Emerson Steam University Virtual Series

A Practical Approach To Understanding Steam Systems

Day 1 – Introduction to Steam Systems

R.E. MASON
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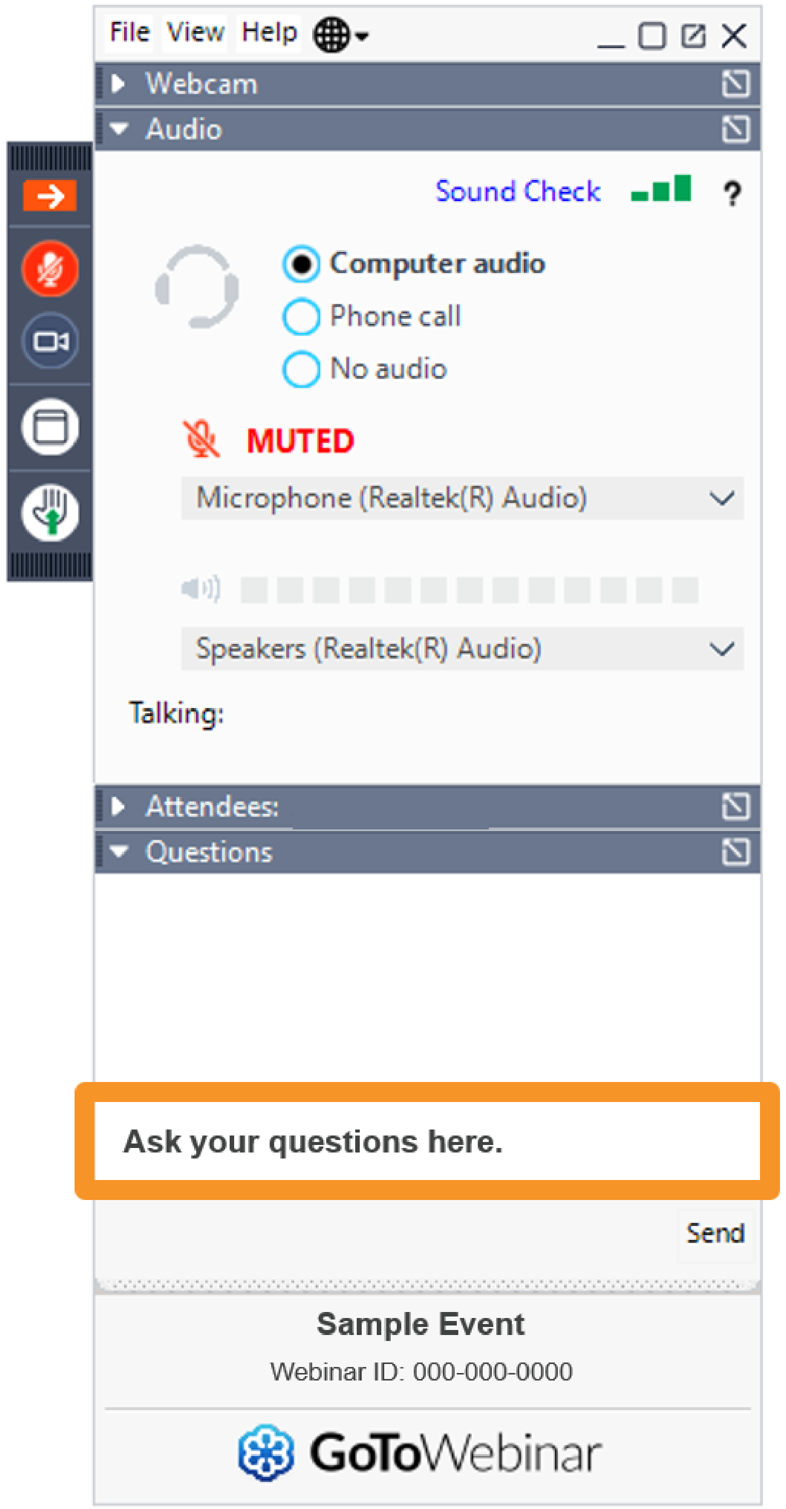
Safety

Slips, trips and falls - most common injuries are contributed to these.

- **Stay clutter-free** – Boxes, files and various items piled in walkways can create a tripping hazard. Stretching cords across walkways or under rugs can be a trip hazard too. Be sure all materials are safely stored in their proper location and cords are properly secured.
- **Step on up** - Standing on chairs, particularly rolling office chairs is a significant fall hazard. Workers who need to reach something at an elevated height should use a stepladder.
- **Maintain a clear line of vision** - Workers can collide when making turns in the hallways and around blind corners. Install convex mirrors at intersections to help reduce collisions. If workers can see who is coming around the corner, collisions are less likely to occur.
- **Get a grip** - Carpeting and other skid-resistant surfaces can serve to reduce falls. Marble or tile can become very slippery, particularly when wet. Placing carpets down can be especially helpful at entranceways, where workers are likely to be coming in with wet shoes from rain or snow.

Housekeeping

- Today's webinar is scheduled to last 1 hr including Q&A
- All participants will be muted to enable the speakers to present without interruption
- Questions can be submitted via the GoToWebinar Questions Panel at any time
- A link to slides & recordings will be emailed 72 hours after the last session in this series has concluded
  - Wednesday, June 2
- Complete polls & surveys to mark attendance for PDH credits
  - Total PDH credits for today's session: 1.0 (Live Session ONLY)
- Tell us how we did by completing the survey
  - The survey will launch after this session



Session Agenda

1	Opening	Jake Henault
2	Introduction to Steam Systems	Kyle Richard
3	Q&A	

Meet Our Experts

Kyle Richard

Strategic Account Manager
R.E. Mason

- 2004 BS Mechanical Engineering Old Dominion University
- Commercial and military nuclear power background
- Certified US Department of Energy Steam System Specialist
- Former Certified AEE Energy Manager
- Former Applications Engineer and Regional Manager at TLV Corporation
- R.E. Mason since 2013
- Natural Gas Strategic Account Manager
- RE Mason Steam Team

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Introduction to Steam Systems

Kyle Richard
R.E. Mason

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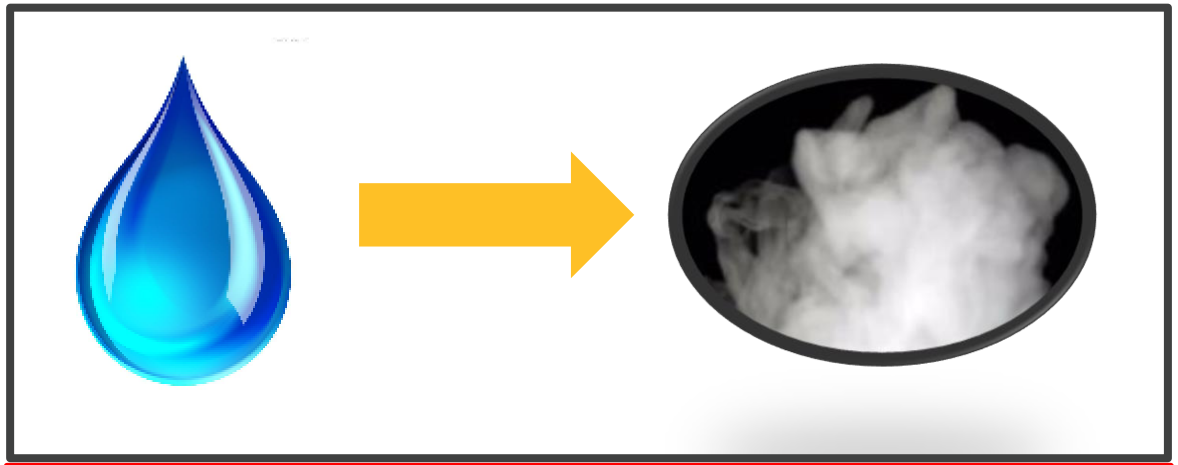
Steam Introduction

