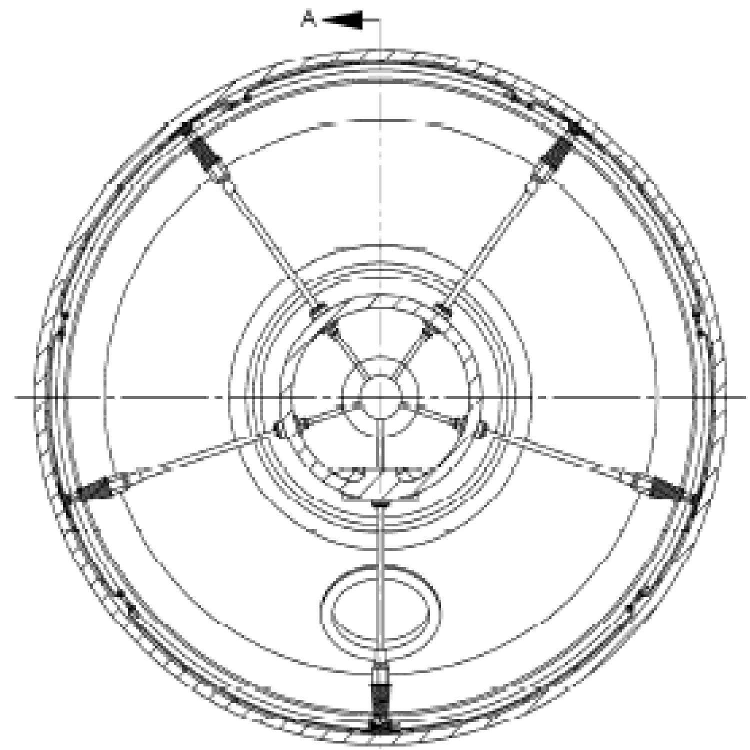
Radial Straws



Circumferential Straws

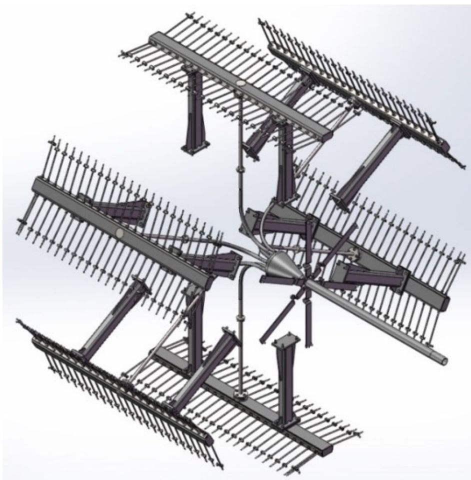
Diameter Smooth Bore Yankee





Estimation Of Blow-through Flows and Differential Pressures

- The most important part of Yankee steam system design is an accurate estimation of blow-through flow and differential pressure required
- Too little blow-through steam
  - Poor cross machine profiles
  - Flooding
- Too much blow-through steam
  - Steam waste (venting)
  - Possible hot spots developing on cylinder
- Blow-through flow can be 40% to 90% of Yankee condensing load
- Differential pressures can range from 5 to 30 psi
- All blow-through flow must be conserved by steam system and reused for good energy efficiency



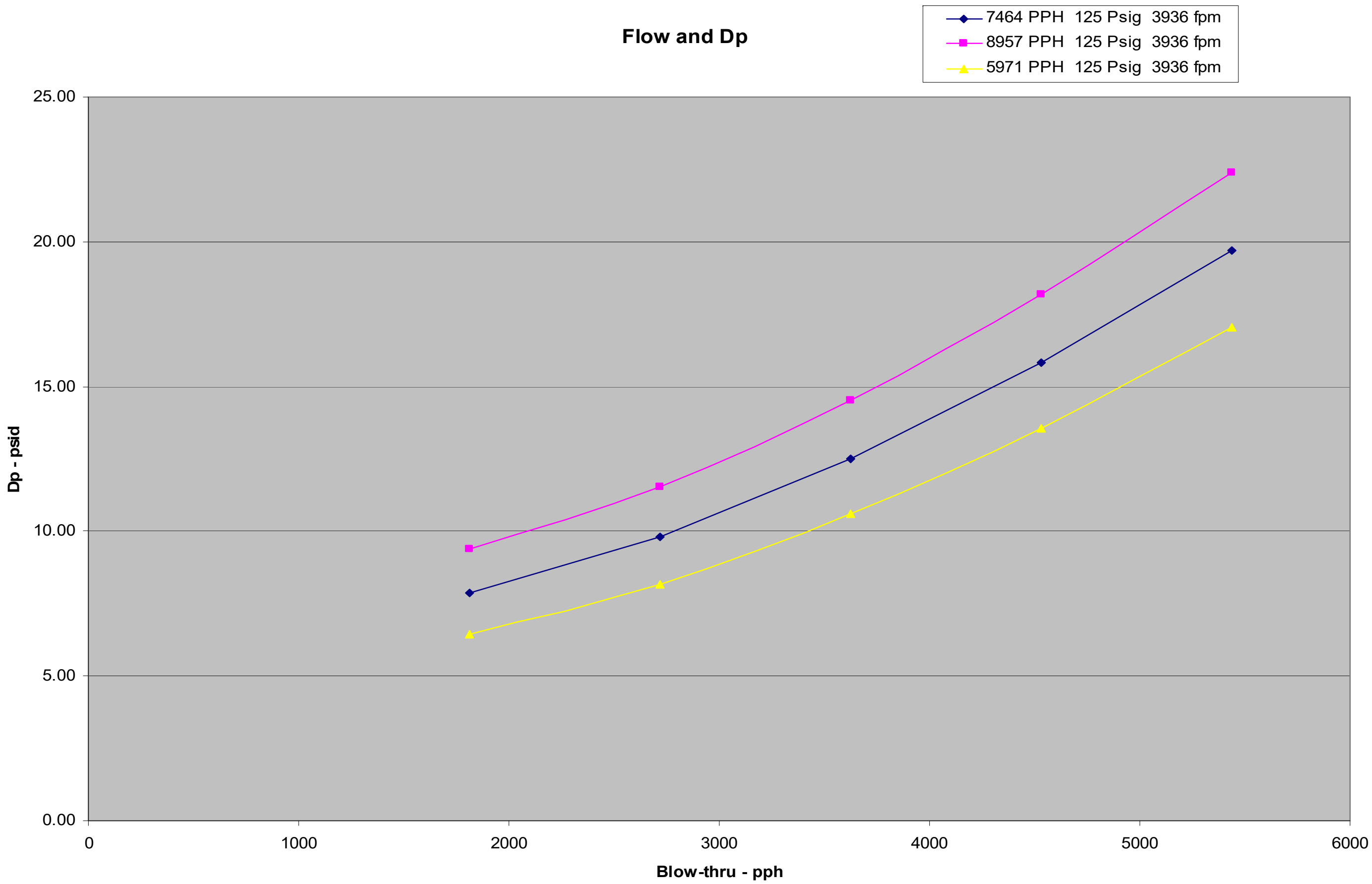
Yankee Syphon Calculation

Steam pressure	43.5	psig	3.00	bar.g
Dryer speed	4825	fpm	1471	mpm
Total steam supply flow	10800	pph	4899	kg/hr
Condensing rate	6400	pph	2903	kg/hr
Blowthrough	**4400**	pph	1996	kg/hr

			"C"		dp (psi)	dp (bar)	Calculated losses as a percent of total
Joint- inlet	Minimum ID	6	0.6		**1.03**	0.071	7.0%
Insulating sleeve -inlet	Minimum ID	6	0.65		**0.89**	0.062	6.0%
Stay supply nozzles	Qty pipes	44	0.65		**0.23**	0.016	1.5%
	Stay pipe ID	1.278					
Straws	Qty straws	303			**5.82**	0.401	39.3%
	Straw Inlet ID	0.157					
Collection header	Riser nozzle ID	1.278			**3.75**	0.258	25.3%
	Riser pipe qty	6					
Riser pipe (length in feet)	Riser pipe ID	1.278					
	Riser pipe length	7			**1.87**	0.129	12.6%
Cent force					**0.72**	0.050	4.9%
Insulating sleeve -outlet	Minimum ID	6	0.5		**0.32**	0.022	2.2%
Joint - outlet	Minimum ID	6	0.65		**0.19**	0.013	1.3%
				Total DP	**14.83**	1.023	

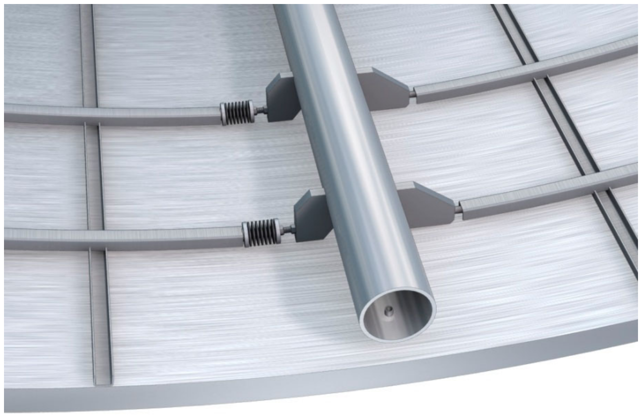
Soda straw velocity	230	fps
Header pipe velocity	175	fps
Riser pipe velocity	209	fps
Estimated flooding velocity	114	fps
Total straw to riser flow area	76%	%
% Blowthrough	69%	%

