Tennessee Valley Chapter
Region VII CRC
Chattanooga, Tennessee

STEAM 101 SEMINAR

February 05,2020

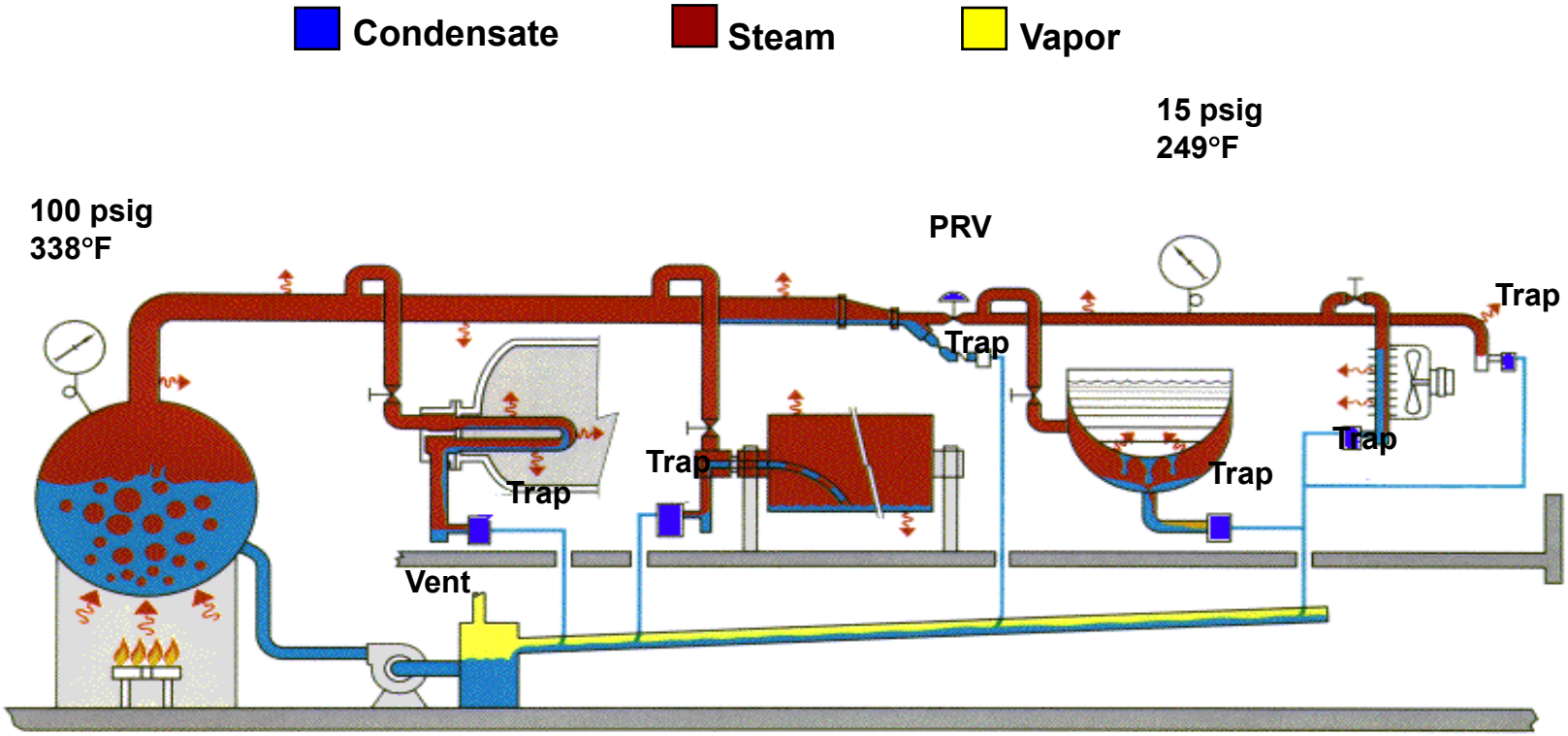
Steam 101 Seminar

- Properties of Saturated Steam
- Steam Quality – Dryness Fraction
- Steam Velocity
- A few Best Piping Practices
- Water hammer
- Steam Traps
- Proper Drainage of Heat Transfer Equipment

THE TYPICAL STEAM SYSTEM

1. Generation - Boiler House
2. Distribution Line- Throughout the facility
3. Utilization – Heat Transfer Equipment
4. Condensate Recovery – send condensate back to the Power House

THE TYPICAL STEAM SYSTEM



Properties of Saturated Steam

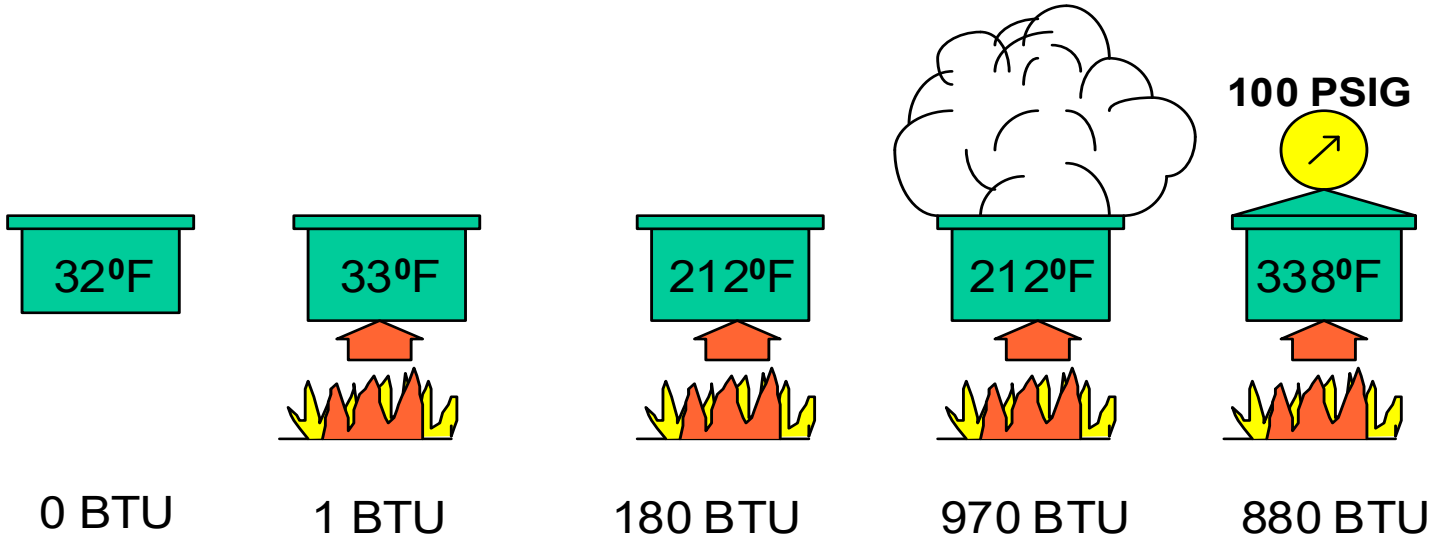
How Do We Create Steam?

Steam is created by adding Heat Energy to water.

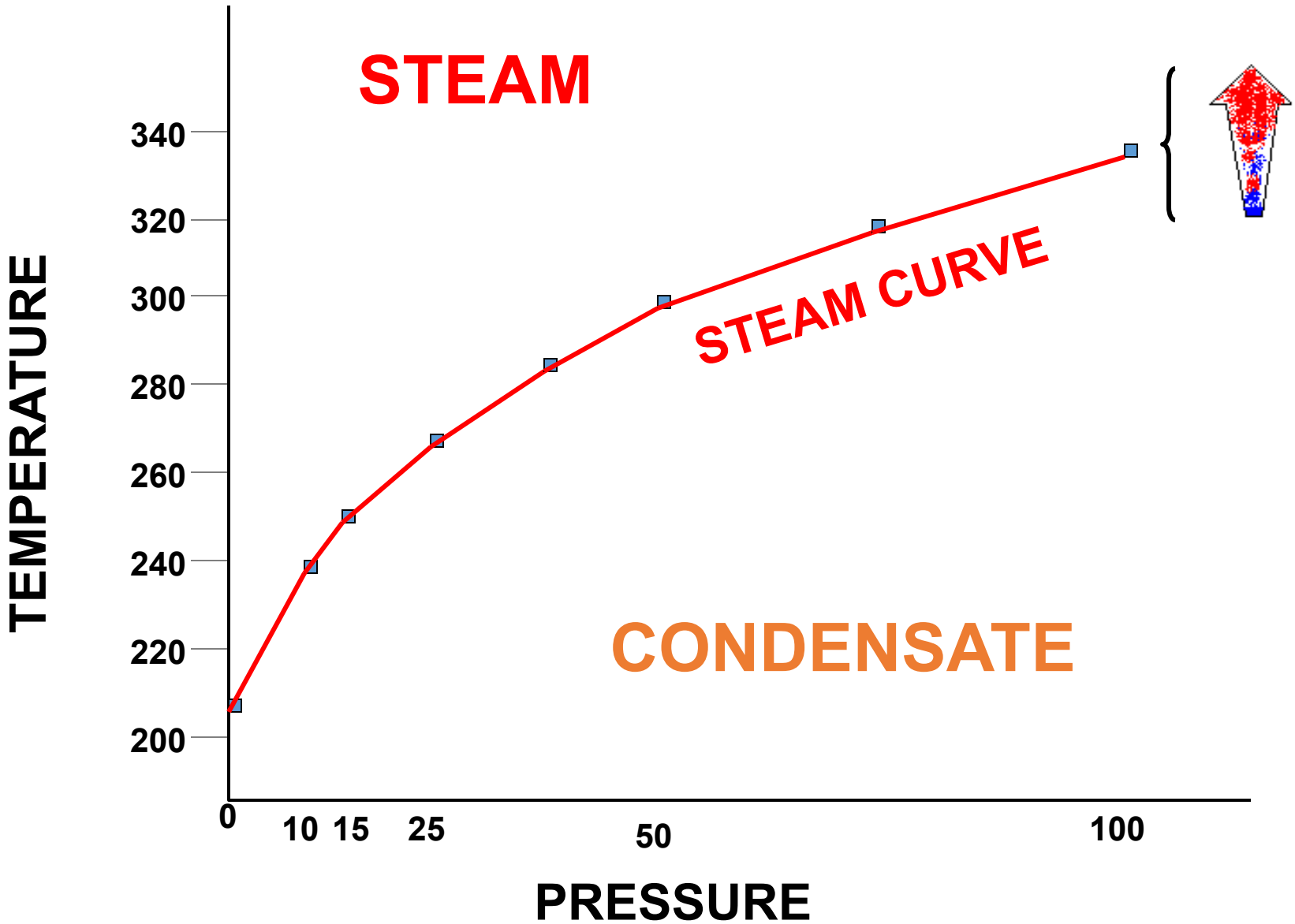
Heat Energy is expressed in Btu's.