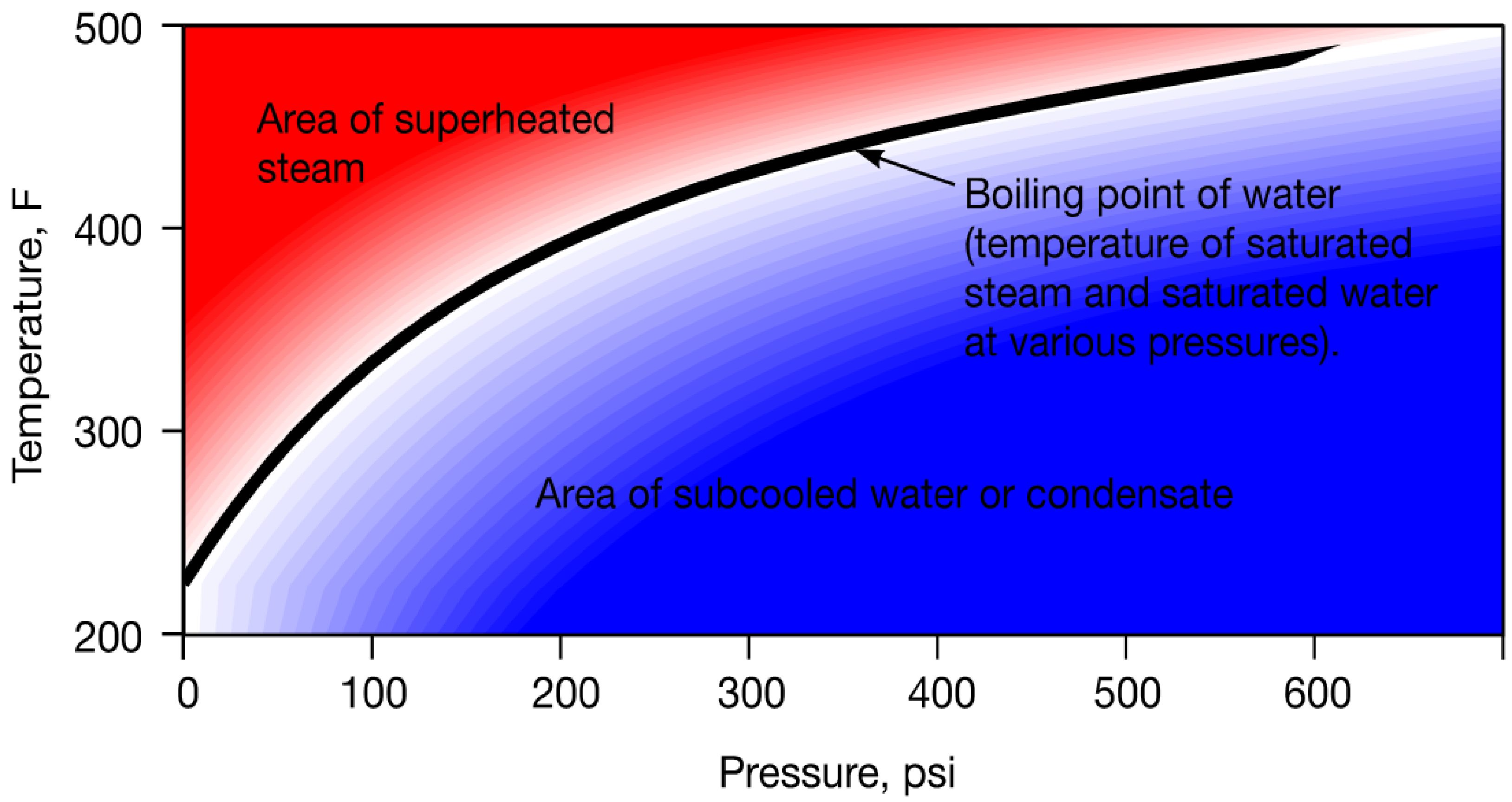
Steam Generation



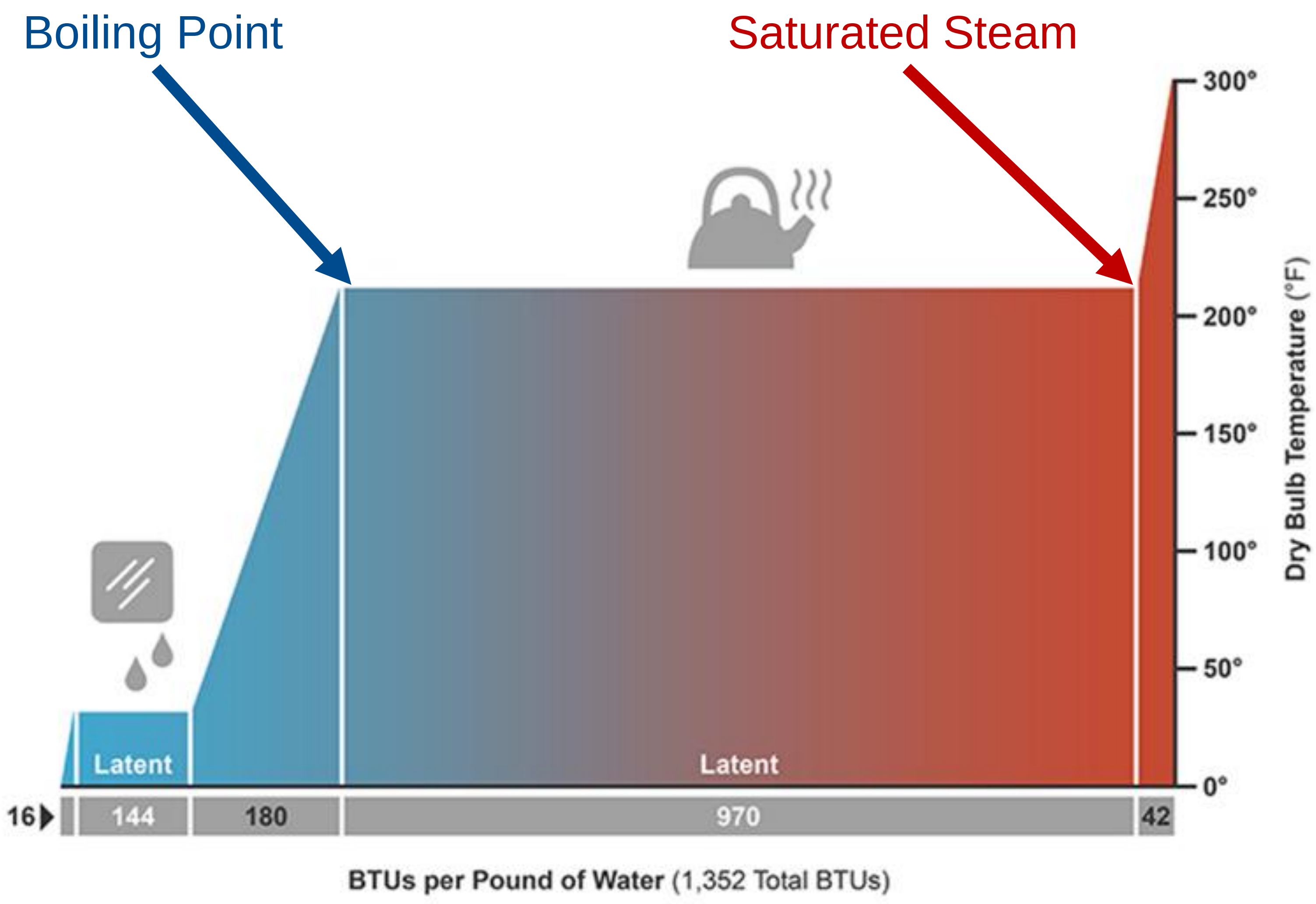
- Pressure is created through the expansion of water from liquid to gas in a container

Saturation Curve

- Graphical representation of the pressure and temperature at which saturated steam and water exist
  - *Boiling point of water increases with boiler pressure*



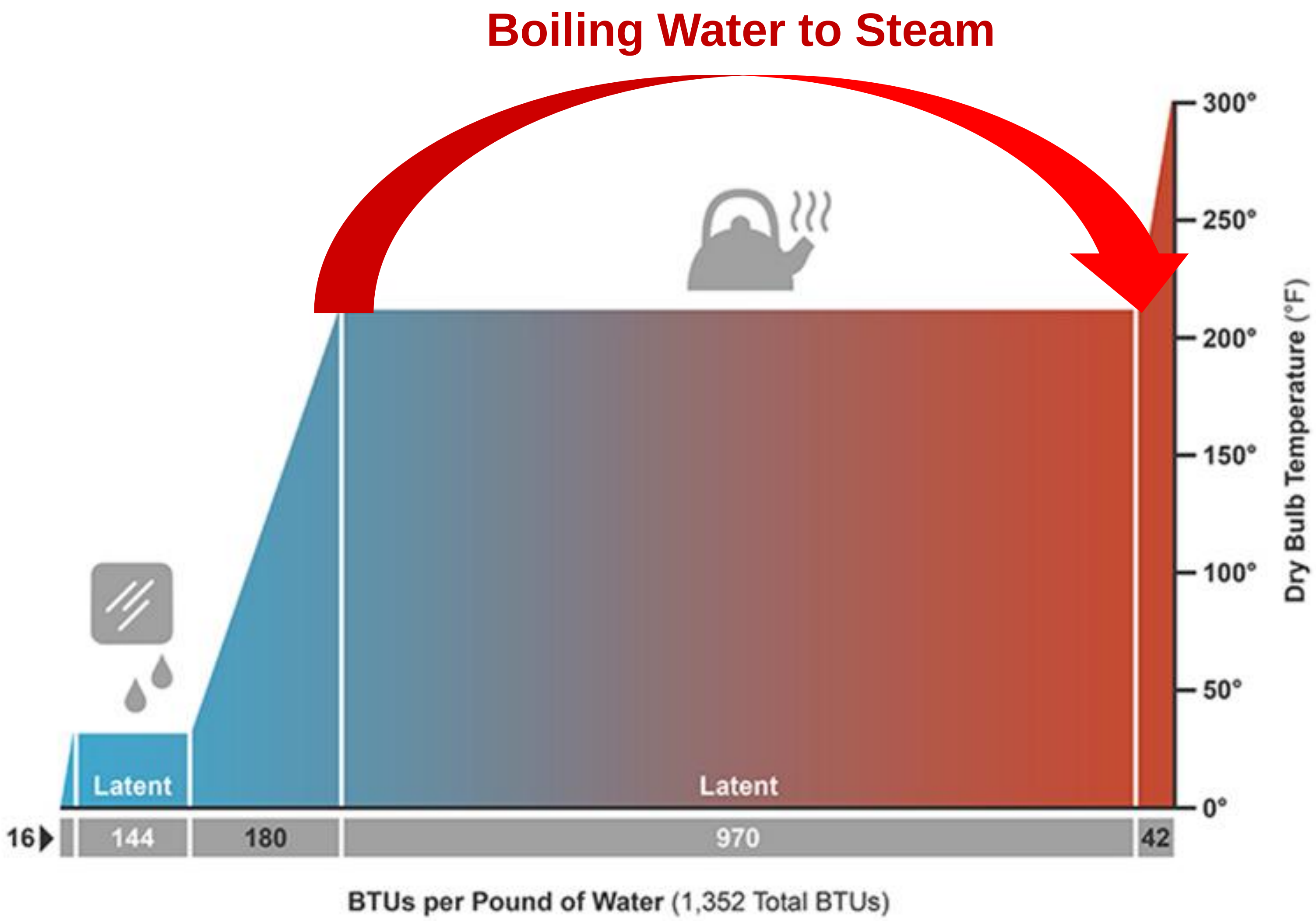
Why Steam?



Review Terms:
BTU
Sensible Heat
Latent Heat
Saturated Steam
Superheat

Phase change has higher concentration of heat compared to staying in one phase

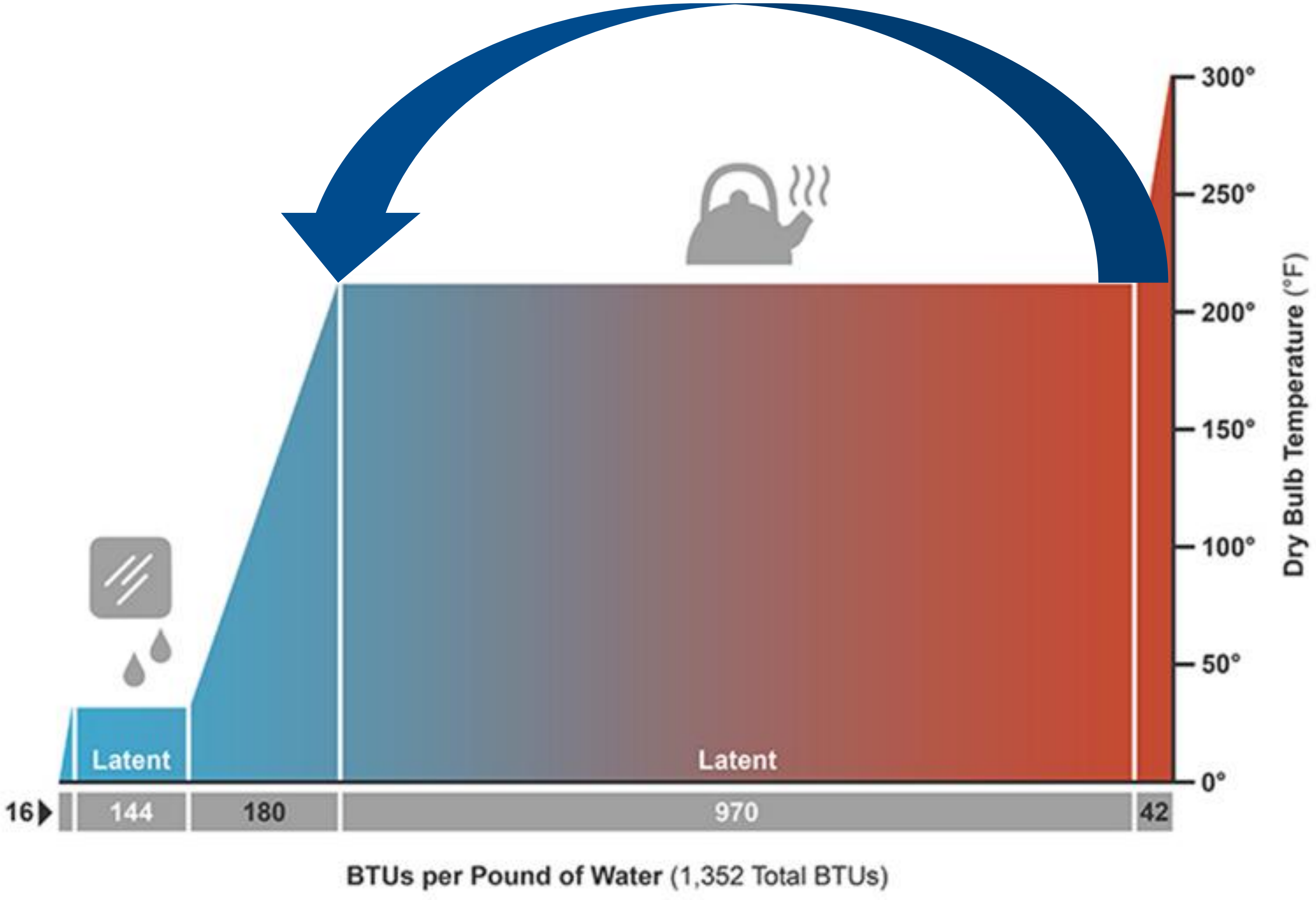
Steam Generation



Steam Generation is adding Energy in the form of Heat to Water to Change the Phase from Liquid Water to Steam

Heat Transfer

Process is absorbing energy from steam



Steam is adding Energy in the form of Heat to the Process, thus Removing Heat from Steam and Converting the Steam to Liquid Water

Saturated Steam Table

- **Key Purposes**
  - Determine saturated steam temperature at a given pressure and vice versa
  - Estimate sensible and latent heat of steam at specific temps and pressures
- Higher pressure = higher temperature or less usable latent heat energy

