FLOWSERVE GESTRA

ASPE Cleveland Chapter

Feb. 8, 2012

Steam Trap Technologies
and
Energy Conservation

Experience In Motion

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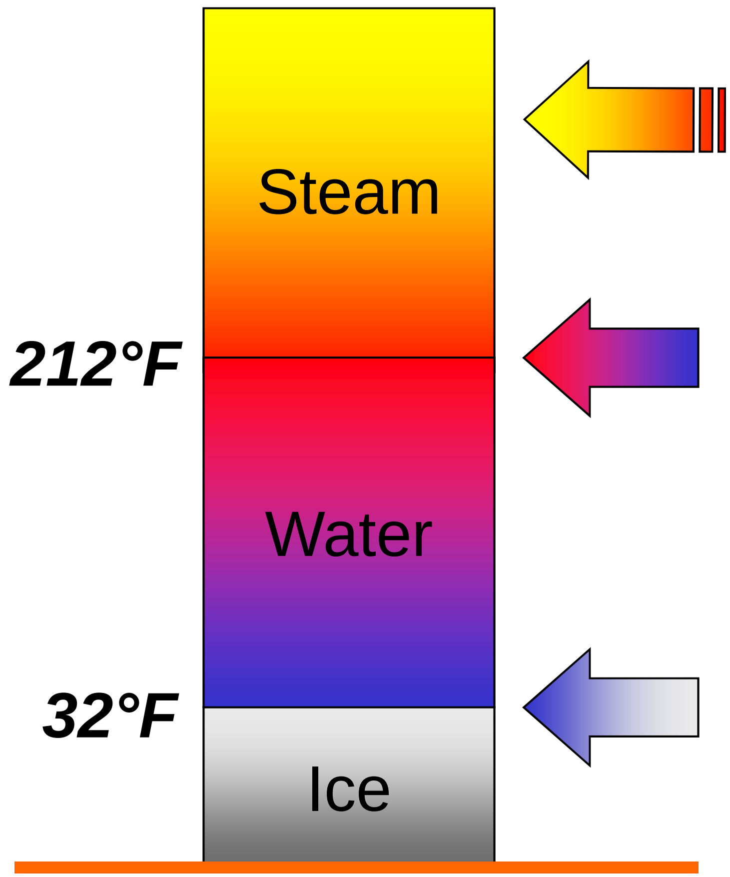
Why do we use steam?

Steam is used as a carrier of heat and pressure.

- **It is produced by the evaporation of water.**
- **a relatively inexpensive and plentiful commodity which is environmentally friendly.**
- **Its temperature can be adjusted very accurately by the control of its pressure.**
- **It carries a large amount of energy in a small mass.**

From ice to water and steam



At atmospheric pressure, water cannot exist as a liquid above 212°F, so any additional heat energy added after it reaches this temperature will cause some of the liquid to boil off as steam.

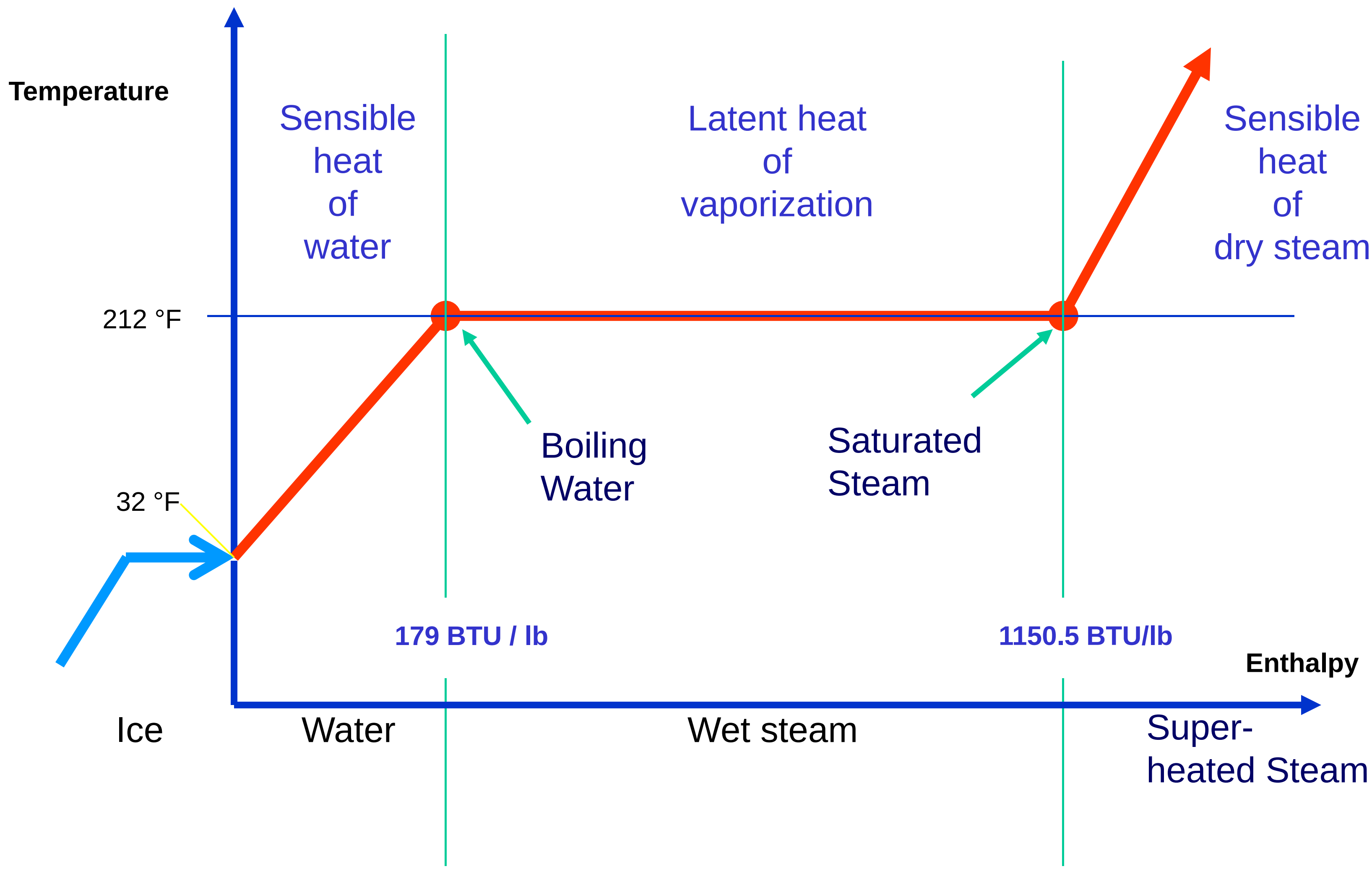
Saturation point

If heat energy is added to water, its temperature rises again to a point at which it can no longer exist as water.

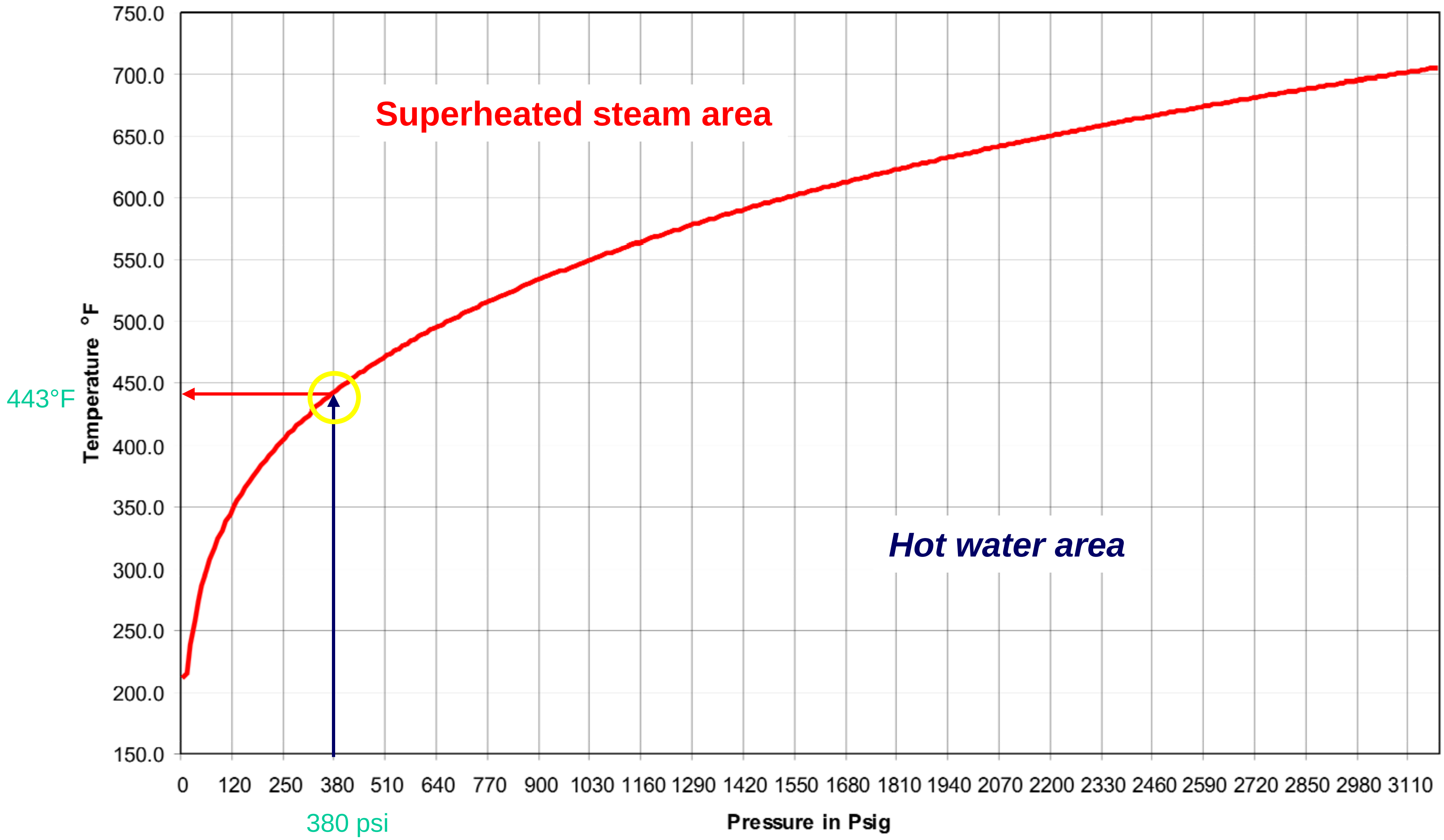
Melting point

If heat energy is added to ice, its temperature rises to a point at which it can no longer exist as ice.

Evaporation of Water at p= 0 psig



Saturated steam curve



Superheated versus Saturated Steam

- Superheated
  - Steam which is found above the saturation curve in temperature and pressure
  - Used for power generation
  - Used for long distance main distribution
  - Condensation found only during startup and shutdown conditions
- Saturated
  - Steam at the saturation curve
  - Highest potential heat transfer versus hot water and superheated steam
  - Quality of steam is extremely important (more energy in dry versus wet steam)
  - Condenses during transmission and the transfer of heat to a process
- Condensate must be removed throughout the steam system

Steam Trap Definition and Requirements

Steam Trap Definition

A steam trap is an automatic condensate control valve that discharges the air, non-condensable gases, and condensate from the steam system, while preventing the passage (loss) of live steam

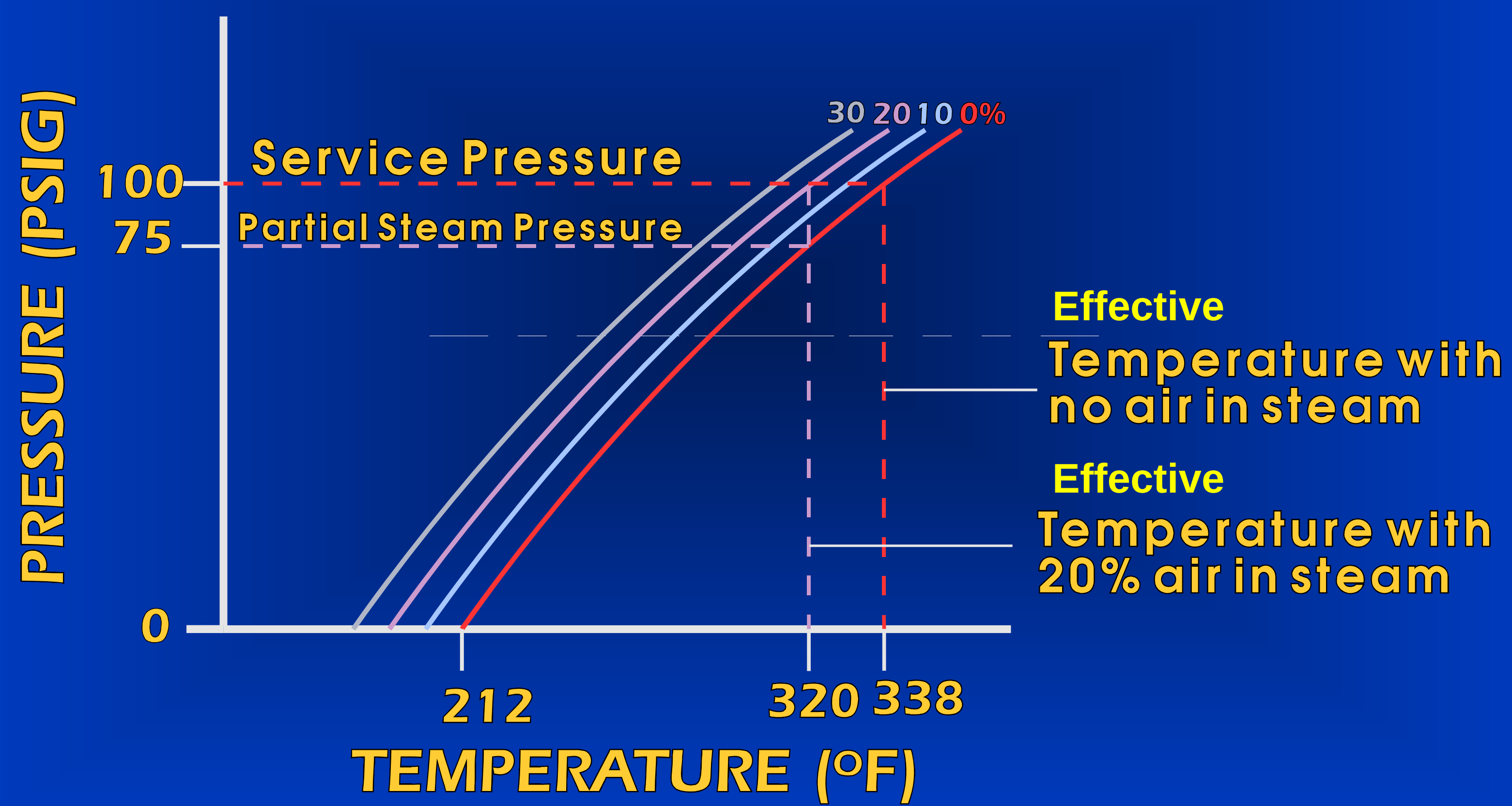
Basic Requirements

- **Discharge of condensate without loss of live steam**
- **Automatic air-venting**