Yankee Syphon Calculation

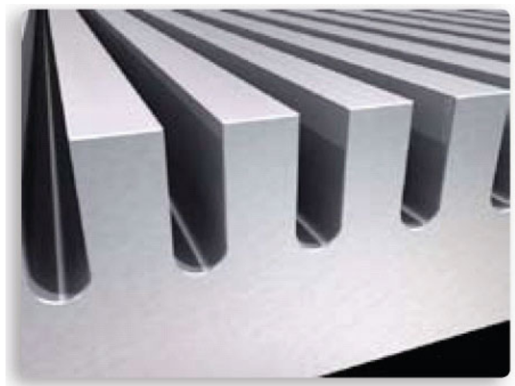


Methods for Increasing Heat Transfer/Drying Capacity

- Turbulator bars



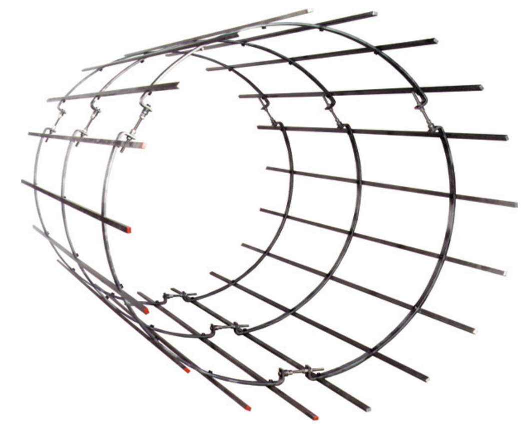
- Internally grooved shell



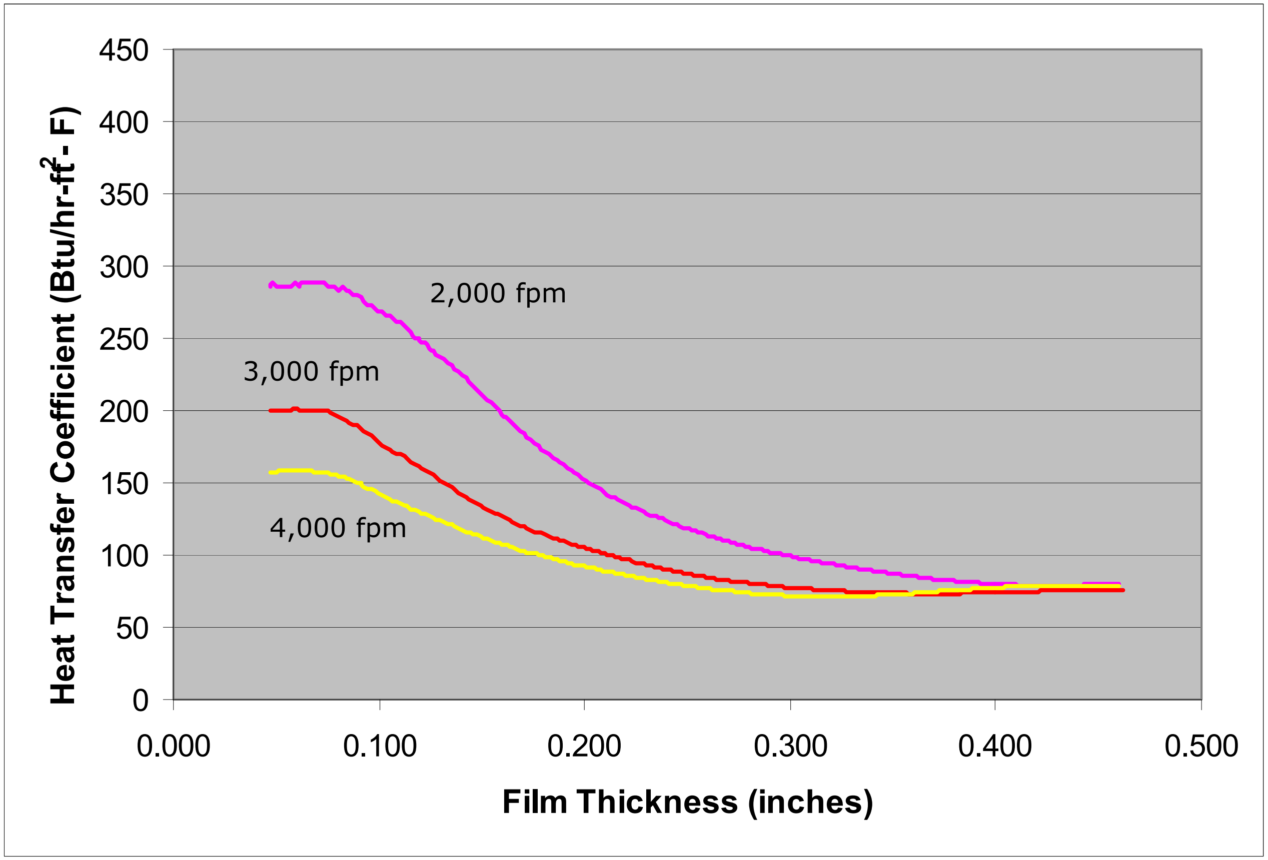
Yankee Turbulator Tube Bars

“to create resonant waves in the condensate film to increase condensate turbulence and therefore, increasing the rate of heat transfer”

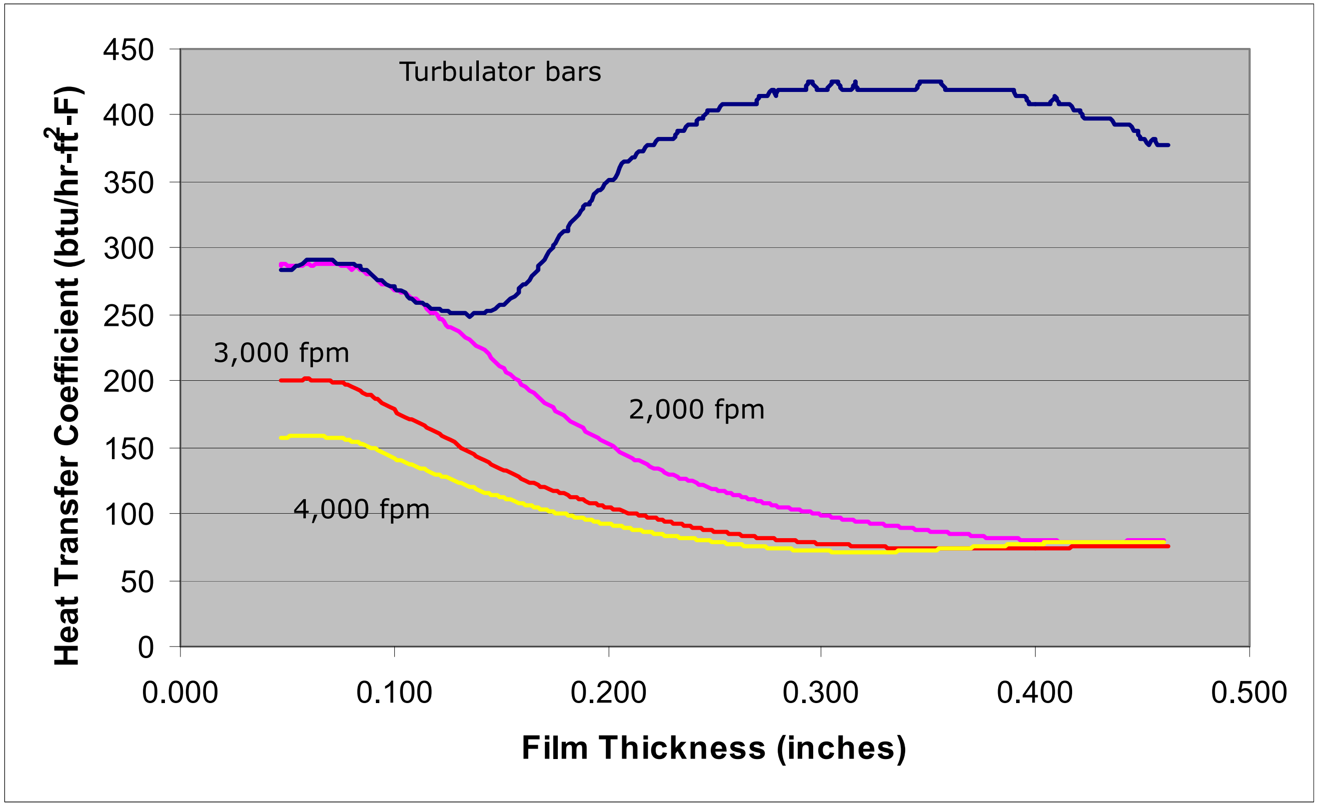
- Axial bars that can be applied to smooth bore Yankee dryers
- Stainless or steel bars
- Held by segmented rings or screwed to the Yankee dryer shell
- Increased condensate turbulence
- Improved heat transfer and drying capacity
- Improved CD surface temperature profile
- Scoop syphons replaced with conventional large shoe rotary syphons
- Potentially extend life of a Yankee