Press (psi)	Temp (F)	Heat (BTU per lb)		
		Sensible	Latent	Total
0	212	180	970	1150
15	250	218	946	1164
25	267	236	934	1170
50	298	267	912	1179
100	338	309	881	1190
150	366	339	858	1997
200	388	362	837	1199
300	422	399	805	1204
400	448	428	776	1204
600	489	475	728	1203

Types of Steam – Saturated Steam

Saturated Steam Overview

- Steam at temperature that corresponds to the boiling point of water (at a given pressure)
  - Only gas phase of water
- **Clear and odorless vapor**
  - Saturated steam is not wet steam
  - Steam is saturated with energy not water
- **Contains both sensible and latent heat**

Applications / Advantages

- Used for most **industrial applications**
  - Most industrial applications only use the latent heat energy of saturated steam
  - Condensate has most of the sensible energy and is returned to the boiler
- **Rapid, even heating throughout the heat transfer process**
- **Ability to control temperature by controlling pressure**
- **High heat transfer coefficient**
  - Key reason why most heat transfer applications use saturated steam instead of superheated steam

Types of Steam – Superheated Steam

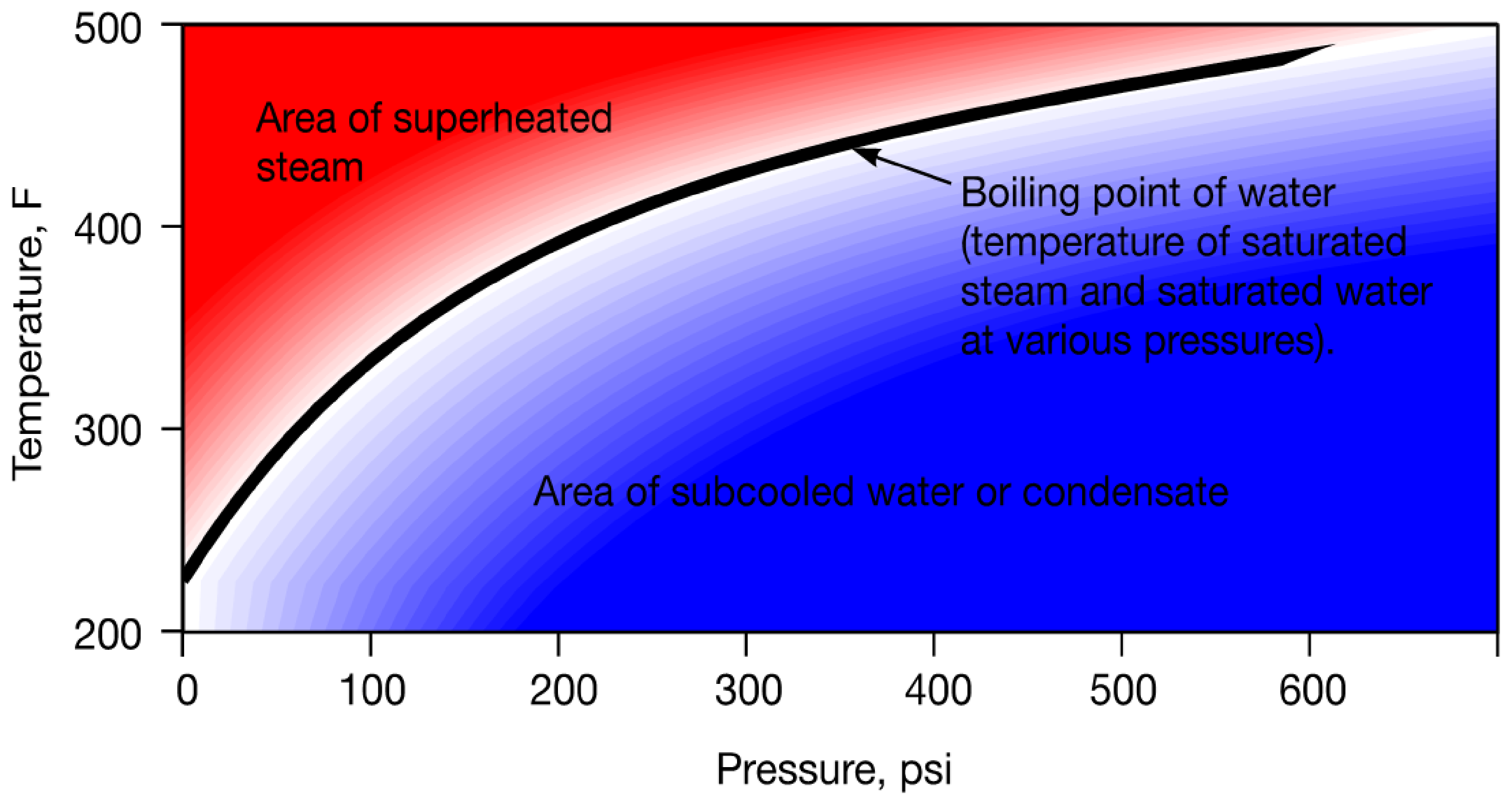
Superheated Steam Overview

- Steam at a temperature higher than its vaporization point (at a given pressure)
  - **Produced by adding more sensible energy to saturated steam**
- Higher temperature and lower density than saturated steam at the same pressure

Applications / Advantages

- Applications include **turbines, soot blowers and certain high-temperature processes**
  - Also used to remove buildup of solids on boiler tubes from different types of fuels
- No phase change occurs with superheated steam

Pressure cuts



Press (psi)	Temp (F)	Heat (BTU per lb)			State
		Sensible	Latent	Total	
200	388	362	837	1199	Saturated
15	250	218	946	1164	Saturated
15	320	253	946	1199	Superheated

Types of Steam - Flash Steam

- Flash Steam results when **condensate is discharged from higher pressure to lower pressure**
  - Condensate boils or flashes into steam because its **boiling point is instantaneously reduced when it is released to a lower pressure**

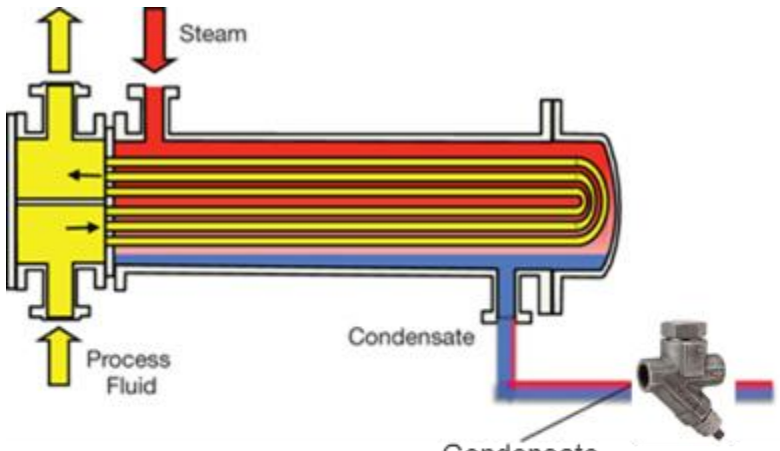
- In a well-designed steam system, flash steam is key in efficiently using steam for various applications at successively reduced pressures

- In a poorly designed steam system, flash steam can reduce the efficiency of the system
  - Saturated water at 15psi will have ~ 1600 times the volume when it flashes into steam
  - This expansion can hinder equipment drainage and steam trap performance

Experience is Required to Distinguish Live Steam From Flash Steam

Types of Steam - Formation of Condensate

- Heat is removed from steam to processes and to atmospheric losses through piping
- Once the heat is removed from the steam it will form into liquid or condensate
- Since condensate is denser than steam it falls to low points in the system

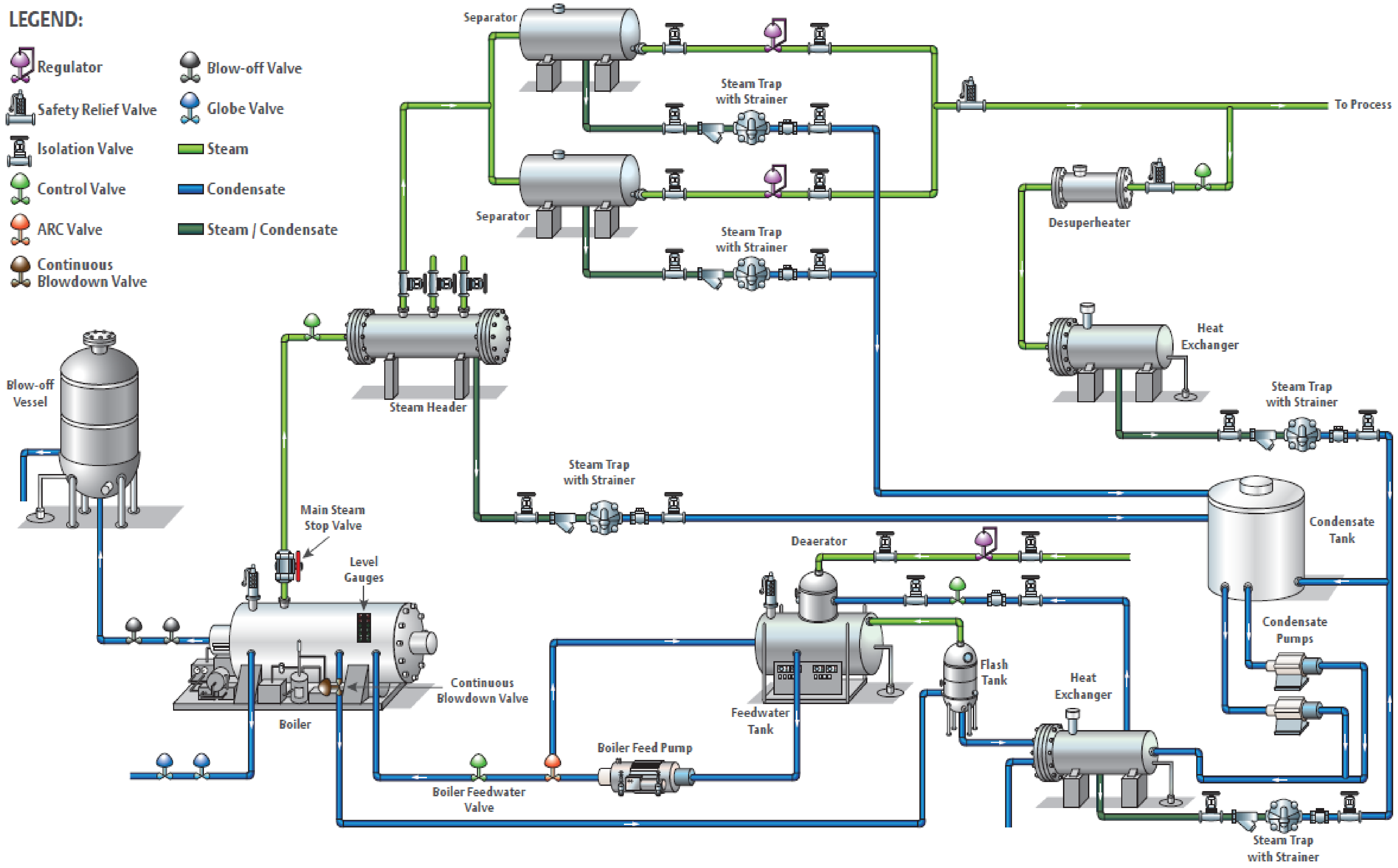


Source: AIChE

Source: Acpfoto

Condensate is Formed When the Heat Energy in Steam is Transferred to the Product, Piping or Equipment Being Heated

Steam System Overview



Steam Application Examples

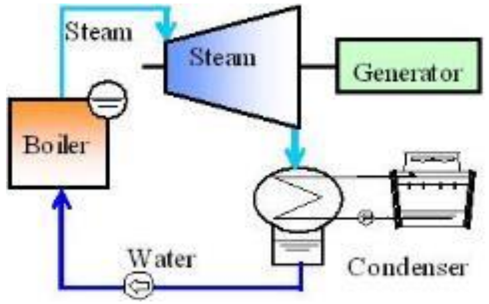
Heating

Heating source for key equipment in process plants. Applications include heat tracing, heat exchangers, reboilers and reactors