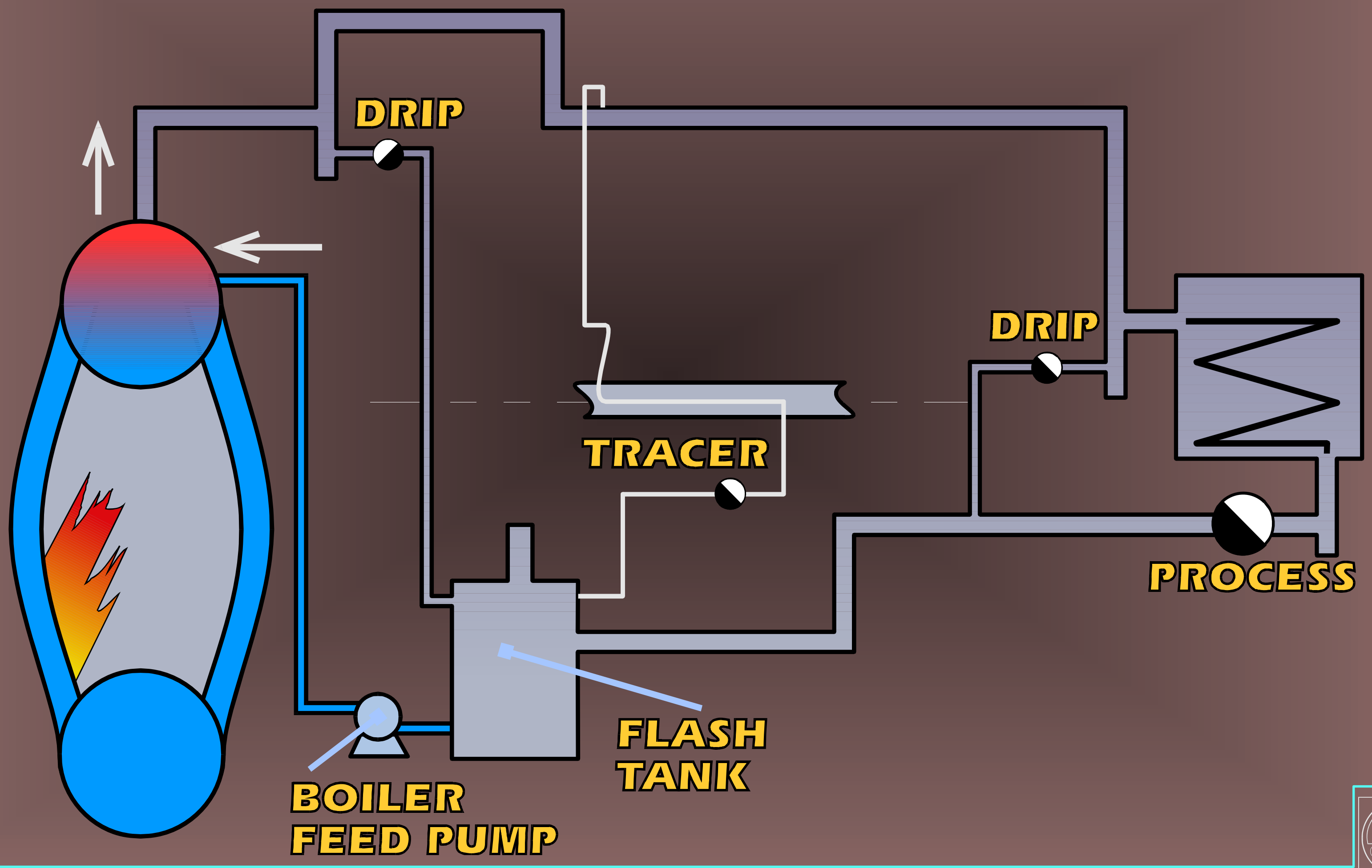
Additional Requirements

- **Must not affect the heating process**
  - **(no backing up of condensate)**
- **Make full use of the condensate heat**
  - **(through backing up of condensate)**
- **Not affected by back pressure**
- **Suitable for pressure and flow rate fluctuations**
- **Easy to install**
- **Corrosion resistant**
- **Unaffected by dirt**
- **Ease of maintenance**
- **Frost proof**
- **Unaffected by water hammer**

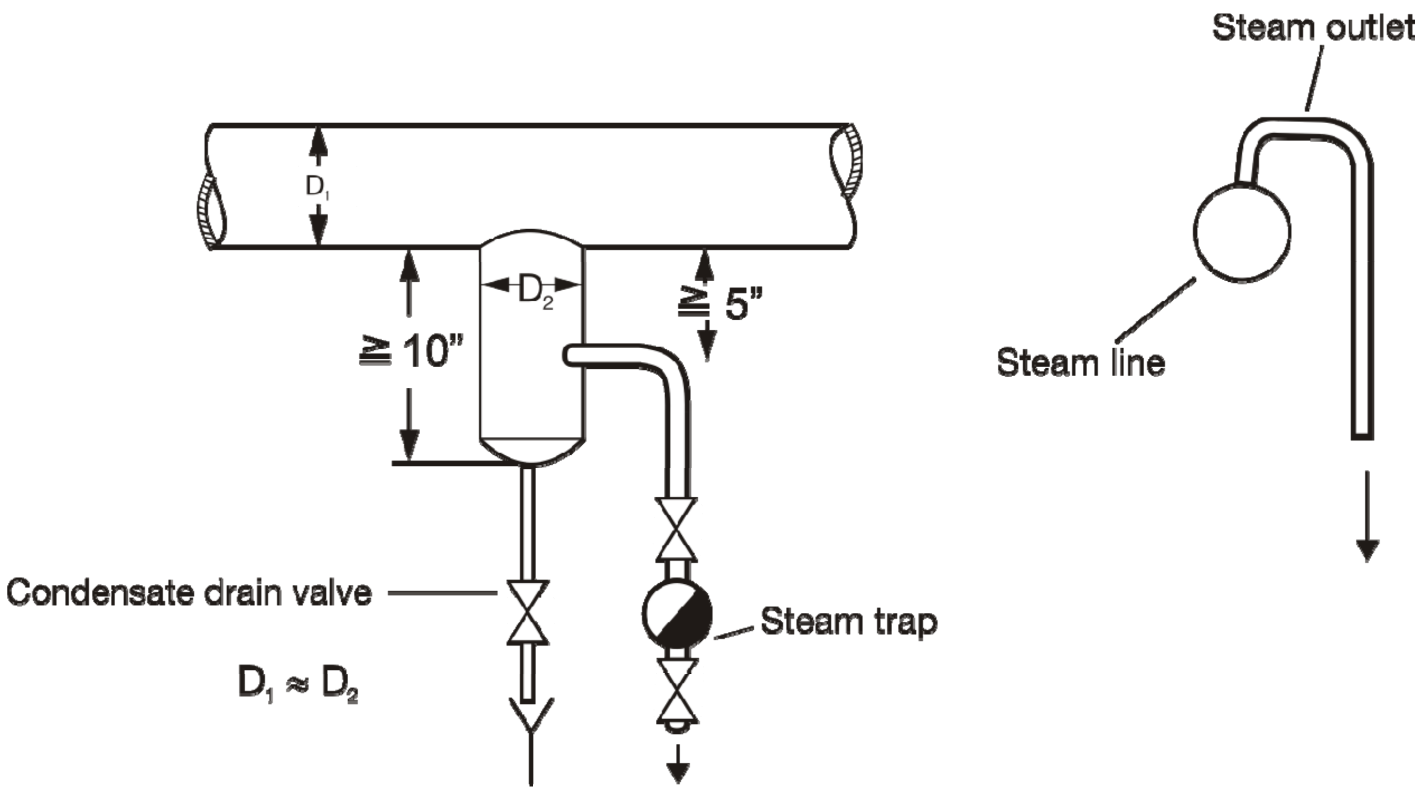
AIR IN STEAM


PRESSURE (PSIG)
100
75
0
Service Pressure
Partial Steam Pressure
30 20 10 0%
Effective
Temperature with no air in steam
Effective
Temperature with 20% air in steam
212
320 338
TEMPERATURE (°F)