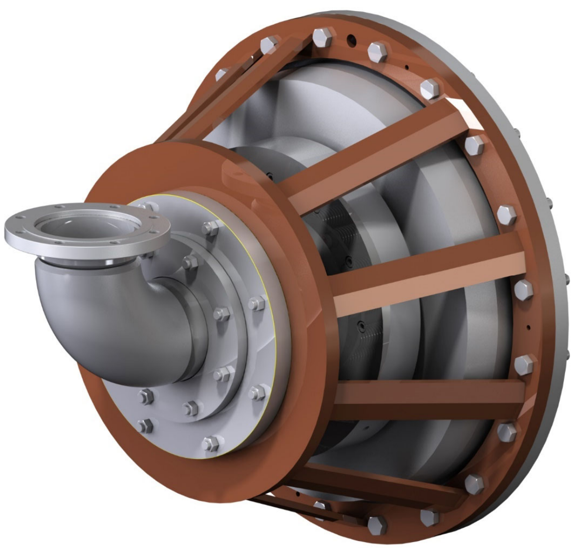
Condensate Coefficient - No Dryer Bars

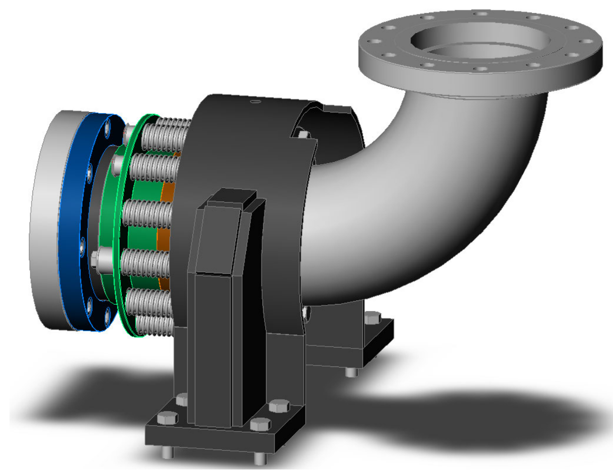


Condensate Coefficient with Turbulator Bars

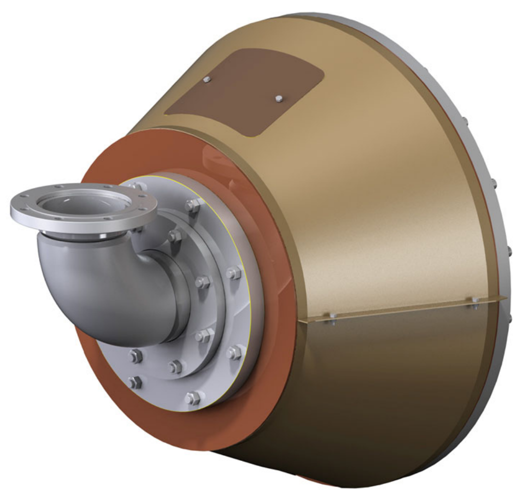


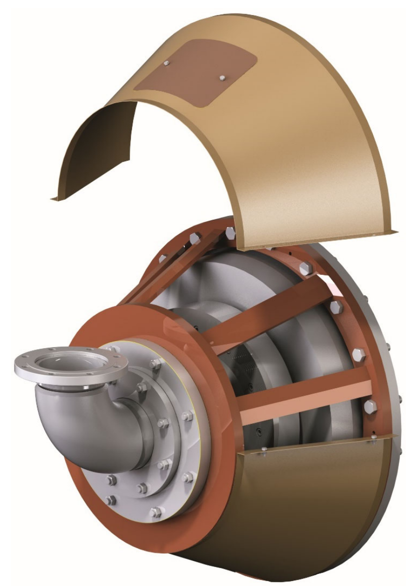
Rotary Joints





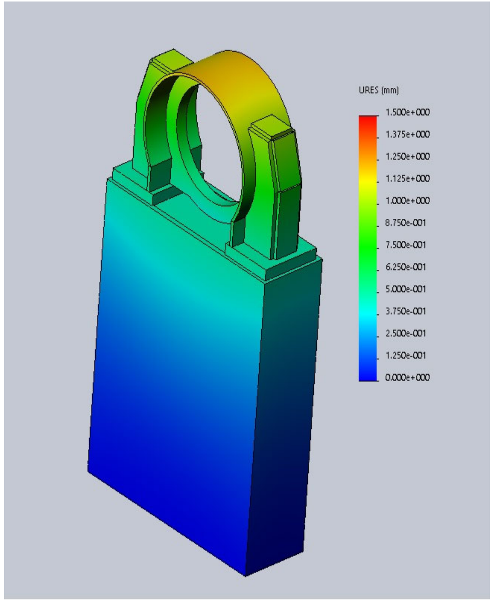
PT Rotary Joint with Safety Cover

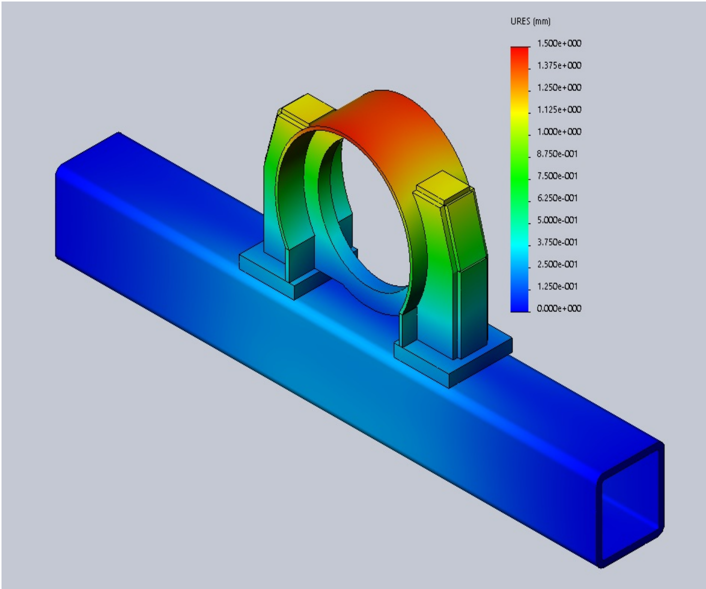




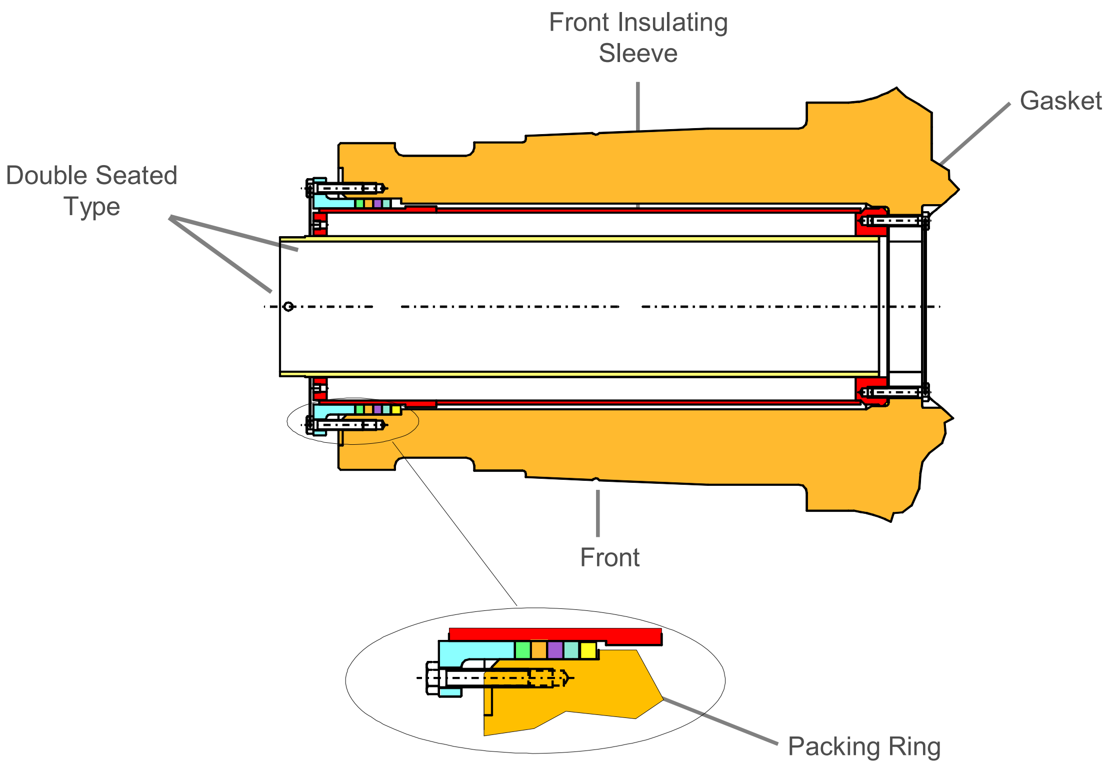
Rotary Joint Mounting Considerations

- Stand and Beam Mounting
  - Deflection and stress analysis

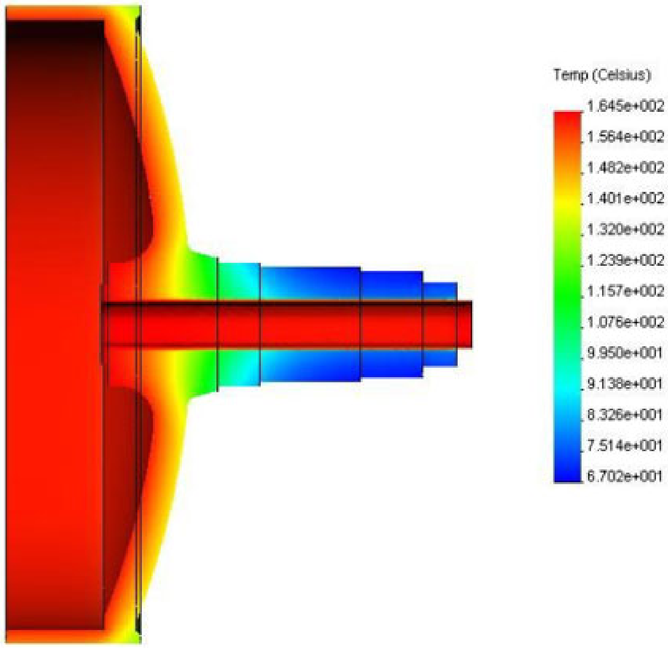


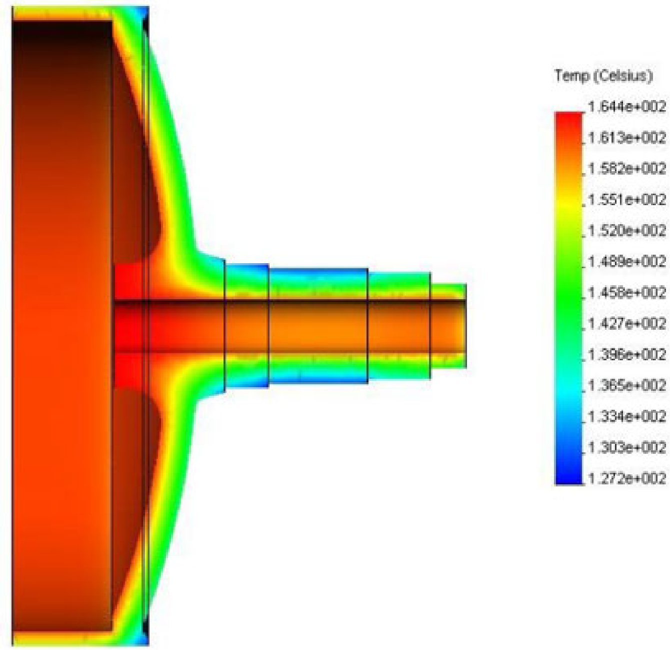


Insulating Sleeve



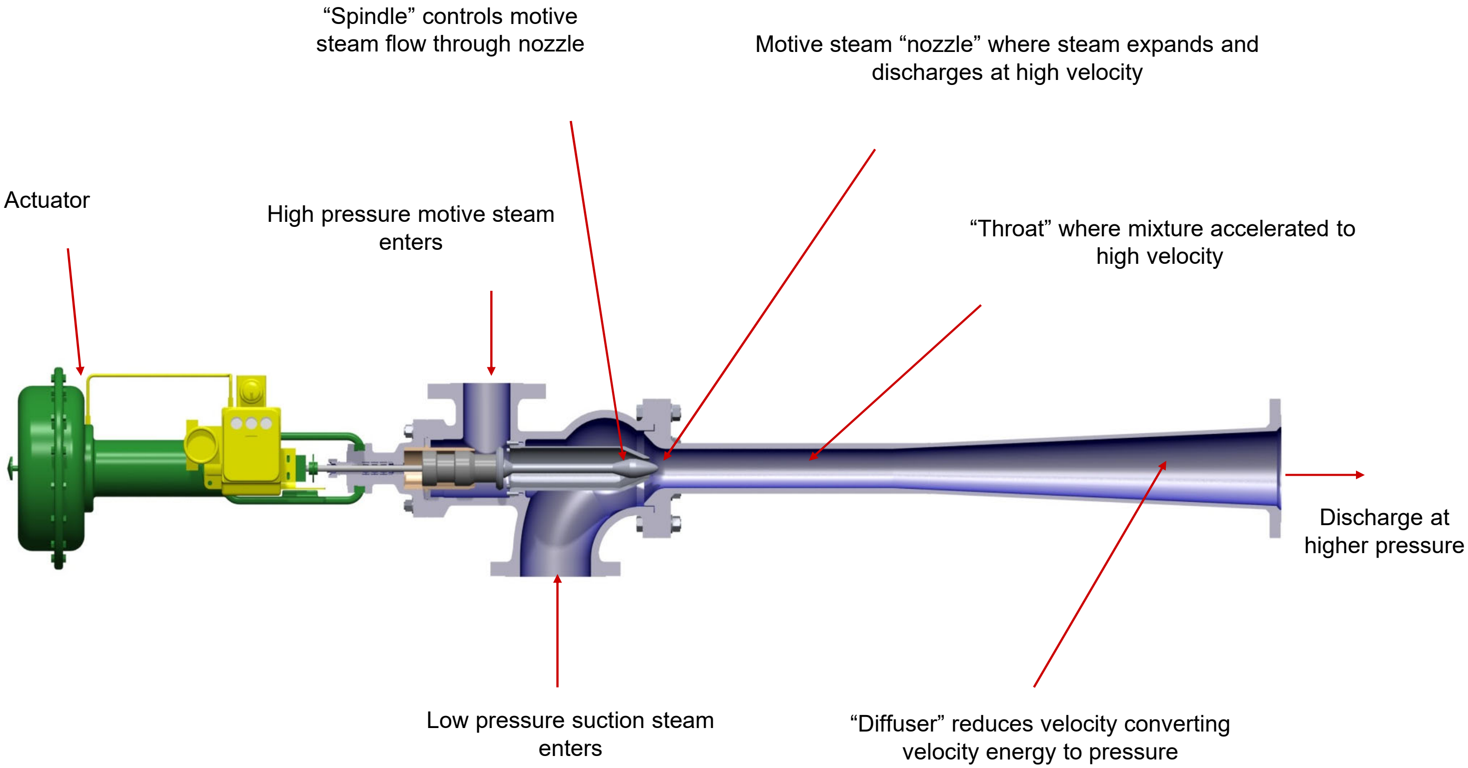
Insulating Sleeves





100 psig steam pressure with and without insulating sleeve

Thermocompressor Components



Bernoulli's Equation