Source: Straight Line Industrial Services

Propulsion

Driving force for steam turbines used in power plants. Steam also used for turbine-driven compressors or pumps



Atomization

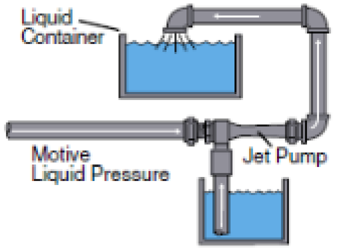
Process used to reduce a fluid to minute particles / mist e.g. break fuel oil in steam boilers into mist to improve combustion efficiency

Source: ResearchGate

Other Applications

Moisturization – add moisture to a process (e.g. paper production to prevent tearing)

Motive Fluid – high pressure fluid that is used to produce flow of another fluid



Steam is Used for a Wide Range of Applications in Various Industries

Steam Generation Overview

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Emerson Impact Partner

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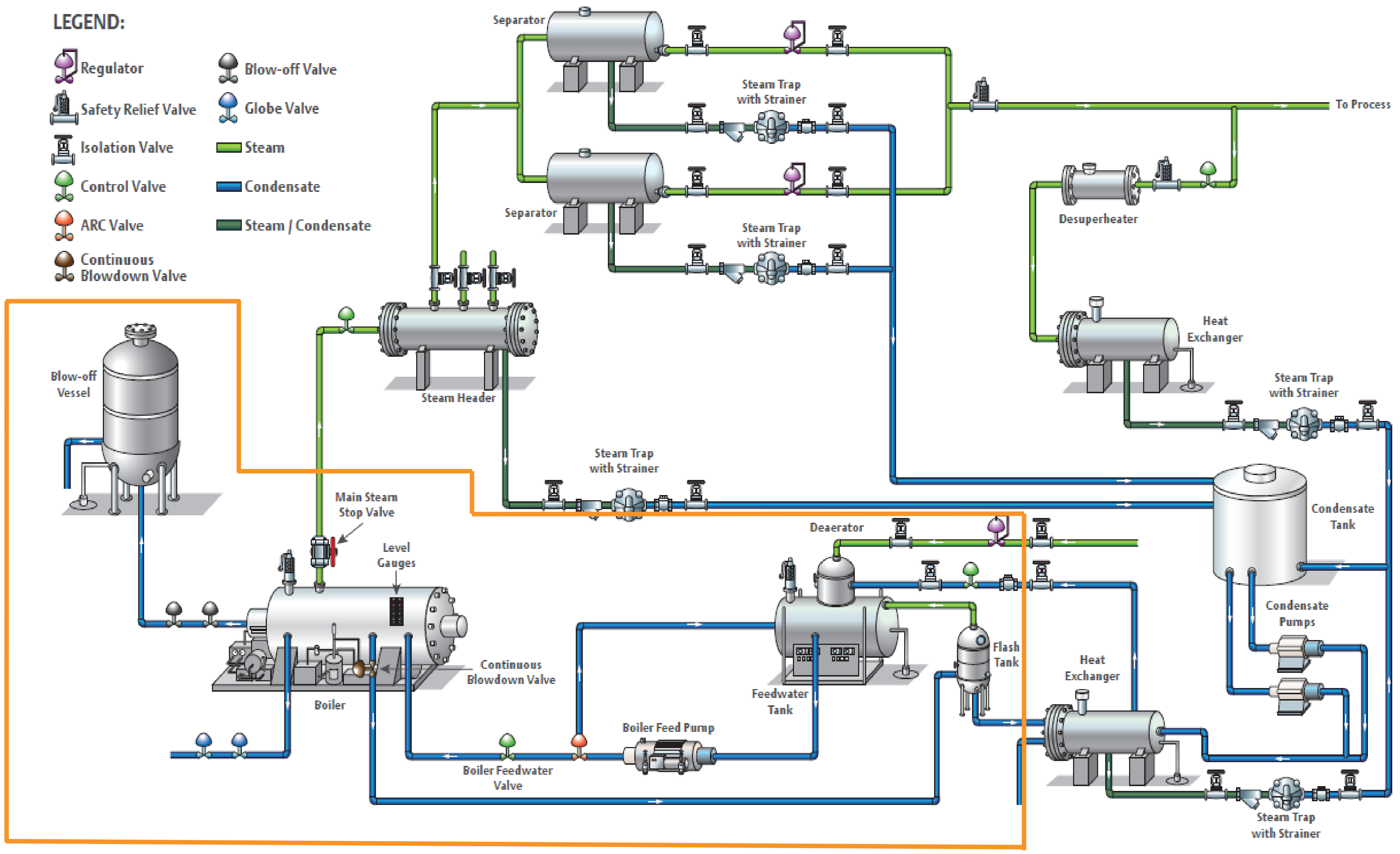
Steam Generation Introduction



Steam is generated in a boiler or a heat recovery steam generator by transferring the heat of combustion gases to water. Under pressure, the steam then flows from the boiler or steam generator into the distribution system. Condensate can be recovered and returned to the boiler to improve energy efficiency.

Boiler System Overview

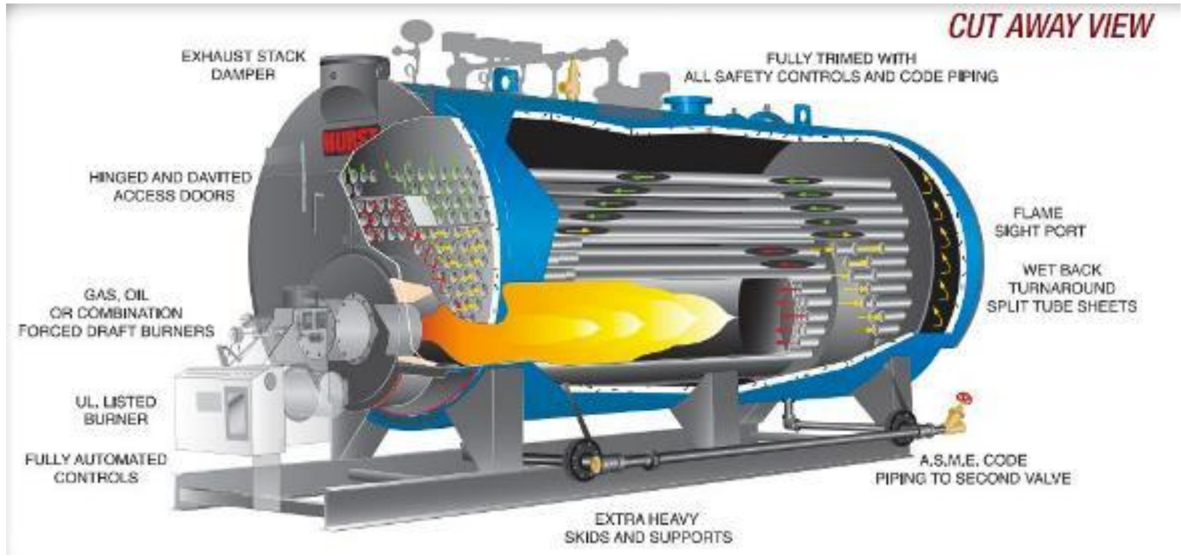
Boiler

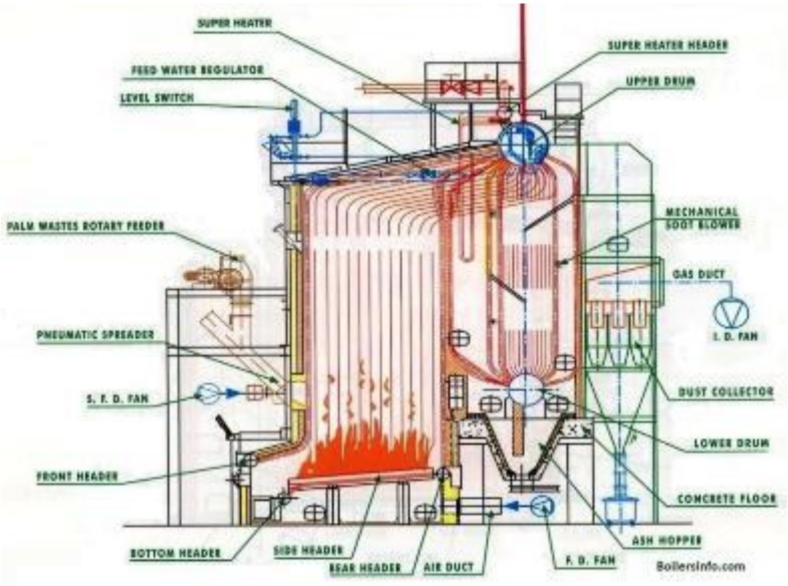
Overview

- Pressure Vessel designed to heat water and convert it to steam
- Heat is supplied by burner that uses fuels like natural gas, coal or oil

Key Operating Facts

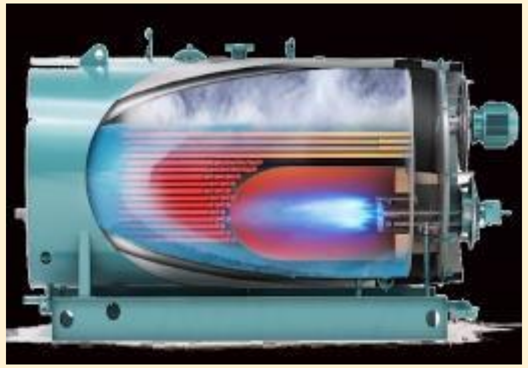
- Water pressure must be monitored and controlled for safe operation
- Water quality is critical for effective operation of boiler and downstream equipment





Boiler Types: Fire-Tube Boilers

Fire-Tube Boiler

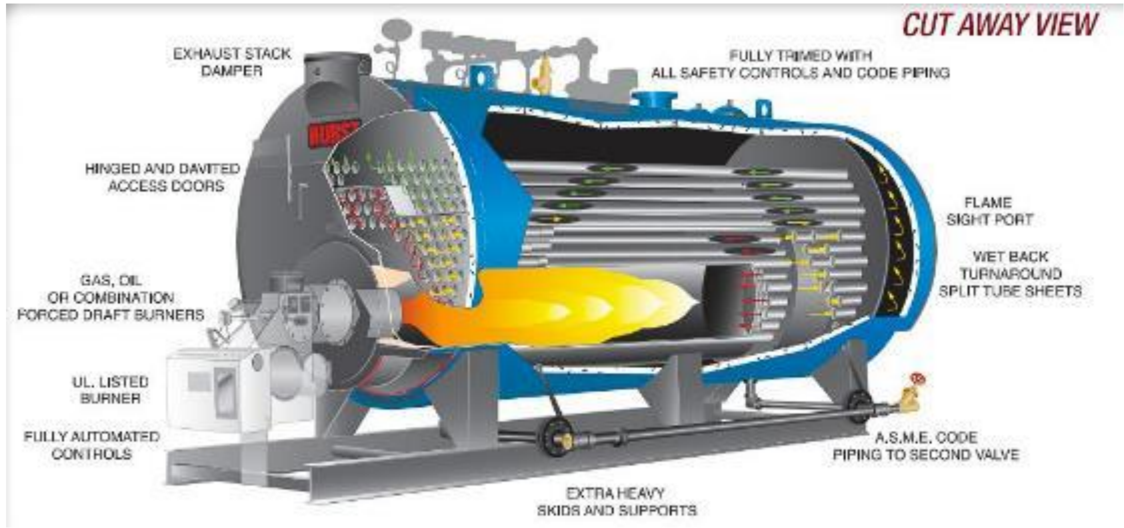


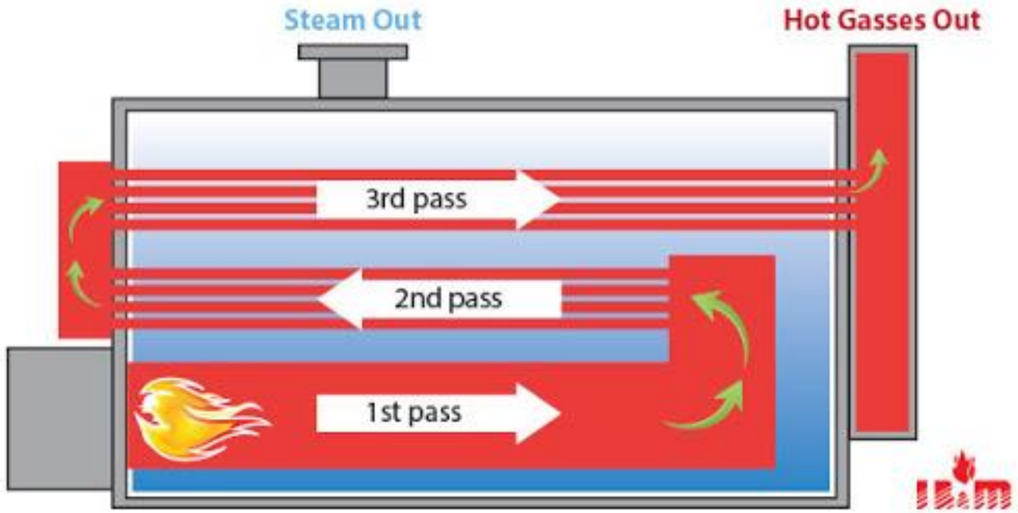
Overview

- Heated gases pass through a series of tubes to heat water contained in the vessel
- Large Quantity of water resulting in slow change to response of heating

