

Optimizing Patient Outcomes Through Steam System Reliability

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Agenda

- Steam Fundamentals
- Generation and Distribution Considerations
- Hospital Applications
 - Domestic Hot Water
 - Sterilization
 - Maintenance of steam systems
- Questions

Why Steam?



Flows naturally

without need
for pumps



Efficient heat transfer

Can be applied onto
heating surfaces or directly
onto product



Natural Water Cycle

Leaves only water for
recovery and reuse



High energy density

enabling effective transfer of
large quantities of energy



Precise temperature control

Easy management of
steam temperature through
pressure control



Smaller infrastructure

Minimise valuable
process space



**NATURAL
TECHNOLOGY**

STEAM IS A NATURAL TECHNOLOGY

IT IS ESSENTIAL FOR CRITICAL APPLICATIONS.
THE ONLY BY-PRODUCT IS WATER.

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Why Steam?

Steam has 50x more energy per pound

	BTU/LB
Water 140 - 180F	20
Water 160 - 190F	36
Steam at 15 psig	947
Steam at 15 psig and condensate down to 60F	1147

5MW of thermal energy using LTHW would require 200mm pipes (flow and return)

Steam at 7 barg would be typically 150mm with 80mm condensate



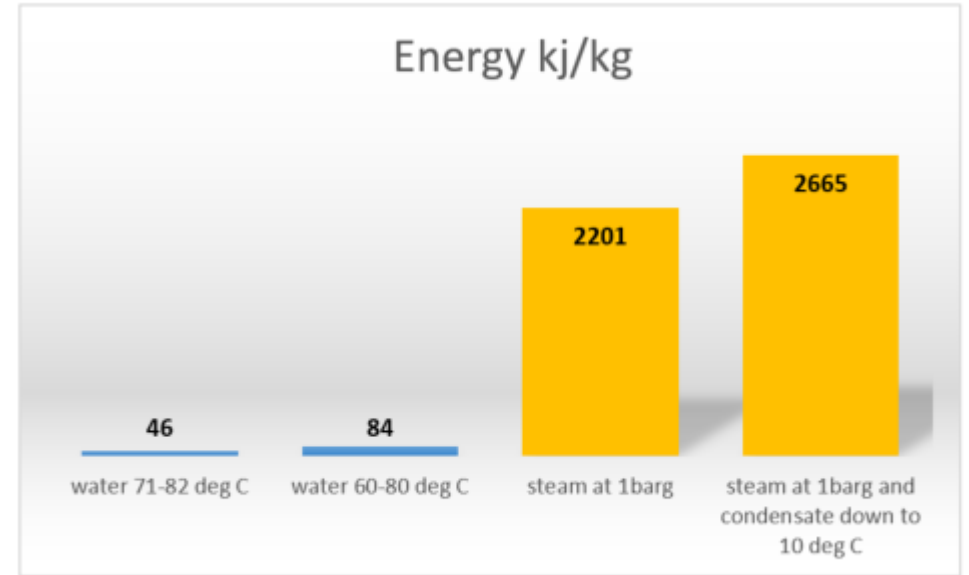
Water – flow and return same size



Steam – Flow smaller, with even smaller condensate



Size to scale

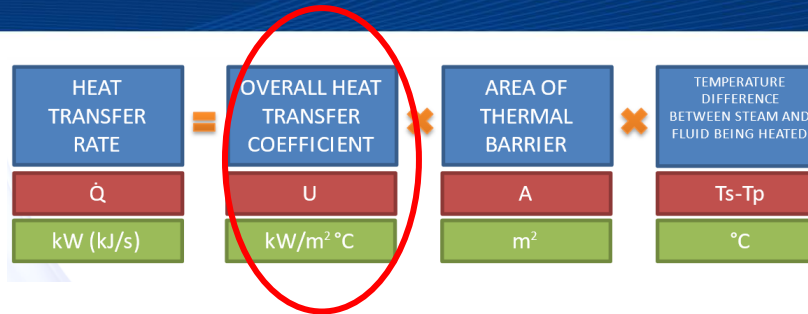


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Steam Efficiency – High Coefficient of Heat Transfer



Speed of heat transfer is 3 x greater than water

Typical overall coefficients

Shell and tube exchangers

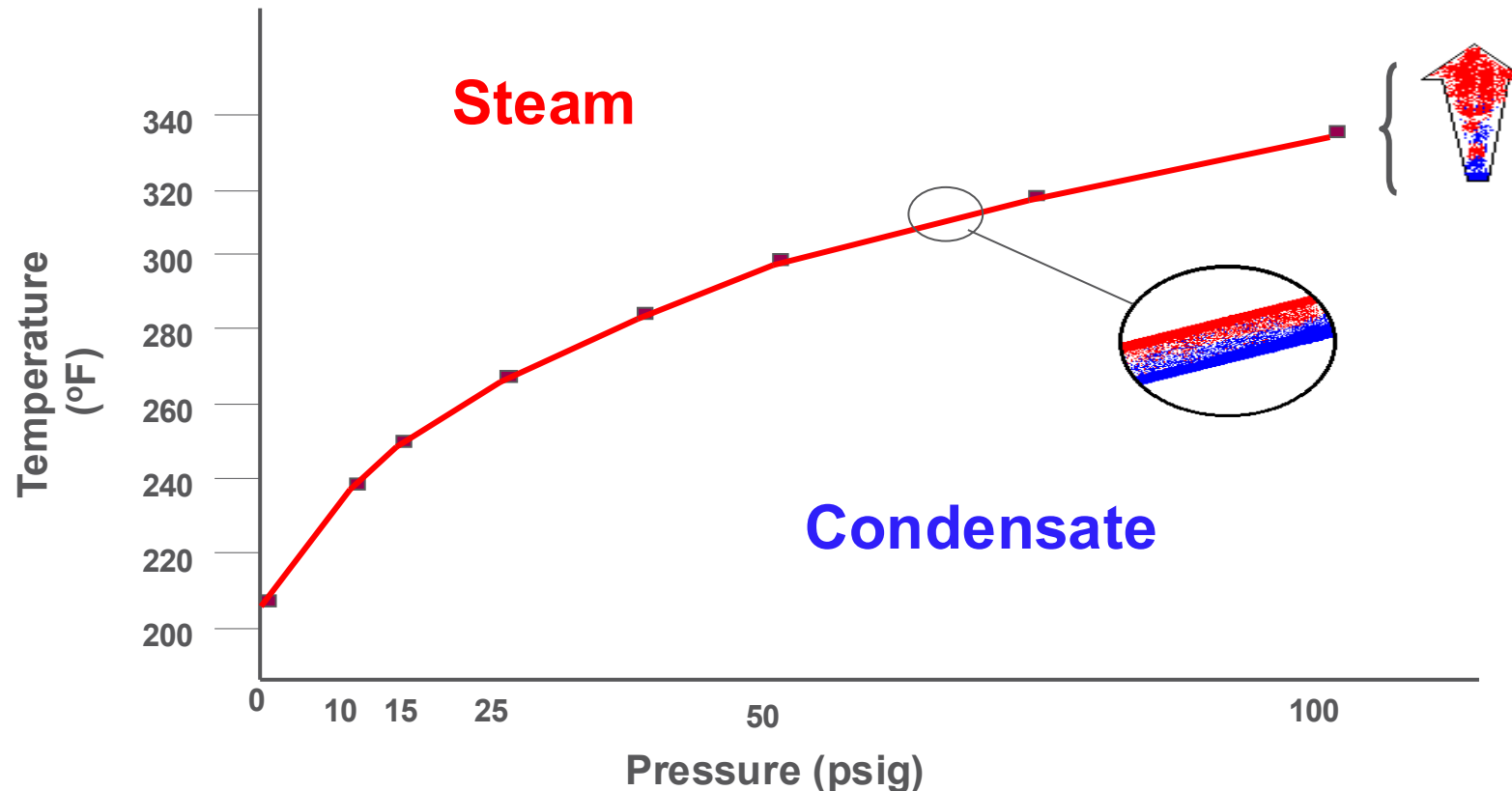
Hot fluid	Cold fluid	U (W/m ² °C)
<i>Heat exchangers</i>		
Water	Water	800–1500
Organic solvents	Organic solvents	100–300
Light oils	Light oils	100–400
Heavy oils	Heavy oils	50–300
Gases	Gases	10–50
<i>Coolers</i>		
Organic solvents	Water	250–750
Light oils	Water	350–900
Heavy oils	Water	60–300
Gases	Water	20–300
Organic solvents	Brine	150–500
Water	Brine	600–1200
Gases	Brine	15–250
<i>Heaters</i>		
Steam	Water	1500–4000

The Steam Saturation Curve

As system pressure rises:

- Water boils at a higher temperature
- Steam is at the same temperature

We can plot the different boiling temperatures: 'saturation curve'.