$$P_1 + \left(\tfrac{1}{2}\rho V_1{}^2\right) = P_2 + \left(\tfrac{1}{2}\rho V_2{}^2\right)$$

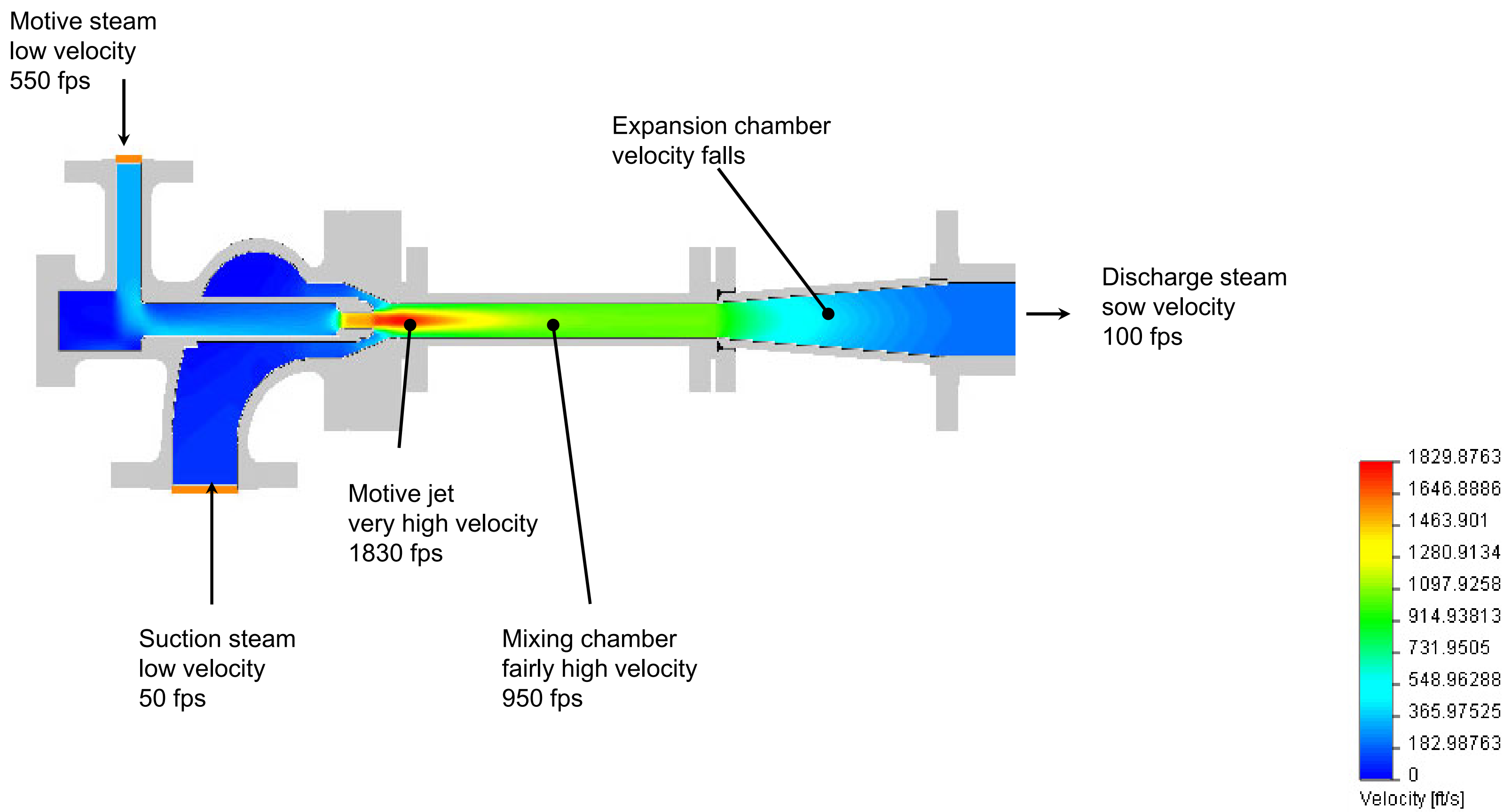
$$P = \text{Static Pressure}$$

$$V = \text{Velocity}$$

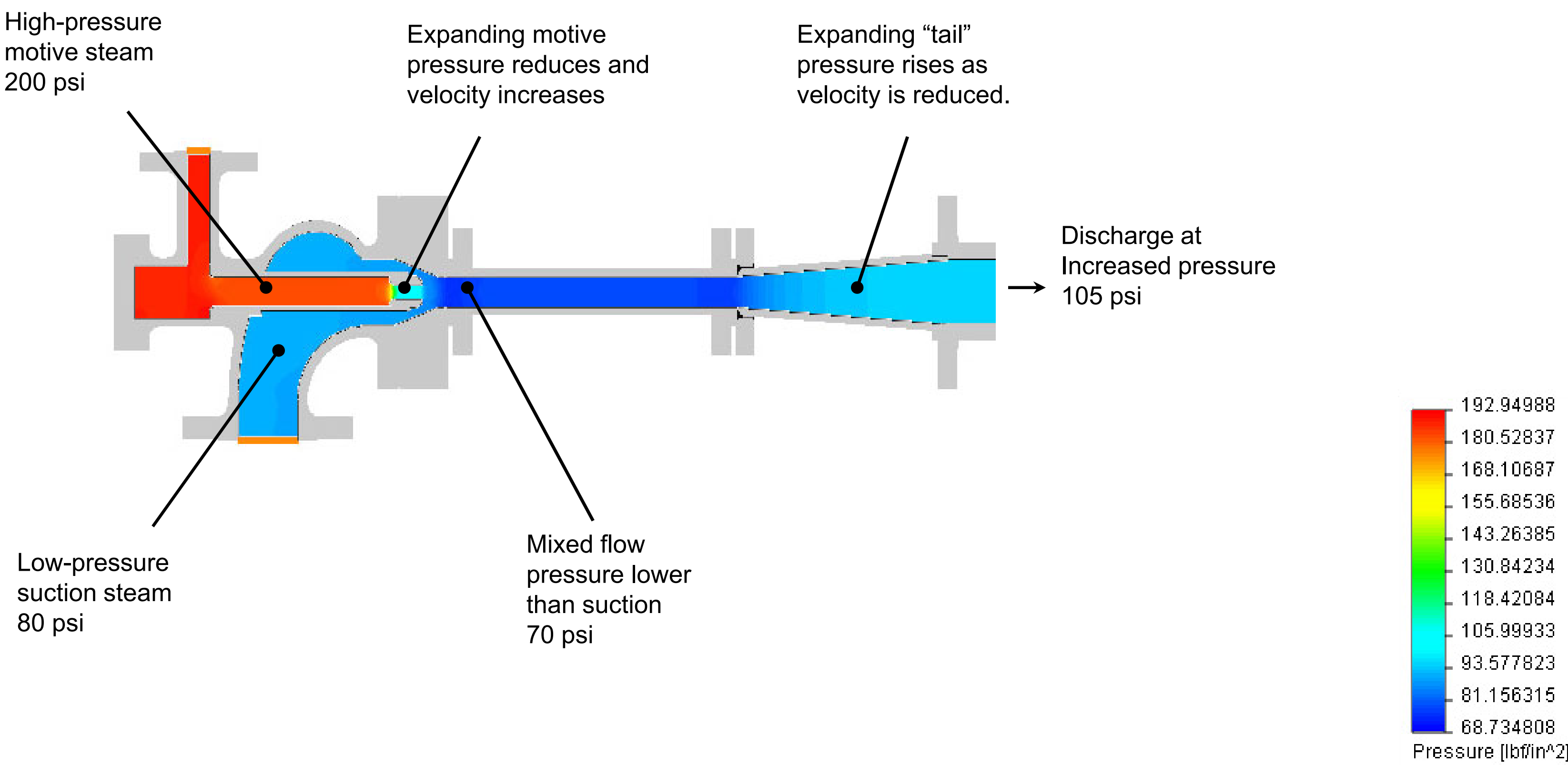
$$\tfrac{1}{2}\rho V_1{}^2 = \text{Velocity Pressure}$$

- As Pressure Is Reduced Velocity Must Increase
  - Motive steam expanding from nozzle to high velocity
- As Velocity Is Reduced Pressure Must Increase
  - Velocity is reduced in diffuser to discharge at higher pressure

Steam Velocity Profile



Steam Pressure Profile



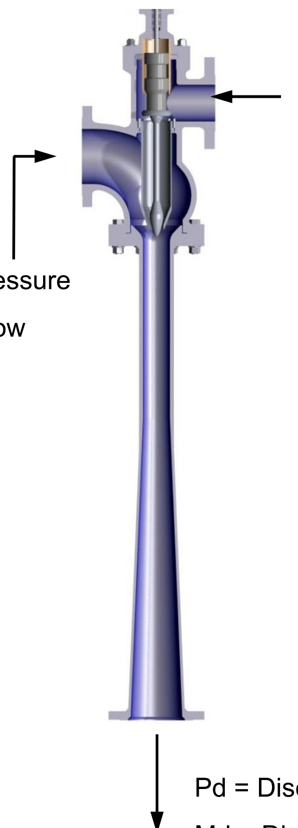
Typical Design Ratios

Pm = Motive Pressure

Mm = Motive Flow

Ps = Suction Pressure

Ms = Suction Flow



$$\text{Expansion Ratio} = P_M / P_S \geq 1.4$$

$$\text{Compression Ratio} = P_D / P_S \leq 2$$

$$\text{Entrainment Ratio} = M_S / M_M$$ = As high as possible!