WHERE STEAM TRAPS ARE FOUND



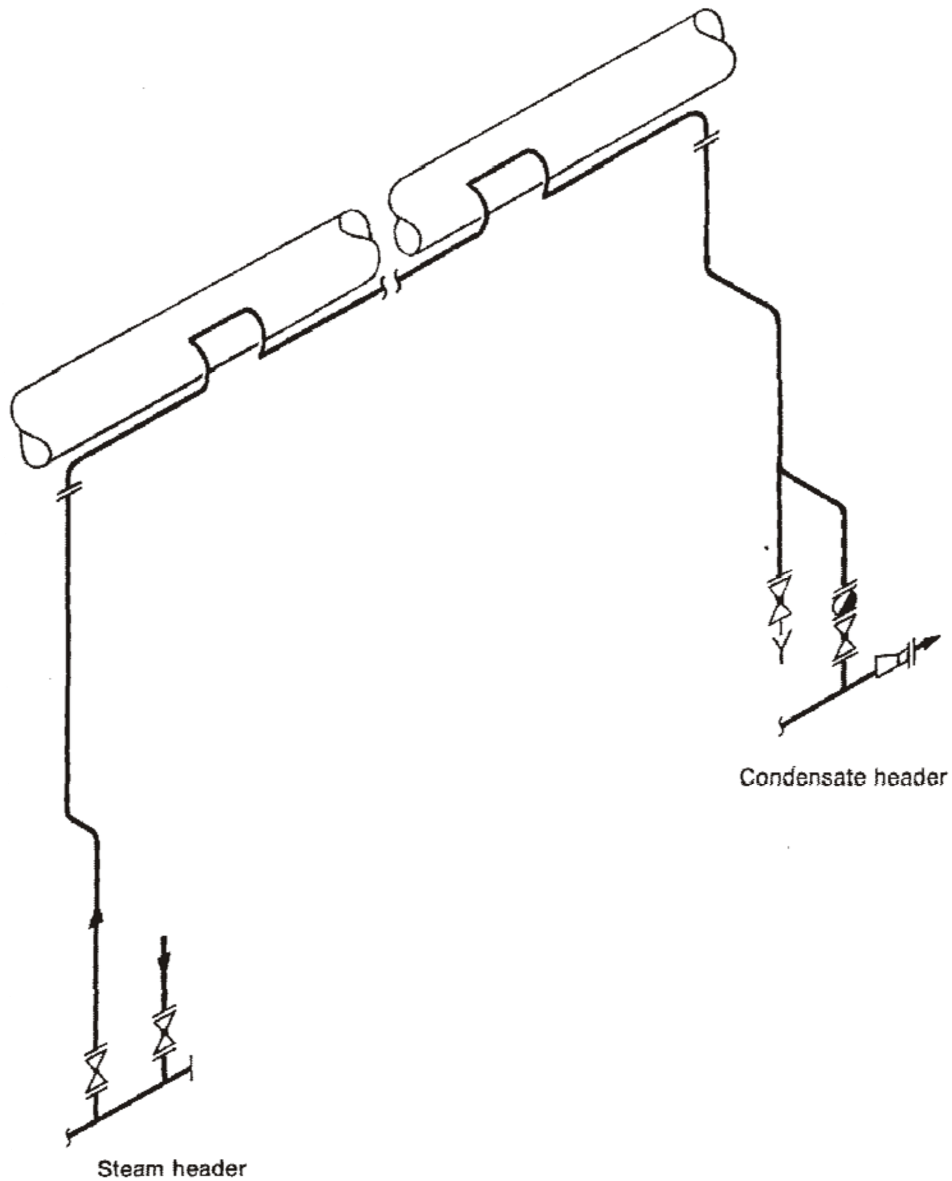
Application - Drip Pockets



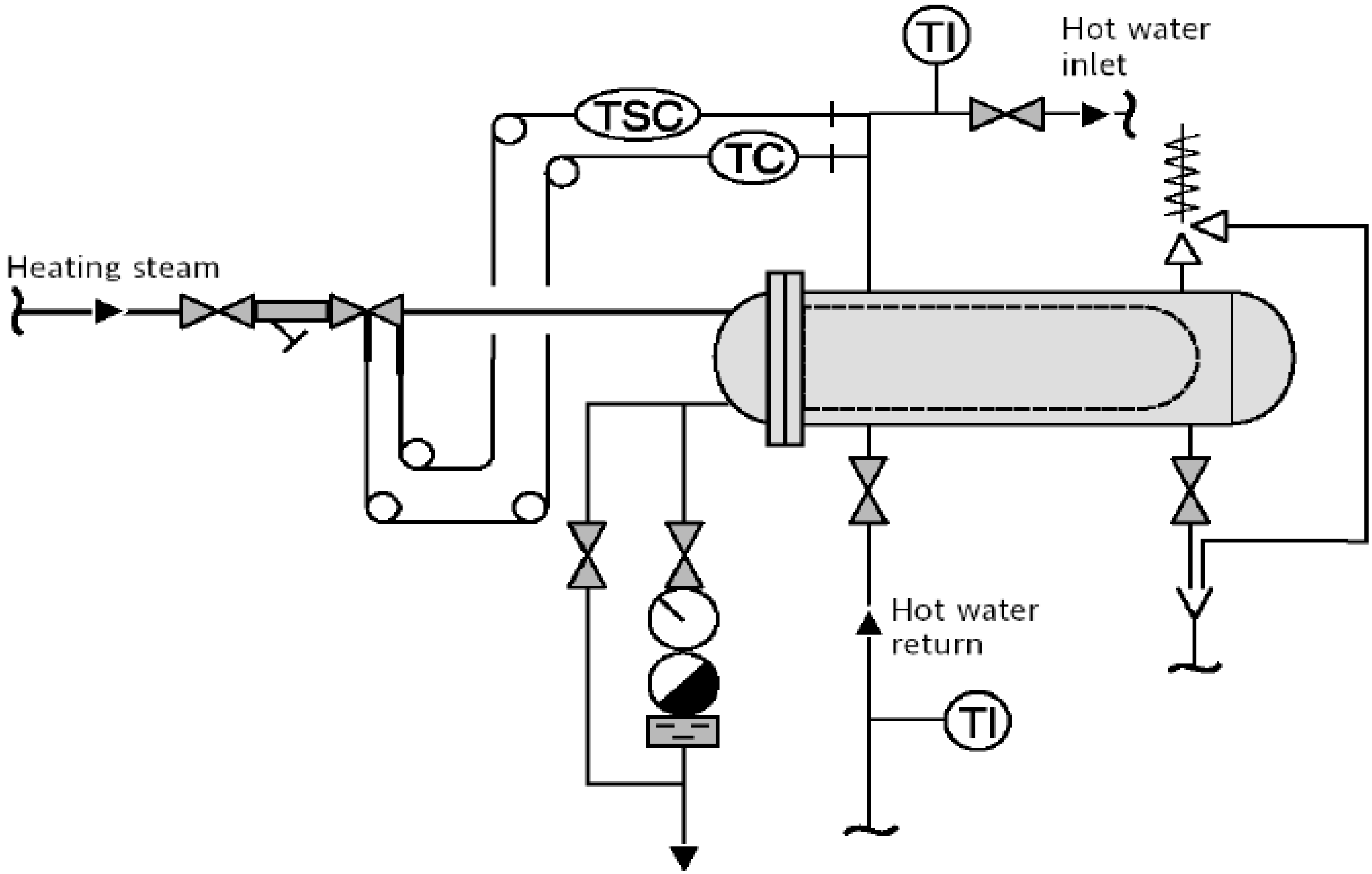
Application Notes: 300 linear ft maximum or at any low point
for 4" and smaller use same diameter as distribution main
for > 4" use ½ diameter of distribution main

Application - Steam Tracing

- **Maximum tracer length ~ 300 linear feet**
- **Expansion loops must be taken into account.**



Application Process



Criteria for the Selection of Steam Traps

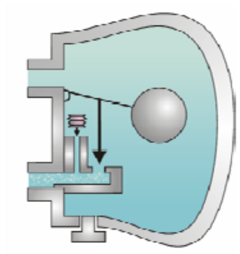
- Failure Mode
- Air Handling Ability
- Operation Near Steam Temperature
- Resistance to Freezing
- Self Draining
- Resistance to Superheat
- Resistance to Water Hammer
- Ease of Installation
- Ease of Checking and Troubleshooting
- Ease of Maintenance

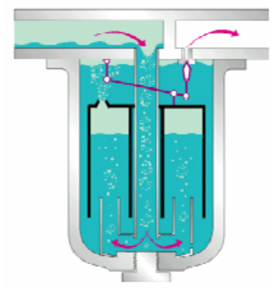
Cost of ownership

initial investment + energy consumption

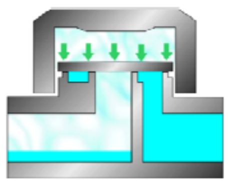
Basic Trap Technologies

- **Mechanical**

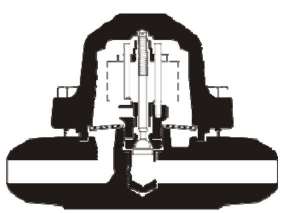




- **Thermodynamic**

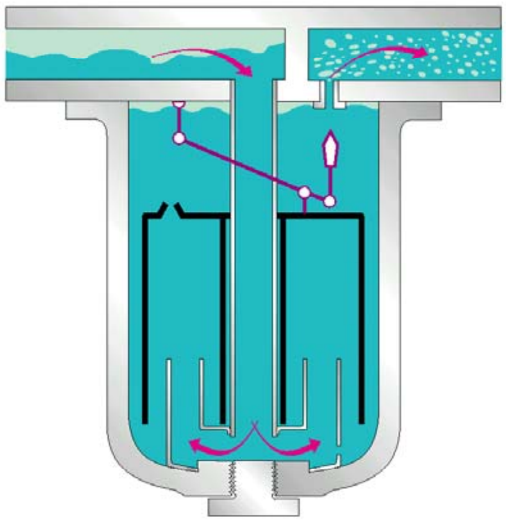


- **Thermostatic**



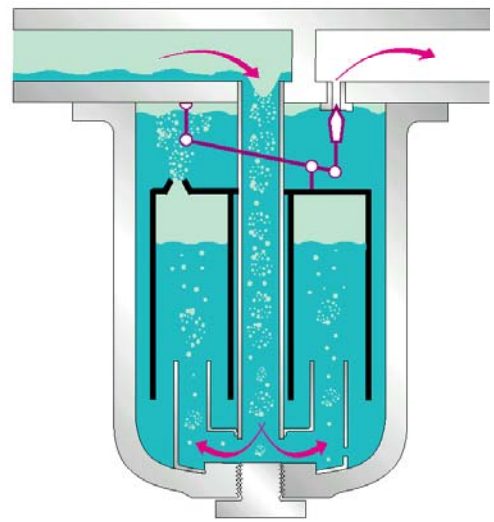

Inverted Bucket Trap

During service



Only condensate is present. The trap is in a open position.

During service



Flashing condensate and steam closes the trap.

Summary of Inverted Bucket Steam Traps

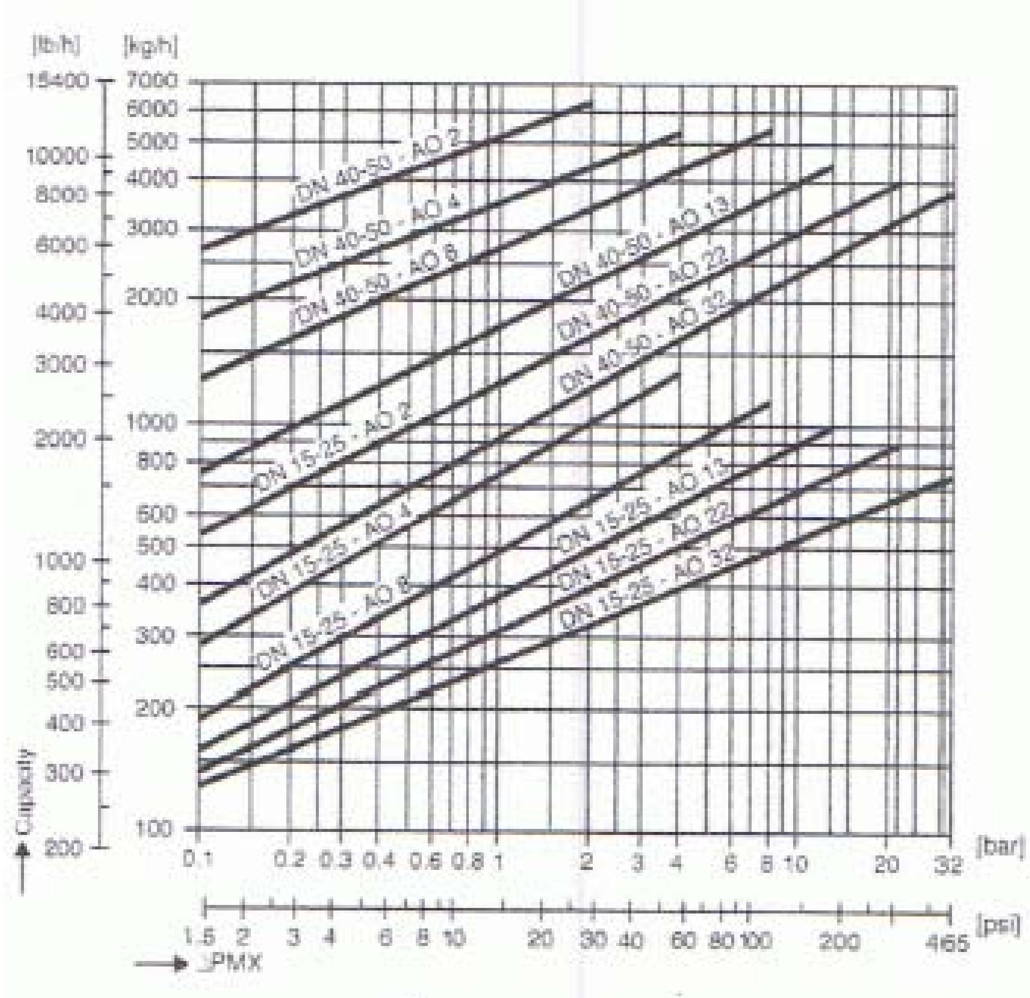
Advantages

- Effective on low pressure systems
- Not back-pressure sensitive
- Orifice on top of trap prevents dirt clogging

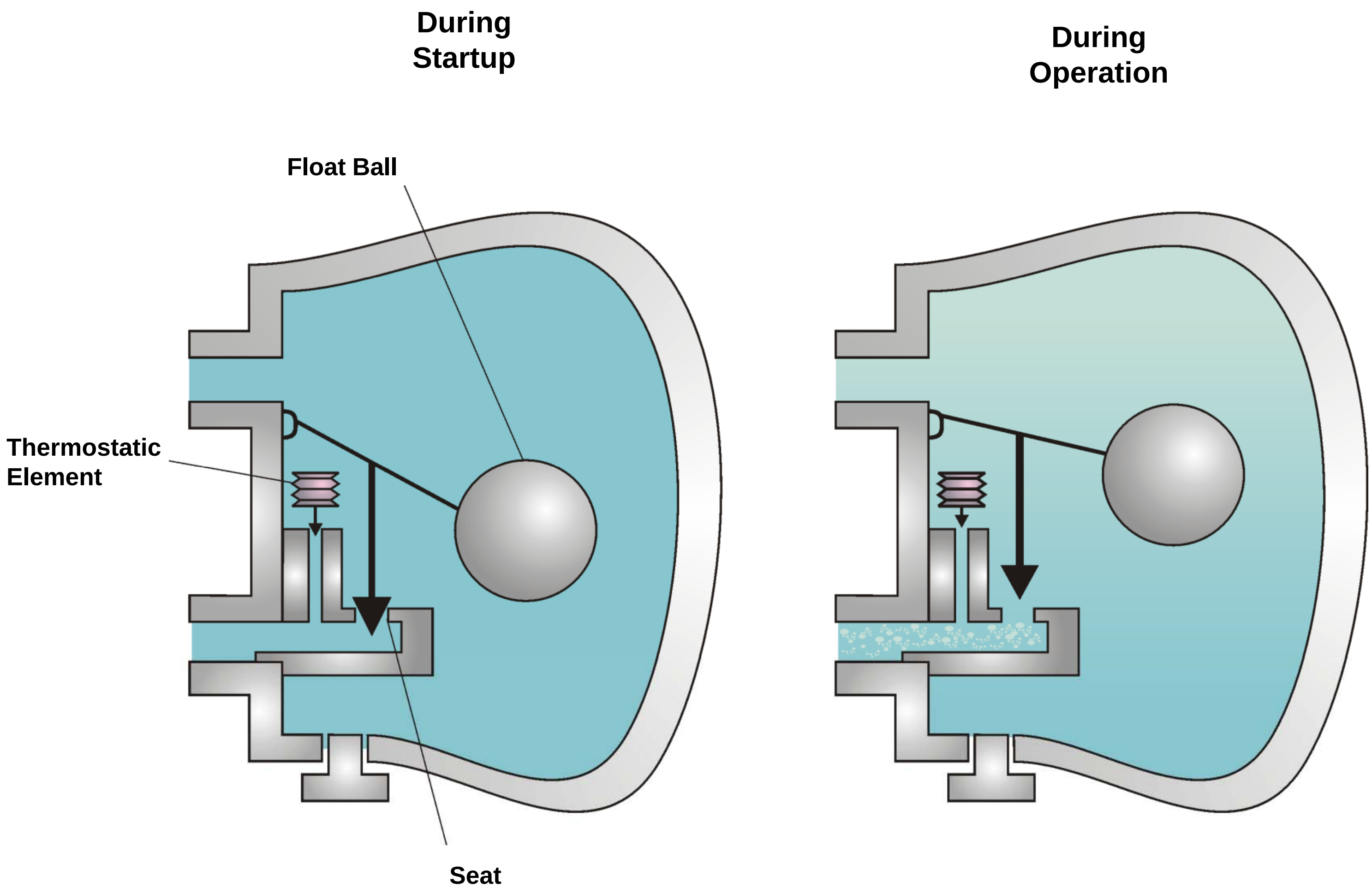
Disadvantages

- Position Sensitive
- Manual Startup Required
- Freezing Issues
- Consumes live steam in operation
- Weep hole sensitive to hematite buildup
- Not suitable for use in superheat
- Multiple and narrow orifice ranges for each model
- Oversize trap for startup loads
- Large in size and weight
- Water hammer sensitive

Multiple Orifices available for various loads.