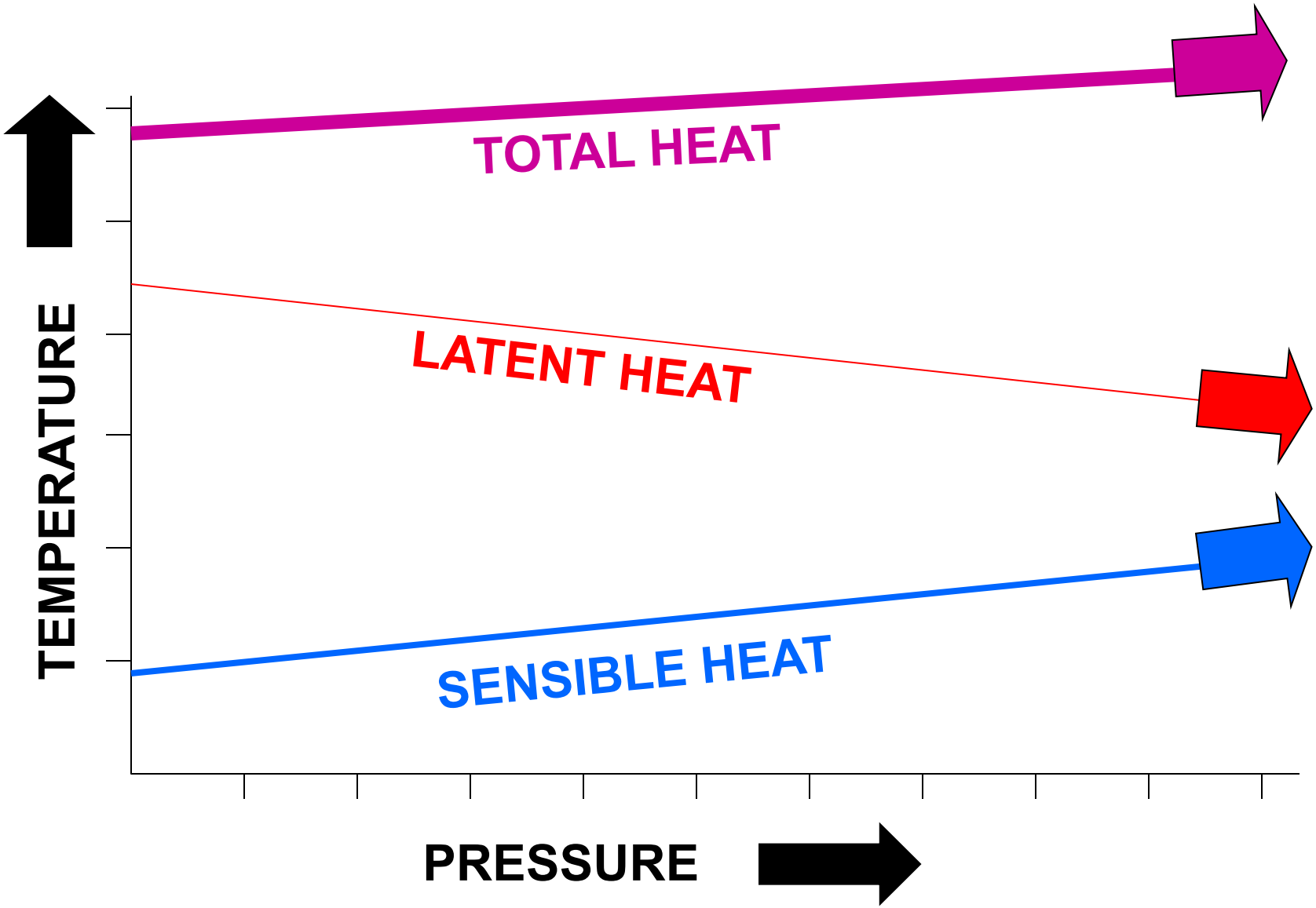
British Thermal Unit is….

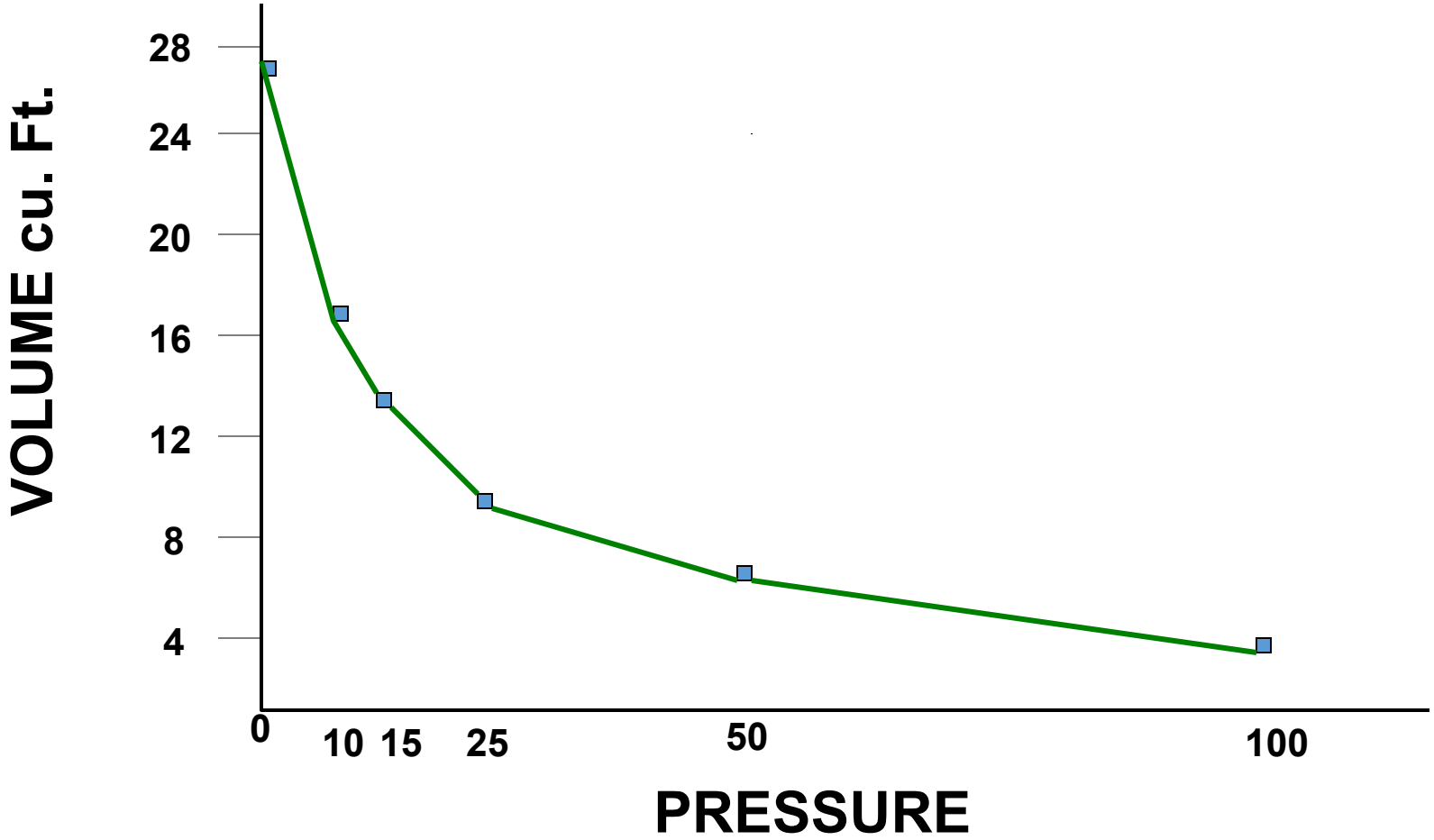
the amount of heat required to raise the temperature of one pound of water by one degree Fahrenheit.



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


STEAM
STEAM CURVE
CONDENSATE
TEMPERATURE
340
320
300
280
260
240
220
200
0
10
15
25
50
100
PRESSURE


TOTAL HEAT
LATENT HEAT
SENSIBLE HEAT
TEMPERATURE
PRESSURE


VOLUME cu. Ft.
28
24
20
16
12
8
4
0
10
15
25
50
100
PRESSURE

150 PSIG vs 15 PSIG

Gauge Pressure	Steam Temp F	Sensible Heat	Latent Heat	Total Heat	Specific Volume
150	365	338	857	1195	2.75
15	250	218	945	1164	13.75

STEAM DISTRIBUTION

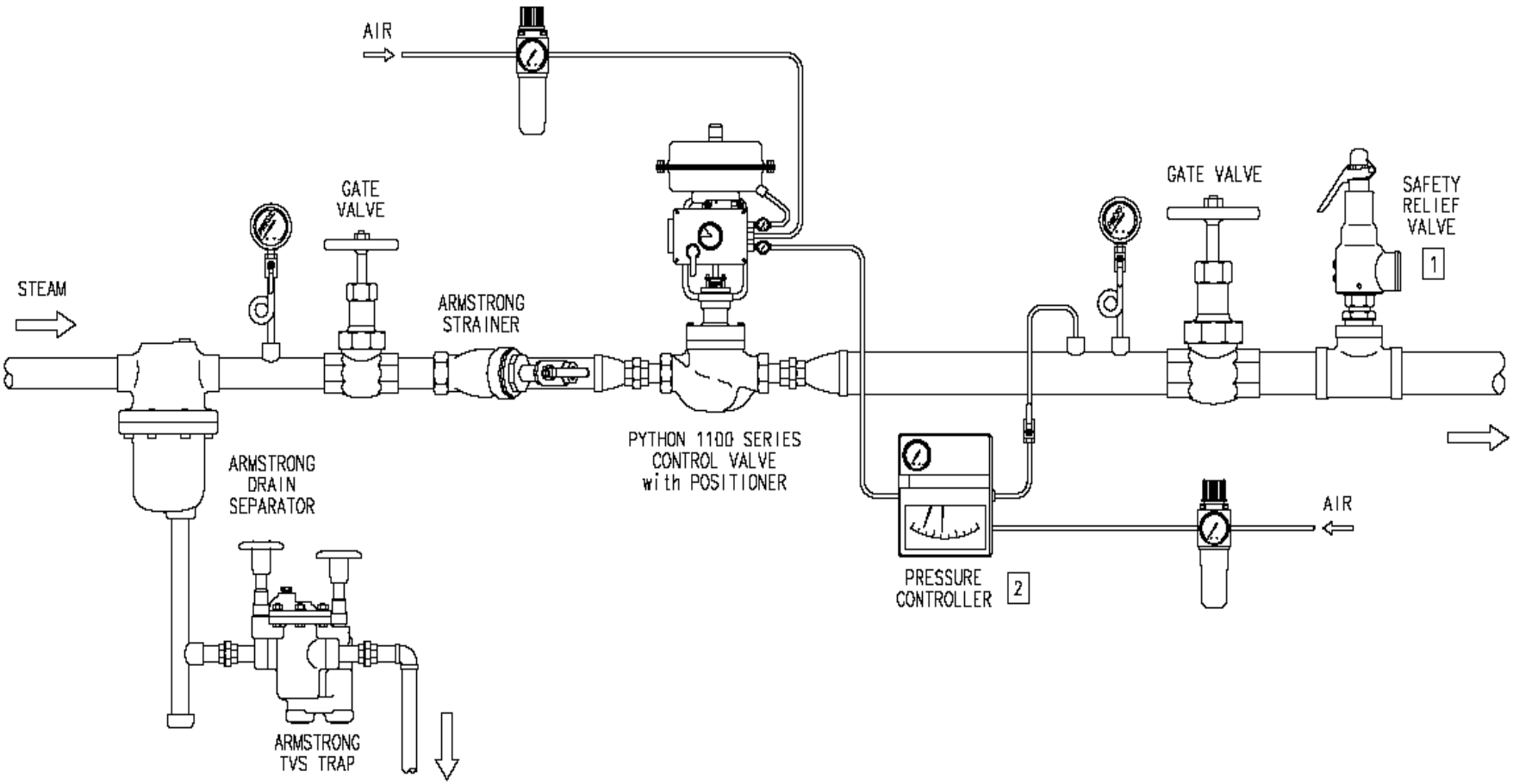
Why generate & distribute High Pressure steam?