Key Facts

- Pressures 400 psig or less (commonly 250psig or less)
- More economical for smaller operations due to increased heating surface





Boiler Types: Water-Tube Boilers

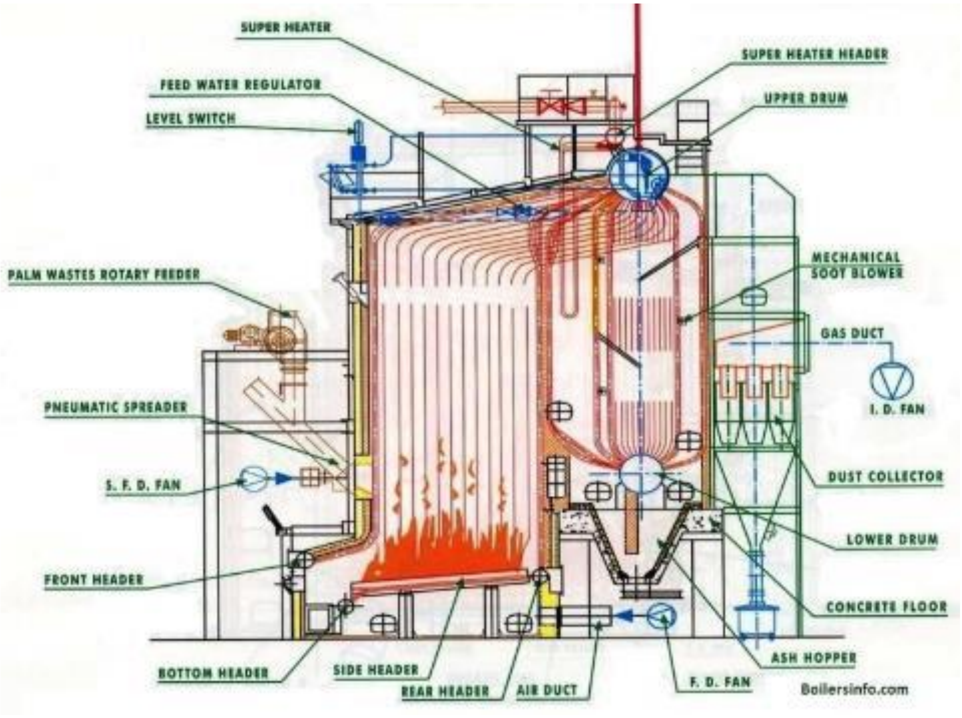
Water-Tube Boiler

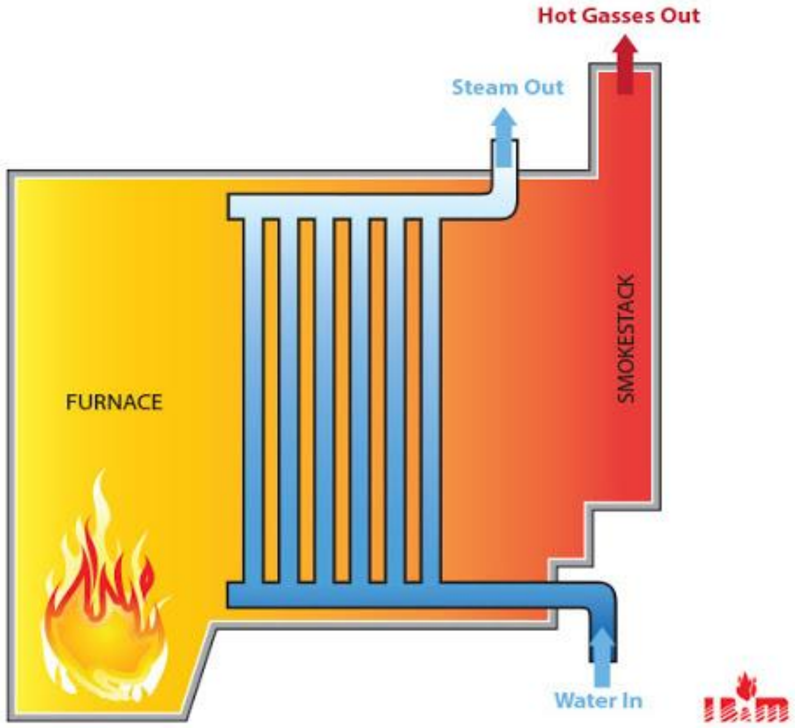
Overview

- Heated gases surrounds a series of tubes to heat water contained in the tubes inside chamber of the vessel
- Small Quantity of water resulting in quicker response to heating water

Key Facts

- Pressures up to 5000 psig
- Larger and more expensive designs
- Easier to create Superheated steam





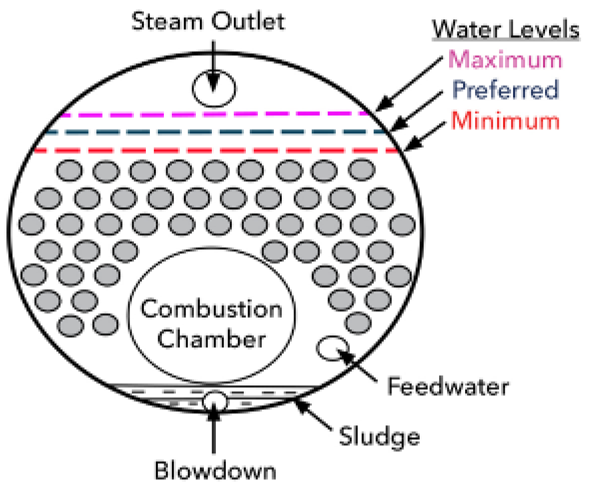
Boiler Operation Critical Components for Safety and Efficiency

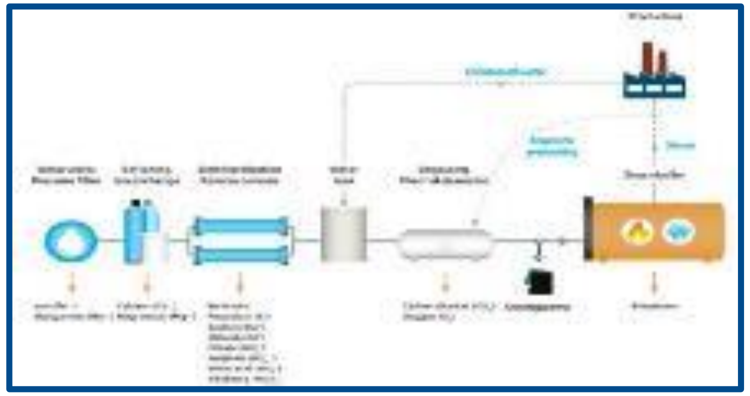
Overview

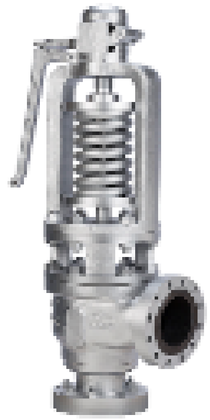
- Pressure Vessel designed to heat water and convert it to steam
- Types include fire-tube and water-tube
- Multiple variables incorporated to ensure safety and efficiency

Key Operating Facts

- Water level and boiler pressure must be monitored and controlled for safe operation
- Water quality is critical for effective operation of boiler and downstream equipment







Water Level and Quality and Boiler Pressure are Critical for Safe, Effective Steam Generation

Steam Distribution Overview

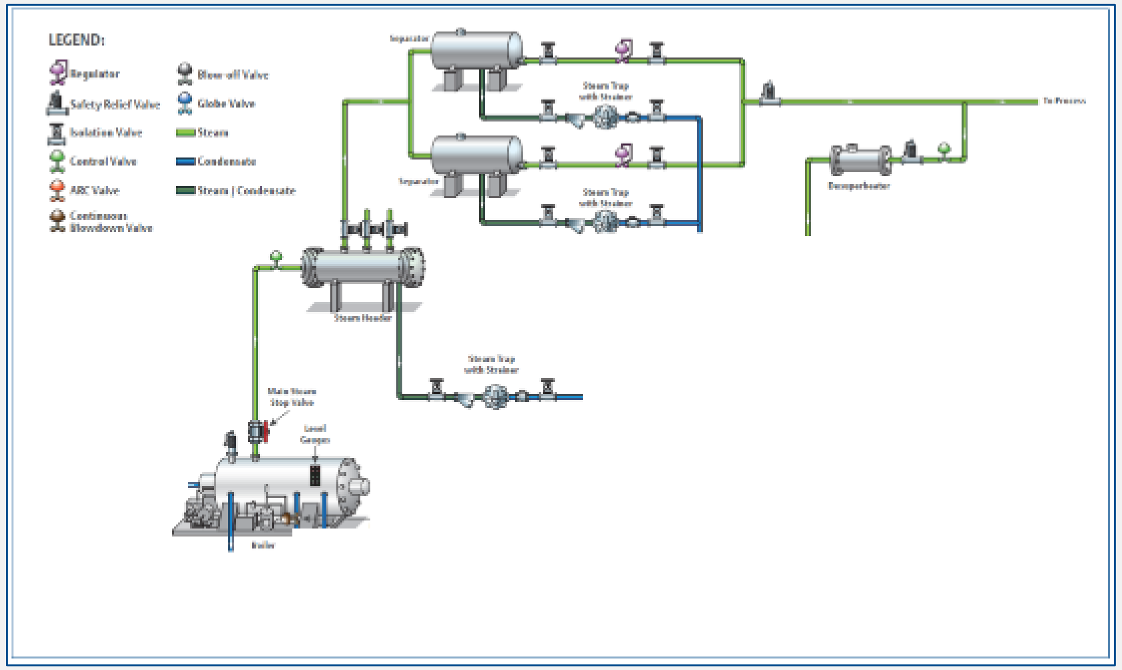
Steam Distribution System Architecture

System Components

- Piping
- Drip legs
- Insulation
- Headers
- etc.

Valves

- Isolation Valves
- Control Valves
- Regulators (Pressure and Temperature)
- Separators
- Steam traps
- Air vents
- Strainers
- Desuperheaters



Key Steam System Components - Distribution

Steam Header

Overview

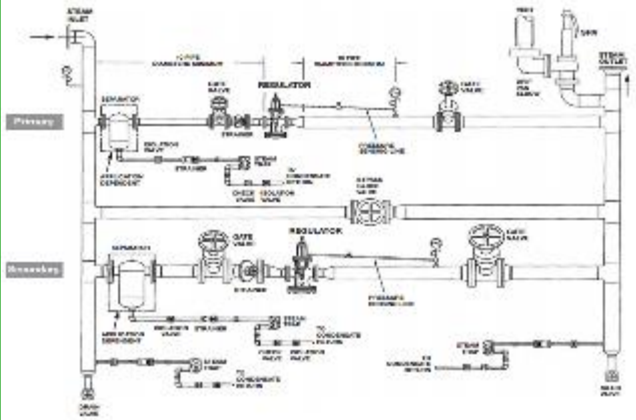
Main connection point for receiving steam from one or more boilers and distributing steam to downstream equipment.