BB pg 6-7

Steam Saturation Tables

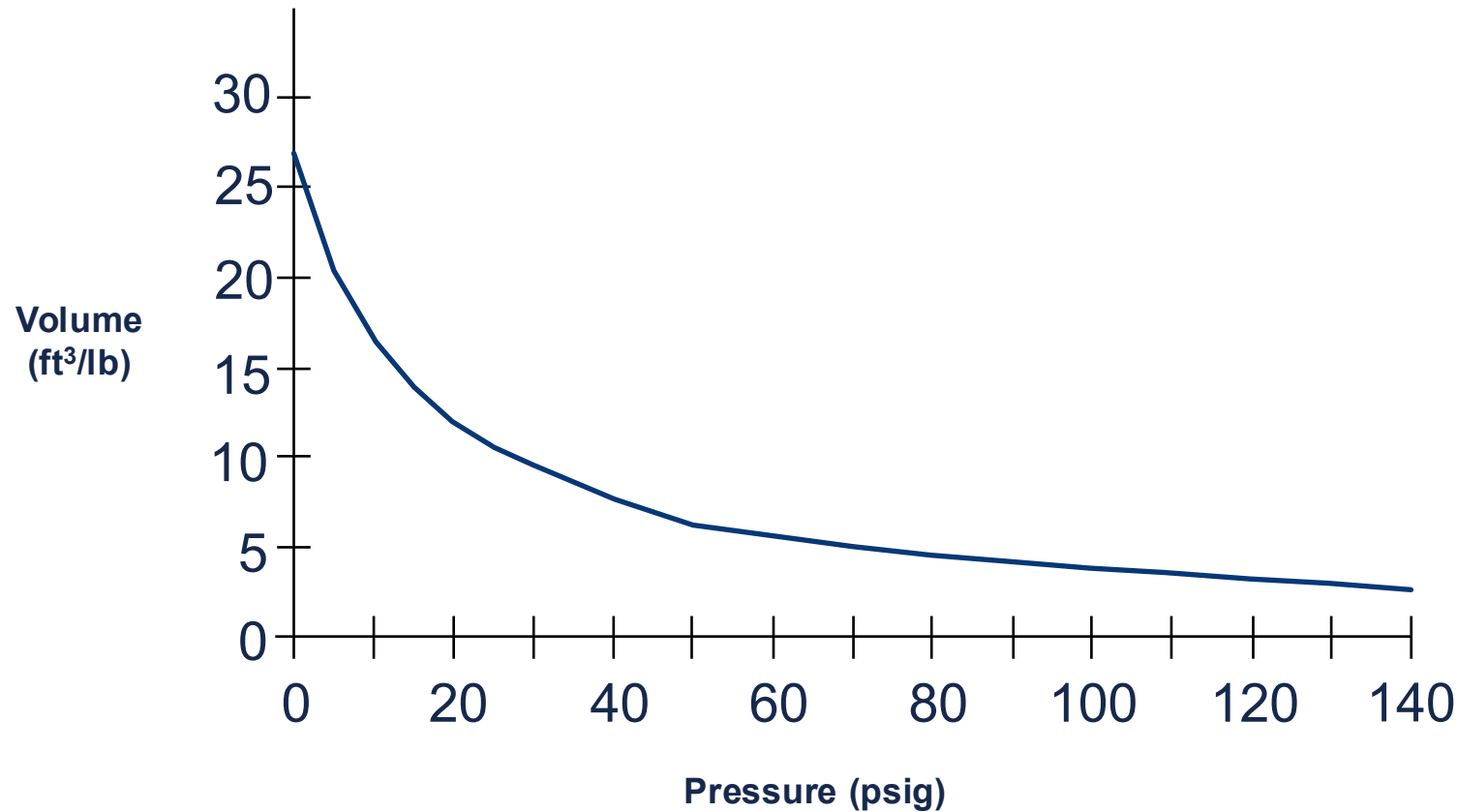
Figure 3: Steam Saturation Table

Gauge Press. in Hg. Vac.	Absolute Pressure psia	Temperature Degrees F	Sensible (hf) BTU/LB	Latent (hfg) BTU/lb	Total (hg) BTU/lb	Spec. Volume Steam (Vg) ft ³ /lb
10	24.7	239.4	207.9	952.9	1160.8	16.5
11	25.7	241.6	210.1	951.5	1161.6	15.9
12	26.7	243.7	212.3	950.1	1162.3	15.3
13	27.7	245.8	214.4	948.6	1163.0	14.8
14	28.7	247.9	216.4	947.3	1163.7	14.3
15	29.7	249.8	218.4	946.0	1164.4	13.9
16	30.7	251.7	220.3	944.8	1165.1	13.4
17	31.7	253.6	222.2	943.5	1165.7	13
18	32.7	255.4	224.0	942.4	1166.4	12.7
19	33.7	257.2	225.8	941.2	1167.0	12.3
20	34.7	258.8	227.5	940.1	1167.6	12
22	36.7	262.3	230.9	937.8	1168.7	11.4
24	38.7	265.3	234.2	935.8	1170.0	10.8
26	40.7	268.3	237.3	933.5	1170.8	10.3
28	42.7	271.4	240.2	931.6	1171.8	9.87
30	44.7	274.0	243.0	929.7	1172.7	9.46
80	94.7	323.9	294.5	892.7	1187.2	4.67
82	96.7	325.5	296.1	891.5	1187.6	4.58
84	98.7	326.9	297.6	890.3	1187.9	4.49
86	100.7	328.4	299.1	889.2	1188.3	4.41
88	102.7	329.9	300.6	888.1	1188.7	4.33
90	104.7	331.2	302.1	887.0	1189.1	4.25
92	106.7	332.6	303.5	885.8	1189.3	4.17
94	108.7	333.9	304.9	884.8	1189.7	4.10
96	110.7	335.3	306.3	883.7	1190.0	4.03
98	112.7	336.6	307.7	882.6	1190.3	3.96
100	114.7	337.9	309.0	881.6	1190.6	3.90

BB pgs 8-10

Steam – Volume and Pressure

As the steam pressure decreases, the same mass of steam uses more volume



Steam Quality at Point of Use

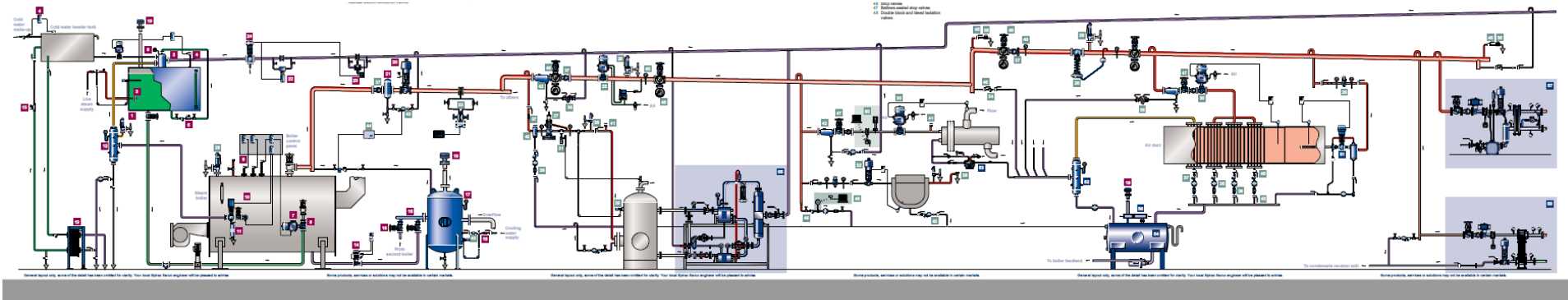
In order for Steam to effectively give up its Heat Energy, we should ensure it arrives at the process in a suitable condition.

Typically, this would mean;

AAMI ST79 2017 - 3.3.3.2 Steam Quality

- Dry > 97%
- Free of Air and NCGs <3.5% by vol.
- Superheat < 25°C (77F)
- Correct Pressure & Temperature acc. to application
- Free from particulates/scale/rust

Steam Quality Influenced by Boiler house + Distribution



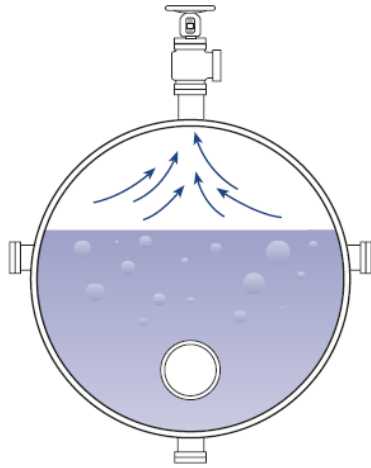
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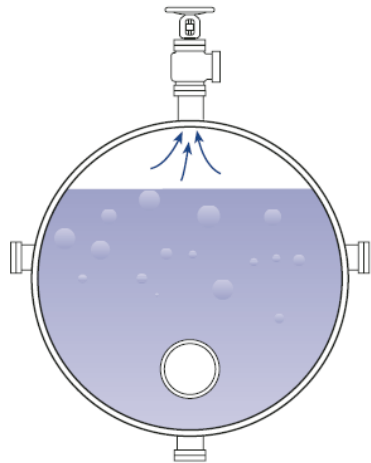
Boiler Operating Pressure

Design Pressure



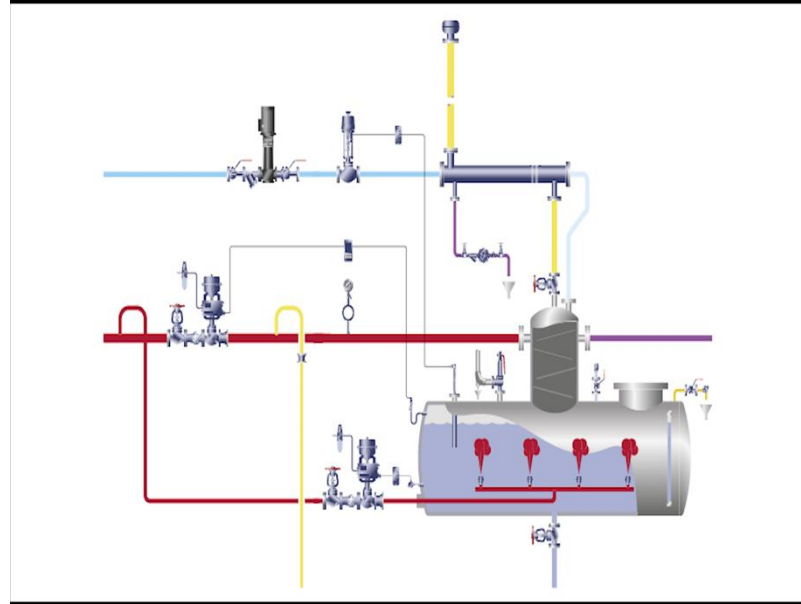
- Smaller specific volume
- Greater separation space
- Dry steam

Reduced Pressure



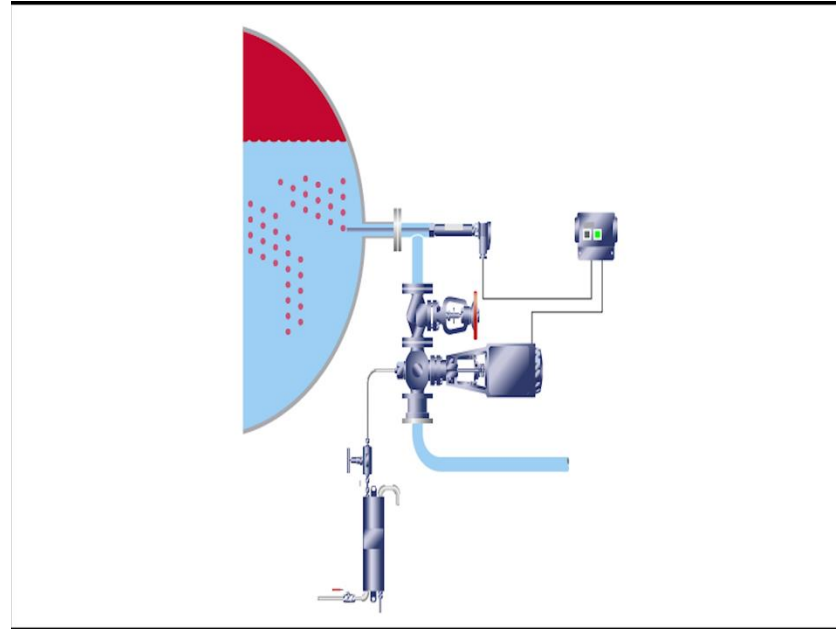
- Greater specific volume
- Decreased separation area
- Lower quality of steam
- Increased steam velocities