- ✓ **Lower Specific Volume at higher pressure**
  - Reduce distribution pipe sizes
  - Reduce valves
  - Reduce capital cost

Specific Volume - 150 PSIG vs 15 PSIG

Gauge Pressure	Steam Temp F	Sensible Heat	Latent Heat	Total Heat	Specific Volume
150	365	338	857	1195	2.75
15	250	218	945	1164	13.75

Why reduce the steam pressure?



Greater Latent Heat in Lower Pressure Steam!!!

150 PSI – 857 BTUs of Latent Heat 15 PSI – 945 BTUs of Latent Heat

Latent Heat – 150 PSIG vs 15 PSIG

Gauge Pressure	Steam Temp F	Sensible Heat	Latent Heat	Total Heat	Specific Volume
150	365	338	857	1195	2.75
15	250	218	945	1164	13.75

Steam Quality or Dryness Fraction

If **steam** contains 10% water by mass, it's said to be 90% dry, or have a **dryness fraction** of 0.9.

Example: Steam Quality (wet steam)

Saturated Steam @ 40 psig and 287 deg. F

- If quality is 100%, latent heat = 919 Btu/lb
- If quality is 50%, latent heat = 459 Btu/lb

Saturated steam tables are for 100% quality dry steam!

Steam Conditioning via Drain Separators

Example: heat exchanger requires 4,645,000 Btu's / hr

Available: 40 psig steam @ 287ºF

@ 100% Dry (saturated) steam supplies 919 Btu / lb.

∴ process requires 5,054 lb/hr.

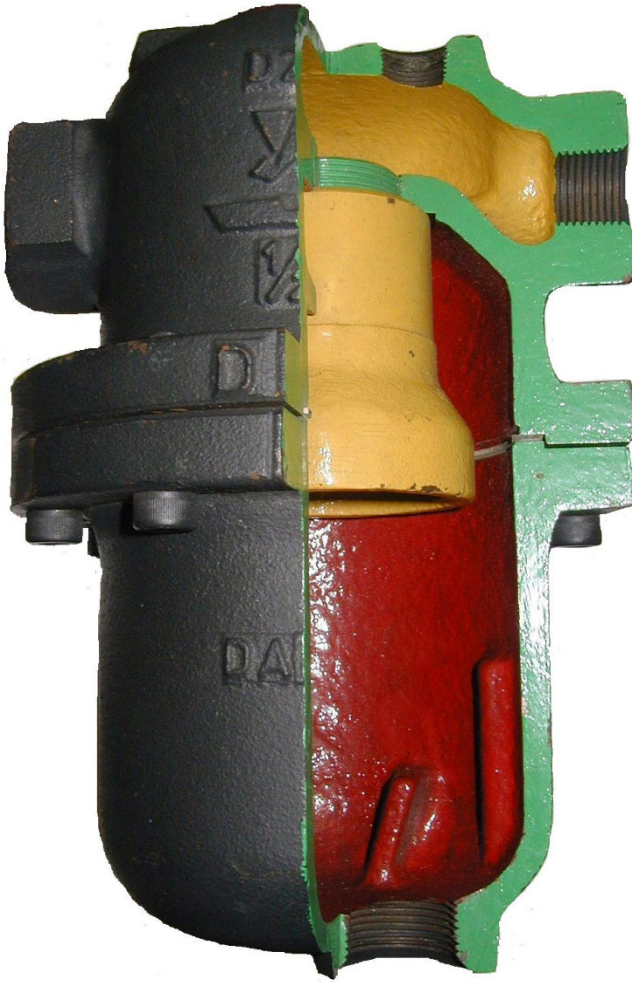
@ 90% Dryness Fraction, steam supplies 827 Btu/lb.

∴ process now requires 5616 lb /hr. **A 11% Increase**

@ 80% Dryness Fraction, steam supplies 735 Btu/lb

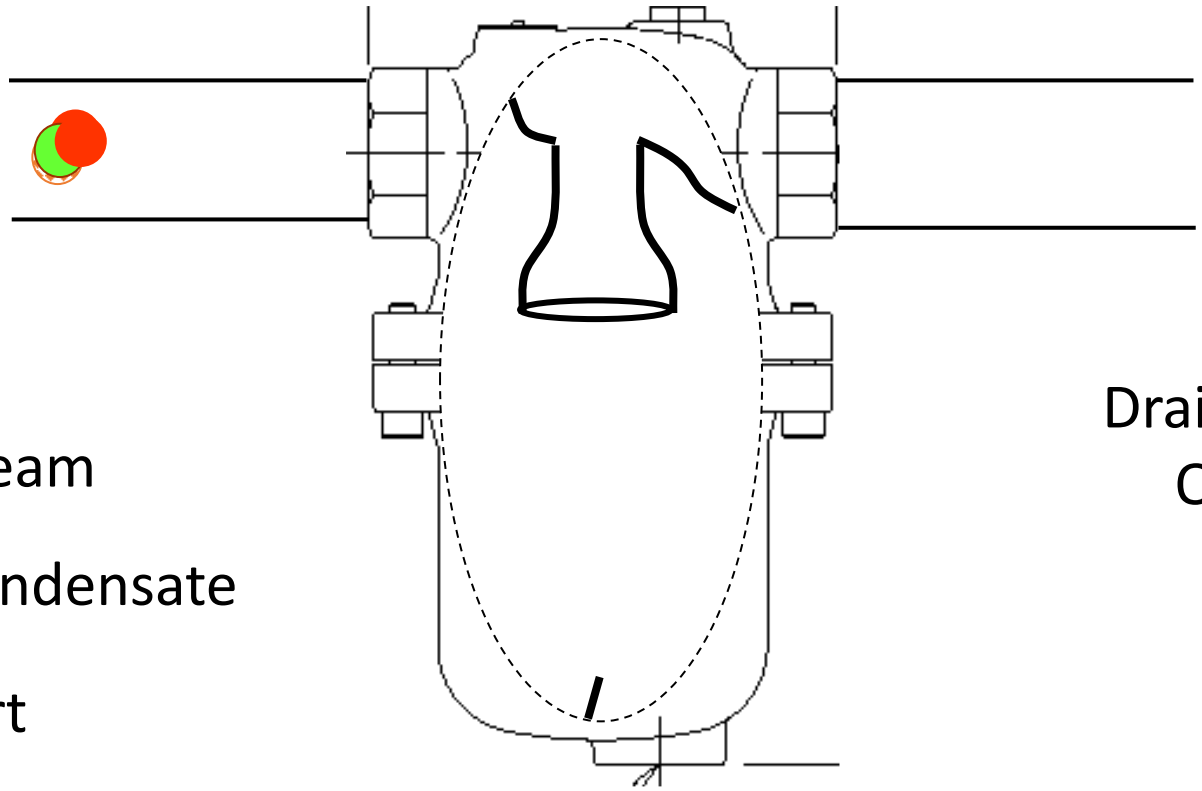
∴ process now requires 6319 lb /hr. **A 25% increase**