Float & Thermostatic Trap



Summary of Float & Thermostatic Steam Traps

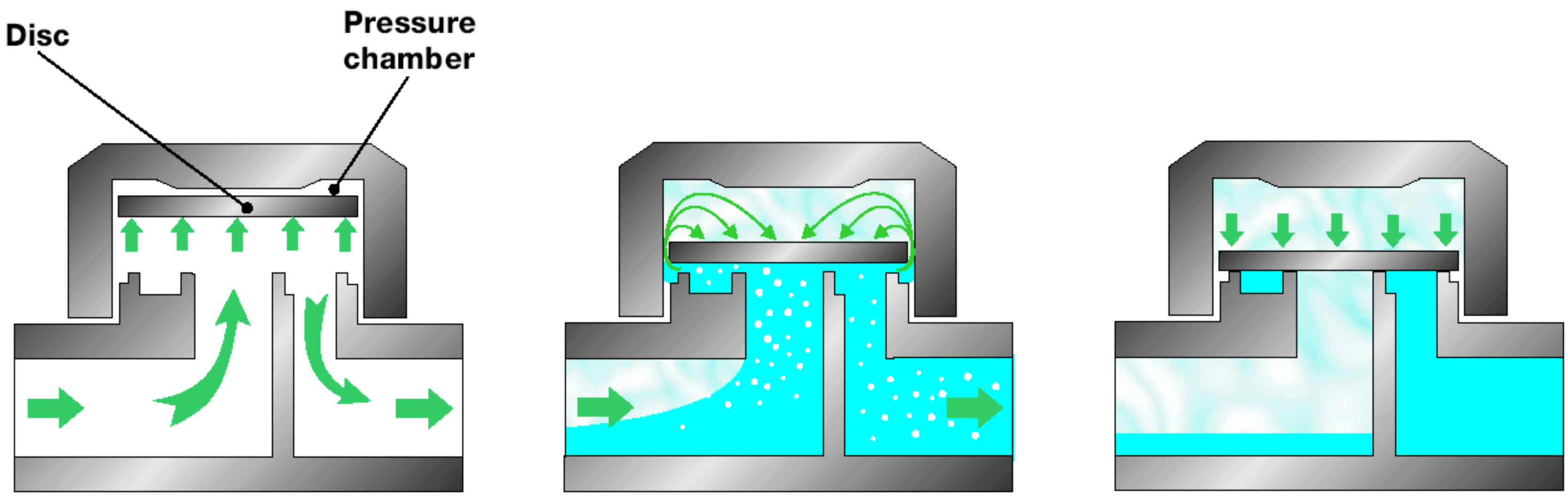
Advantages

- Automatic Start-Up
- Not Sensitive to Backpressure
- Effective at Low Pressures
- Effective for Vacuum Service
- Effective as Level Control
- Energy efficient due to water-seal
- Loss of water-seal does not lead to malfunction (compared to inverted bucket for example)

Disadvantages

- (Position Sensitive)
- Not for use with superheat
  - (if bellows thermostatic element is used)
- Multiple and narrow orifice ranges for each model
- Freezing Issues
- Oversize trap for startup loads
- Large in size and weight
- Water hammer sensitive

Thermodynamic Disc Trap



Trap is fully open.
Cold condensat can escape.

Trap starts to close.
Higher velocity underneath the disc leads to decreasing pressure.

Trap is totally closed.
Pressure in the pressure chamber is acting on a bigger area than the pressure underneath the disc.

Summary of Thermodynamic Steam Traps

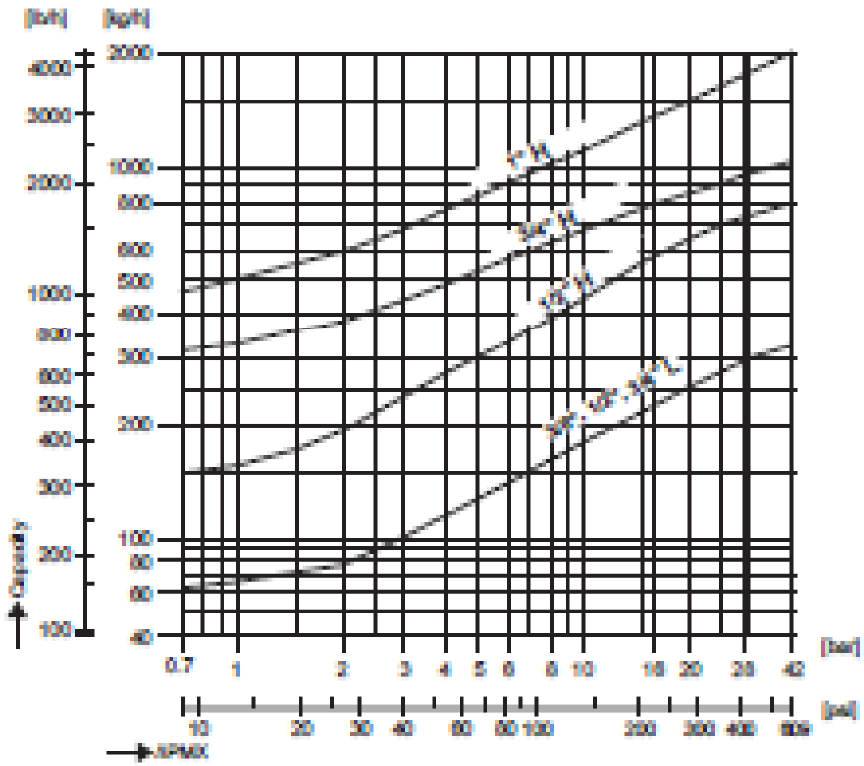
Advantages

- Economical initial investment
- Familiarity – years of application use
- Easy to diagnose failures without special equipment due to positive discharge
- Suitable for superheat
- Fail open failure mode

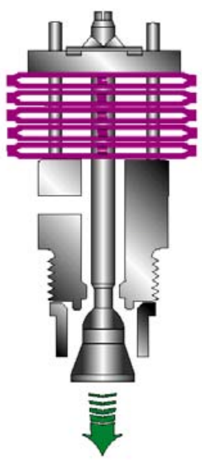
Disadvantages

- Back Pressure Sensitive
- Position Sensitive (preferred orientation)
- Ambient Condition Sensitive
- Consumes live steam in operation
- Poor air venting
- Rapid destruction of sealing ability with dirty steam
- Large Steam Losses / trap wear
- Not repairable
- Small startup-to-hot load ratio
- Potential safety issue with open discharge

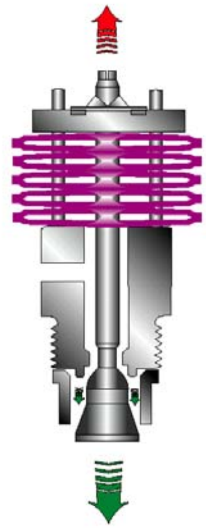
One Sizing curve per Line Size



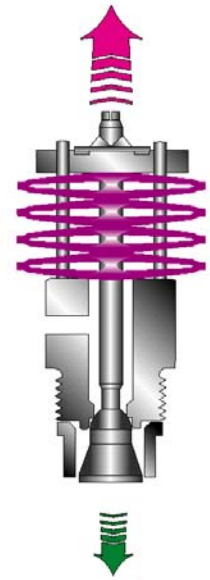
Bimetallic Thermostatic Trap Operation



During starting-up of a plant and in the presence of cold condensate and air the Duo steel plates are flat. The service pressure acts in the opening direction, the valve is completely open.



With rising condensate temperature the plates deflect and draw the stage nozzle towards the closing position, a thermostatic process. The service pressure and the pressure built up in the stage-nozzle chamber by flashing produce an opposite force, a thermodynamic process.



Immediately below saturation temperature the stage nozzle is almost closed. The pressure in the stage-nozzle chamber decreases and breaks down as the flashing across the stage-nozzle decreases. The stage-nozzle then closes. Thermostatic and spring charakteristics of the Duo steeel plates are balanced so that the opening and closing temperatures are always just a few degrees below saturation temperature.

Summary of Bimetallic Thermostatic Steam Traps

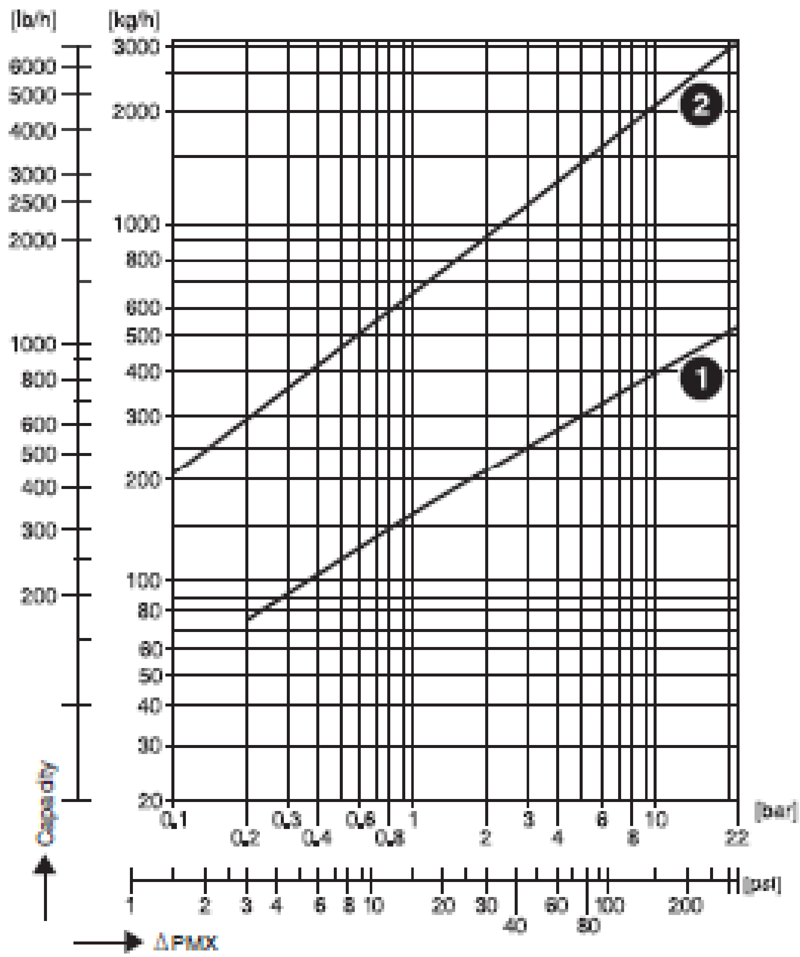
Advantages

- Automatic startup - large cold-to-hot startup and running load ratios
- Fail open failure mode
- Sub-cooled discharge allows for water seal resulting in no loss of live steam
- Not affected by water hammer
- Not affected by ambient conditions
- Excellent for superheat applications
- Not position sensitive
- Effective for very high pressure applications (4,000 psi)
- Repairable via new regulator assembly