Feedwater Conditioning - Deaerators



- Pressurised to 5-10 psig: Less O₂ & NCGs in water = less corrosion
- Rapid response whenever steam required: Less O₂ & NCGs = fewer chemicals required
- Less thermal stress placed on boiler: Lower TDS of water = fewer blowdown losses
- Less energy required to raise steam: Able to hold water at pressure = less flash steam loss

TDS Control



- TDS = Total Dissolved Solids
- Probes / Sensors to monitor TDS (timed vs continuous monitoring)
- Automated TDS Blowdown Control
- Provides safe, correct and energy efficient TDS Control
- Helps to minimize foaming/carryover in Boiler & maintain optimum operating conditions

Best Practices Minimize Risk of Carryover



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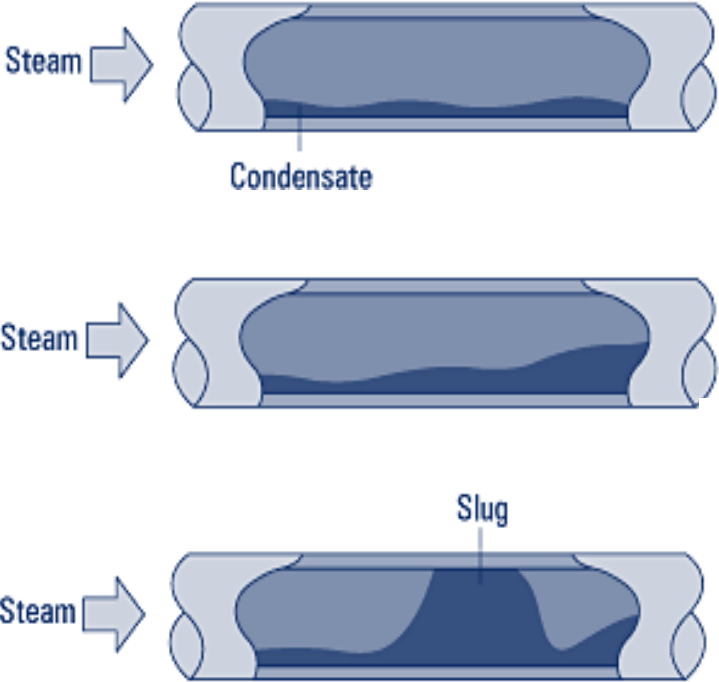
Steam Distribution

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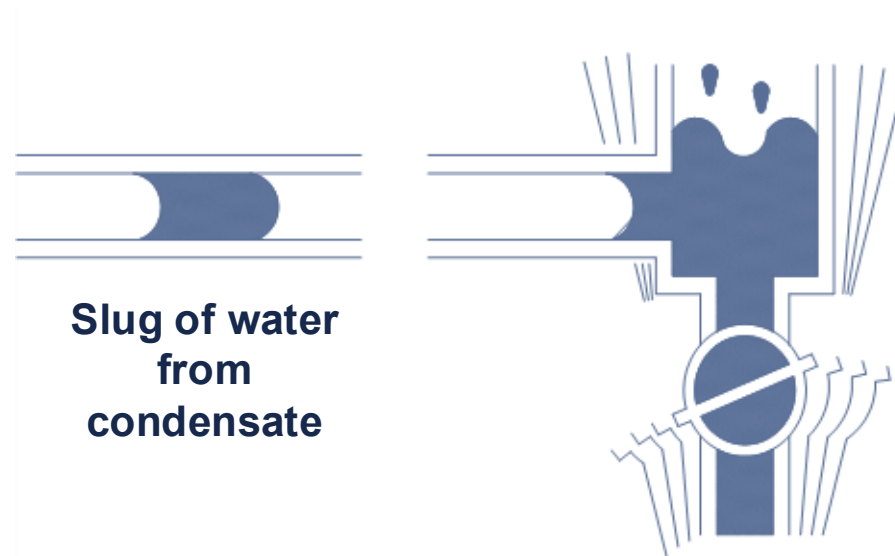
Inadequate Drainage



Condensate backs up into the steam main and results in higher steam velocities and potential for waterhammer

Waterhammer

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Steam Distribution Best Practices

- Horizontal run should fall $\frac{1}{2}$ " in 10 feet towards drip station
- Drip traps located at regular intervals on horizontal runs
- Located at all low points in the distribution
- D1: Drip pocket same size steam main up to 6" (150mm), diameter > 6" should be $\frac{1}{2}$ the nominal pipe size but no less than 6"
- D2: Vertical drop 1 $\frac{1}{2}$ times diameter of steam main but not less than 18"

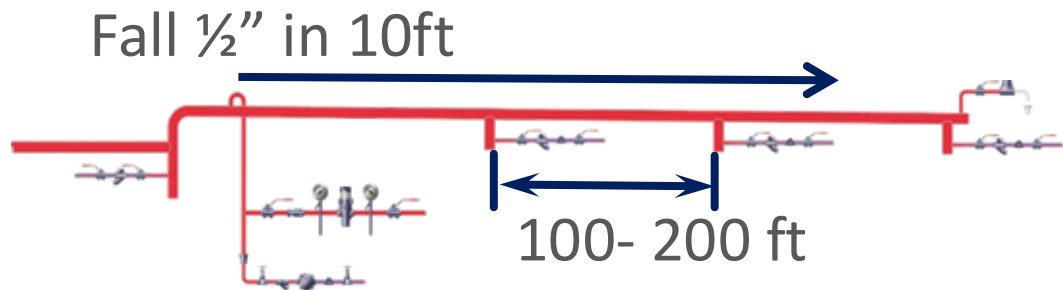
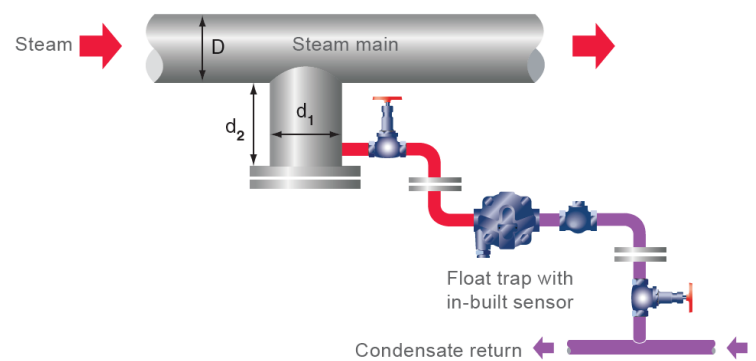


Table 11.11.1 Drain pocket dimensions

Mains diameter - D	Pocket diameter - d_1	Pocket depth - d_2
Up to 100 mm nb	$d_1 = D$	Minimum $d_2 = 100$ mm
125 - 200 mm nb	$d_1 = 100$ mm	Minimum $d_2 = 150$ mm
250 mm and above	$d_1 \geq D/2$	Minimum $d_2 = D$



Steam Distribution Best Practices

- Steam take-offs
- Moisture separators

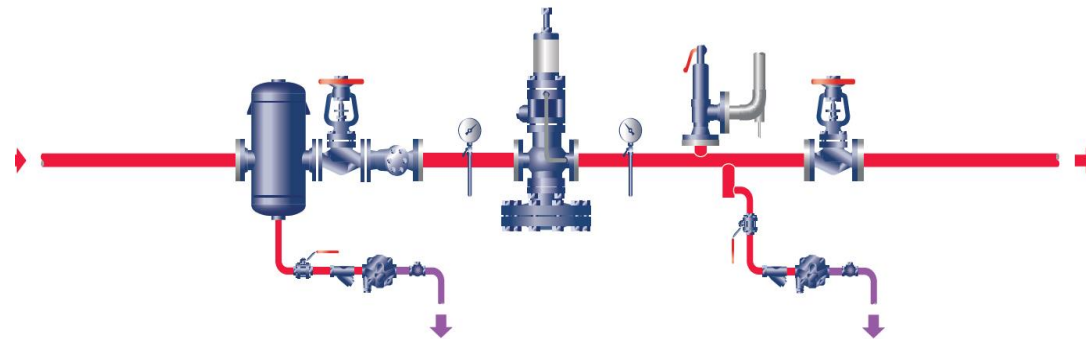
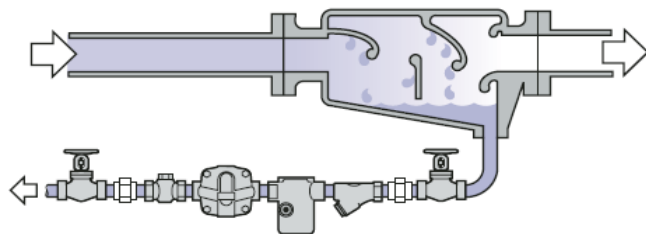
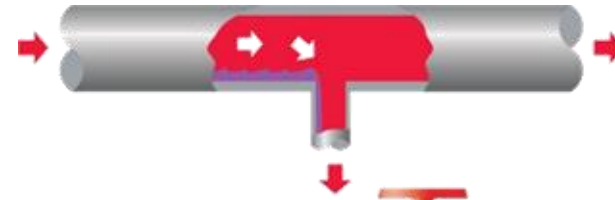


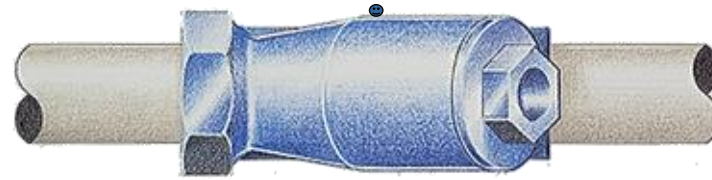
Fig. 11.11.7 Standard pressure reducing valve station

Strainer Design Consideration

How would you install a strainer in a steam system?