Drain Separator Cut Away



Drain Separator

Designed to eliminate 98% of entrained liquids



Dry Steam Outlet

Drain Separator Operation

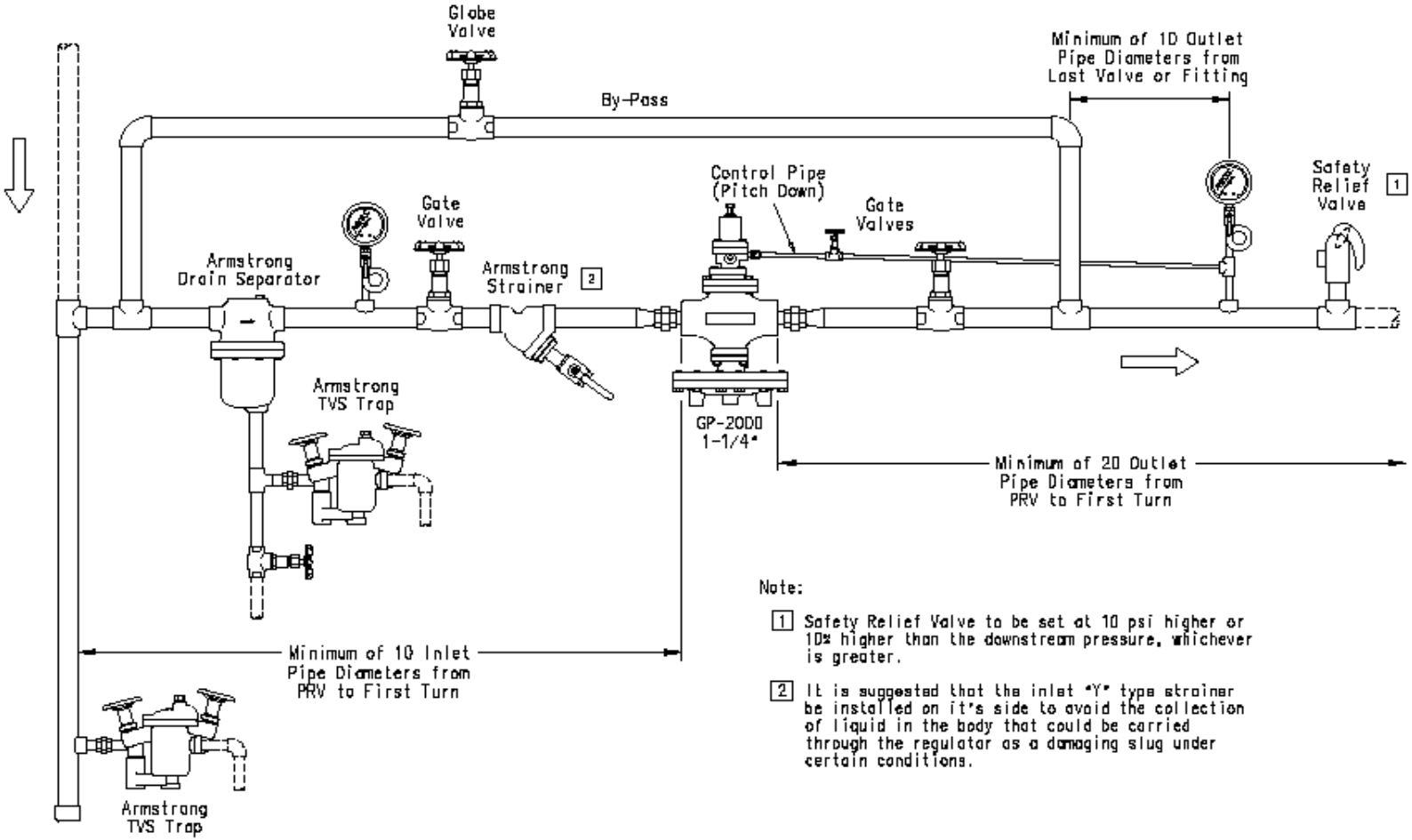
Steam

Condensate

Dirt

Drain for condensate and dirt

Drain Separators



Note:

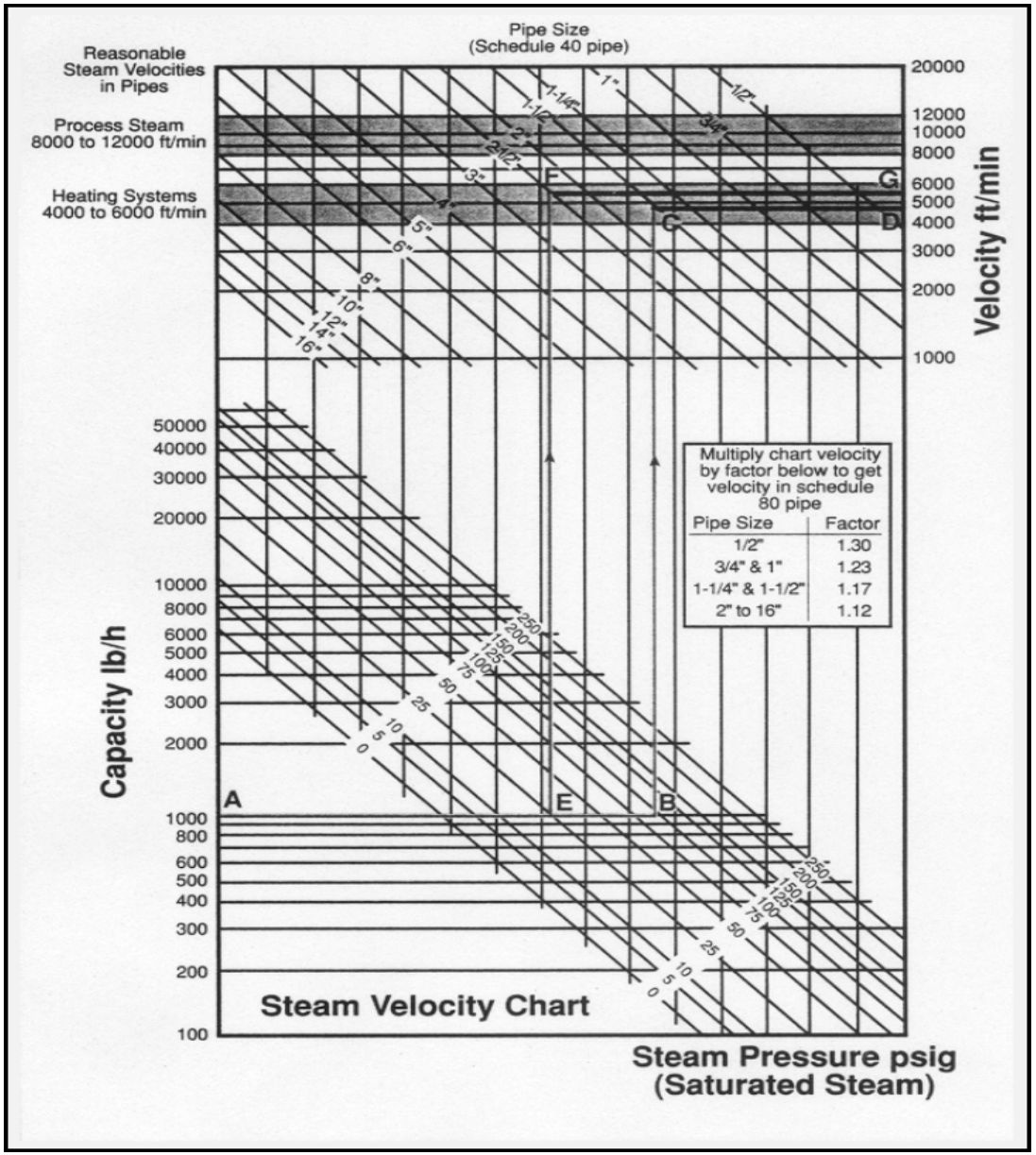
1 Safety Relief Valve to be set at 10 psi higher or 10% higher than the downstream pressure, whichever is greater.

2 It is suggested that the inlet "Y" type strainer be installed on it's side to avoid the collection of liquid in the body that could be carried through the regulator as a damaging slug under certain conditions.

Drain Separators - User Benefits

- Improves steam quality
- Reduces maintenance cost and downtime
- Increases control valve life
- Removes risk of water hammer damage
- Requires no maintenance

How fast does steam travel in a pipe?