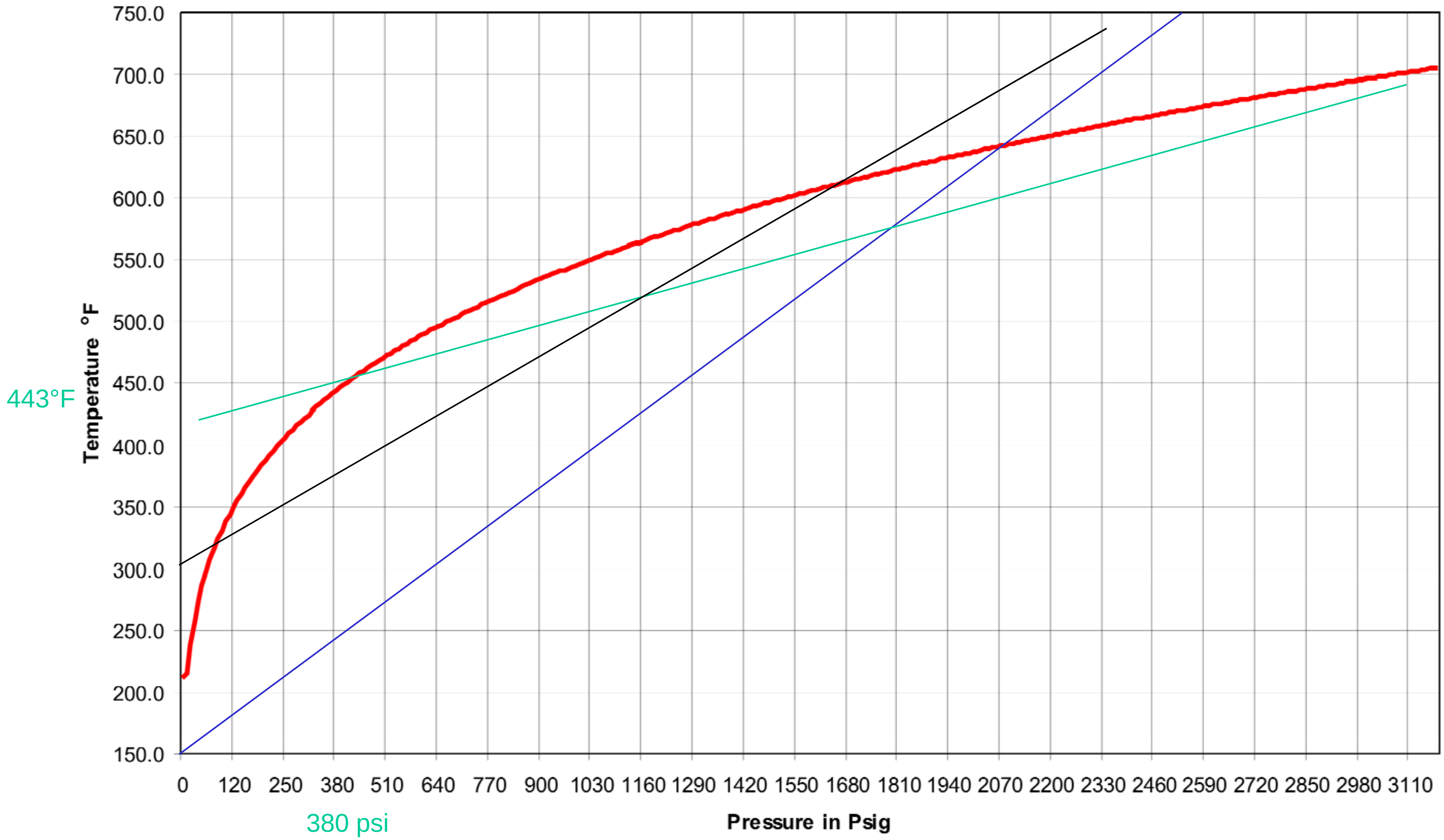
Disadvantages

- Not suitable for low differential pressure applications
- Sub-Cooled discharge causes backing-up concern in the design of some manufacturers
- Various manufacturer designs use different discharge temperatures
- Modulating discharge requires increased product and operation knowledge to diagnose trap failures

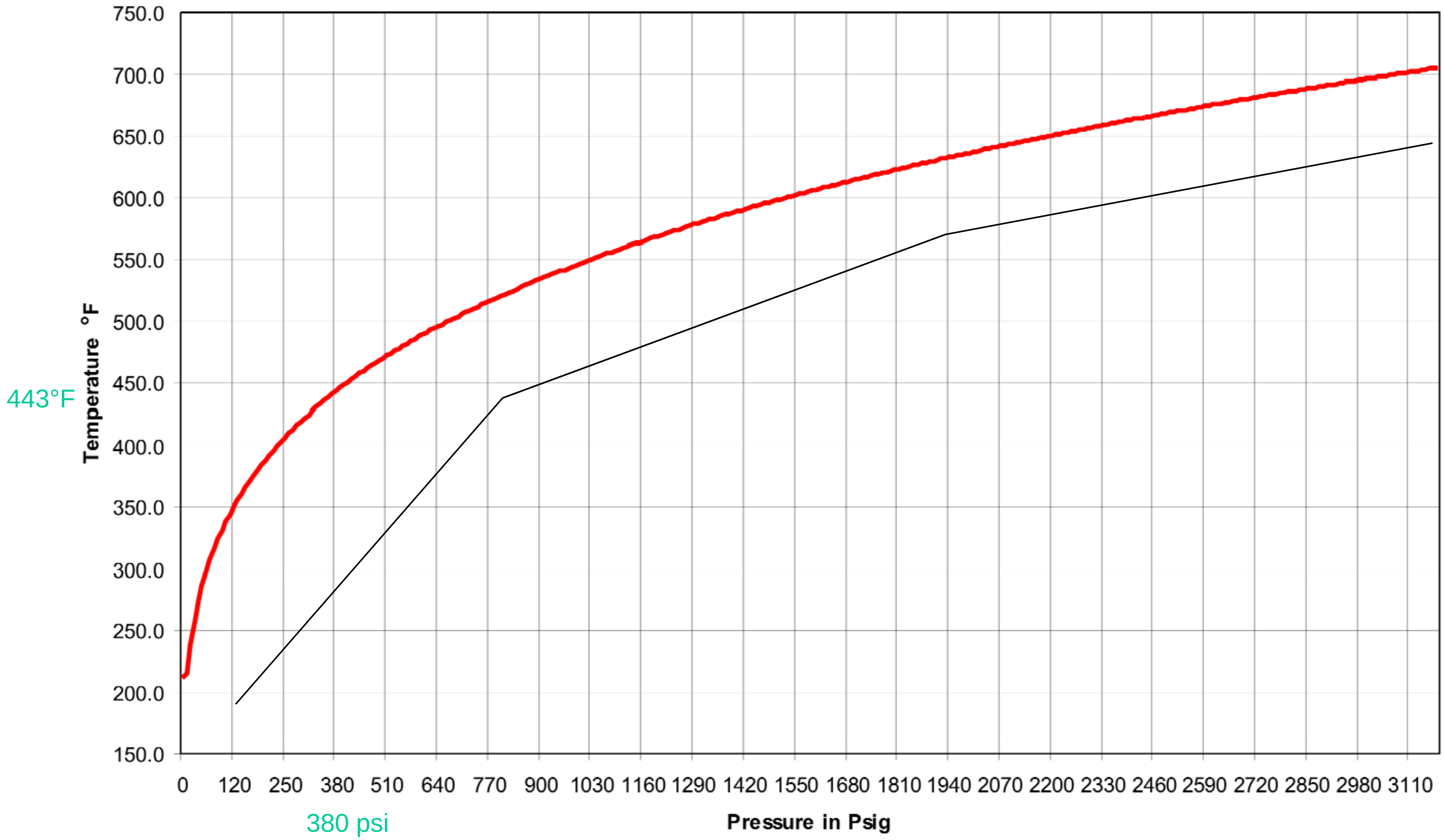
2 sizing Curves for each line size – Cold (start-up) and Hot



Potential Problem of Bi-metalic – Linear response

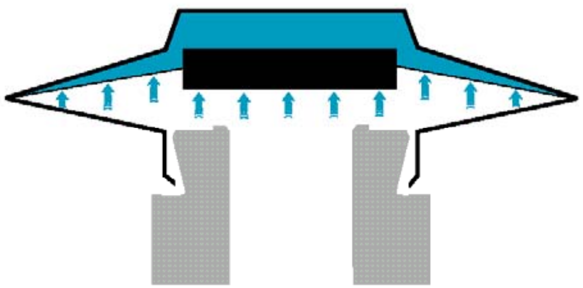


Engineering Fix



Membrane Thermostatic Trap Operation

Opening



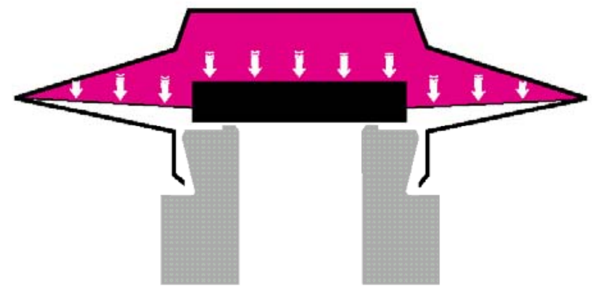
<u>During shut-down of the plant:</u>

With decreasing temperature the filling starts to condense.

<u>During start-up of the plant:</u>

The filling is condensed. Condensate and air can escape.

Closing



With rising condensate temperature the liquid filling starts to evaporate.

The pressure in the capsule rises; the membrane with the valve disc is moved in the closing direction.

Summary of Membrane Thermostatic Steam Traps

Advantages

- Not position sensitive
- Parallels saturated steam curve over entire range of the trap without orifice change-out
- Sub-cooled discharge allows for water seal resulting in no loss of live steam
- Automatic startup - large cold-to-hot startup and running load ratios
- Not affected by ambient conditions
- Repairable via replacement seat and/or membrane

Disadvantages

- Not suitable for vacuum service
- Not suitable for very low differential pressure applications (less than 1.5 psi differential)
- Not suitable for superheated steam service
- Maximum differential pressure limited to 465 psi

Steam Trap Selection

Not all Steam Trap types are equally suitable for a given application. Depending on the operating conditions and service in question, one or more technologies will be particularly well suited.

Trap Selection Criteria

Size	¼” – 4”
Upstream Pressure	Maximum: 5,040 psig @ 100 °F
Downstream Pressure	Minimum: slight vacuum
Flow:	Maximum: 140,000 lb/h @ 100 psi Δp
Temperature:	Maximum: 1,090 °F
Connection Type:	Butt-weld, Socket-weld, Flanged, NPT
Design Pressure:	Maximum: 5,040 psig @ 100 °F
Design Temperature:	Maximum: 1,090 °F
Application:	Drip, Tracer, Process Equipment (Which piece)

FLOWSERVE GESTRA

Steam Loss Testing

Cost of Ownership

Experience In Motion

Steam Loss Testing

- Formal testing program initiated at the Gestra factory in Bremen, Germany
- Test apparatus and procedure in accordance with the following standards and certified by TÜV
  - ASME PTC 39-2005
  - DIN EN 27 841
- Extensive series of tests for each trap tested
  - Multiple pressures
  - Various condensate loads
  - Horizontal versus vertical pipeline orientation
- Multiple manufacturers, technologies, and product models tested

TÜV NORD
Environmental Protection
- Power and Heat -

ZERTIFIKAT

Certification of the Test Stand according to DIN EN 27 841 and ASME PTC 39-2005

The Technical Controlling Organisation for Environmental Issues TÜV NORD Umweltschutz GmbH & C. KG

certificates

GESTRA AG
Flowserve GESTRA
Münchener Straße 77, D-28215 Bremen

conducting a Test Stand which enables to determine steam loss of automatic Steam Traps and which is according to DIN EN 27 841 (Oct. 1991) method A and ASME PTC 39-2005

date of the audit: 14 August 2008
This approval encloses an appendix with the Report of the inspection. The appendix is a constituent of this certificate.

This Certificate is guilty until:
August 2010

Certifikate-register-no.:108WTC023
Hamburg, 02 September 2008

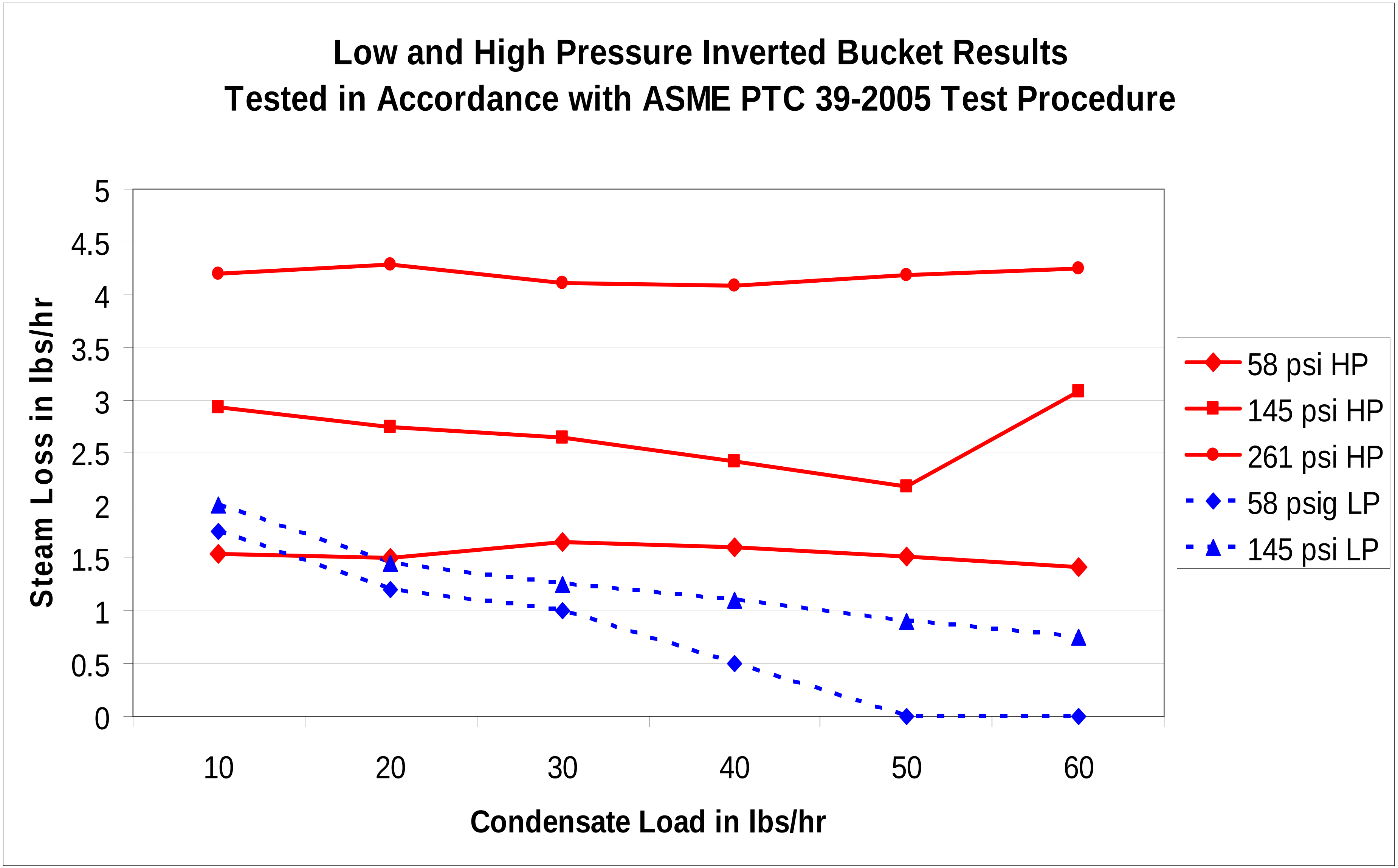
Dipl. Ing. Klaus Schwieger
Department Chief Region North