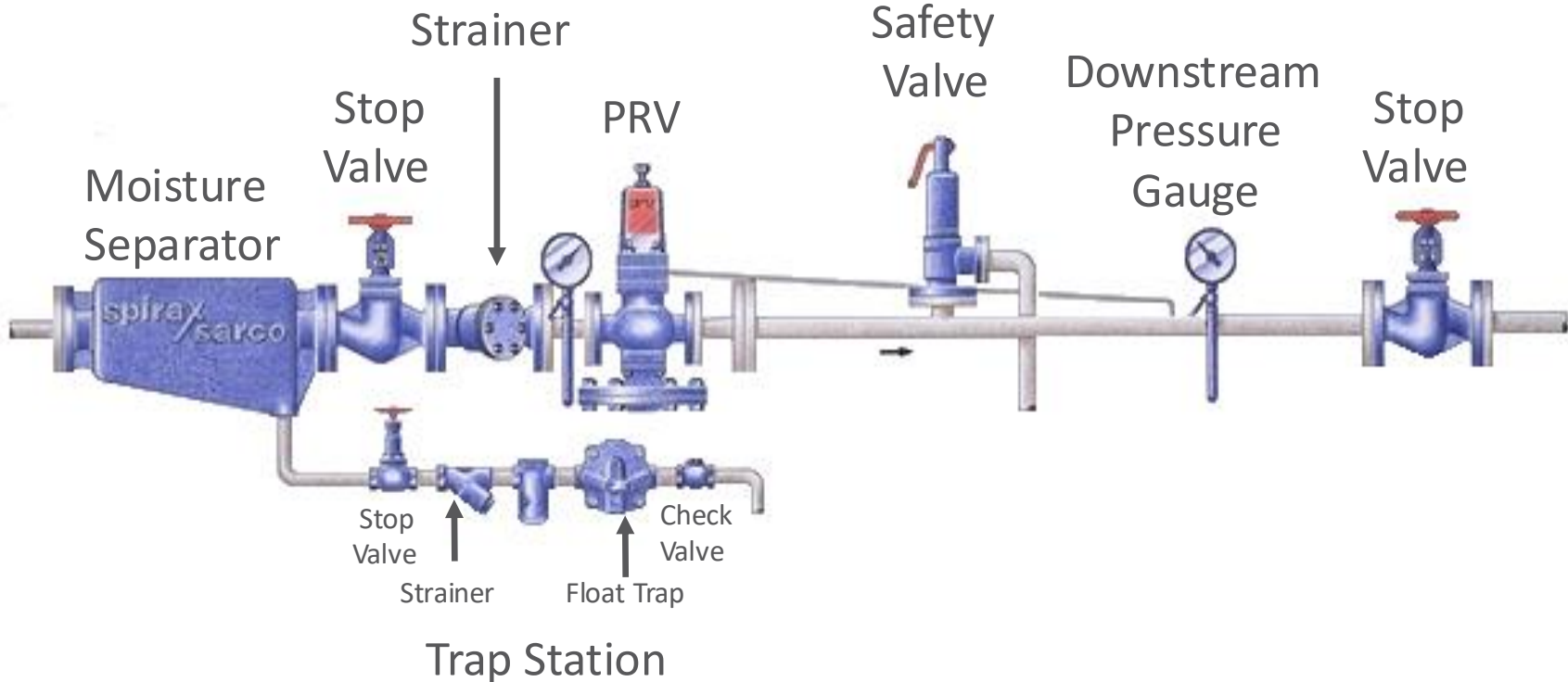


Vertical



Horizontal

Pressure Reduction



Hot Water Systems

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Old versus new Domestic HX



Domestic Hot Water Heat Exchange

Traditional storage calorifier method for DHW :

- Large footprint of tube bundle assembly
- Inefficient / small heat transfer area
- Vessel / tube area (and therefore duty) is fixed
- Therefore either high U value or **high** press / temp required
- Risk of Legionella

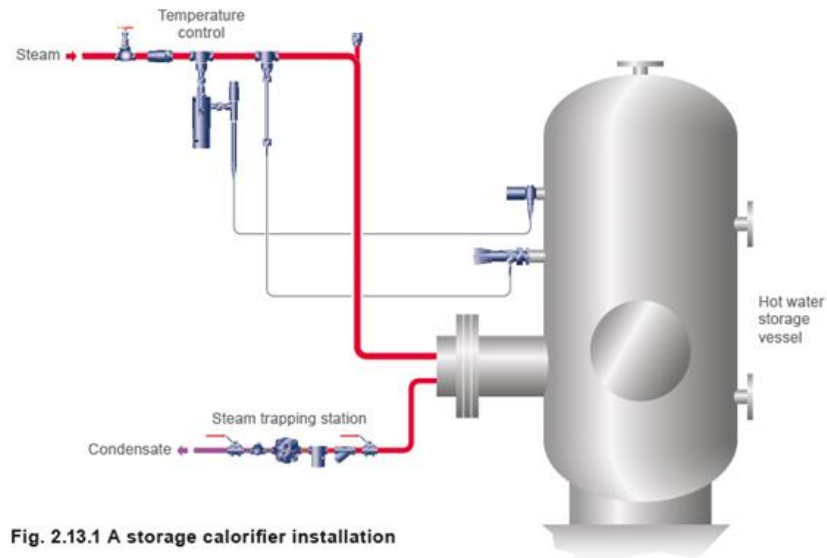
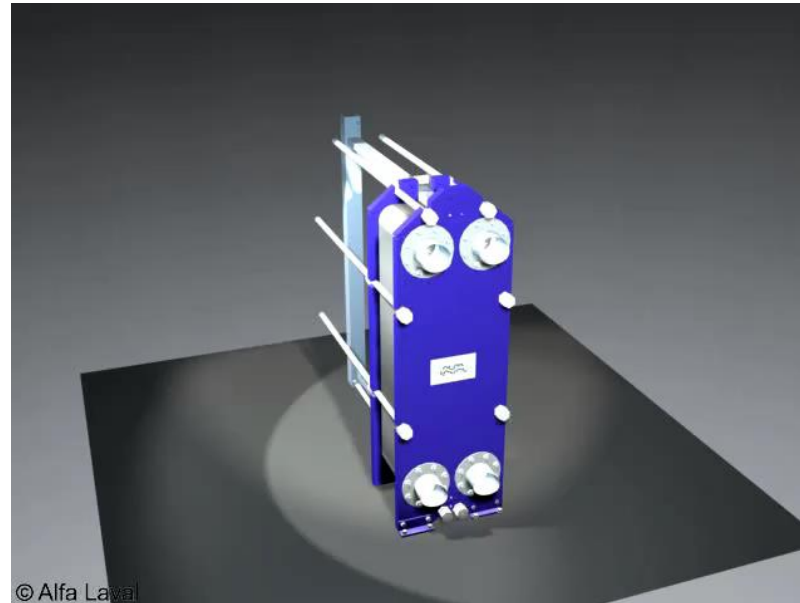


Fig. 2.13.1 A storage calorifier installation

Domestic Hot Water Heat Exchange

Modern instantaneous plate heat exchange solution:

- Small footprint of overall package
- Efficient / large heat transfer area
- Plates are gasketed, therefore easy to add / remove plates
- High U value + large area = **low** press / temp required
- No stored water reduces risk of Legionella
- Precise temperature control and high limit temperature protection

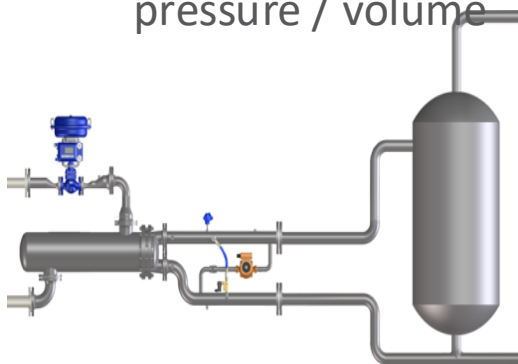


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Health & Safety -Water Storage vs Instantaneous Hot Water Generation

Calorifiers:

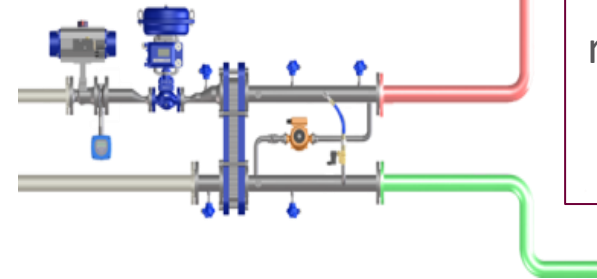
Calorifiers must meet pressure regulations based on pressure / volume



Requirement of water storage
(Legionella risk)

Packaged heat exchange solution:

Packaged HES are normally *exempt from insurance inspections based on pressure regulations**



No requirement for water storage

* This will be dependent on local pressure vessel directives and regulations

Heat Exchange Technologies

Traditional shell & tube storage calorifiers using tube bundles for heat exchanger require frequent maintenance (downtime) for

- A) Cleaning & pasteurising to prevent legionella risk
- B) Insurance Inspection for PED purposes
- C) Descaling (due to higher heat exchange temperatures required)

The size and weight of the tube bundles may require multiple trained personnel plus appropriate lifting equipment in the plant room

Packaged Heat Exchangers generating heat instantaneously do not use tube bundle technology and as such the manual handling risks have been greatly reduced



Heat Exchanger Stall

What is stall?