Steam Velocity

Process Steam

8000 to 12000 ft/min

90 to 136 MPH

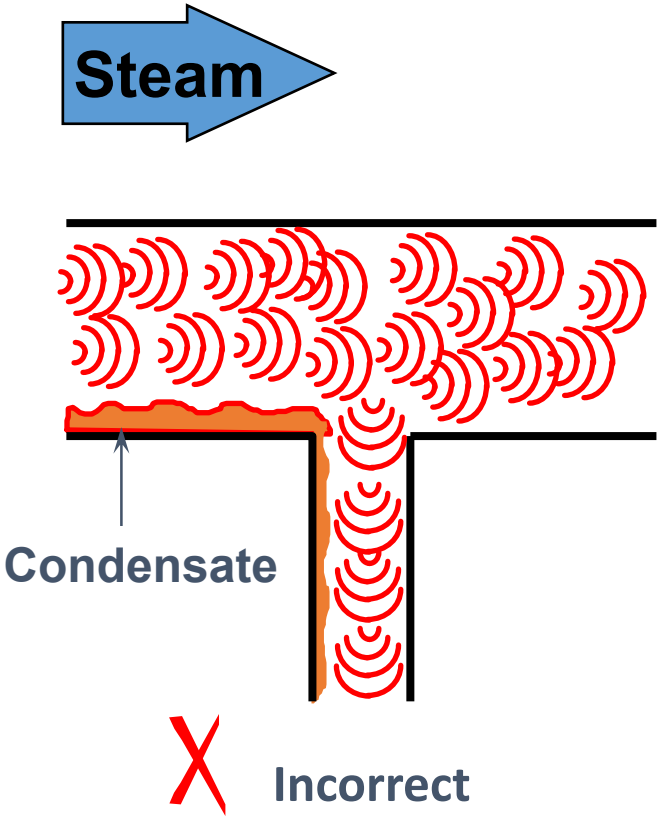
Heating System

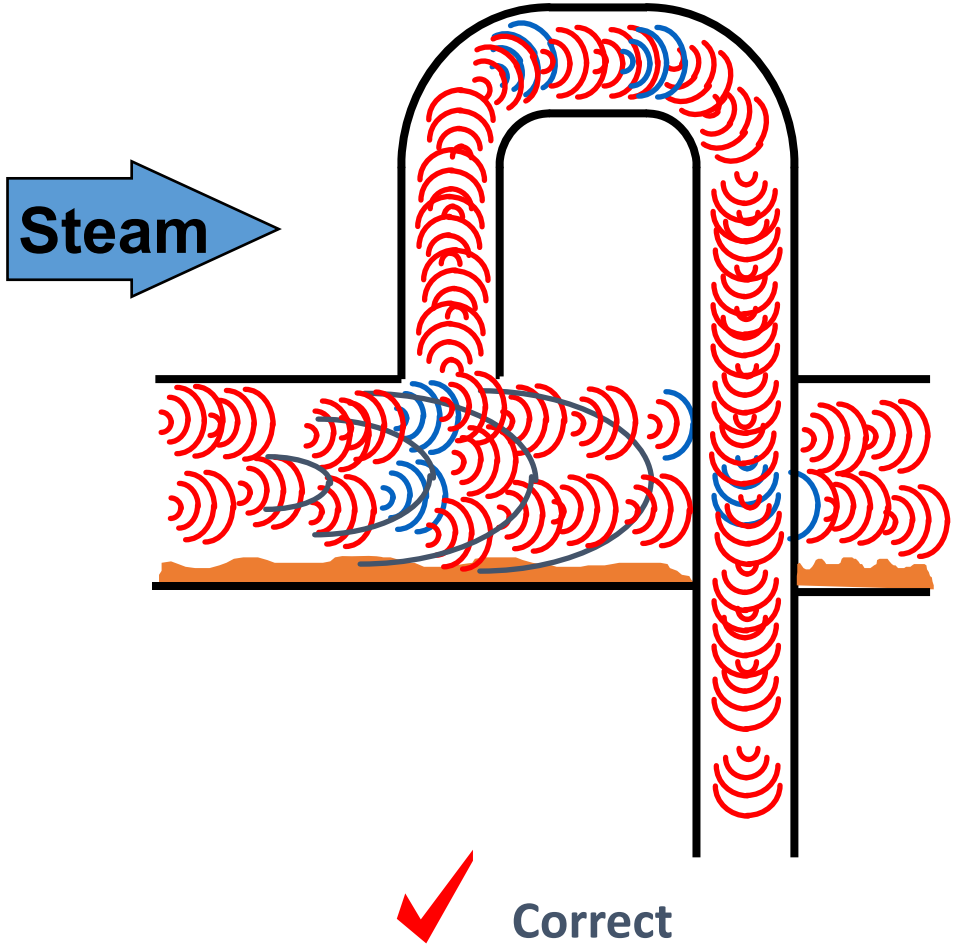
4000 to 6000 ft/min

45 to 68 MPH

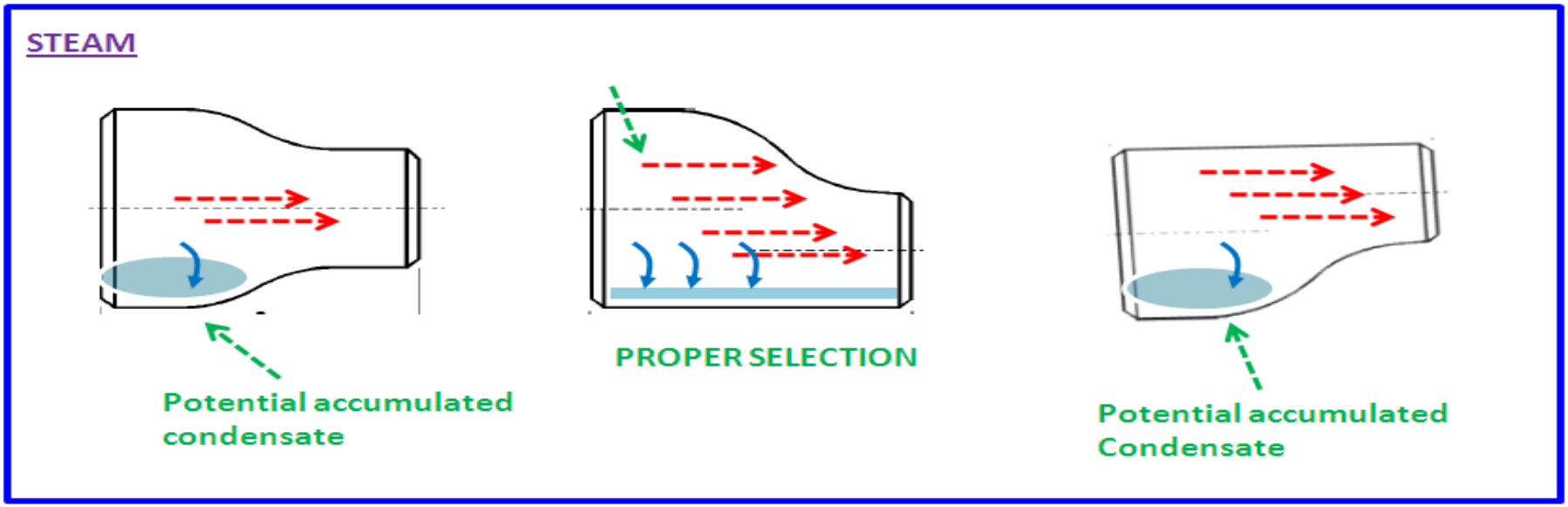
SOME BEST PIPING PRACTICES

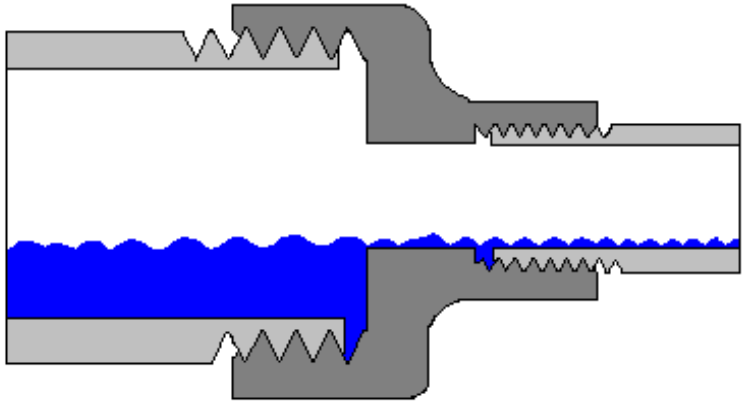
Branch Connections

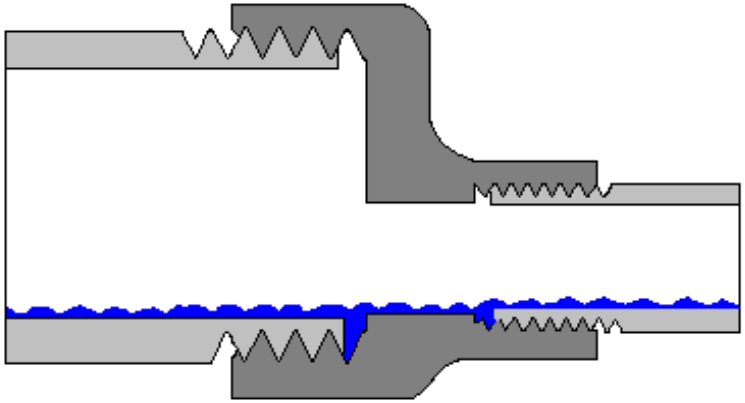




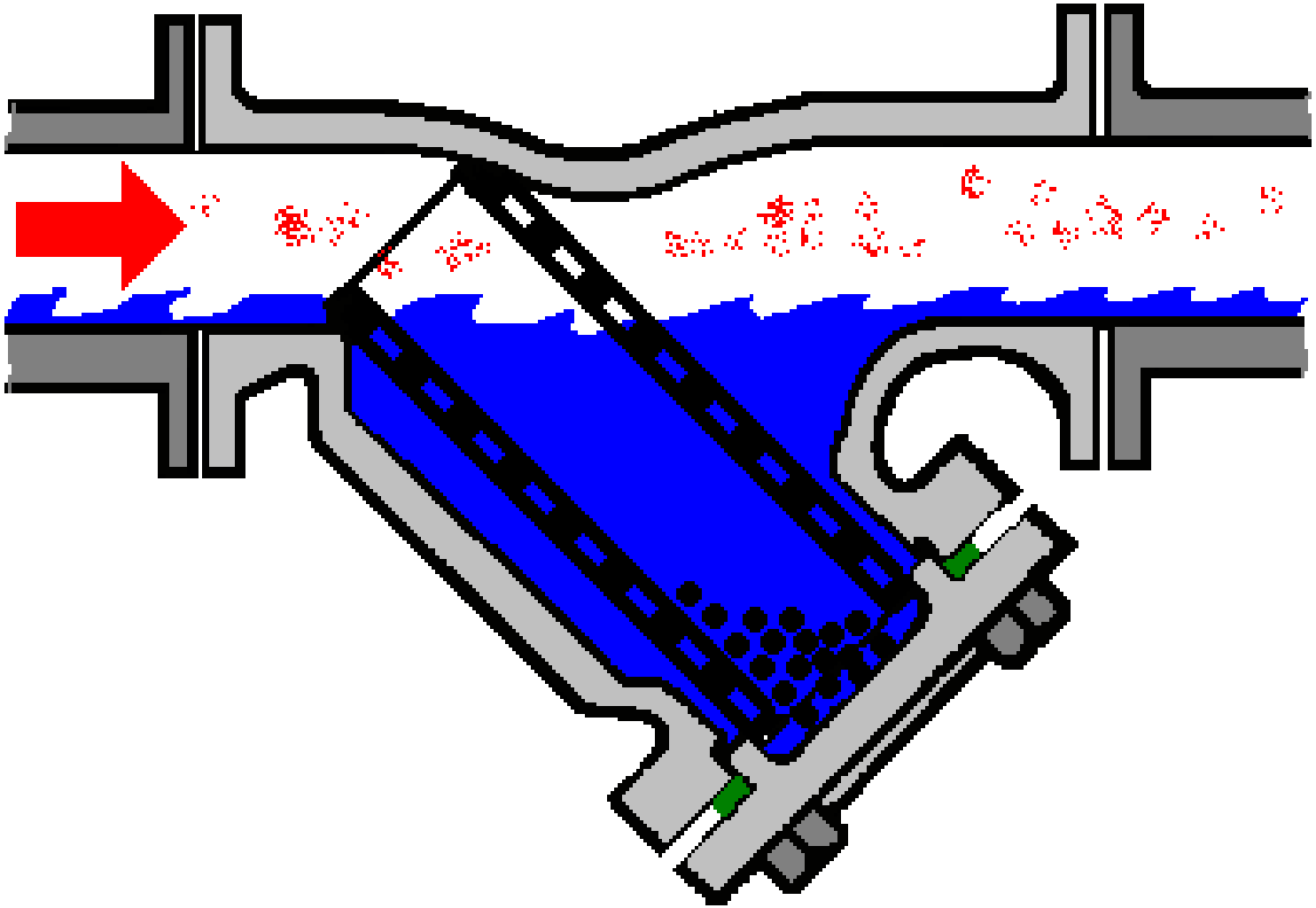
Concentric Vs. Eccentric Reducers







Strainers

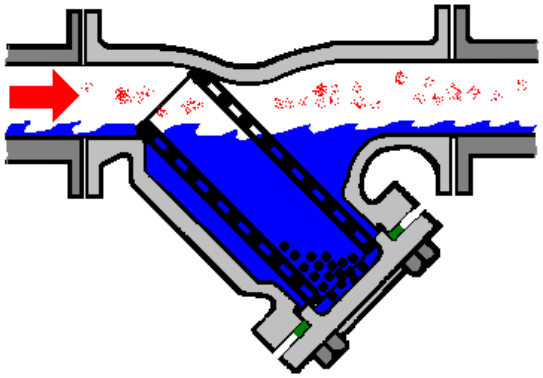


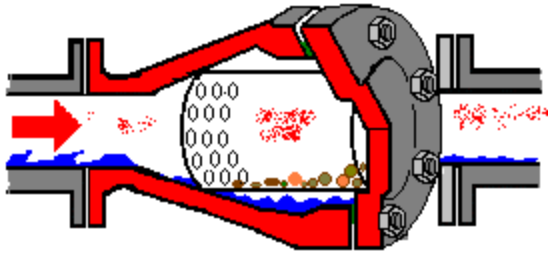
Is there a better way to install a strainer in your steam system?