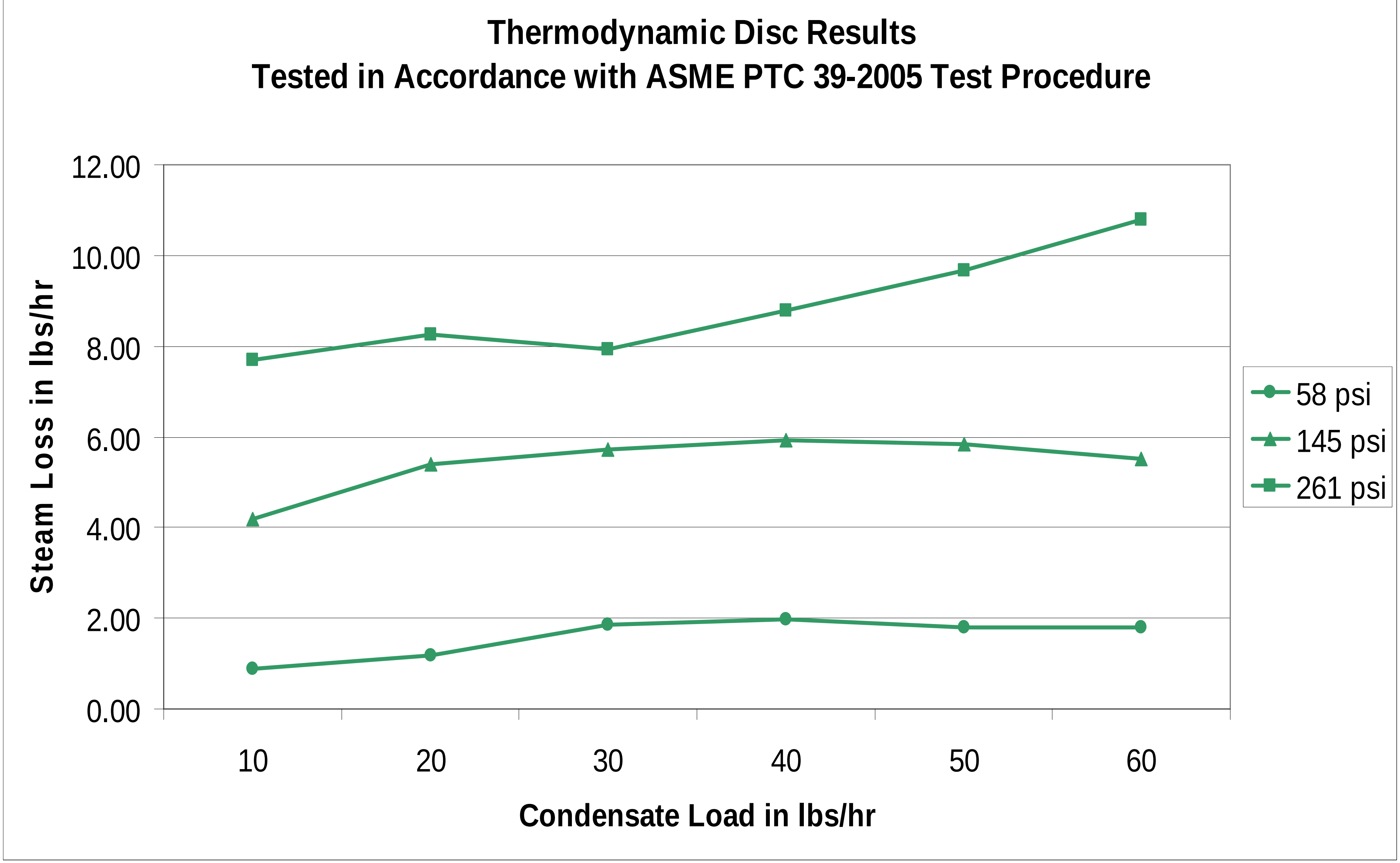
Dipl.-Ing. Thure von Wahl
Technical Expert

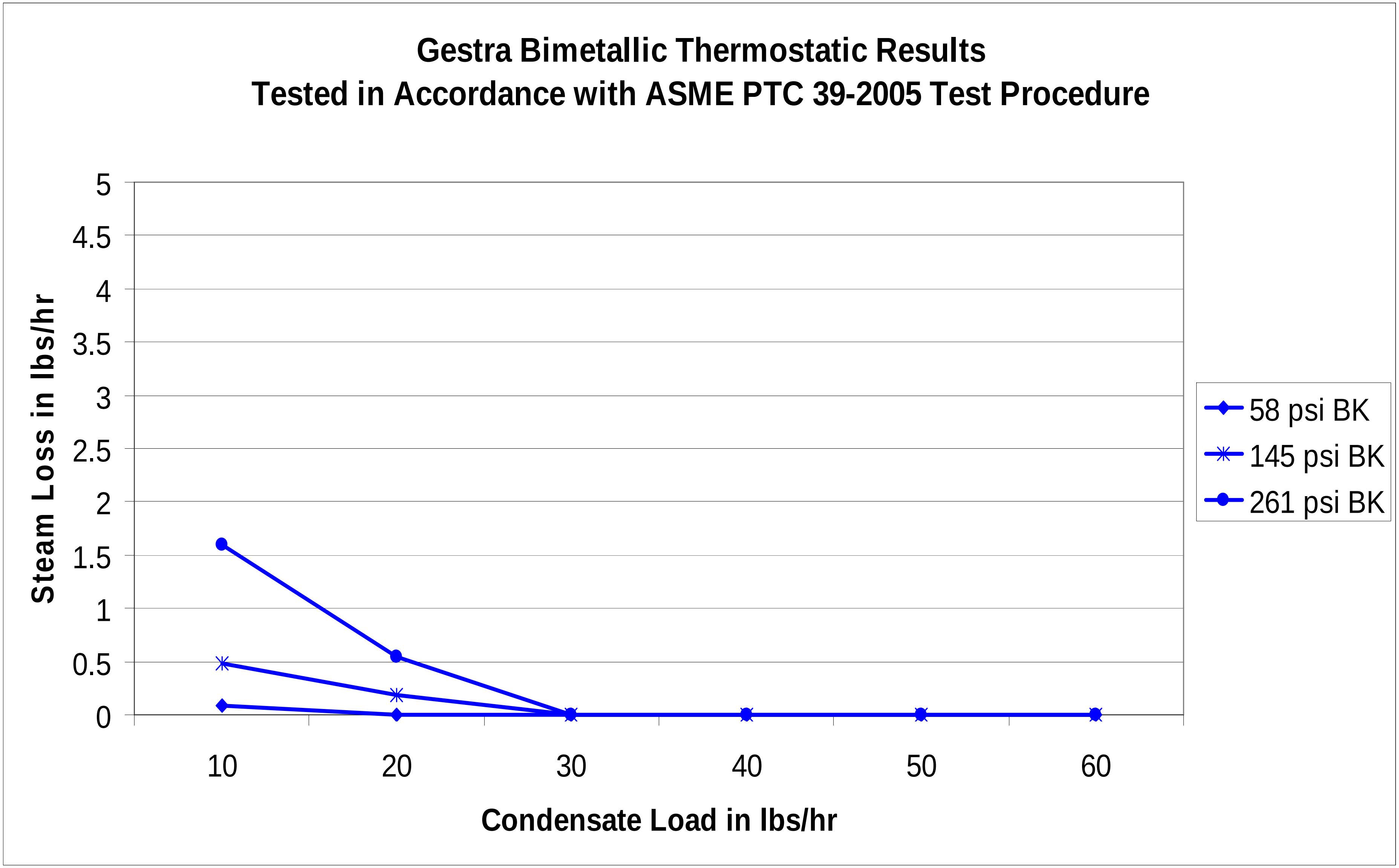
TÜV NORD Umweltschutz GmbH & Co. KG
Große Bahnstraße 31 - 22525 Hamburg
Tel.: 040 / 8557-2491 Fax.: 040 / 8557 - 2142

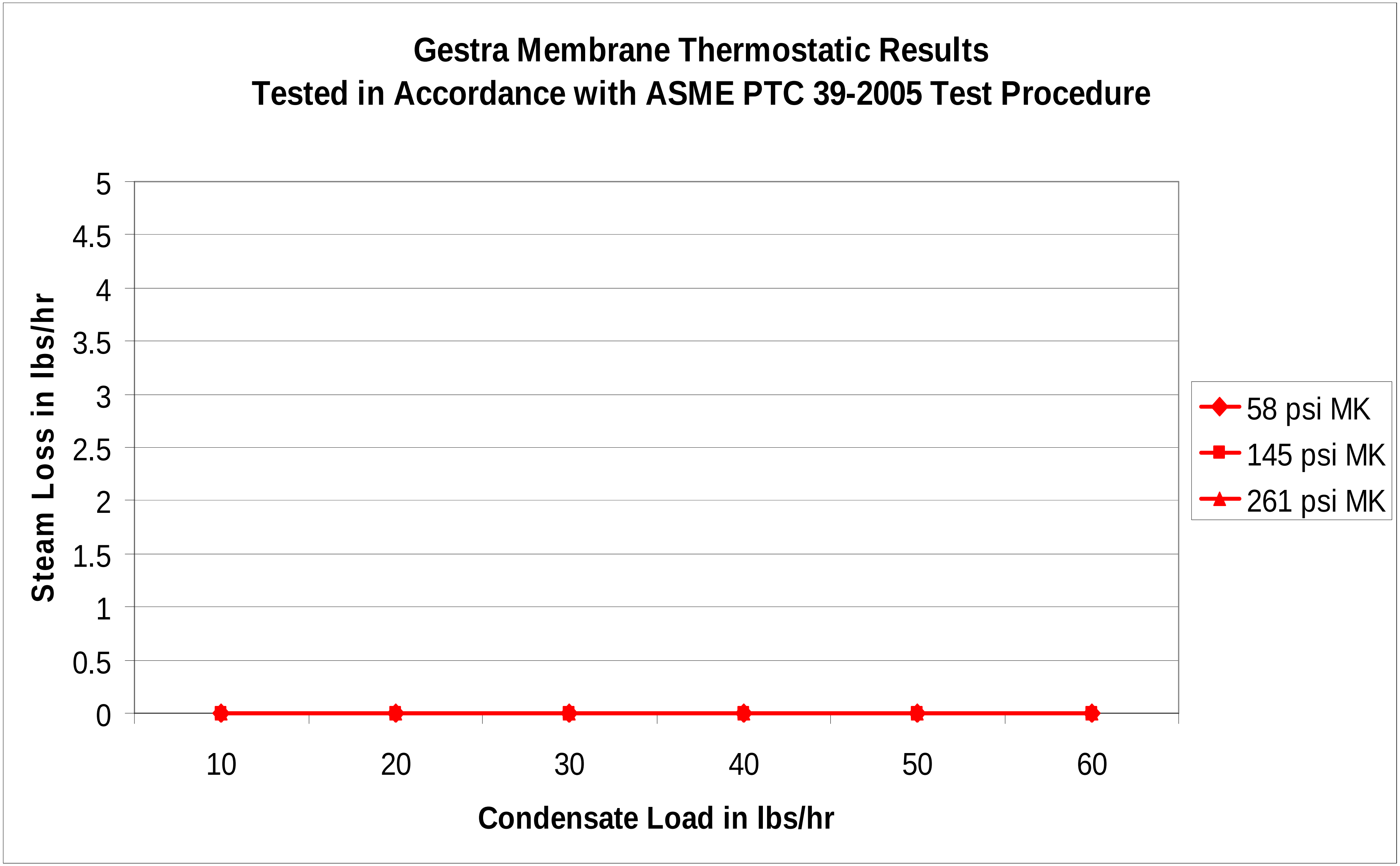
Cost of Ownership by Technology

- Thermodynamic and Inverted Bucket technologies consume live steam in normal operation versus zero consumption of a thermostatic type
- Under normal operations a loss of 2 lbs per hour costs $175.20 per year to operate
  - Based on steam cost of $10.00/1,000 lbs
  - (2 lbs/hr x 8,760 hours / 1,000 lbs) x $10.00 = $175.20
- With the typical life cycle of 5 years, this would equal $876 during normal operation
- Price Comparison between technologies
  - Thermodynamic $170
  - Inverted Bucket $225
  - Thermostatic $190 - $269
- 5 Year Cost of Ownership Including Initial Cost of Trap
  - Thermodynamic $1,046
  - Inverted Bucket $1,101
  - Thermostatic $190 - $269