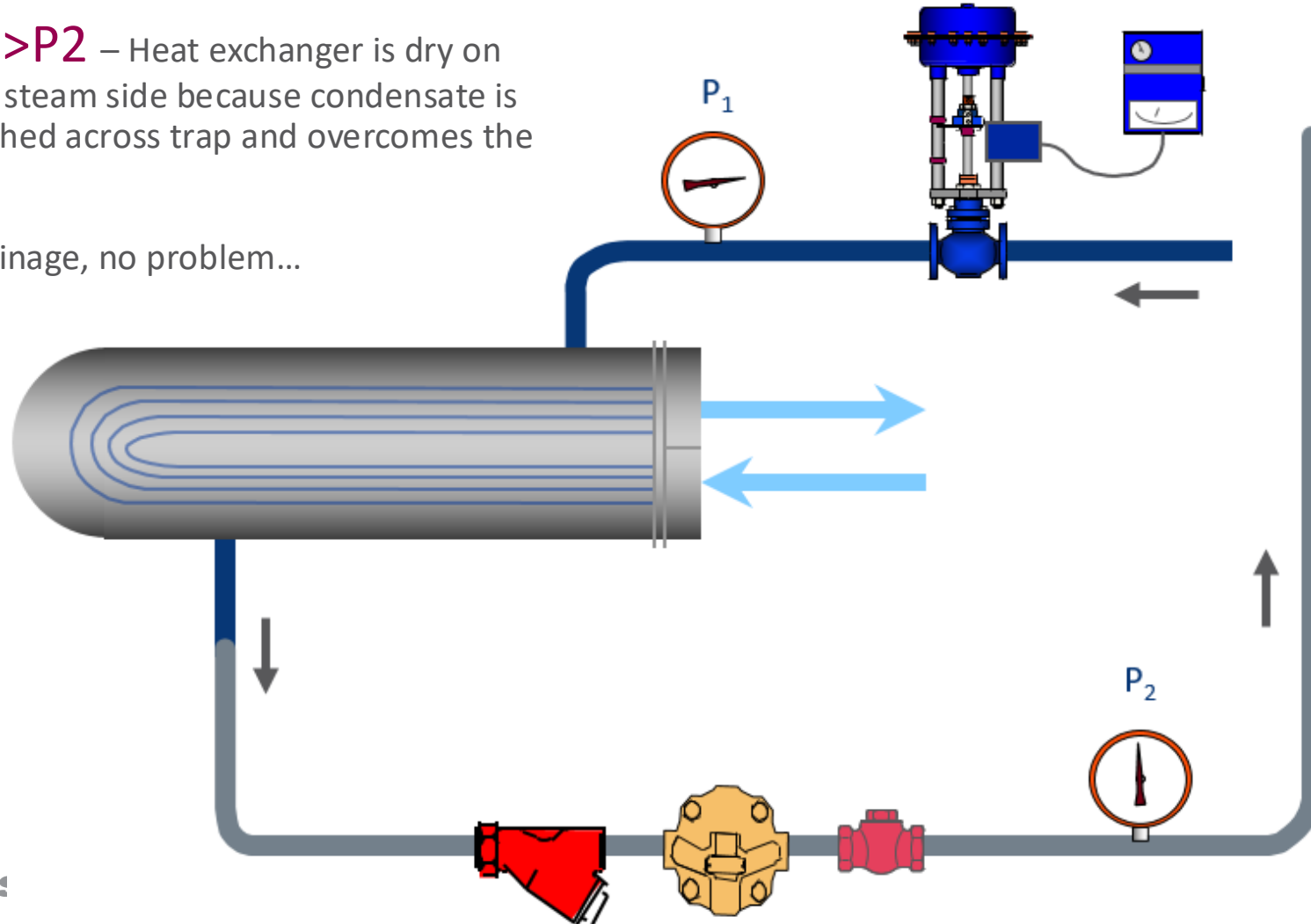


- A system state in which there is insufficient pressure differential across the steam trap to remove condensate. (i.e., no condensate drains so the system “stalls”).

Heat Exchanger Condensate Removal - Heavy Load

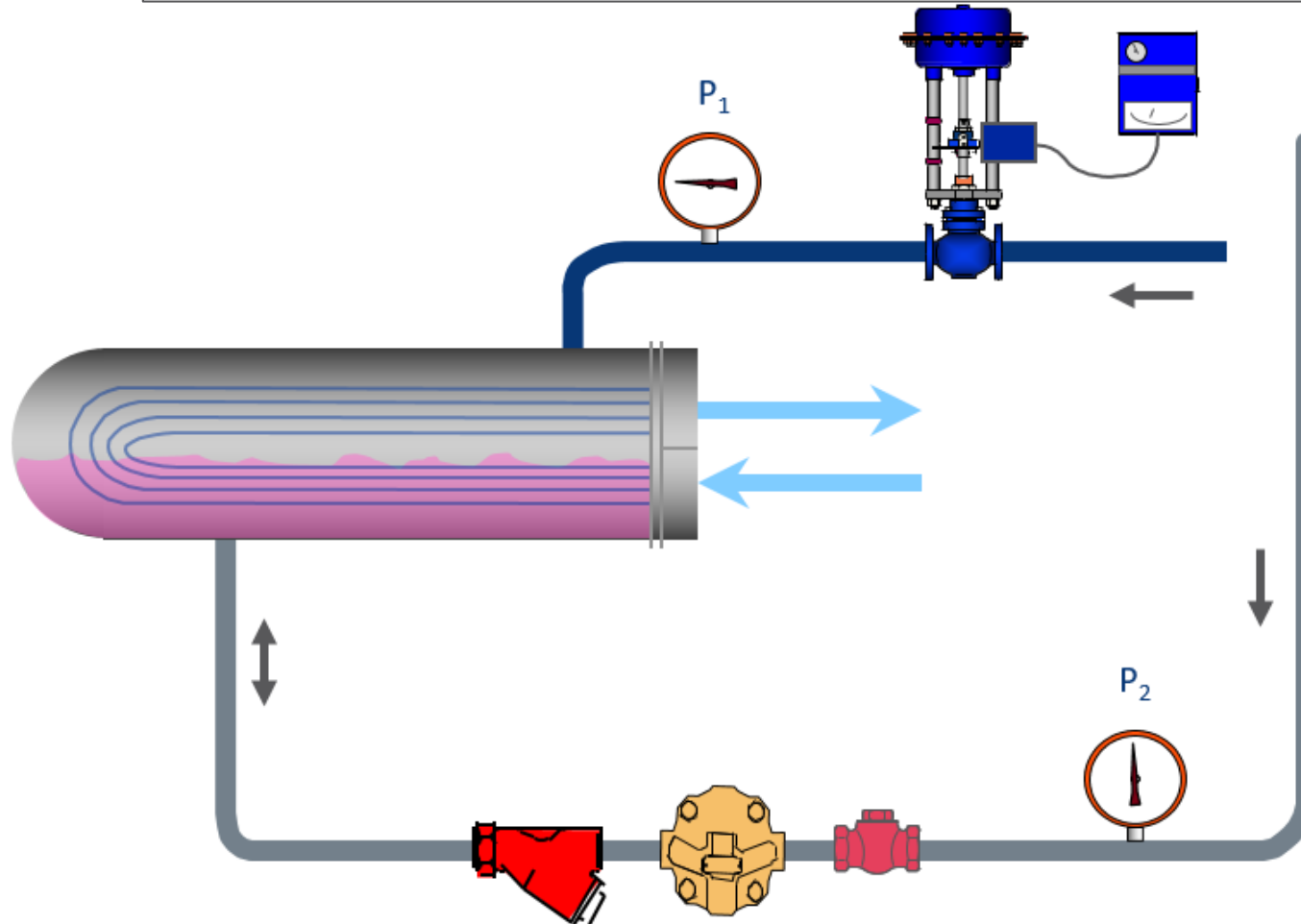
- $P_1 > P_2$ – Heat exchanger is dry on the steam side because condensate is pushed across trap and overcomes the lift.

Drainage, no problem...



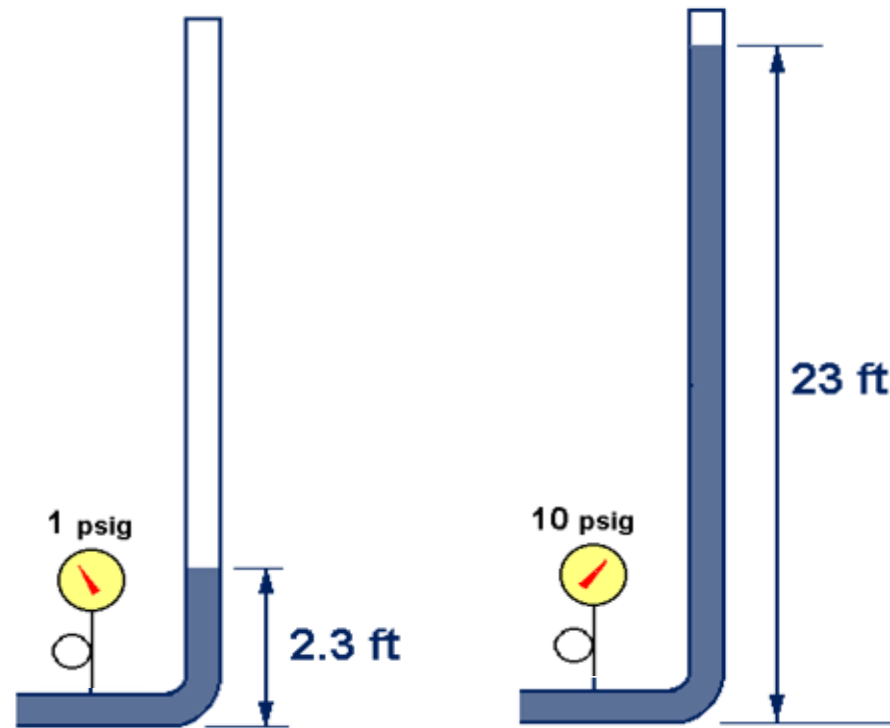
Heat Exchanger - Heavy Load

Stall occurs when the backpressure is higher than the pressure in the heat exchanger ($P_1 < P_2$)



Static Head

Rule of thumb:
1 psig \approx 2 ft. lift



Symptoms to Determine Stall

- Cold or cool steam trap
- Hunting control valve
- Fluctuating outlet temperature
- Stratified heater temperatures
- Waterhammer
- Reduced heat output
- Corroding heat exchangers
- Leaking heat exchangers
- Failing heat exchangers



HB pg 36

Steam in Sterilization

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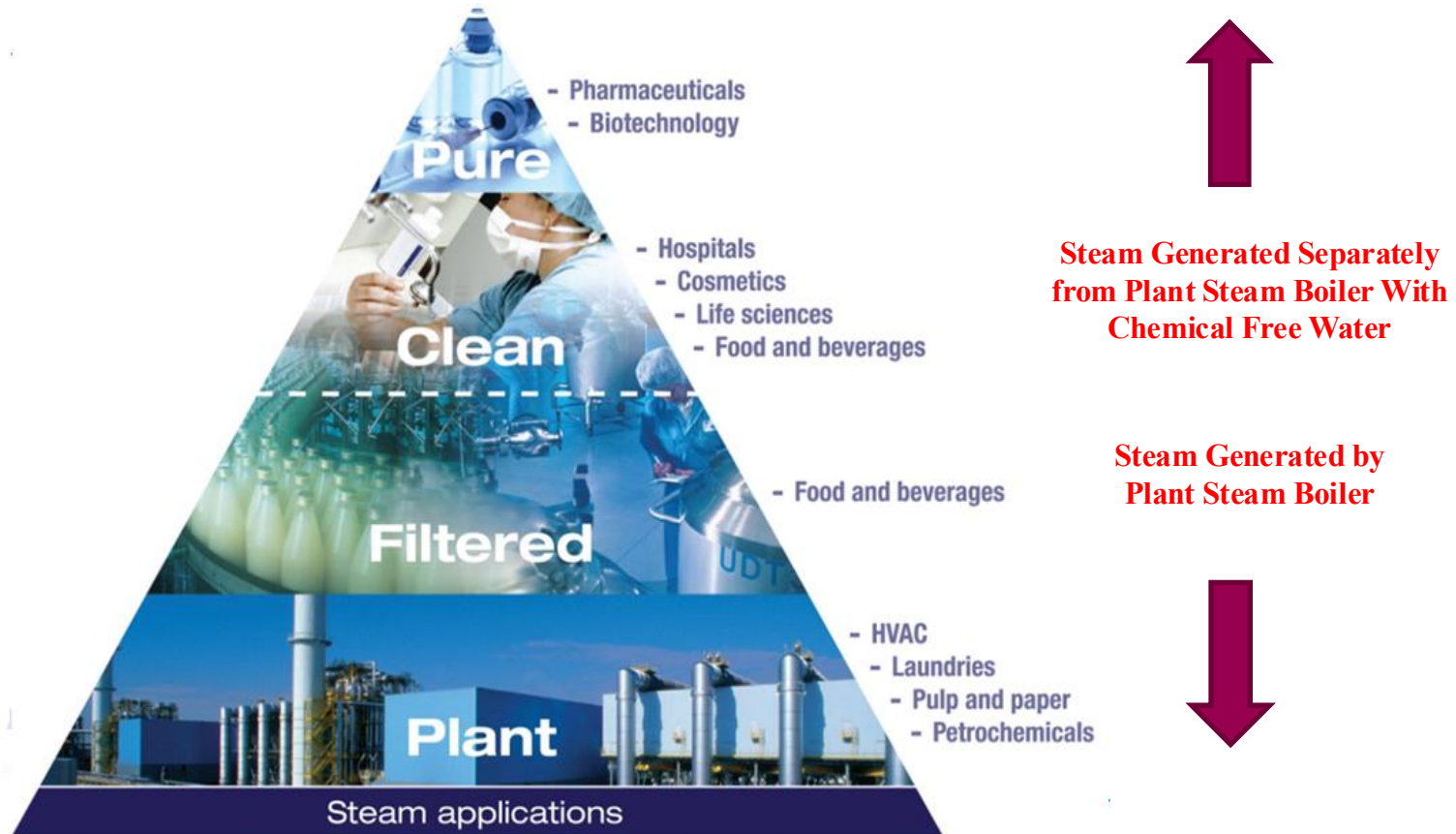
Wet Packs