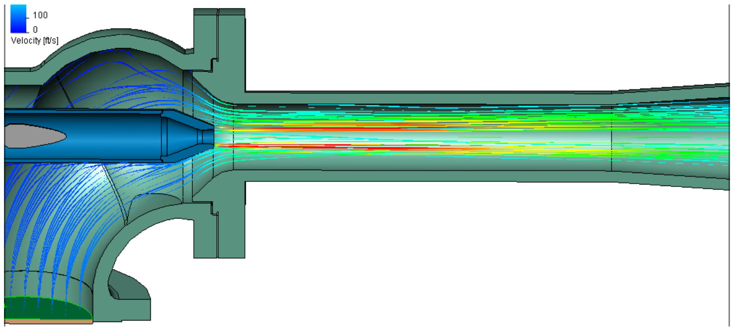
P = Absolute Pressure

Pd = Discharge Pressure

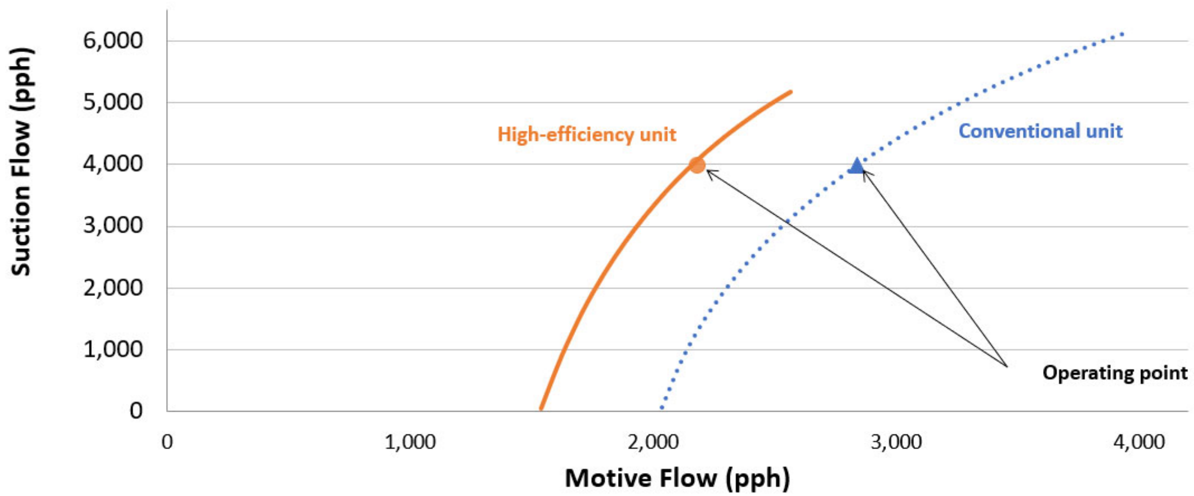
Md = Discharge Flow = Ms + Mm

Thermocompressor Efficiency

- High-efficiency thermocompressors are an advantage on Yankee systems
  - Blow-through flows and differential pressure are high
  - Motive steam flow can often equal or exceed Yankee condensing load
    - Causes system to vent
  - High-efficiency thermocompressors reduce the motive steam requirement and reduce venting
    - Can reduce motive steam use by 20% to 25% over conventional thermocompressor designs



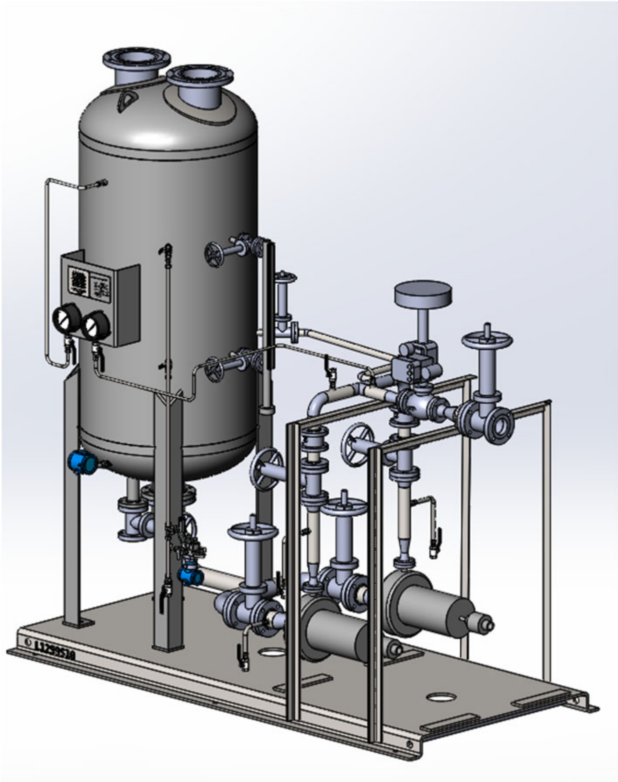
Thermocompressor Efficiency



An optimized high-efficiency consumes 25% less motive steam for the same suction flow vs. a conventional unit.

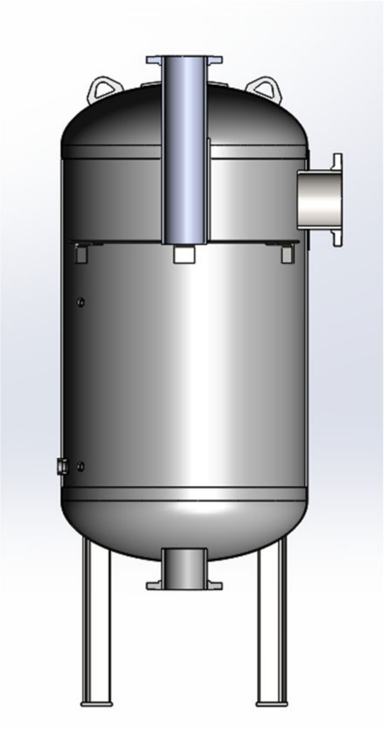
Condensate Separator Stations

- Condensate separator stations must remove all free condensate from the blow-through steam
  - Condensate carry over to thermocompressor will cause erosion
  - Condensate carry over will add to load
    - Reduced drying capacity
    - Higher differential pressures
    - Flooding
    - Unstable blow-through control



Separator Station Design

- Vapor velocity through tank is used as key sizing criteria to determine separation efficiency
  - 98% to 99% steam quality leaving tank
  - Vapor velocities vary with dryer pressure and steam density
- Tank baffling determines vapor distribution within tank
  - Vapor distribution must be uniform for efficient separation
- Liquid retention time should be taken into consideration
  - 1.5 to 3 minutes
- Pump is critical
  - Liquid height for NPSH
  - Minimum losses to pump inlet
  - Ensure proper level control (no dumping of condensate)
  - Mechanical seal w/ seal cooler vs. seal water