Condensate must be removed from the header as soon as it forms. A drip leg and steam trap should be installed at the end of the header to prevent water hammer.

Pressure Reduction

Overview

Pressure Reducing Stations reduce high-pressure steam from the boiler to lower pressures required at the point of use.

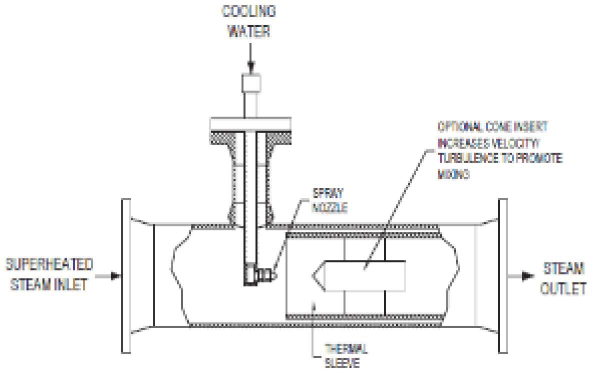


Pressure regulators or control valves are typically used to lower the steam pressure.

Desuperheater

Overview

Desuperheating is the process used to restore superheated steam to its saturated state or lower temperature.



Steam conditioning solutions typically include a control valve for pressure reduction and a desuperheater for temperature control.

Steam Distribution – Piping Overview

- Steam distribution piping must be **engineered to ensure that steam is transferred from the boiler to the end-use applications efficiently**

- Suboptimal piping layout can decrease efficiency and create safety issues

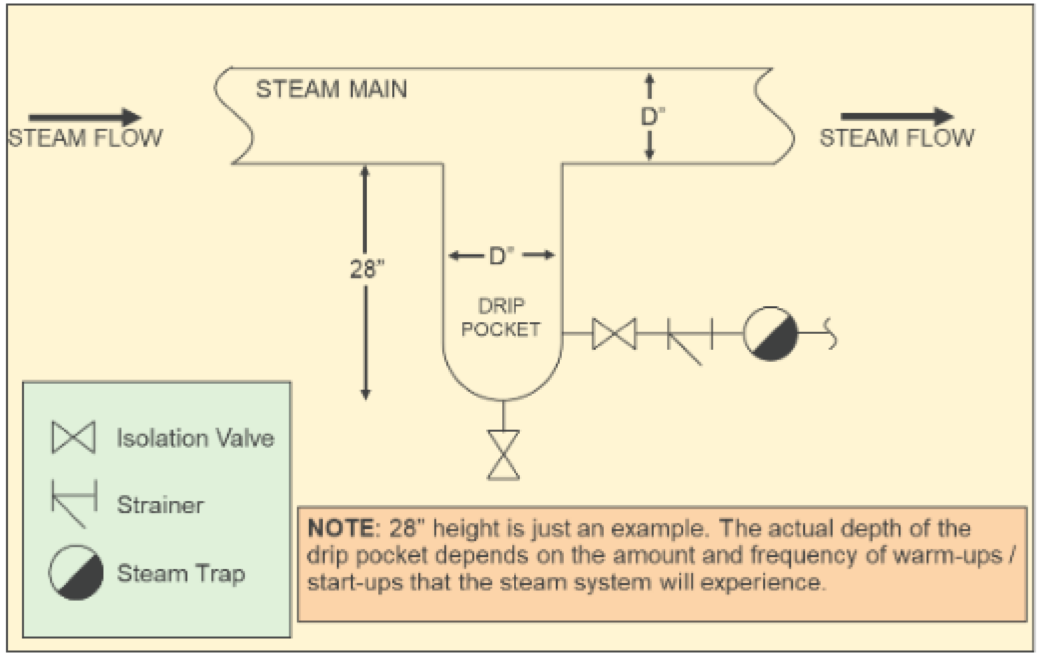
- Key piping factors that affect efficiency are:
  - **Areas to remove condensate**
  - **Branch lines**
  - **Slope**
  - **Trajectory**
  - **Size (diameter / thickness)**

Source: depositphotos

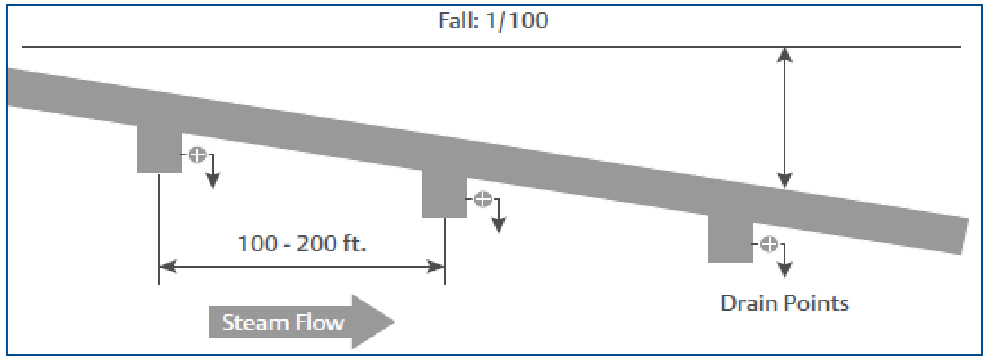
Steam Distribution Piping Must be Designed for Efficiency

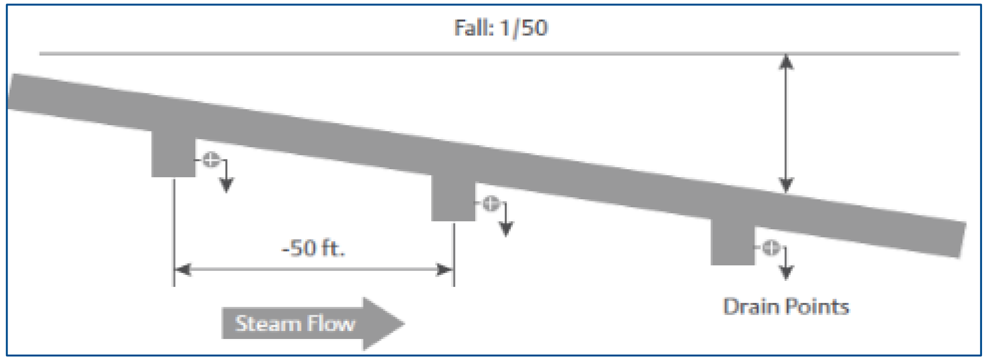
Steam Distribution – Condensate Removal

Drainage Points "Drip Leg"



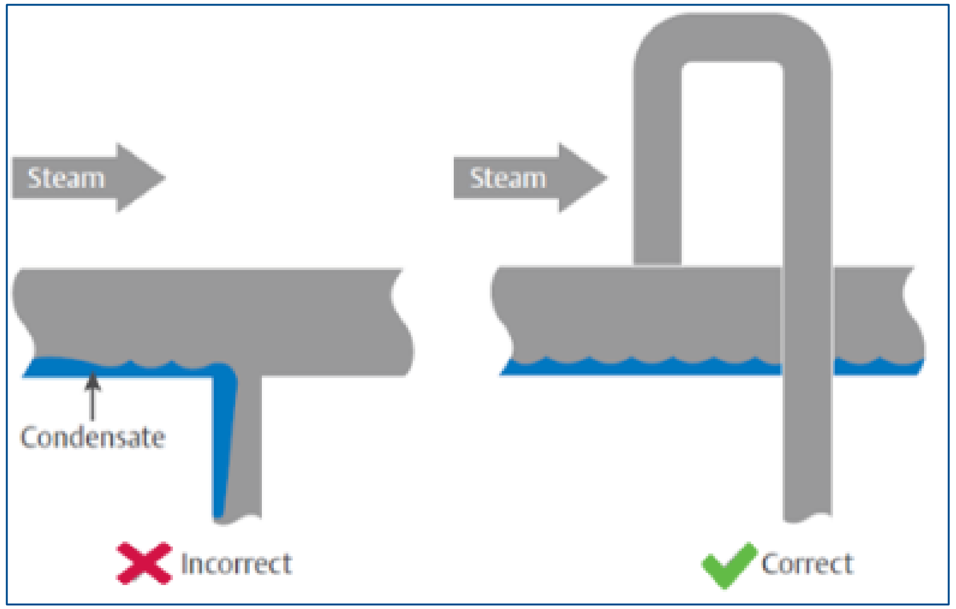
Sloping and Drainage Spacing

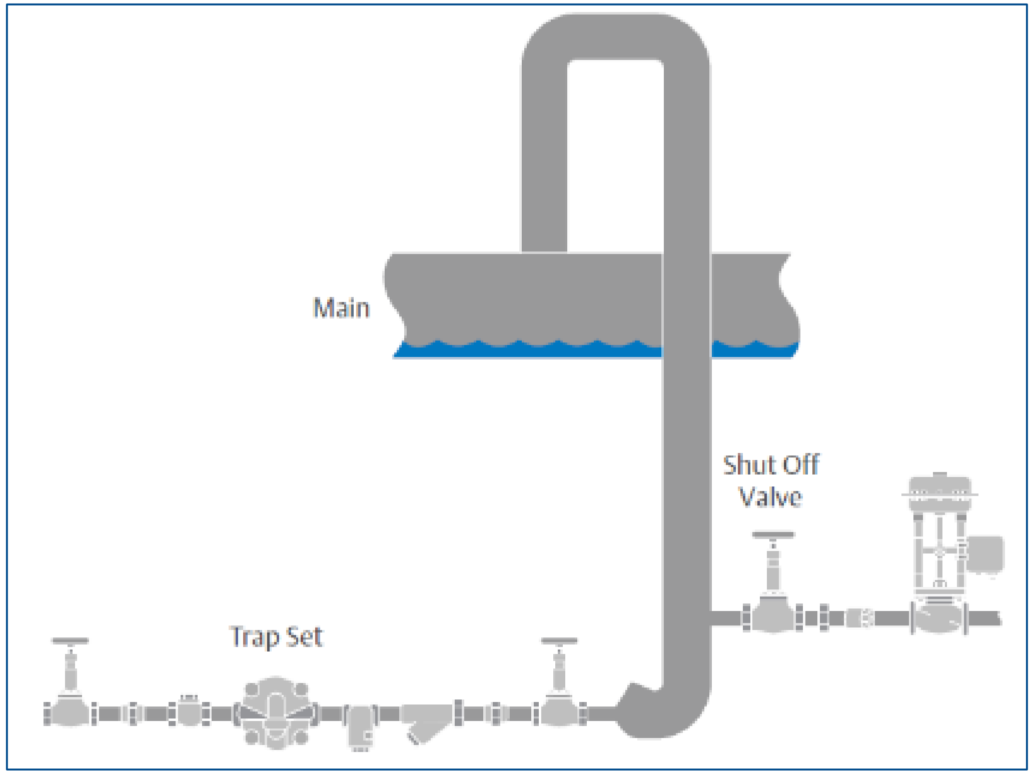




Steam distribution piping must have proper drainage points to remove water

Branches for Steam Distribution





Water will run to the bottom of pipes, thus the need to take steam from the top of steam piping to distribute without taking condensate

Steam Distribution – Pipe Size

Correct diameter piping ensures the pipe can withstand steam pressure and temperature

- Less chance of water hammer, optimal capacity, and lower heat loss
- Size for current and future needs
- Size for proper velocity at operating pressure

Oversized Piping	Undersized Piping
• Greater Heat Loss • Higher Cost • Greater amounts of condensate formed	• Higher Pressure Drops • Not enough Steam • Greater risk of water hammer