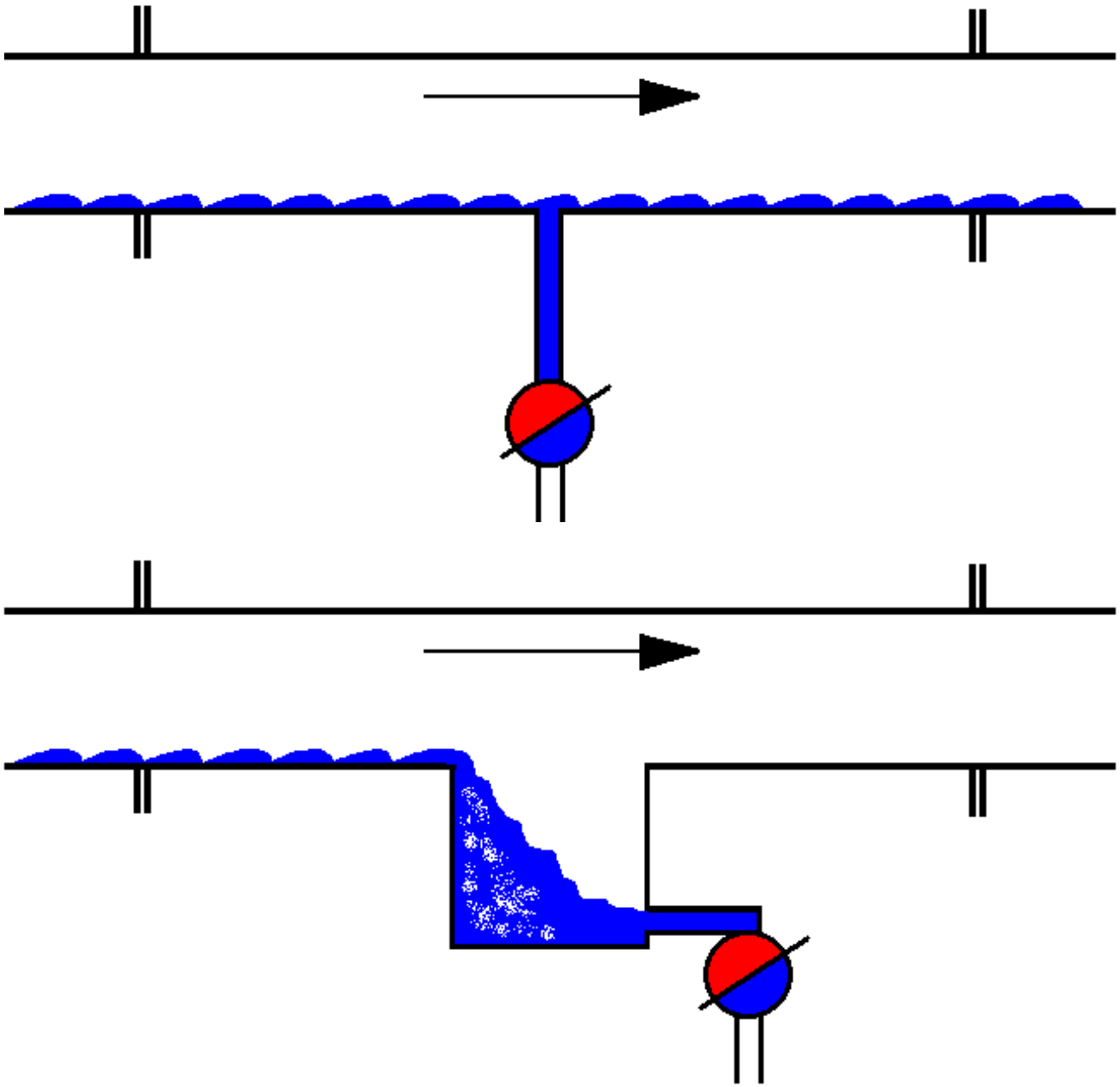
Strainers

Strainers should be fitted on their Sides giving:

- **Greater free area of strainer screen in steam space**
- **Reduces collecting pocket for cooled condensate**
- **100 Mesh Screen Preferable**

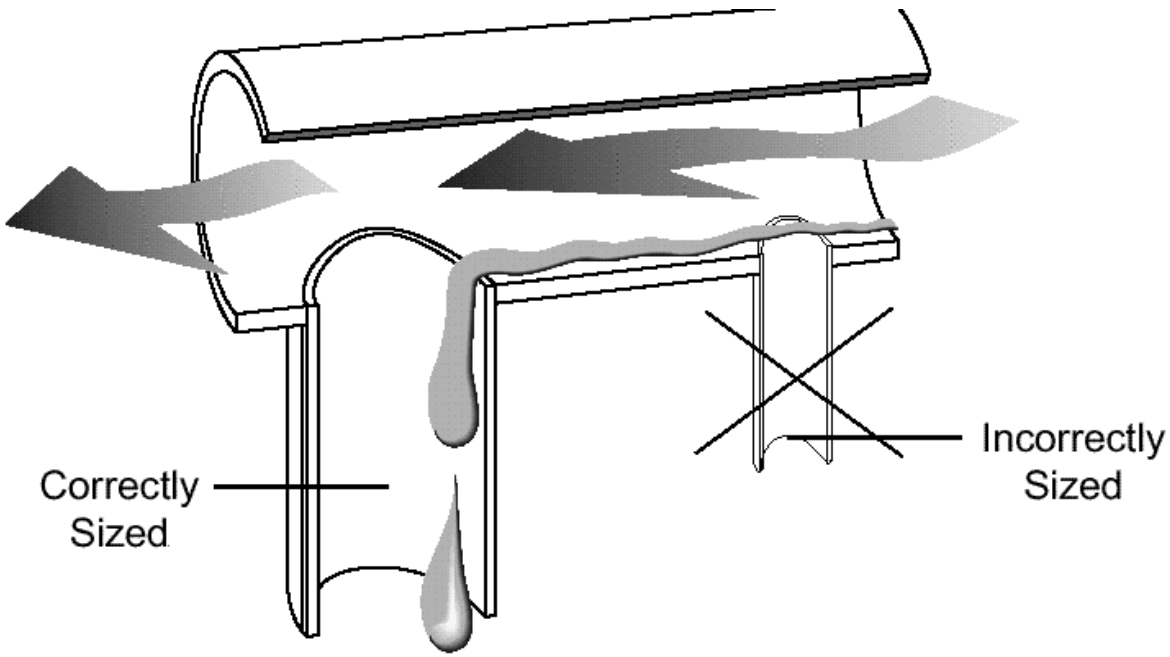




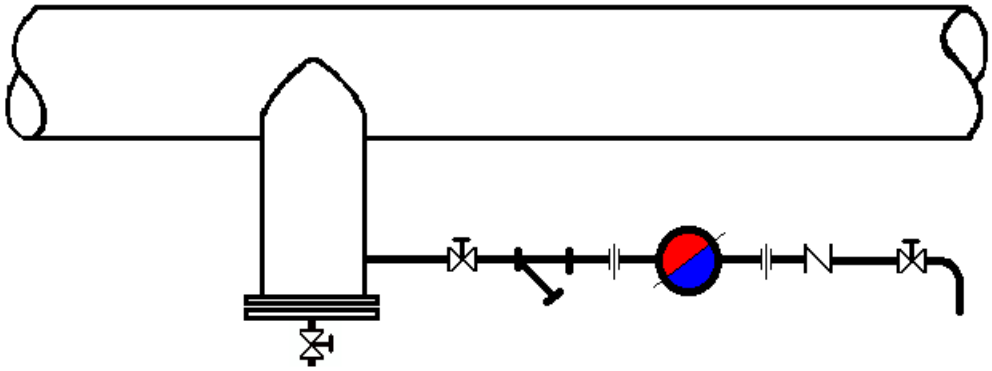


Drip Leg Sizing

An Incorrectly Sized Drip Leg Will Not Allow Condensate to Reach the Trap

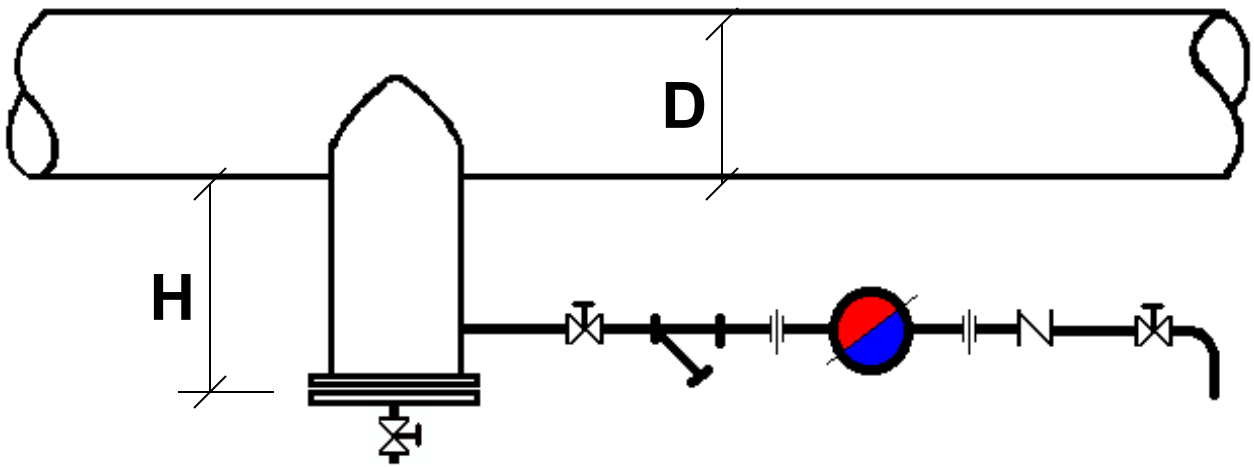


8” Steam Headers at 150 psig



What size diameter drip leg?