Low and High Pressure Inverted Bucket Results
Tested in Accordance with ASME PTC 39-2005 Test Procedure
Steam Loss in lbs/hr
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
Condensate Load in lbs/hr
58 psi HP
145 psi HP
261 psi HP
58 psig LP
145 psi LP


Thermodynamic Disc Results
Tested in Accordance with ASME PTC 39-2005 Test Procedure
Steam Loss in lbs/hr
12.00
10.00
8.00
6.00
4.00
2.00
0.00
10
20
30
40
50
60
Condensate Load in lbs/hr
58 psi
145 psi
261 psi


Gestra Bimetallic Thermostatic Results
Tested in Accordance with ASME PTC 39-2005 Test Procedure
Steam Loss in lbs/hr
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
Condensate Load in lbs/hr
58 psi BK
145 psi BK
261 psi BK


Gestra Membrane Thermostatic Results
Tested in Accordance with ASME PTC 39-2005 Test Procedure
Steam Loss in lbs/hr
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
10
20
30
40
50
60
Condensate Load in lbs/hr
58 psi MK
145 psi MK
261 psi MK

Cost of Ownership

Cost of Steam (Fuel, Boiler Chemicals, Water, Maintenance, etc.)

Loss of 2 lb/hr	$7.50	$10.00	$15.00	$20.00	$25.00
100 Traps	$13,140	$43,800	$65,700	$87,600	$109,500
250 Traps	$32,850	$43,800	$65,700	$87,600	$109,500
500 Traps	$65,700	$87,600	$131,400	$175,200	$219,000
1,000 Traps	$131,400	$175,200	$262,800	$350,400	$438,000
2,500 Traps	$328,500	$438,000	$657,000	$876,000	$1,095,000
5,000 Traps	$657,000	$876,000	$1,314,000	$1,752,000	$2,190,000
10,000 Traps	$1,314,000	$1,752,000	$2,628,000	$3,504,000	$4,380,000

Example: (1,000 traps x 2 lbs/hr x 8,760 hours / 1,000 lbs) x $15.00 = $262,800

Justifying a Change in Technology

consider a facility with a mixed population of 1,000 traps with different technologies and different differential pressures

Trap Population	50 psi	150 psi	250 psi	Total
Thermodynamic	100	200	200	500
Inverted Bucket	200	200	100	500
Total	300	400	300	1000

Steam Loss by Trap	50 psi	150 psi	250 psi
Thermodynamic	2.0	5.8	8.0
Inverted Bucket	1.0	1.2	4.0

Steam Loss by Hour	50 psi	150 psi	250 psi	Total
Thermodynamic	200	1,160	1,600	2,960
Inverted Bucket	200	240	400	840
Total	400	1,400	2,000	3,800

Example: (3,800 lbs/hr x 8,760 hours / 1,000 lbs) x $15.00 = $499,320 of wasted steam

What Does It Cost to Change Steam Trap Technologies? Consider a 5 Year Plan

- Traps fail and must be replaced - Assume 5 year trap life equating to 20% failure rate
- Minor pipe work required - typical installations have a coupling on one or both sides of the trap
- Thermostatic purchase price could be $0 - $100 more per trap depending upon make, model, size, etc.
  - All Gestra traps are designed to be field repairable at a fraction of the cost of a new trap
  - All Gestra traps carry a two or three year warranty depending upon model
- Let's assume an average price premium of $50 per trap
- Based on a trap population of 1,000 traps, each year we replace 200 traps
- 200 traps at a $50 price premium = thermostatic investment of $10,000
- Based on our previous example, with every 200 traps replaced with thermostatic technology, we see a savings of 760 lbs/hr (3,800 lbs/hr x 20%)
- 760 lbs/hr x 8,760 hours / 1,000 lbs x $15.00 = $99,864 in steam savings
- $99,864 in steam savings - $10,000 possible price premium = net savings of $88,864 per year

Importance of Trap Management

- On average 20% of steam traps within a facility are failed
- Failure mode can be leaking/blowing, plugged, or incorrectly sized
- Typically of the failed traps, a minimum of 50% are leaking or blowing live steam equating to 30-80 lbs/hour of steam loss per trap
- Plugged or cold traps can affect the operation or efficiency of the process equating to off spec product, lower production rates, and frozen lines

	Failed Open	$5.00	$7.50	$10.00	$12.50	$15.00
1,000 Traps	100	$131,400	$197,100	$262,800	$328,500	$394,200
2,000 Traps	200	$262,800	$394,200	$525,600	$657,000	$788,400
3,000 Traps	300	$394,200	$591,300	$788,400	$985,500	$1,182,600
4,000 Traps	400	$525,600	$788,400	$1,051,200	$1,314,000	$1,576,800
5,000 Traps	500	$657,000	$985,500	$1,314,000	$1,642,500	$1,971,000

Example: 200 failed traps x 30 lbs/hr x 8,760 hours / 1,000 lbs x $7.50 = $394,200

Gestra Steam Trap Management Solutions

- Steam trap tagging and survey route definition
- Database creation in Excel® format
- Ultrasonic testing with Gestra VKP-40EX management system
- Recommendations for failed traps
- Identify and recommend process improvements
    - Incorrect piping, undersized steam traps, condensate recovery, etc.
- Estimate steam and monetary loss
- Prioritize failed trap replacement utilizing VKP-40EX ultrasonic signature graph
- Provide bill of materials for trap replacement

In Conclusion

- There are multiple trap technologies available in the market place for a very wide range of applications
- Thermostatic steam traps are the most energy efficient technology available in the market
- Consider the total cost of ownership when selecting trap technologies (initial investment plus annual energy consumption)
- With the ever increasing cost of energy, thermostatic technologies offer quantifiable cost savings equating to increased bottom line profits for the end user
- Gestra is the world leader in thermostatic steam trap development and production
- Gestra trap management solutions offer a platform for reduced energy costs and improved plant efficiency
- Gestra products offer the lowest cost of ownership for steam traps and boiler blowdown equipment

Energy Tips – Steam

Steam Tip Sheet #15 • January 2006

Industrial Technologies Program

Suggested Actions

- Determine your annual fuel costs based on utility bills.
- Install a steam flowmeter in your facility and calculate your steam generation cost. Compare this with the benchmark value.
- Using a systems approach, do a thermoeconomic analysis to determine the effective cost of steam. (See page 2: Effective Cost of Steam.)

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool* and *Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

Visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices to access these and many other industrial efficiency resources and information on training.

Benchmark the Fuel Cost of Steam Generation

Benchmarking the fuel cost of steam generation, in dollars per 1,000 pounds ($/1,000 lb) of steam, is an effective way to assess the efficiency of your steam system. This cost is dependent upon fuel type, unit fuel cost, boiler efficiency, feedwater temperature, and steam pressure. This calculation provides a good first approximation for the cost of generating steam and serves as a tracking device to allow for boiler performance monitoring. Table 1 shows the heat input required to produce 1 lb of saturated steam at different operating pressures and varying feedwater temperatures. Table 2 lists the typical energy content and boiler combustion efficiency for several common fuels.

Table 1. Energy Required to Produce One Pound of Saturated Steam, Btu*

Operating Pressure, psig	Feedwater Temperature, °F				
	50	100	150	200	250
150	1,178	1,128	1,078	1,028	977
450	1,187	1,137	1,087	1,037	986
600	1,184	1,134	1,084	1,034	984

* Calculated from steam tables based on the difference between the enthalpies of saturated steam and feedwater.

Table 2. Energy Content and Combustion Efficiency of Fuels

Fuel Type, sales unit	Energy Content, Btu/sales unit	Combustion Efficiency, %
Natural Gas, MMBtu	1,000,000	85.7
Natural Gas, thousand cubic feet	1,030,000	85.7
Distillate/No. 2 Oil, gallon	138,700	88.7
Residual/No. 6 Oil, gallon	149,700	89.6
Coal, ton	27,000,000	90.3

Note: Combustion efficiency is based on boilers equipped with feedwater economizers or air preheaters and 3% oxygen in flue gas.

Data from the tables above can be used to determine the cost of usable heat from a boiler or other combustion unit. The calculations can also include the operating costs of accessories such as feedwater pumps, fans, fuel heaters, steam for fuel atomizers and soot blowing, treatment chemicals, and environmental and maintenance costs.

Example

A boiler fired with natural gas costing $8.00/MMBtu produces 450-pounds-per-square-inch-gauge (psig) saturated steam and is supplied with 230°F feedwater. Using values from the tables, calculate the fuel cost of producing steam.

Steam Cost = ($8.00/MMBtu/$10^6$ Btu/MMBtu) x 1,000 lb x 1,006 (Btu/lb)/0.857
= $9.39/1,000 lb

Effective Cost of Steam

The effective cost of steam depends on the path it follows from the boiler to the point of use. Take a systems approach and consider the entire boiler island, including effect of blowdown, parasitic steam consumption, and deaeration. Further complications arise because of the effects of process steam loads at different pressures, multiple boilers, and waste heat recovery systems. To determine the effective cost of steam, use a combined heat and power simulation model that includes all the significant effects.

Multi-Fuel Capability

For multi-fuel capability boilers, take advantage of the volatility in fuel prices by periodically analyzing the steam generation cost, and use the fuel that provides the lowest steam generation cost.

Higher Versus Lower Heating Values

Fuel is sold based on its gross or higher heating value (HHV). If, at the end of the combustion process, water remains in the form of vapor, the HHV must be reduced by the latent heat of vaporization of water. This reduced value is known as the lower heating value (LHV).

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January 2006
Steam Tip Sheet #15

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Energy Tips – Steam

Steam Tip Sheet #1 • January 2006

Industrial Technologies Program

Suggested Actions

Steam traps are tested primarily to determine whether they are functioning properly and not allowing live steam to blow through.

- Establish a program for the regular systematic inspection, testing, and repair of steam traps.
- Include a reporting mechanism to ensure thoroughness and to provide a means of documenting energy and dollar savings.

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool* and *Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

Visit the BestPractices Web site at www.eere.energy.gov/industry/bestpractices to access these and many other industrial efficiency resources and information on training.

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.

Example

In a plant where the value of steam is $10.00 per thousand pounds ($10.00/1,000 lb), an inspection program indicates that a trap on a 150-pound-per-square-inch-gauge (psig) steam line is stuck open. The trap orifice is $1/8$th inch in diameter. The table shows the estimated steam loss as 75.8 pounds per hour (lb/hr). After the failed trap is repaired, annual savings are:

Annual Savings = 75.8 lb/hr x 8,760 hr/yr x $10.00/1,000 lb
= $6,640

Leaking Steam Trap Discharge Rate*

Trap Orifice Diameter, inches	Steam Loss, lb/hr			
	Steam Pressure, psig			
	15	100	150	300
1/32	0.85	3.3	4.8	–
1/16	3.4	13.2	18.9	36.2
1/8	13.7	52.8	75.8	145
3/16	30.7	119	170	326
1/4	54.7	211	303	579
3/8	123	475	682	1,303

* From the Boiler Efficiency Institute. Steam is discharging to atmospheric pressure through a re-entrant orifice with a coefficient of discharge equal to 0.72.

Steam Trap Testing Facts

Steam traps are tested to determine if they are functioning properly and not cold plugging or failing in an open position and allowing live steam to escape into the condensate return system. There are four basic ways to test steam traps: temperature, sound, visual, and electronic.

Recommended Steam Trap Testing Intervals

- High-Pressure (150 psig and above): Weekly to Monthly
- Medium-Pressure (30 to 150 psig): Monthly to Quarterly
- Low-Pressure (below 30 psig): Annually

Adapted from an Energy TIPS fact sheet that was originally published by the Industrial Energy Extension Service of Georgia Tech.

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January 2006
Steam Tip Sheet #1

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Energy Tips – Steam

Steam Tip Sheet #8 • January 2006

Industrial Technologies Program

Suggested Actions

Reduce operating costs through maximizing the return of hot condensate to the boiler. Consider the following actions:

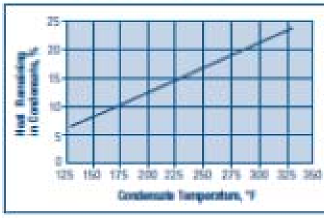
- If a condensate return system is absent, estimate the cost of a condensate return and treatment system (as necessary) and install one if economically justified.
- Repair steam distribution and condensate return system leaks.
- Insulate condensate return system piping to conserve heat and protect personnel against burns.

Return Condensate to the Boiler

When steam transfers its heat in a manufacturing process, heat exchanger, or heating coil, it reverts to a liquid phase called condensate. An attractive method of improving your power plant's energy efficiency is to increase the condensate return to the boiler.