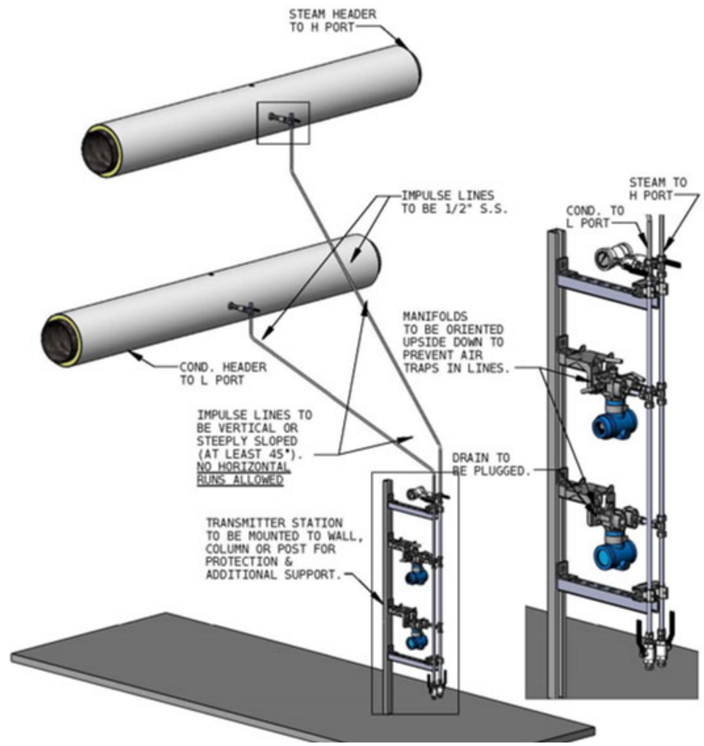


Magnetic Level Indicators

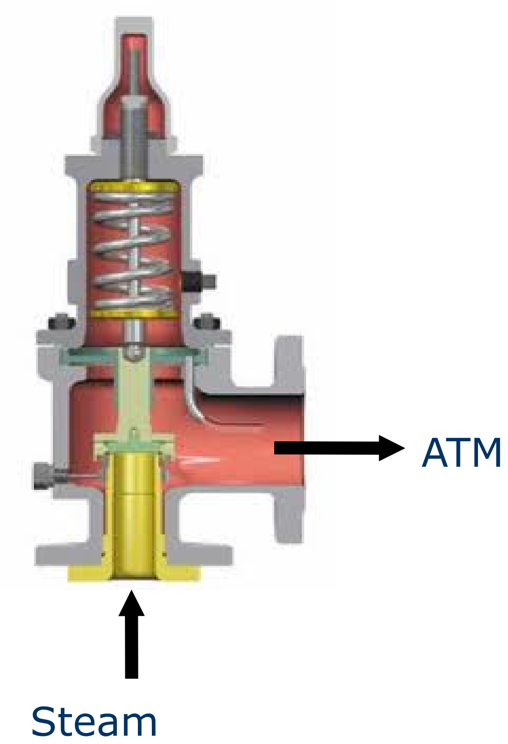
Pump By-Pass

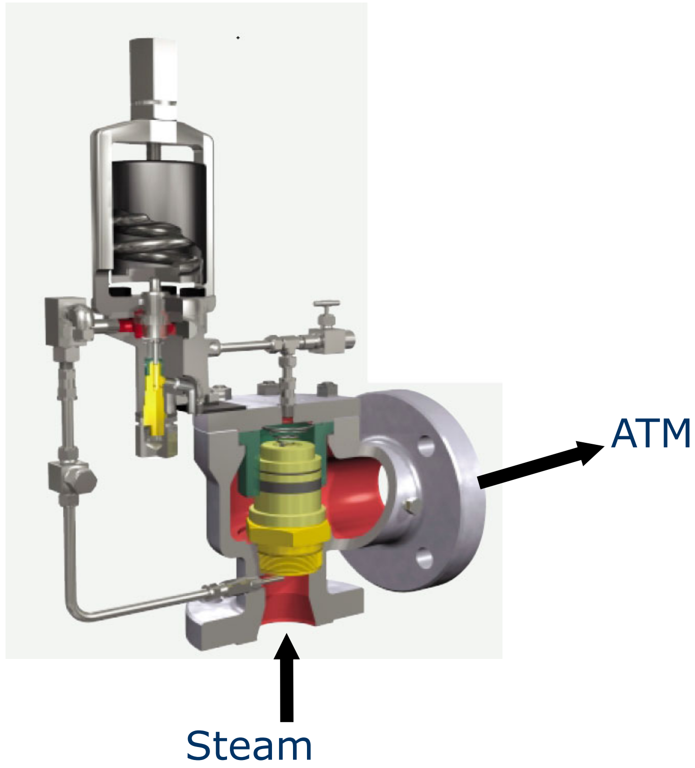
Steam Control Valves

Transmitters



Safety Valves - Conventional vs Pilot Operated

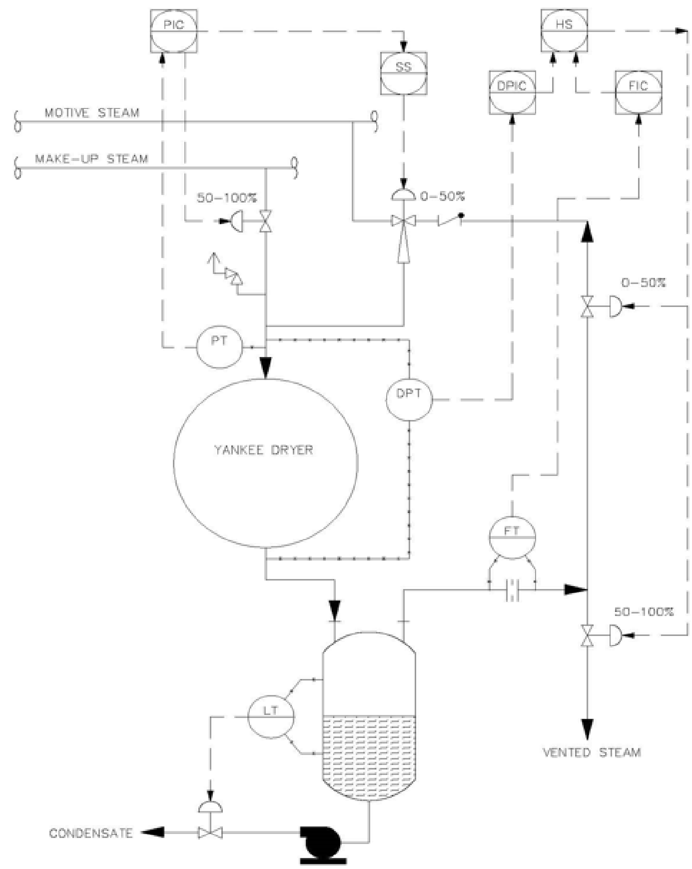




Yankee Control Methods

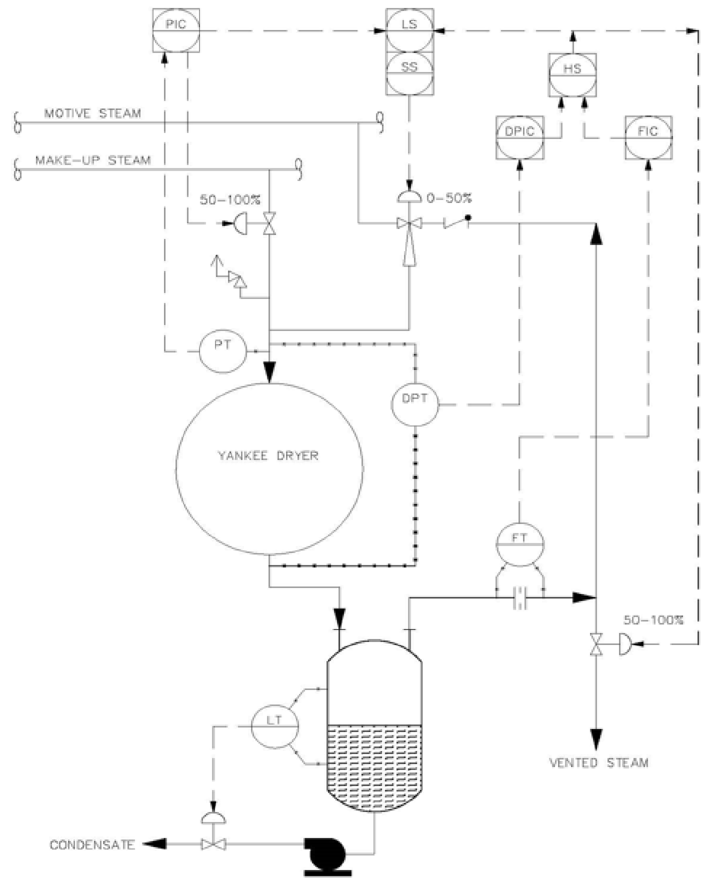
Thermocompressor Control

- Method 1 - Control thermocompressor from pressure control loop (preferred)
  - Thermocompressor opens fully, then make-up valve
  - Blow-through meter controls valve at thermocompressor inlet
  - Used when make-up and motive steam from same source with no electrical power generation
  - Used when motive steam pressures are low and Blow-through rates are high
  - Used if motive flow is a high percentage of total make-up
  - Avoids the controller deadband that can exist with traditional logic (with "low select" function block)

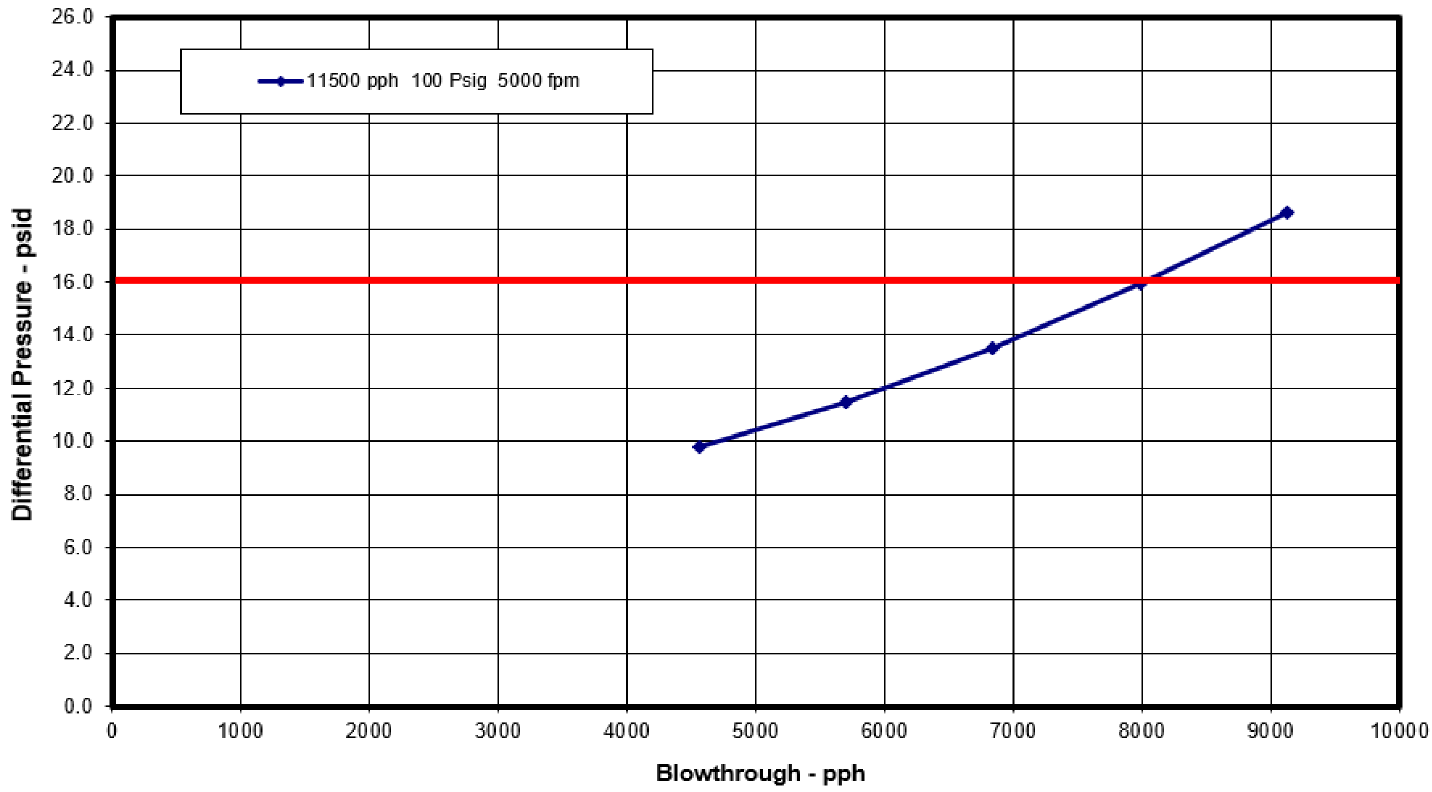


Thermocompressor Control

- Method 2 - Control thermocompressor motive based on blow-through flow or DP transmitter
  - Used if motive steam pressure is high
  - Used if blow-through flow rates are relatively low
  - Motive steam much more costly than make-up steam
  - Motive steam flow is only a small portion of Yankee condensing load
  - Yankee might be operated over such a wide pressure range there is risk of thermocompressor “choking