Typical Steam Main Drip Station

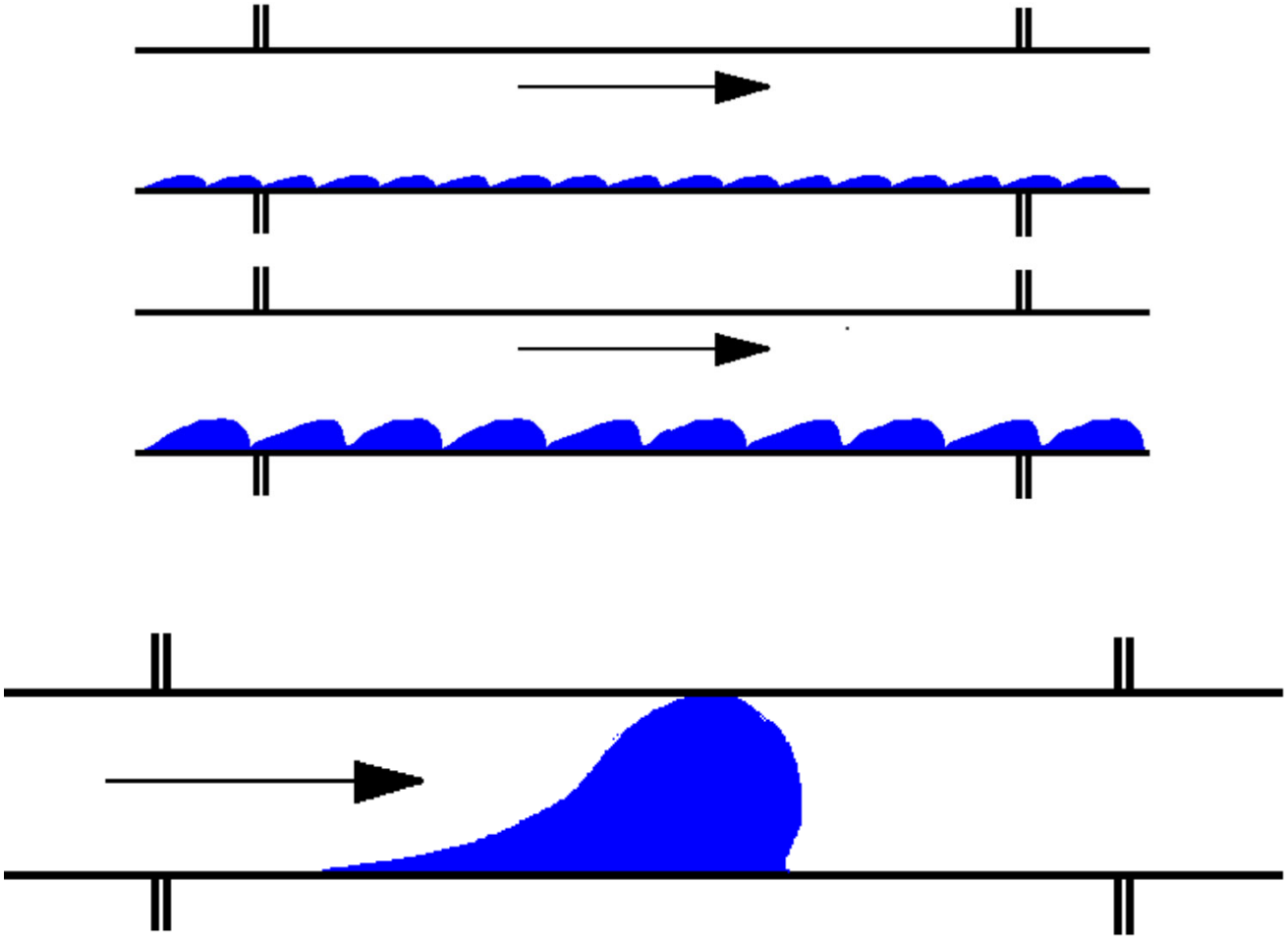


Size of Main ‘D’	Collection Leg Diameter
1/2” to 4”	Same dia. as main ‘D’
5” & larger	2 to 3 Pipe Sizes Smaller than Main, But Never Smaller than 4”

Length of Collection Leg ‘H’
Automatic Start up: ‘H’ to be 28” or more
Supervised Start up: Length to be1.1/2 times steam Main Diameter, but never shorter than 8”

20” Header with 1” Drip Pocket

Waterhammer



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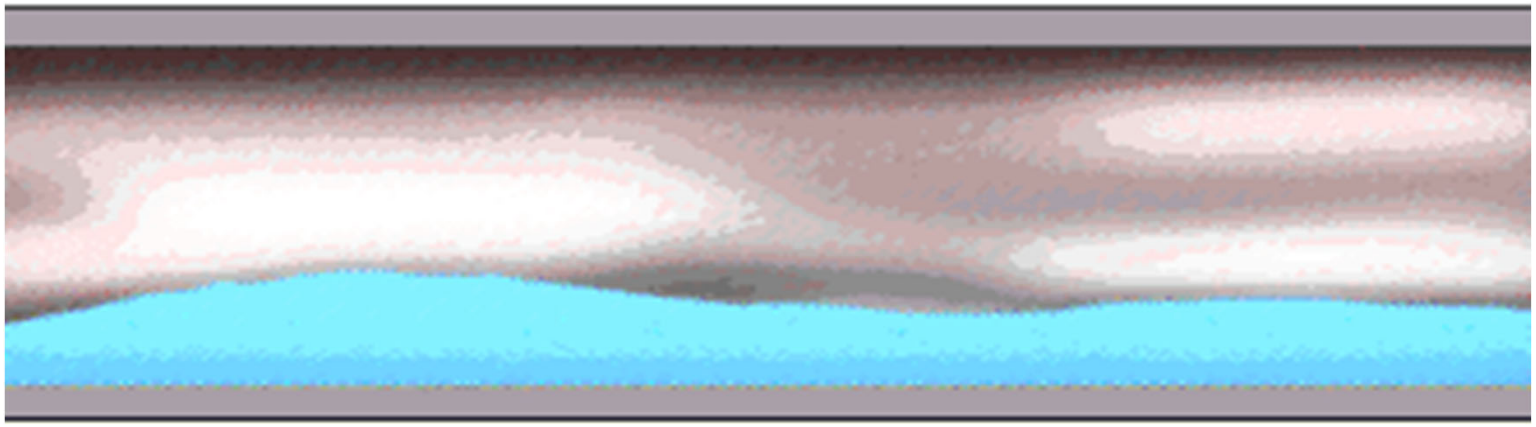
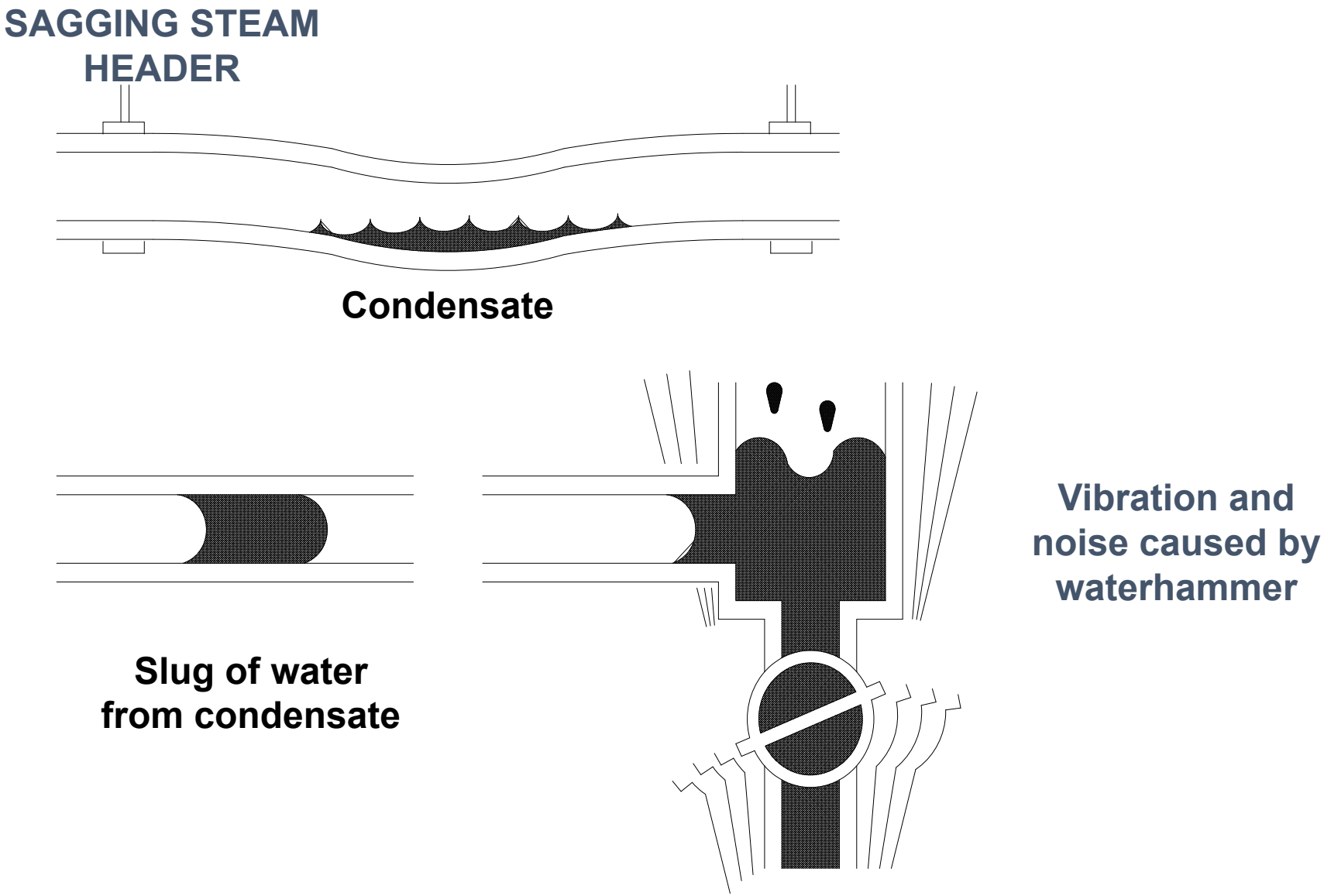


Waterhammer



New York Steam Explosion

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Steampipe test shows safety valve was faulty

BY ADAM LISBERG
DAILY NEWS CITY HALL BUREAU
Thursday, August 16th 2007, 4:00 AM

Print Email Suggest a Story

A crucial Con Edison steam valve wasn't working just before last month's deadly steampipe explosion, a bombshell affidavit from a top state regulator says.

The "steam trap," just feet away from the blast site at 41st St. and Lexington Ave., was supposed to drain water out of the steampipe to prevent a catastrophic condition called "water hammer," which causes water to slam into itself with incredible pressure.

The stainless-steel trap was installed in December 2006, but preliminary tests after the explosion revealed it wasn't operating and had a possible debris buildup, according to the sworn statement by Thomas Dvorsky, an engineer who heads the state Public Service Department office in charge of steam service.

"The nondestructive testing was inconclusive; it just showed the trap assembly was not working properly," Dvorsky wrote.

He said the trap should be cut open to look for "sediment or foreign materials in the trap that prevented functioning."

But a representative for the trap's manufacturer told the Daily News the company believes the valve did not contribute to the blast, because it is designed to fail in a way that releases water.

The affidavit surfaced yesterday in a bitter fight in Brooklyn Supreme Court between lawyers for Con Ed and the family of Gregory McCullough, a tow-truck driver who was badly burned in the July 18 blast and who may lose a leg and an arm.

Con Ed wants to cut open thetrap, saying it will record thetests and allow lawyers for those suing the utility to observe. State regulators support that approach.