Problems Identified by Hospital Personnel

- “Heat up” cycles require longer times
- “Rouging” of the surface area
- Wet and/or Dirty Steam
- Poor Sterilization despite all efforts
- “Test Samples” are wet too many times
- Repeated sterilization cycles to get just one “clean” run.



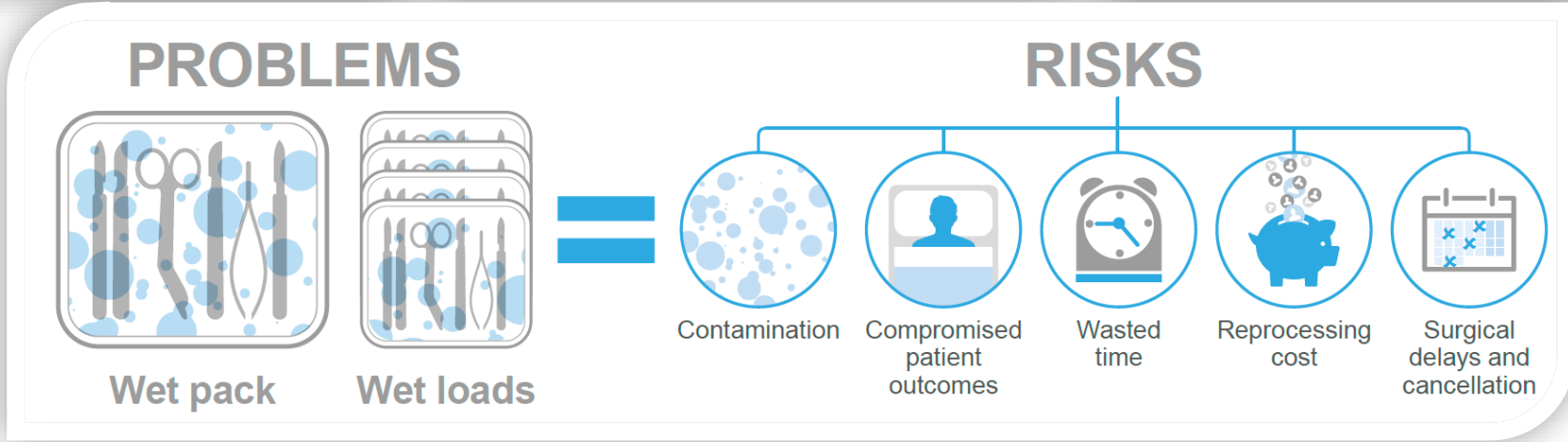
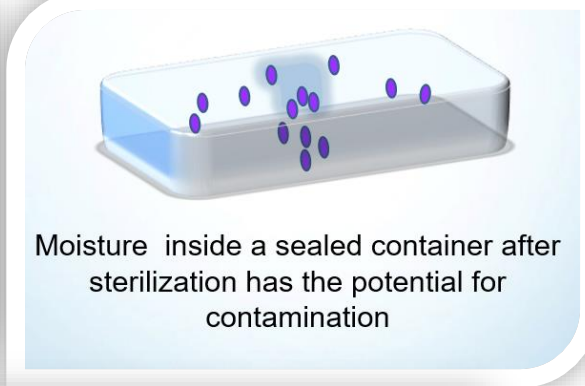
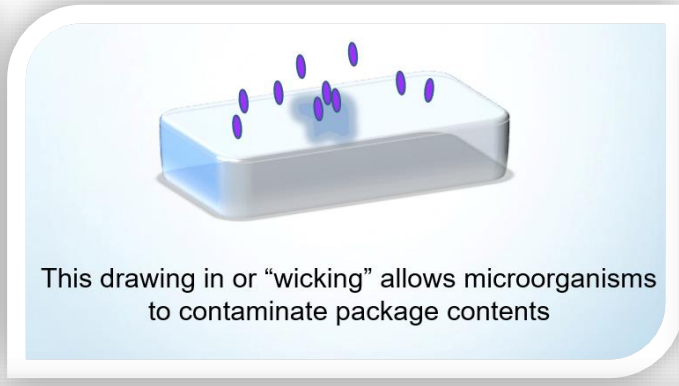
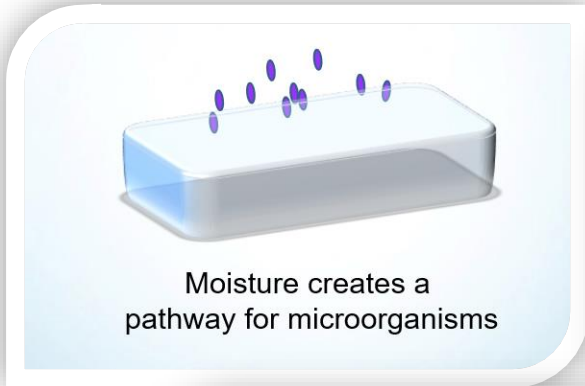
Grades of Steam



AAMI ST79 (2017) - Outline

- *AAMI guidelines state - Steam quality, purity and quantity can be affected by the design, use, and maintenance of the overall steam system. Steam systems should be designed to ensure that the steam delivered to the sterilizer is saturated steam having a steam quality of 97% to 100%.*
- *Steam of poor quality can contribute to wet packs and to sub-optimal steam sterilization cycles that might or might not be identified by biological monitoring. In certain circumstances, house steam from hospital steam boiler systems might not be acceptable for sterile processing due to the design of the overall system and the type and method of using boiler feed water treatment chemicals.*

Effects of Moisture in Sterilization



- Unsterile instruments are a contamination risk
- Delayed or cancelled surgical procedures
- Compromised patient outcomes
- Reprocessing costs – water, energy and technician time
- Additional time spent troubleshooting and investigating



AAMI ST79 2017 - 3.3.3.2 Steam Quality

3.3.3 Steam for sterile processing

3.3.3.1 General considerations

The system for steam delivery should be designed, monitored, and maintained to ensure that the quality, purity, and quantity of the steam provided are appropriate for effective sterile processing. There are two common sources for steam used for sterile processing: hospital steam boiler systems and self-contained electric boilers. Both systems should include a treated water supply to remove total dissolved solids. See AAMI TIR34:2014, *Water for reprocessing of medical devices*.

Steam sterilizers having a chamber volume less than or equal to 2 cubic feet generate their own steam. The user should follow the sterilizer manufacturer's written IFU regarding water purity requirements, filling, draining, and general maintenance of the system. Distilled or deionized water might be recommended to help prevent the buildup of minerals in the sterilizing system and to ensure the purity of the steam generated for sterilization.

Rationale: Steam quality, purity, and quantity can be affected by the design, use, and maintenance of the overall steam system, which includes the boilers and steam distribution lines.

3.3.3.2 Steam quality

Facility engineering personnel should ensure steam quality by

- a) monitoring, controlling, and documenting the process of generating steam;
- b) testing steam against the following critical variables:
 - steam dryness between 97% and 100%.
 - noncondensable gases (e.g., air) at a level (less than 3.5% w/v condensate) that will not impair steam penetration into sterilization loads.
 - superheat of steam (expressed as a temperature in degrees above saturation point) of less than 25°C (77°F);
- c) maintaining steam traps and boilers/generators; and
- d) assessing and documenting the steam quality upon installation or relocation of the sterilizer and after any change to the steam distribution lines or boiler supply water.

Rationale: Steam that is too dry can contribute to superheating and, consequently, to suboptimal steam sterilization conditions. Steam that is too wet can lead to wet packs after sterilization and compromise sterility.

AAMI ST79 2017 - 3.3.3.3 Steam Purity

3.3.3.3 Steam purity

To maintain steam purity and minimize the presence of potential contaminants in the steam, facility engineering personnel should

- a) treat the feedwater with boiler additives and/or feedwater conditioners so that its condition and/or chemistry do not damage the boiler or steam lines;
- b) monitor boiler additives and feedwater conditioners;
- c) use only additives and conditioners approved for use in the food and drug industries (21 CFR 173.310 and 21 CFR 200.11);
- d) install in-line filters that are as close to the sterilizer as possible and include a drip leg or trap for condensate material; and
- e) develop procedures to monitor steam purity and provide corrective action.

Facilities should not

- a) use boiler additives and feedwater conditioners on a batch basis;
- b) add boiler additives or feedwater conditioners to the steam in the steam distribution system; or
- c) use amines for conditioning steam lines (as opposed to the use of amines in feedwater treatment).

Rationale: It is important that boiler additives and feedwater conditioners be monitored to prevent carryover of excessive chemicals into the steam used for sterilization. Additives can cause pack and instrument staining and/or instrument damage. Amines can stain packaged items within the sterilizer.