Source: Midway Structural Pipe and Supply

Source: agoodsteel.com

Steam distribution piping must be sized properly for the steam needs of the facility

Steam Distribution – Expansion

- Increases / decreases in temperature will cause the pipe to expand / contract
- Thermal expansion joints within a distribution system allow the pipe to expand and prevents:
  - Leaking
  - Cracking
  - Rupturing
- Three main thermal expansion joint types
  - Slip
  - Bellows (normally indoors)
  - Loop

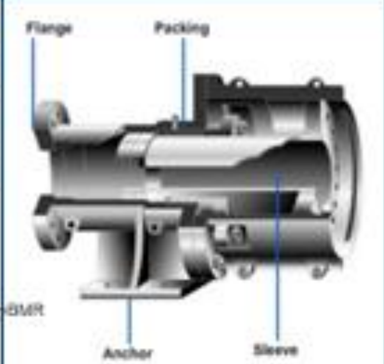
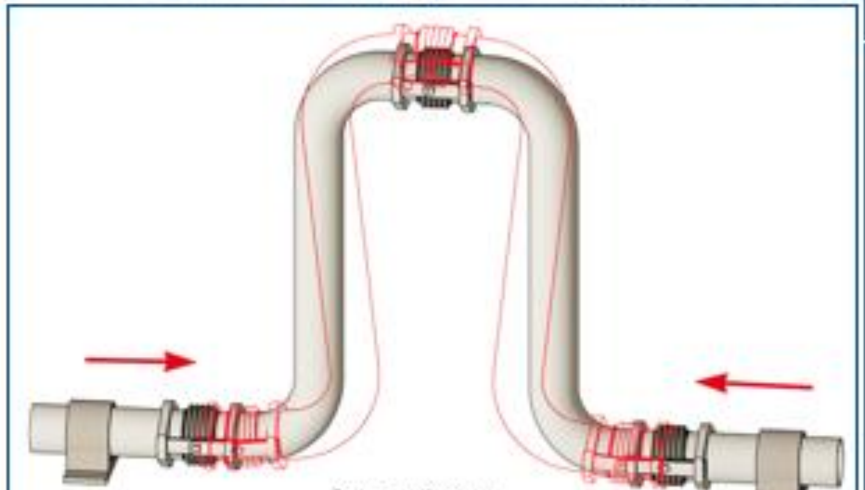


Figure 10-24 — Slip-type expansion joint.



Source: terrylove.com

Figure 10-25 — Bellows-type expansion joint.

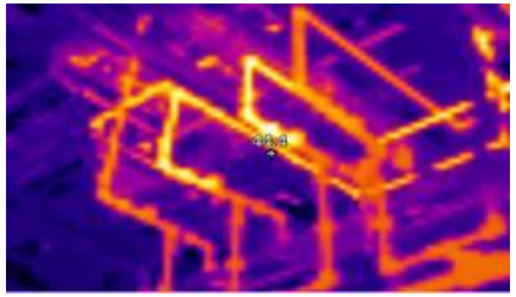
Source: NavyBMR

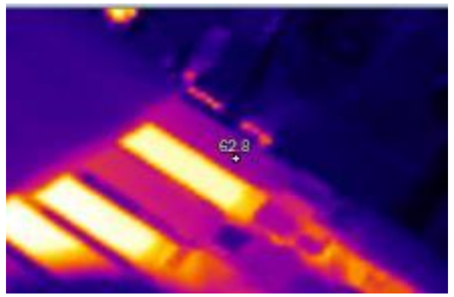
Steam distribution piping must be allowed to expand with changes in temperature

Steam Distribution – Thermal Insulation

Overview

- Steam distribution piping temperature will always be slightly lower than actual saturated steam temperature; however, it is typically much higher than the temperature of the environment which results in continuous heat loss to atmosphere.

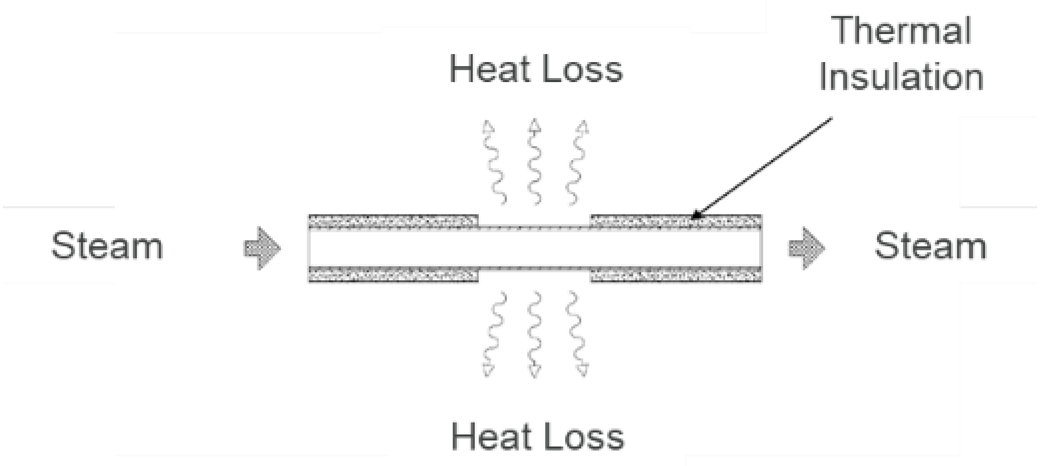




Exposed hot surfaces represent heat losses and pose safety risks!

Benefits

- Steam distribution piping must be insulated to reduce the risk of burns for people working near steam pipes. Insulation also improves efficiency by reducing thermal energy loss to atmosphere.

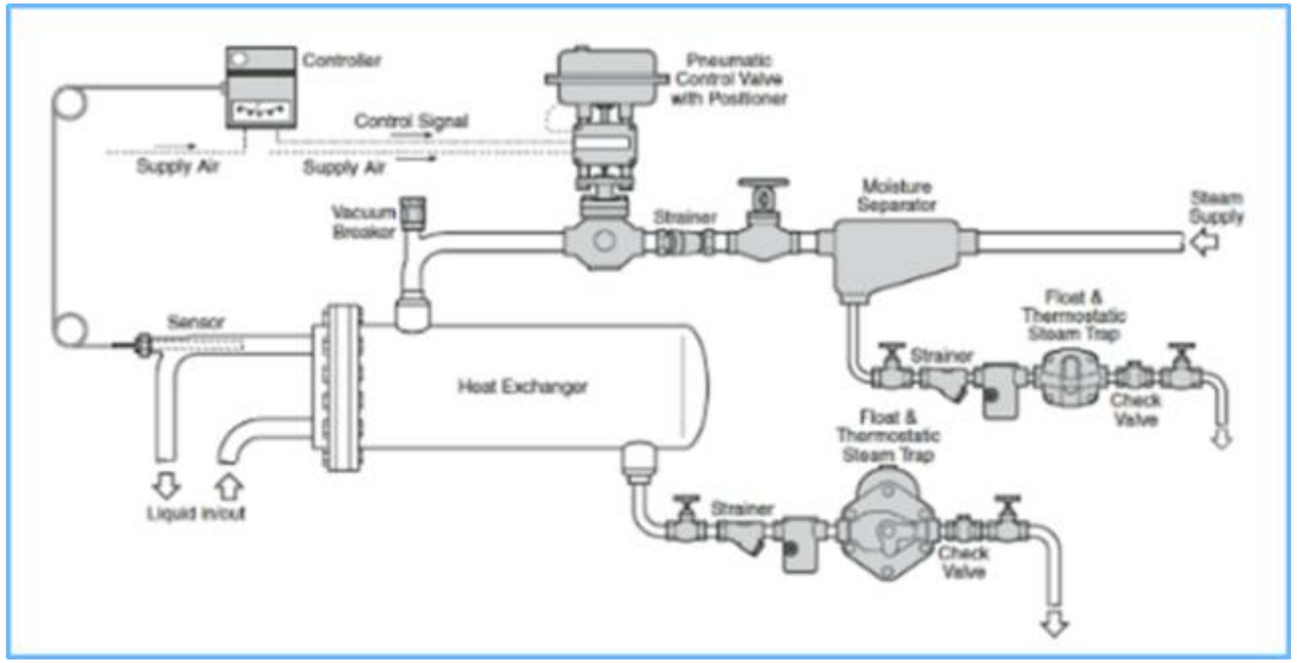


Key Process Applications

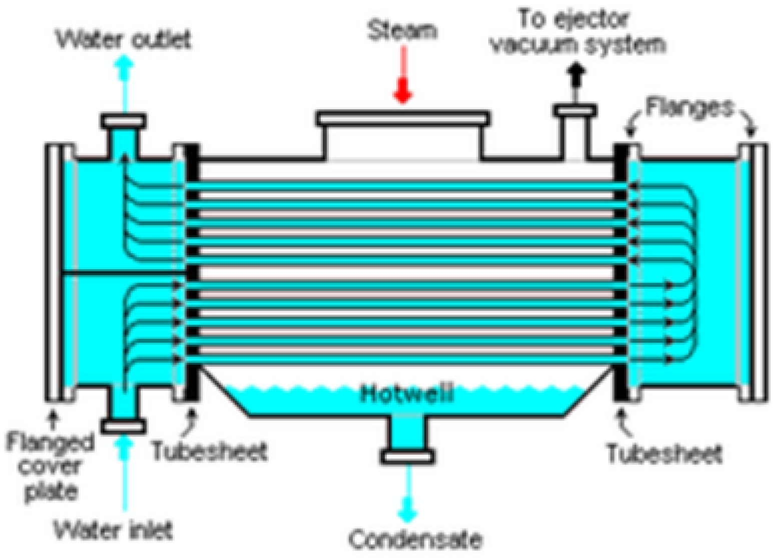
Process Applications

Continuous		Batch
Stable +P For processes with continuous steam supply, the internal pressure has minimal variation and always exceeds atmospheric pressure (or back-pressure).	**Varied P** Processes with a controlled steam supply can have wide pressure swings. In some cases, the steam pressure drops below atmospheric pressure.	**Batch** The steam supply for batch processes can either be direct or controlled. Fluctuating condensate load changes are typical. Non-condensable gases are sometimes present.
		
Hot Tanks	Water Heating Systems & Pasteurizers	Cooking Vats, Reactors & Distillers

Generic Process Application – Heat Exchanger



Source: C&S Companies



Steam System Challenges / ASME Code

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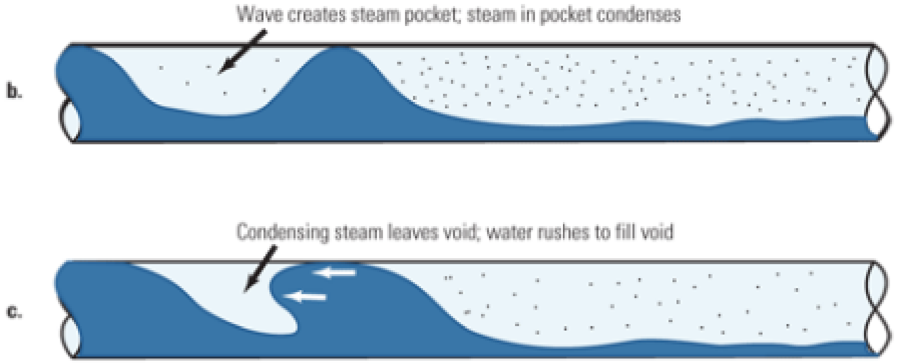
Common Challenges in Steam Systems

- **Water Hammer** – pressure surge created by a sudden change in fluid motion
  - Condensate collects in the low points of a steam system
  - Steam flowing through the main pipe at high speed can pick up slugs of condensate and slam them into valves, elbows, steam traps or other equipment



Source: Power Magazine


Source: 3Phase Power Systems

- **Air** – reduces efficiency of steam systems because it is a poor conductor of heat
  - Removed from boilers and steam systems by using thermostatic air vents and steam traps
- **Freezing** – steam lines that have been shut down and condensate return lines with low flow are susceptible to freezing
  - Certain steam trap designs are more susceptible to freezing
  - Tracing can be used to protect equipment from freezing