Returning hot condensate to the boiler makes sense for several reasons. As more condensate is returned, less make-up water is required, saving fuel, makeup water, and chemicals and treatment costs. Less condensate discharged into a sewer system reduces disposal costs. Return of high purity condensate also reduces energy losses due to boiler blowdown. Significant fuel savings occur as most returned condensate is relatively hot (130°F to 225°F), reducing the amount of cold makeup water (50°F to 60°F) that must be heated.

A simple calculation indicates that energy in the condensate can be more than 10% of the total steam energy content of a typical system. The graph shows the heat remaining in the condensate at various condensate temperatures, for a steam system operating at 100 pounds per square inch gauge (psig), with makeup water at 55°F.



Let:

h_c = enthalpy of condensate at 180°F = 148 Btu/lb

h_m = enthalpy of makeup water at 55°F = 23 Btu/lb

h_s = enthalpy of steam at 100 psig = 1,189 Btu/lb

Heat remaining in condensate (%):

$= (h_c - h_m)/(h_s - h_m) \times 100$

$= (148 - 23)/(1{,}189 - 23) \times 100 = 11.0\%$

Example

Consider a steam system that returns an additional 10,000 pounds per hour (lb/hr) of condensate at 180°F after distribution modifications. Assume this system operates 8,000 hours annually with an average boiler efficiency of 80%, and makeup water temperature of 55°F. The water and sewage costs for the plant are $0.002 per gallon ($/gal), and the water treatment cost is $0.002/gal. The fuel cost is $8.00 per million Btu ($8.00/MMBtu). Assuming a 12% flash steam loss*, calculate overall savings.

Annual Water, Sewage, & Chemicals Savings = (1 – Flash Steam Fraction) x (Condensate Load, lb/hr) x Annual Operating Hours x (Total Water Costs, $/gal) / (Water Density, lb/gal)

$$= \frac{(1 - 0.12) \times 10{,}000 \times 8{,}000 \times \$0.004}{8.34}$$

= **$33,760**

* When saturated condensate is reduced to some lower pressure, some condensate flashes off to steam again. This amount is the flash steam loss.

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool* and *Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

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Annual Fuel Savings = (1 – Flash Steam Fraction) x (Condensate Load, lb/hr) x Annual Operating Hours x (Makeup Water Temperature Rise, °F) x (Fuel Cost, \$/MMBtu) x (Heat Capacity of Water, Btu/lb-°F) /(Boiler Efficiency x 10^6 Btu/MMBtu)

$$= \frac{(1 - 0.12) \times 10{,}000 \times 8{,}000 \times (180 - 55) \times \$8.00}{(0.80 \times 10^6)}$$

= **\$88,000**

Total Annual Savings Due to Return of an Additional 10,000 lb/hr of Condensate = **\$33,760 + \$88,000**
= **\$121,760**

Condensate Recovery Produces Savings

A large specialty paper plant reduced its boiler makeup water rate from about 35% of steam production to between 14% and 20% by returning additional condensate. Annual savings added up to more than \$300,000.

Adapted from an Energy TIPS fact sheet that was originally published by the Industrial Energy Extension Service of Georgia Tech.

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January 2006
Steam Tip Sheet #8

Revised from DOE/GO-10099-953 • June 2001

Energy Tips – Steam

Steam Tip Sheet #9 • January 2006

Industrial Technologies Program

Suggested Actions

- Review your blowdown practices to identify energy saving opportunities.
- Examine operating practices for boiler feedwater and blowdown rates developed by the American Society of Mechanical Engineers (ASME). Considerations include operating pressure, steam purity, and deposition control.
- Consider an automatic blowdown control system (see page 2).

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool* and *Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

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Minimize Boiler Blowdown

Minimizing your blowdown rate can substantially reduce energy losses, as the temperature of the blown-down liquid is the same as that of the steam generated in the boiler. Minimizing blowdown will also reduce makeup water and chemical treatment costs.

As water evaporates in the boiler steam drum, solids present in the feedwater are left behind. The suspended solids form sludge or sediments in the boiler, which degrades heat transfer. Dissolved solids promote foaming and carryover of boiler water into the steam. To reduce the levels of suspended and total dissolved solids (TDS) to acceptable limits, water is periodically discharged or blown down from the boiler. Mud or bottom blowdown is usually a manual procedure done for a few seconds on intervals of several hours. It is designed to remove suspended solids that settle out of the boiler water and form a heavy sludge. Surface or skimming blowdown is designed to remove the dissolved solids that concentrate near the liquid surface. Surface blowdown is often a continuous process.

Insufficient blowdown may lead to carryover of boiler water into the steam, or the formation of deposits. Excessive blowdown will waste energy, water, and chemicals. The optimum blowdown rate is determined by various factors including the boiler type, operating pressure, water treatment, and quality of makeup water. Blowdown rates typically range from 4% to 8% of boiler feedwater flow rate, but can be as high as 10% when makeup water has a high solids content.

Example

Assume that the installation of an automatic blowdown control system (see page 2) reduces your blowdown rate from 8% to 6%. This example assumes a continuously operating natural gas-fired, 150-psig, 100,000-pound-per-hour (lb/hr) steam boiler. Assume a makeup water temperature of 60°F, boiler efficiency of 80%, with fuel valued at \$8.00 per million Btu (\$8.00/MMBtu), and the total water, sewage, and treatment costs at \$0.004 per gallon. Calculate the total annual cost savings.

Boiler Feedwater:

$$\text{Initial} = \frac{100{,}000}{(1 - 0.08)} = 108{,}695 \text{ lb/hr}$$

$$\text{Final} = \frac{100{,}000}{(1 - 0.06)} = 106{,}383 \text{ lb/hr}$$

Makeup Water Savings = 108,695 – 106,383 = 2,312 lb/hr

Enthalpy of Boiler Water = 338.5 Btu/lb; for makeup water at 60°F = 28 Btu/lb

Thermal Energy Savings = 338.5 – 28 = 310.5 Btu/lb

Annual Fuel Savings = 2,312 lb/hr x 8,760 hr/year x 310.5 Btu/lb x \$8.00/MMBtu /(0.80 x 10^6 Btu/MMBtu)

= **\$62,886**

$$\text{Annual Water and Chemical Savings} = \frac{2{,}312 \text{ lb/hr} \times 8{,}760 \text{ hrs/yr} \times \$0.004/\text{gal}}{8.34 \text{ lb/gal}}$$

$$= \$9{,}714$$

$$\text{Annual Cost Savings} = \$62{,}886 + \$9{,}714$$

$$= \$72{,}600$$

Automatic Blowdown Control Systems

These systems optimize surface blowdown by regulating water volume discharged in relation to amount of dissolved solids present. Conductivity, TDS, silica or chlorides concentrations, and/or alkalinity are reliable indicators of salts and other contaminants dissolved in boiler water. A probe provides feedback to a controller driving a modulating blowdown valve. An alternative is proportional control — with the blowdown rate set proportional to the makeup water flow.

Cycles of Concentration

"Cycles of concentration" refers to the accumulation of impurities in the boiler water. If the boiler water contains 10 times the level of impurities in the makeup water, it is said to have 10 cycles of concentration.

References

1. "Consensus Operating Practices for Control of Feedwater/Boiler Water Chemistry in Modern Industrial Boilers," published by the ASME, 1994.
2. "Recommended Rules for the Care and Operation of Heating Boilers," Section VI of the ASME Boiler and Pressure Vessel Code, 1995.
3. "Recommended Guidelines for the Care of Power Boilers," Section VII of the ASME Boiler and Pressure Vessel Code, 1995.

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Steam Tip Sheet #9

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Energy Tips – Steam

Steam Tip Sheet #23 • January 2006

Industrial Technologies Program

Suggested Actions

- Review your blowdown and makeup water treatment practices; compare them with American Society of Mechanical Engineers (ASME) practices.
- If a continuous-blowdown system is in place, determine the savings an automatic blowdown-control system could attain. Install conductivity monitoring and automatic blowdown control equipment if the proposed project meets your cost-effectiveness criteria.
- Determine the energy savings and cost-effectiveness from using a heat exchanger to recover energy from the blowdown and preheat boiler makeup water. Blowdown heat-recovery systems may be economical for boilers with blowdown rates as low as 500 lb/hr.

Resources

U.S. Department of Energy—DOE's software, the *Steam System Assessment Tool* and *Steam System Scoping Tool*, can help you evaluate and identify steam system improvements. In addition, refer to *Improving Steam System Performance: A Sourcebook for Industry* for more information on steam system efficiency opportunities.

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Install an Automatic Blowdown Control System

Background

To reduce the levels of suspended and total dissolved solids in a boiler, water is periodically discharged or blown down. High dissolved solids concentrations can lead to foaming and carryover of boiler water into the steam. This could lead to water hammer, which may damage piping, steam traps, or process equipment. Surface blowdown removes dissolved solids that accumulate near the boiler liquid surface and is often a continuous process.

Suspended and dissolved solids can also form sludge. Sludge must be removed because it reduces the heat-transfer capabilities of the boiler, resulting in poor fuel-to-steam efficiency and possible pressure vessel damage. Sludge is removed by mud or bottom blowdown.

During the surface blowdown process, a controlled amount of boiler water containing high dissolved solids concentrations is discharged into the sewer. In addition to wasting water and chemicals, the blowdown process wastes heat energy, because the blowdown liquid is at the same temperature as the steam produced—approximately 366°F for 150-pounds-per-square-inch-gauge (psig) saturated steam—and blowdown heat recovery systems, if available, are not 100% efficient. (Waste heat may be recovered through the use of a blowdown heat exchanger or a flash tank in conjunction with a heat recovery system. For more information, see Steam Tip Sheet #10, *Recover Heat from Boiler Blowdown*.)

Advantages of Automatic Control Systems

With manual control of surface blowdown, there is no way to determine the concentration of dissolved solids in the boiler water, nor the optimal blowdown rate. Operators do not know when to blow down the boiler, or for how long. Likewise, using a fixed rate of blowdown does not take into account changes in makeup and feedwater conditions, or variations in steam demand or condensate return.

An automatic blowdown-control system optimizes surface-blowdown rates by regulating the volume of water discharged from the boiler in relation to the concentration of dissolved solids present. Automatic surface-blowdown control systems maintain water chemistry within acceptable limits, while minimizing blowdown and reducing energy losses. Cost savings come from the significant reduction in the consumption, disposal, treatment, and heating of water.

How it Works

With an automatic blowdown-control system, high- or low-pressure probes are used to measure conductivity. The conductivity probes provide feedback to a blowdown controller that compares the measured conductivity with a set-point value, and then transmits an output signal that drives a modulating blowdown release valve.

Conductivity is a measure of the electrical current carried by positive and negative ions when a voltage is applied across electrodes in a water sample. Conductivity increases when the dissolved ion concentrations increase.

The measured current is directly proportional to the specific conductivity of the fluid. Total dissolved solids, silica, chloride concentrations, and/or alkalinity contribute to conductivity measurements. These chemical species are reliable indicators of salts and other contaminants in the boiler water.

Applications

Boilers without a blowdown heat-recovery system and with high blowdown rates offer the greatest energy-savings potential. The optimum blowdown rate is determined by a number of factors, including boiler type, operating pressure, water treatment, and makeup-water quality. Savings also depend upon the quantity of condensate returned to the boiler. With a low percentage of condensate return, more makeup water is required and additional blowdown must occur. Boiler blowdown rates often range from 1% to 8% of the feedwater flow rate, but they can be as high as 20% to maintain silica and alkalinity limits when the makeup water has a high solids content.

Price and Performance Example

For a 100,000 pound-per-hour (lb/hr) steam boiler, decreasing the required blowdown rate from 8% to 6% of the feedwater flow rate will reduce makeup water requirements by approximately 2,300 lb/hr. (See Steam Tip Sheet #9, *Minimize Boiler Blowdown*.) Annual energy, water, and chemicals savings due to blowdown rate reductions for a sample system are summarized in the table below. In many cases, these savings can provide a 1- to 3-year simple payback on the investment in an automatic blowdown control system.

Savings Through Installation of Automatic Blowdown-Control System

Blowdown Reduction, lb/hr	Annual Savings, $		
	Fuel	Water and Chemicals	Total
1,000	27,200	4,200	31,400
2,000	54,400	8,400	62,800
4,000	108,800	16,800	125,600

Note: Based on continuous operation of a 150-psig, natural gas-fired steam boiler with fuel valued at $8.00 per million Btu ($8.00/MMBtu), a makeup water temperature of 60°F, and a boiler efficiency of 80%. Water, sewage, and chemical treatment costs are estimated at $0.004 per gallon.

Purchasing and installing an automatic blowdown-control system can cost from $2,500 to $6,000. The complete system consists of a low- or high-pressure conductivity probe, temperature compensation and signal conditioning equipment, and a blowdown-modulating valve. Some systems are designed to monitor both feedwater and blowdown conductivity from multiple boilers. A continuous conductivity recording capability might also be desired. The total cost of the automatic blowdown system is dependent upon the system operating pressure and the design and performance options specified.

Recommended Practices

The American Society of Mechanical Engineers (ASME) has developed a consensus on operating practices for boiler blowdown. Sections VI and VII of the ASME Boiler and Pressure Vessel Code describe recommended practices. The ASME Boiler and Pressure Vessel Code can be ordered through the ASME Web site at www.asme.org.

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