3.3.3.4 Monitoring steam systems

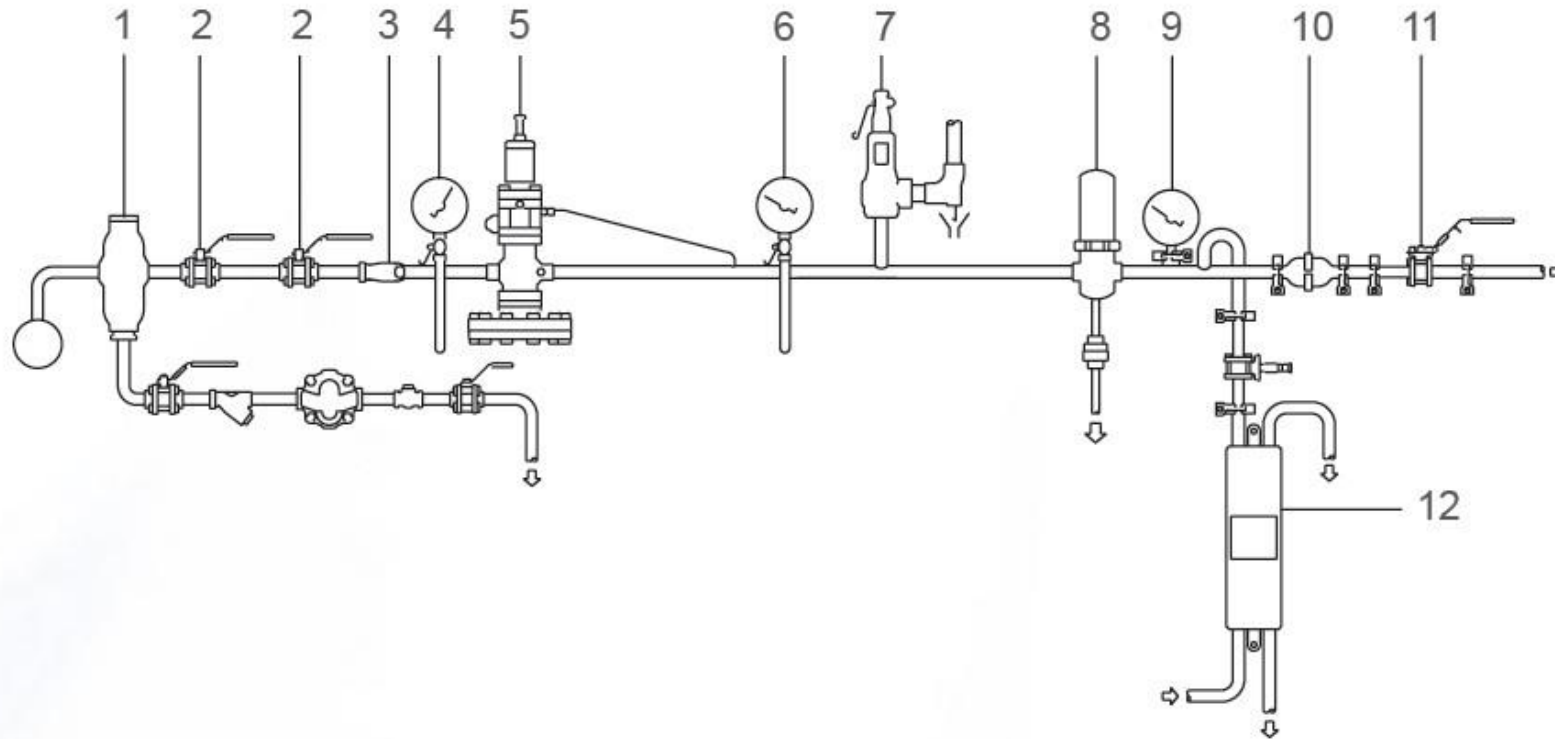
Health care facilities should provide for the preventive maintenance, repair, and monitoring of boilers and steam distribution lines that provide steam for sterile processing and for the documentation of corrective actions. (See also 3.3.3.3 and Annex L.) The monitoring and testing program for boilers should generally include determination of

- a) incoming water hardness, pH, iron content, and alkalinity;
- b) boiler water alkalinity and pH; and
- c) condensate return alkalinity, conductivity, sulfites, and pH.

Condensate Sample taken from plant steam before Autoclave - without protection



Typical Filter Station

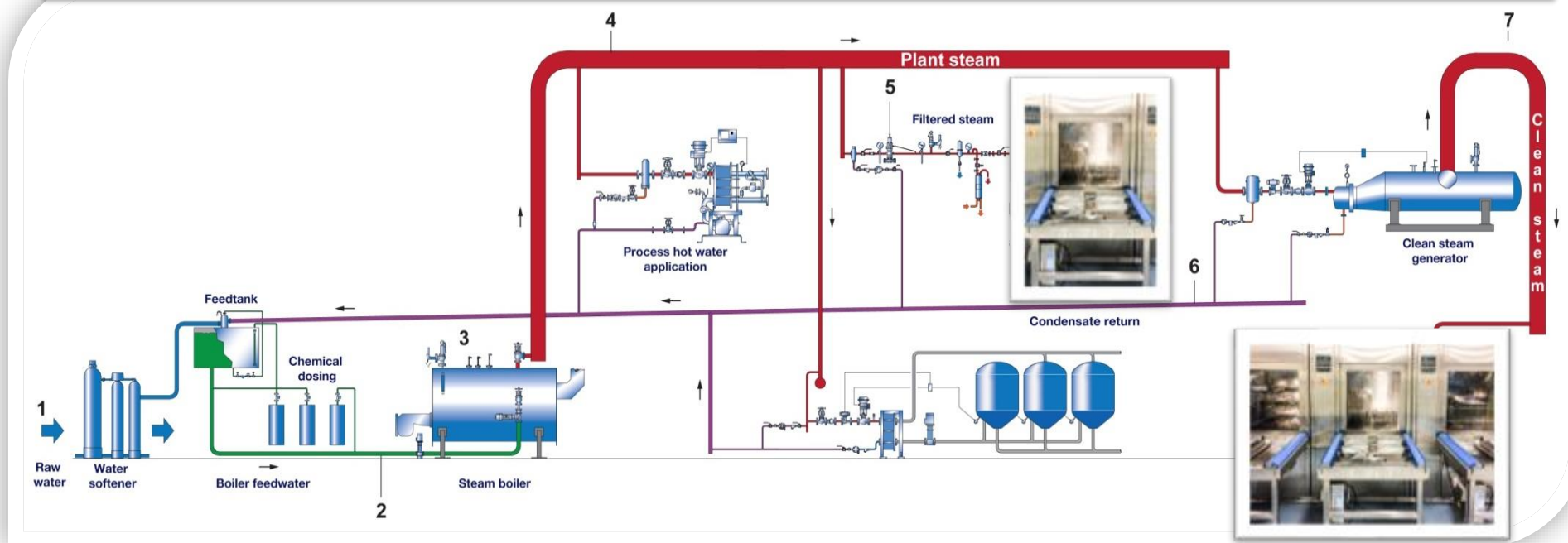


- | | | | |
|---|----------------------------------|----|-------------------------|
| 1 | Steam separator | 7 | Safety valve |
| 2 | Ball valve (x2) double isolation | 8 | Culinary steam filter |
| 3 | Strainer | 9 | Sanitary pressure gauge |
| 4 | Pressure gauge | 10 | Sanitary check valve |
| 5 | Pressure reducing valve | 11 | Sanitary ball valve |
| 6 | Pressure gauge | 12 | Sample cooler |

Figure 4: Typical filtered steam station

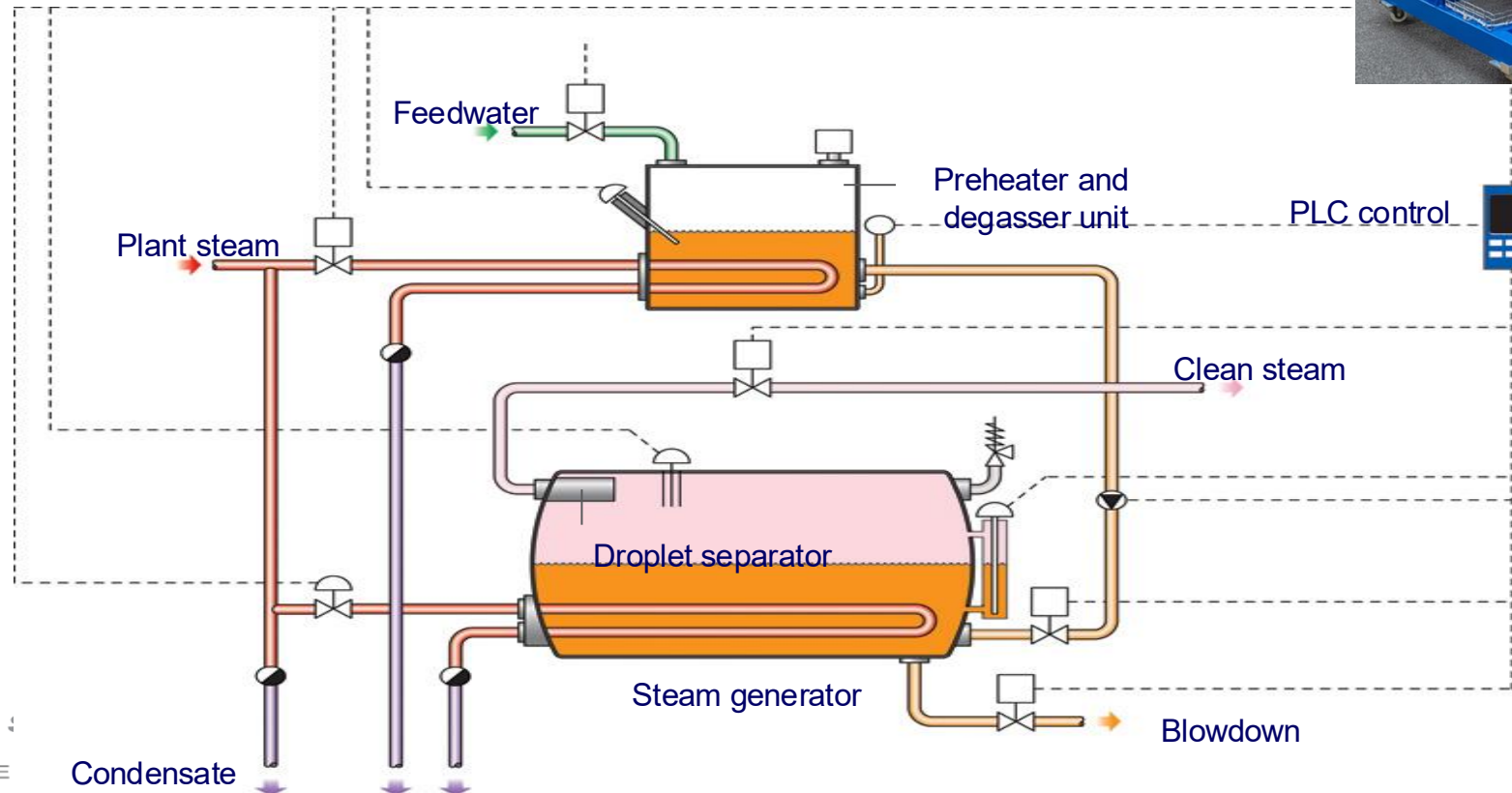
Good quality clean steam requires good quality plant steam

- Raw water management: Water softening equipment
- Water treatment – DA & Boiler water management (Blowdown & TDS control)
- Steam distribution system design
- Steam trap management: trap testing and monitoring



Clean Steam Generators

- Independent Steam-steam Generator
- 316L Stainless Steel Construction
- Produces steam that is free from Chemicals, Scale & Particles
- High feedwater quality (e.g. demineralised, RO etc.)