Common Challenges in Steam Systems

Common Challenges in Steam Systems

- **Gases / Corrosion** – Carbon dioxide and oxygen are present in steam systems and must be removed to minimize corrosion
  - Corrosion affects boiler tubes, steam mains, heat exchangers, valve components and fittings such as steam traps
  - Boiler feedwater treatment system that controls the gases (oxygen and carbon dioxide) is key to minimizing corrosion

Source: Valve Magazine

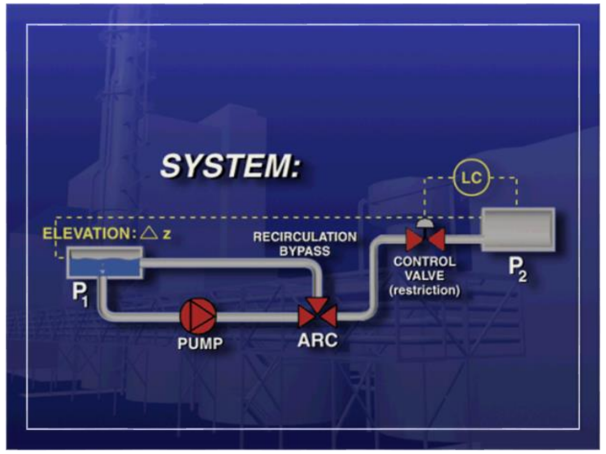
Source: Wilhelmson

- **Dirt** – debris accumulates in steam systems over time and must be removed to minimize the probability of valve damage
  - Debris can also cause sluggish flow in condensate return lines which can result in freezing

Common Challenges in Steam Systems

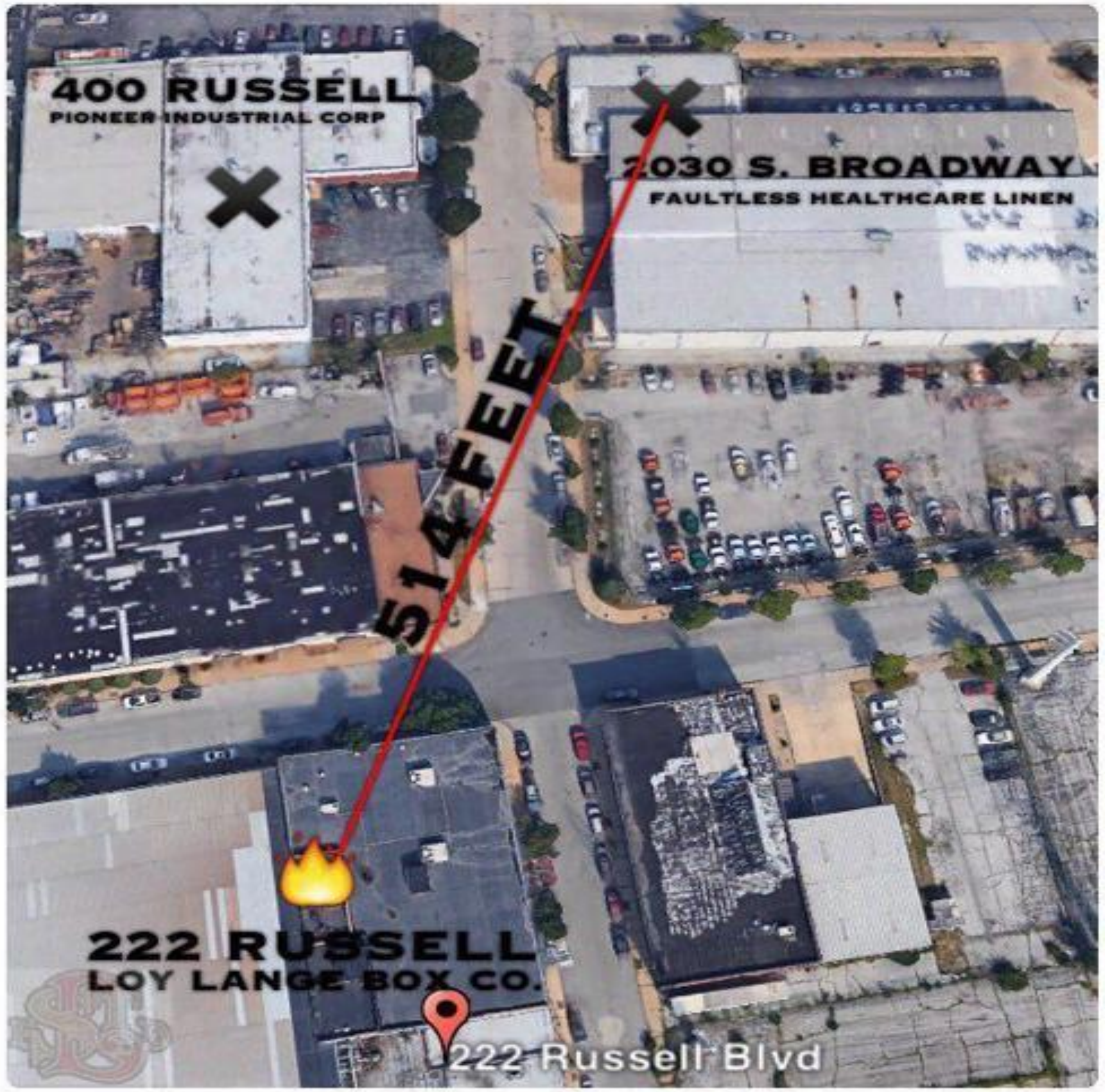
- **Cavitation** - In condensate pumps, when condensate pressure drops below saturated steam pressure, vapor cavities formed from flashing obstruct the impeller rotation and reduce the pumping efficiency. The impeller and pump casing can be damaged when the vapor cavities condense and implode.
  - Cavitation can also occur in boiler feed pumps
  - Yarway ARC Valves provide the minimum flow required for pump protection

Source: Flow Control Network

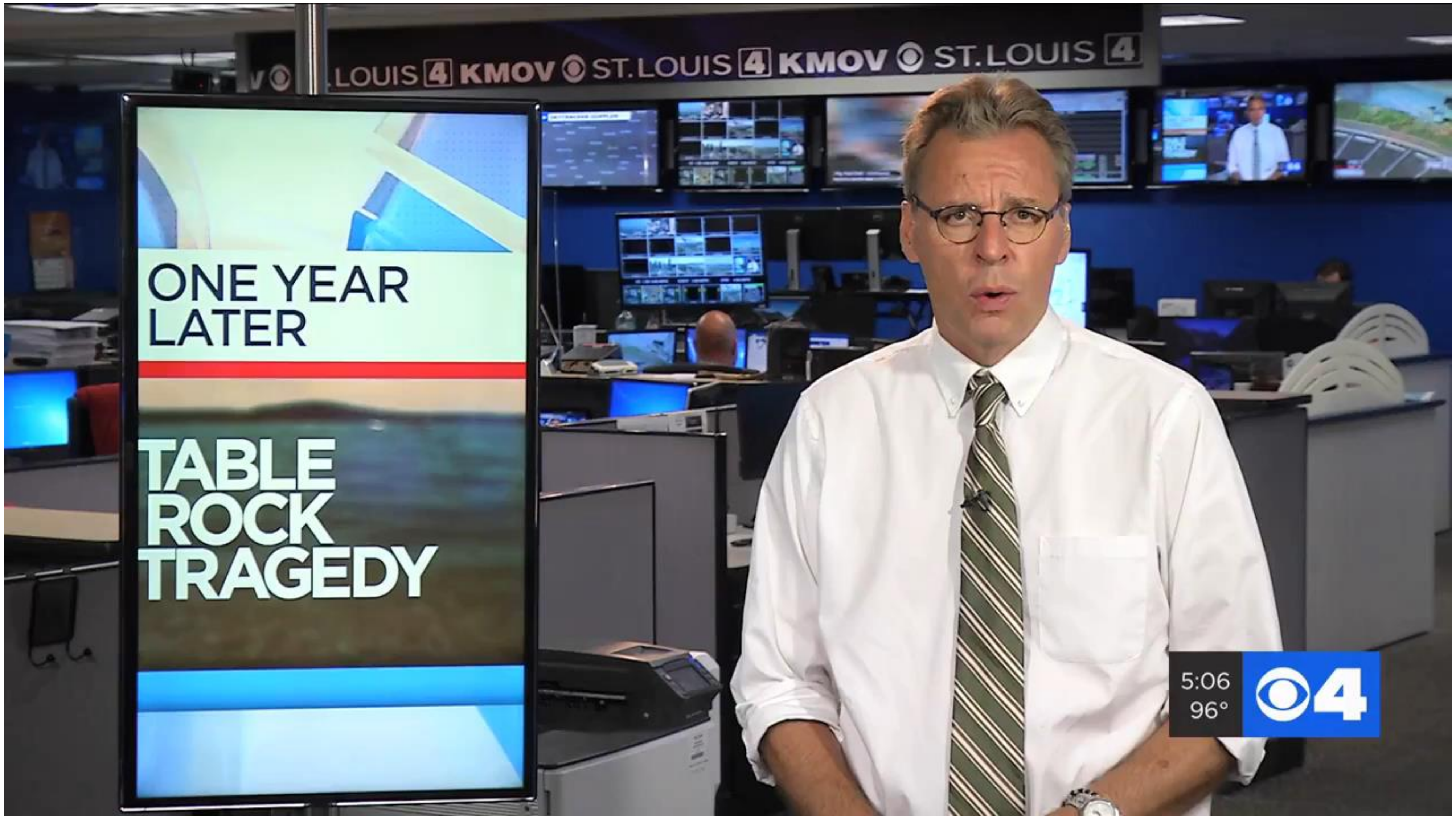


- **Safety** – Understanding key codes is critical for safe operation of steam systems
  - Explosions and severe injury can result from unsafe steam practices

Boiler Explosion Examples



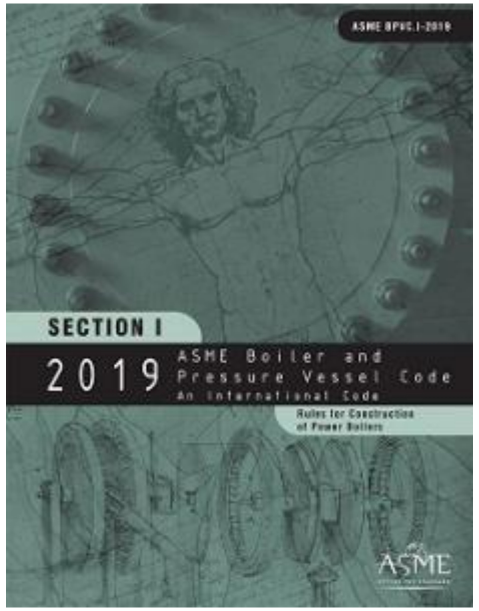
St. Louis Boiler Explosion



ASME Code

- Boilers have been used since the 1700s with many instances of boiler failures
  - Major boiler explosion in 1905 triggered action to make boilers safer
- ASME Code introduced in 1915
  - 1815-1915 – nearly 70 major, recorded instances of boiler failures
  - 1915-Present – less than 30 boiler failures with only 6 since 1980
- **ASME Code**
  - Includes rules for construction of **power boilers, electric boilers, miniature boilers, and high-temperature water boilers**
  - **Scope includes the boiler and all boiler extended piping,** such as:
    - Safety Relief Valves
    - Level Gauges
    - Blowoff / Blowdown Valves
    - Isolation Valves

Source: Wikipedia



ASME code covers many components in steam systems to ensure safety for everyone involved

Key Takeaways

1. Saturated steam temperature is related to its pressure

2. Condensate always finds its way to system low spots

3. Address condensate buildup by eliminating low spots or install appropriately sized drip pockets.

Quiz

Please take a moment to answer the 2 questions about to pop up on your screen.

Reminder: This also serves as an attendance requirement for PDH credits.

Thank you.
Questions?

Reminder: Questions can be submitted via the GoToWebinar Questions Panel

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