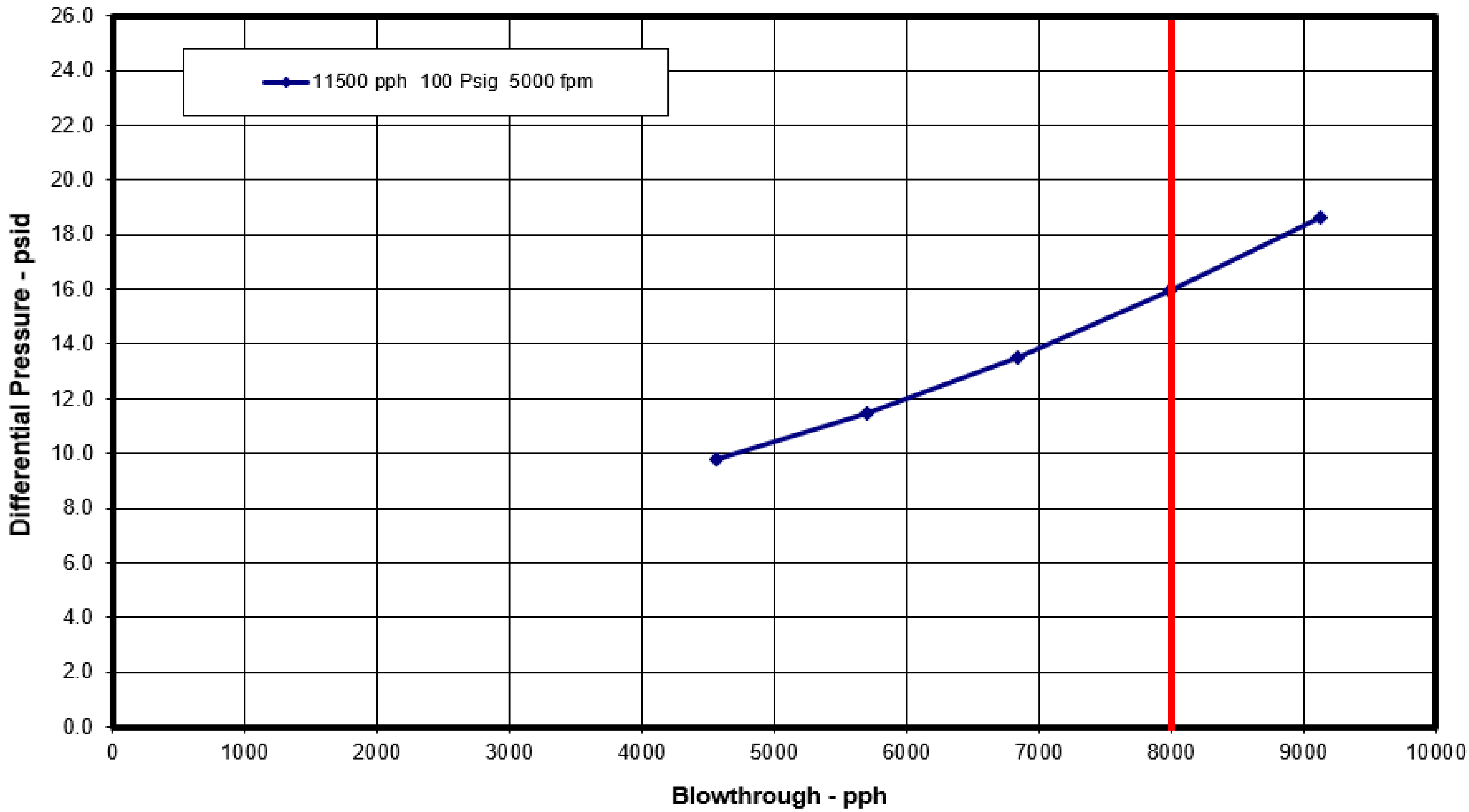
Differential Pressure Control



Differential Pressure Control

- Advantages
  - Simple to understand and operate
  - Can be set at a "safe" level to handle all operating points
  - Reliable and well accepted method
  - Less equipment
- Disadvantages
  - Operators are required to set differential pressures
  - "Worst case" differential pressures are usually used
  - Higher blow-through steam flows when "worst case used"
    - Steam venting and waste possible
    - Increased losses to condenser
    - Potentially high motive steam use depending on the thermocompressor control method
  - Excessive venting & waste on breaks

Blow-through Control



Blow-through Control

- Advantages
  - Reduced venting on sheet breaks
  - Adjusts blow-through flow as Yankee pressures & condensing loads change
  - Adjusts to flooding Yankee or high load situations
  - Senses loss of blow-through flow and automatically increases differential pressure
- Disadvantages
  - More difficult to understand
  - Requires more equipment flow orifice, flow transmitter, & differential transmitter
  - Tanks must have good condensate separation to provide a good control signal

Yankee Steam System Design

- Vortex flow meters are preferred in most cases where Yankee will be operated over a narrow pressure range
  - Measures steam velocity
  - Good turndown
  - Reliable
  - Accurate
  - Simple
  - Velocity in blow-through line is proportional to soda straw velocity
- For cases where Yankees will be operated over a wide pressure range, consider blow-through control with an orifice plate flow meter instead
  - Maintains constant <u>momentum</u> of blow-through (Vortex does not.)

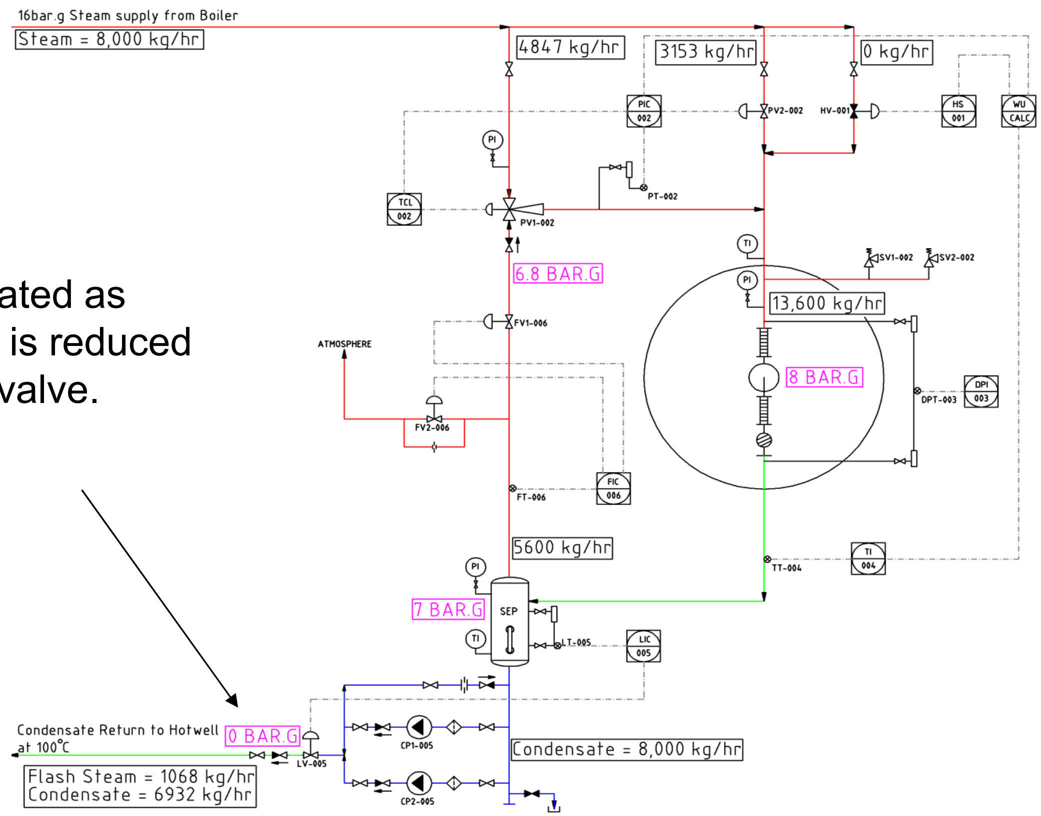
Yankee Steam System Design

- Yankees should be equipped with both a blow-through flow meter and a DP transmitter
  - Instrumentation is needed to allow monitoring of syphon condition.
  - If blow-through increases relative to differential pressure, there is likely a breach in the syphoning system.
  - If blow-through decreases relative to differential pressure, soda straws and/or riser pipes might be plugging with magnetite.