Steam Systems Maintenance

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Steam Trap Repairs

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ENERGY

Energy Efficiency &
Renewable Energy

ADVANCED MANUFACTURING OFFICE

Energy Tips: STEAM

Steam Tip Sheet #1

Inspect and Repair Steam Traps In steam systems that have not been maintained for 3 to 5 years, between 15% to 30% of the installed steam traps may have failed—thus allowing live steam to escape into the condensate return system. In systems with a regularly scheduled maintenance program, leaking traps should account for less than 5% of the trap population. If your steam distribution system includes more than 500 traps, a steam trap survey will probably reveal significant steam losses.

Steam Traps Failed Open

Poor visibility, risk of scalds.



Health and Safety issues



Steam vented to atmosphere.



- Increased fuel costs and CO₂ emissions
- Increased water consumption
- Increased water treatment chemical costs



Pressurising condensate lines - process stalls.



- Inefficient process
- Lost production



Financial impact generally easily to measure

Steam Trap Surveys

Steam Trap Condition

During this survey, we located steam traps. Of these, 14% were identified as requiring immediate attention to resolve potential safety concerns, energy losses and reduced system efficiency. At the time of testing the following trap conditions were identified:

Trap Condition	Number	%
Functioning correctly	500	61
Failed open	52	6
Rapid cycling	0	0
Failed closed	60	7
Not in Use	102	12
Cold	0	0
Disconnected or <u>Removed</u>	11	1
Not Tested	22	3
Not In Service	0	0
Redundant		



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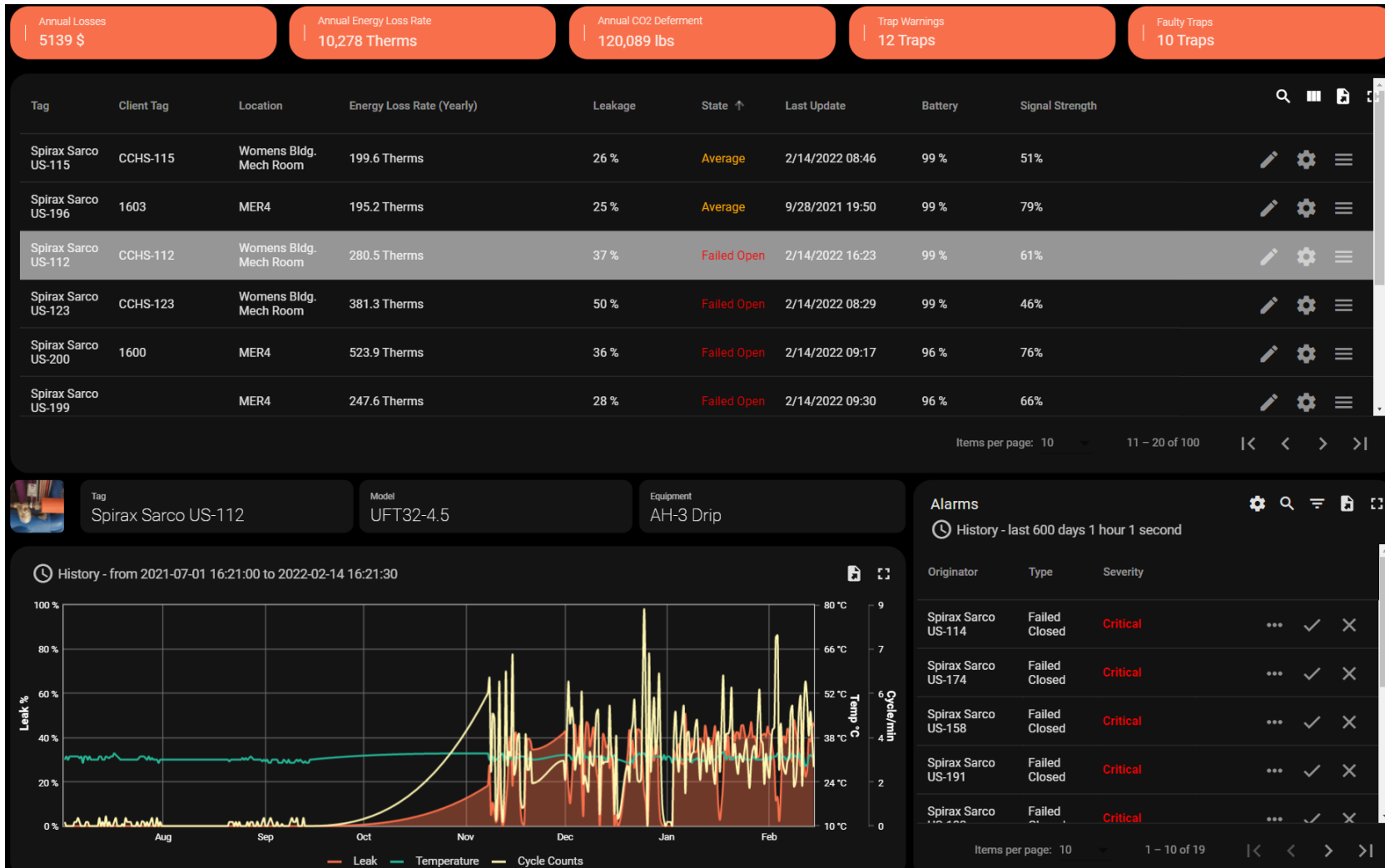


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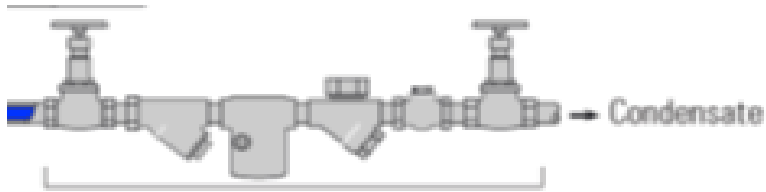
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Steam Traps Monitoring



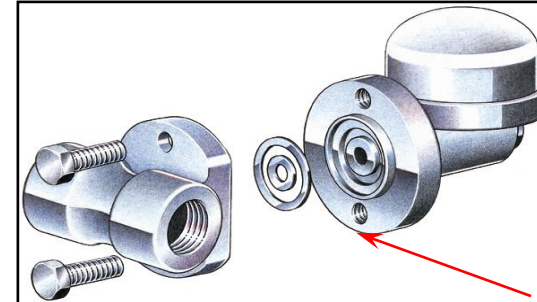
Integrated Steam Trap Stations



Typical Steam Trap Set



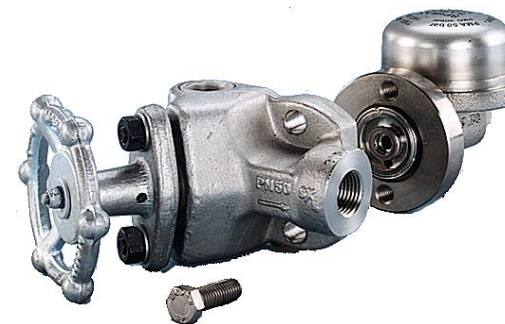
Quick-fit connector traps



Flange rotation to suit pipeline connector

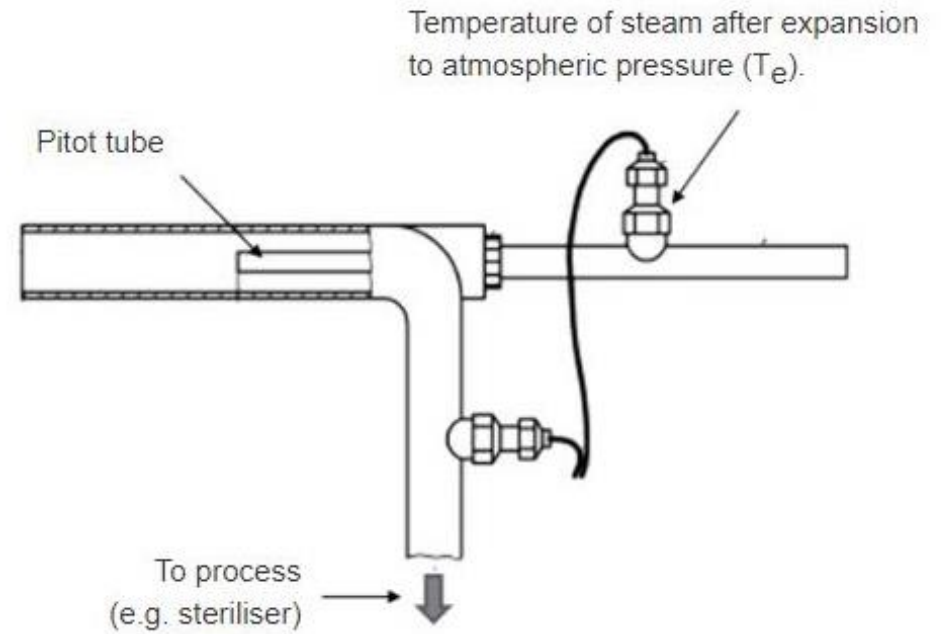
Compatible steam traps

<p>UBP32</p>  <p>Balanced pressure thermostatic steam traps operate below steam saturation temperature, depending on the capsule fitted. Suitable for non-critical systems.</p>	<p>USM21 and USM32</p>  <p>Bimetallic steam traps operate below steam saturation temperature, depending on the bimetal setting. Suitable for non-critical systems.</p>	<p>UFT32</p>  <p>Ball float steam traps provide condensate drainage at steam temperature and include excellent air venting ability.</p>	<p>UIB30 and UIB30H</p>  <p>Inverted bucket steam traps operate at steam temperature with complete condensate drainage.</p>	<p>UTD30 series</p>  <p>Thermodynamic disc type steam traps will ensure complete condensate drainage without energy wastage. Longlasting, compact and robust.</p>
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Steam Quality Testing

- *Dryness Fraction*
- *Non- condensable gasses*
- *Degree of superheat*



How can we help you?



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Thank you

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