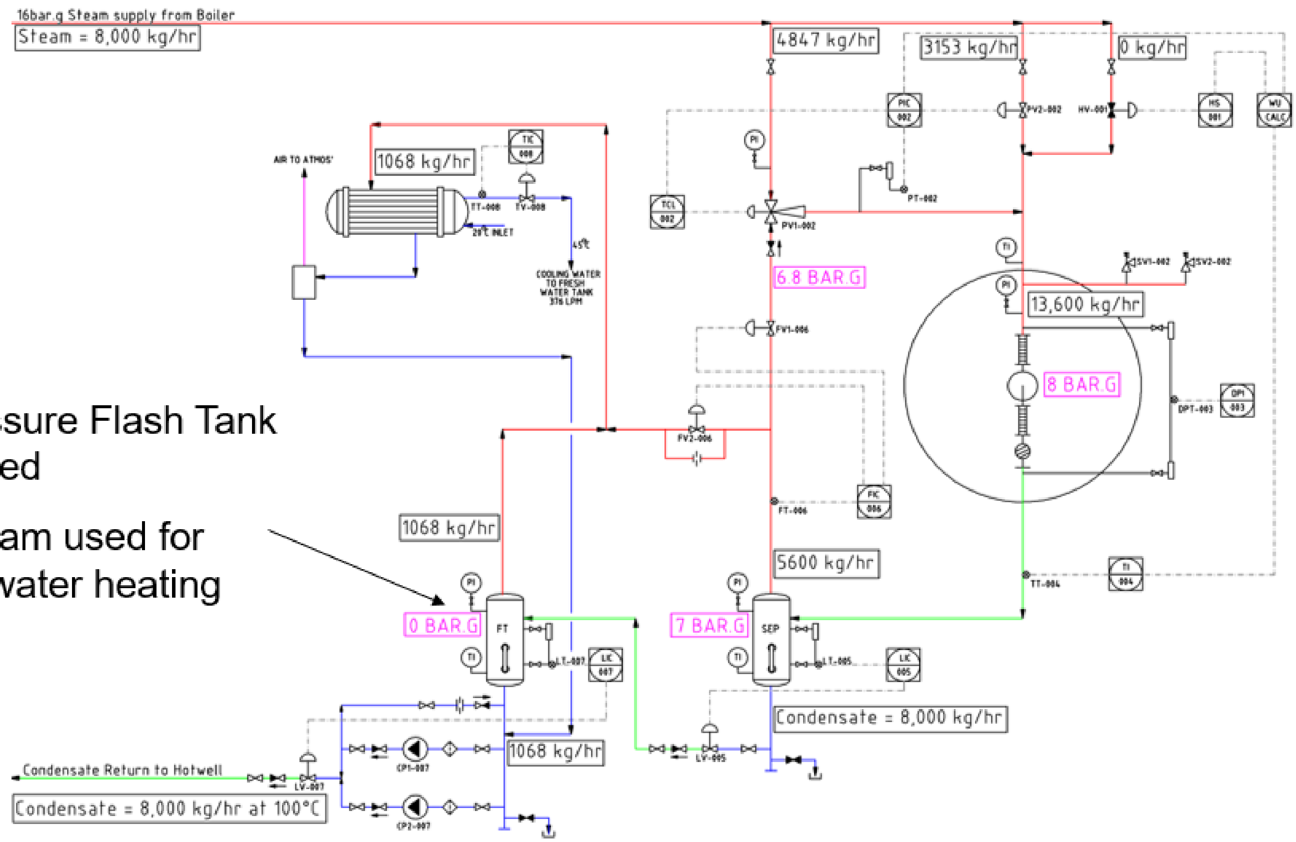
Flash Steam Utilization

No Flash Steam Recovery

Flash steam is generated as condensate pressure is reduced through level control valve.



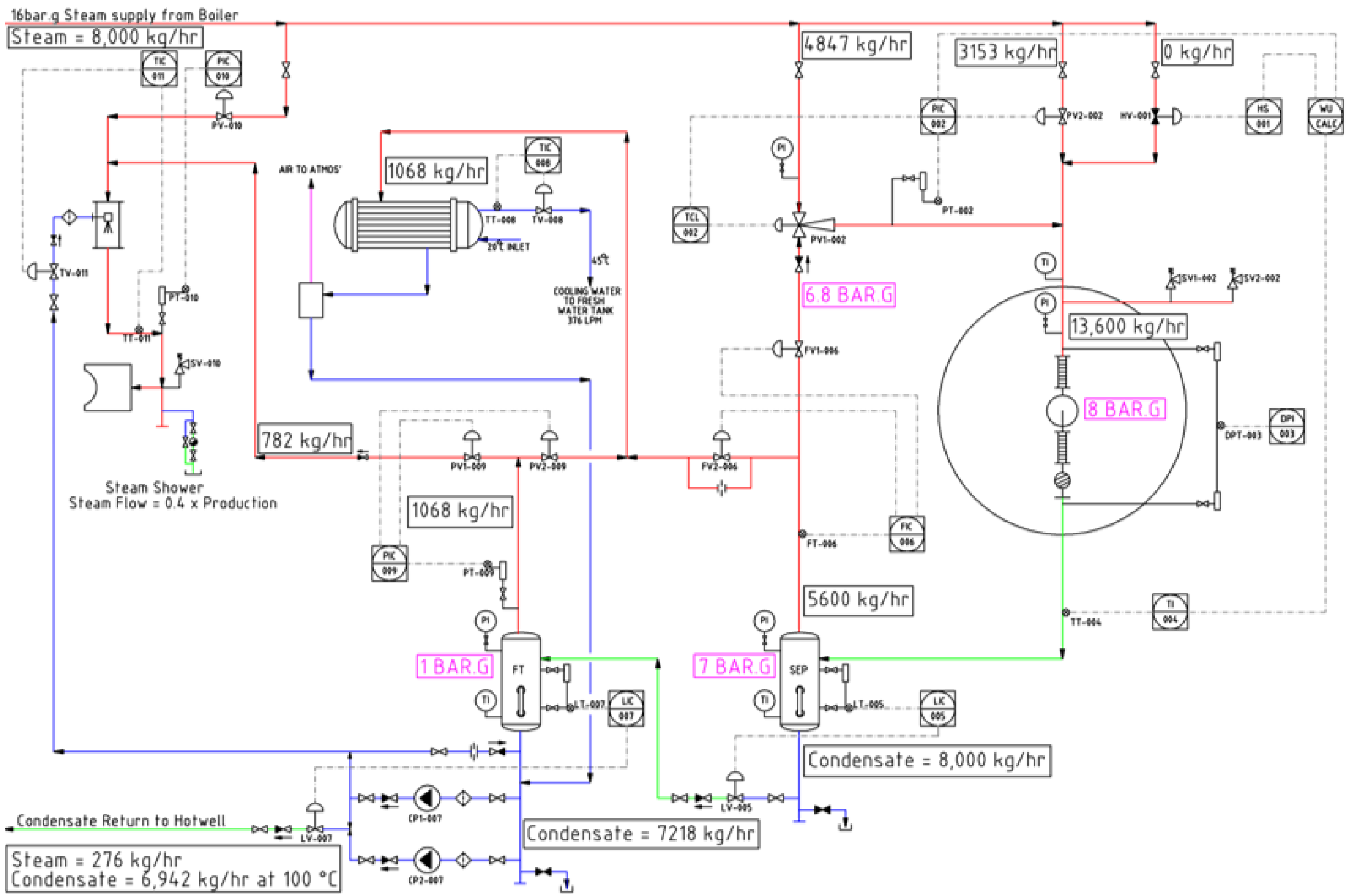
With Flash Steam Recovery - Condenser



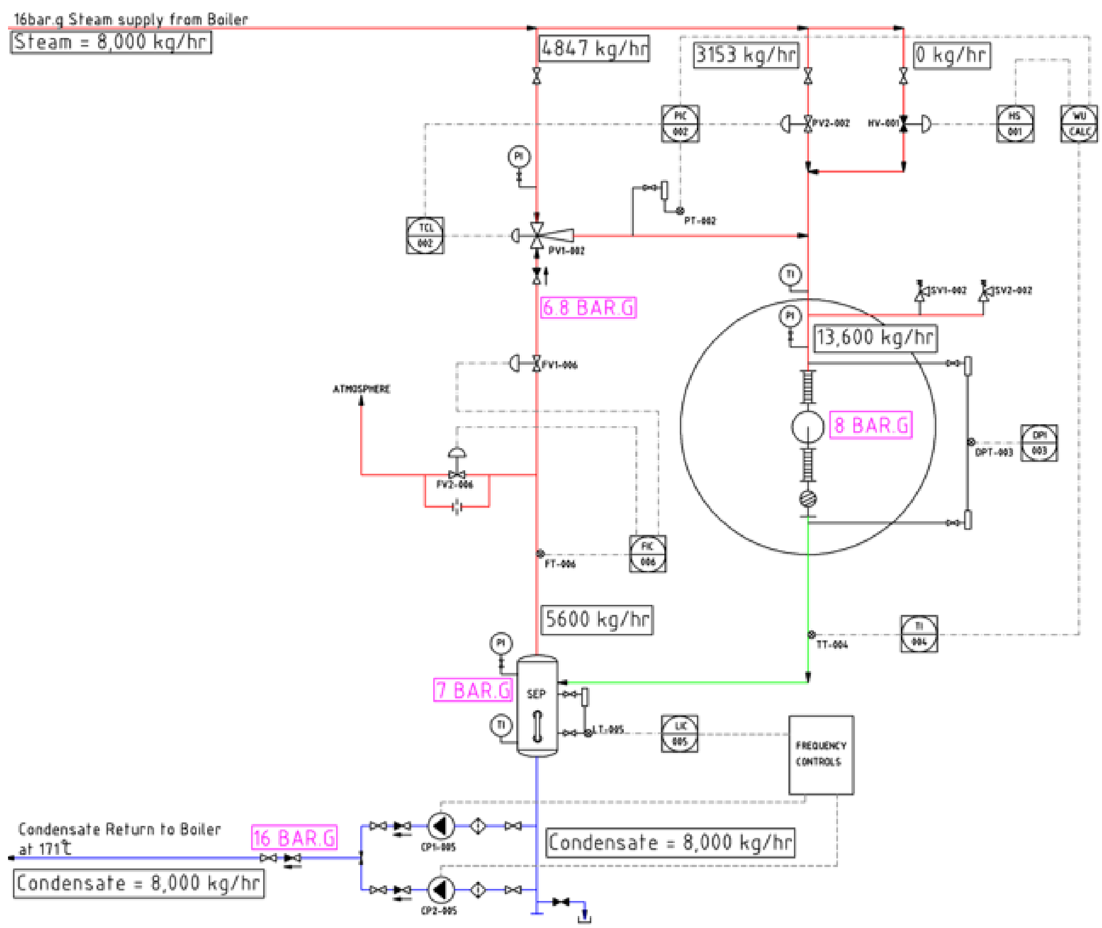
Low Pressure Flash Tank Established

Flash steam used for process water heating

With Flash Recovery – Condenser + Shower



Condensate Direct to Boiler



Summary – Safety

- Avoid rapid temperature changes and uneven heating or cooling
- Have the cylinder rotating whenever possible
- Ensure your de-rate records are complete and accurate
- Inspect when accidents happen and investigate the impact
- Keep thorough records of all Yankee Cylinder maintenance and incidents
- Use manufacturer instructions for Yankee Cylinder operations

Summary – Steam System

- Thermocompressor systems used almost exclusively on Yankee dryers
- Blow-through steam is required to evacuate condensate from the Yankee
- Very high blow-through flows and differential pressures typical
- Design of thermocompressor is critical and must match syphon curve
  - High-efficiency designs are advantageous
- Separator design is extremely important
- Vortex flow meter are commonly used for condensate evacuation
  - Produces correct velocity in syphon straws and risers
- Yankees should be equipped with both a blow-through flow meter and a DP transmitter for trending and troubleshooting
- Flash steam from high temperature condensate should be used in process

Thank You!

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