McCullough's lawyer Kenneth Thompson has blocked the tests, saying the utility can't be trusted to investigate itself.

"I do not want this to happen to any other family," said McCullough's mother, Tanya McCullough-Stewart. "He does cry. You can see the pain in his eyes."

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STEAM TRAPS

Steam Trap

Two Main Functions of a Steam Trap…..

- Remove Condensate from the steam system
- Remove Air from the steam system

Steam Traps (CG-4)

Mechanical Traps – respond to the volume of condensate

- Inverted Bucket
- Float and Thermostatic

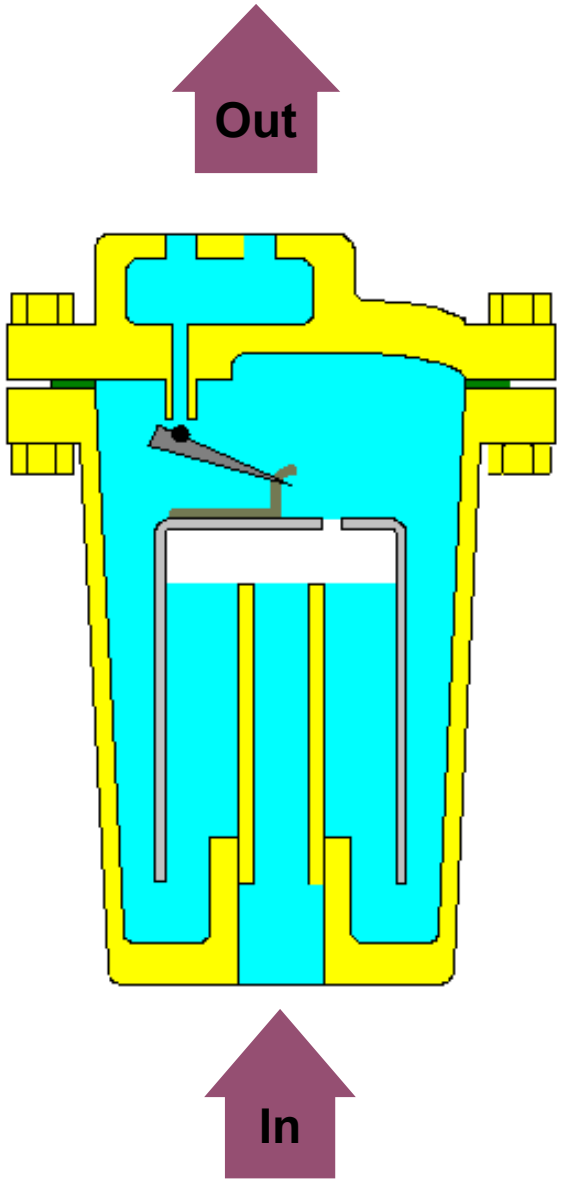
Thermostatic Traps – respond to temperature of condensate

- Bi- metallic
- Thermostatic

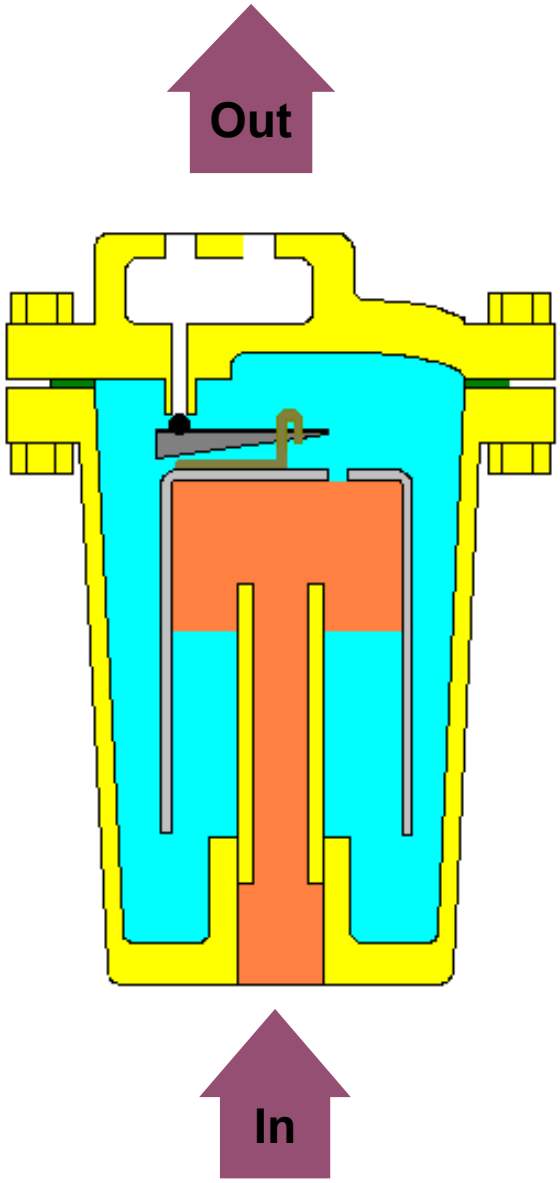
Thermodynamic Traps – respond to kinetic energy in the condensate

- TD or Disc

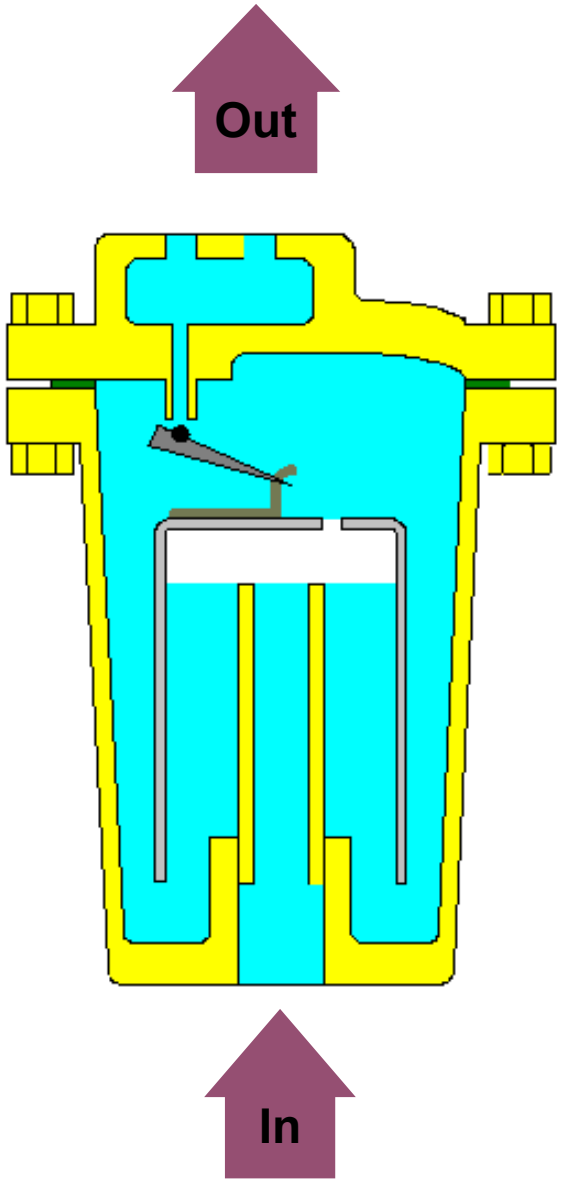
Inverted Bucket Trap



Operation of Inverted Bucket Trap



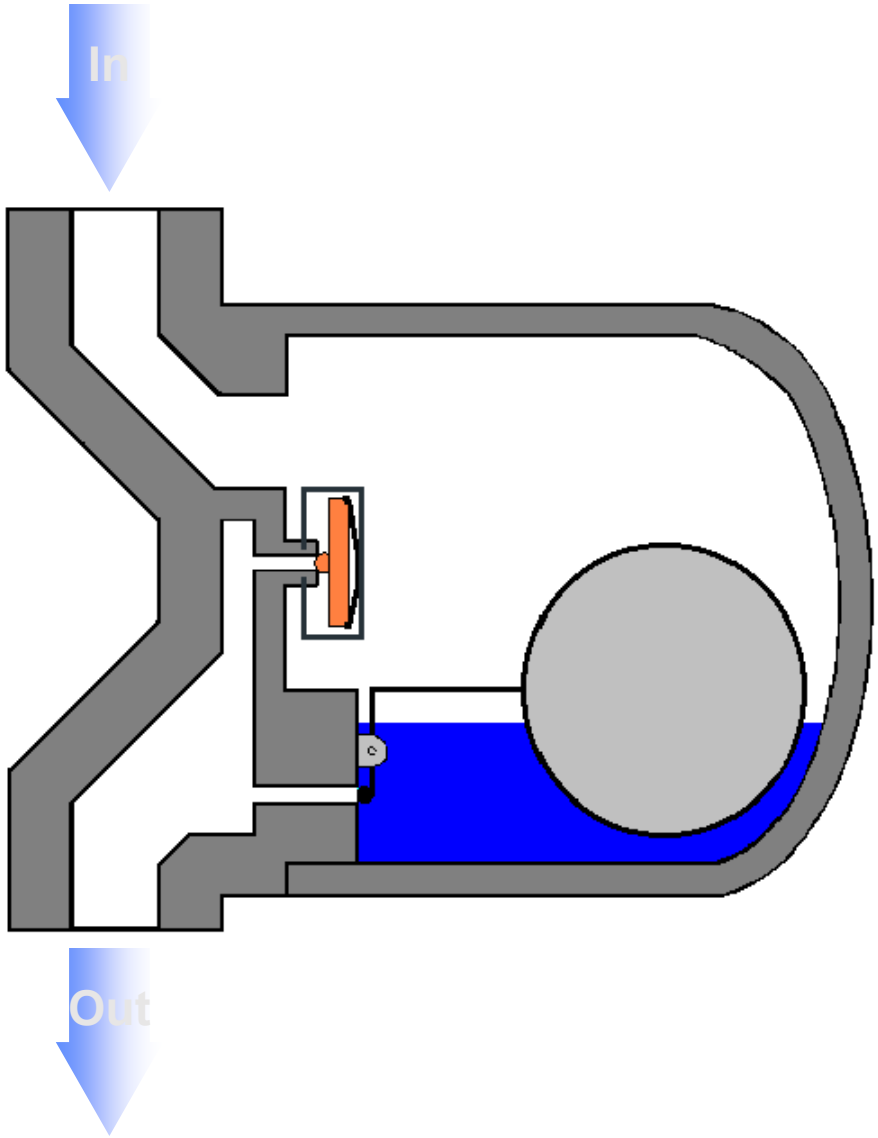
Inverted Bucket Trap



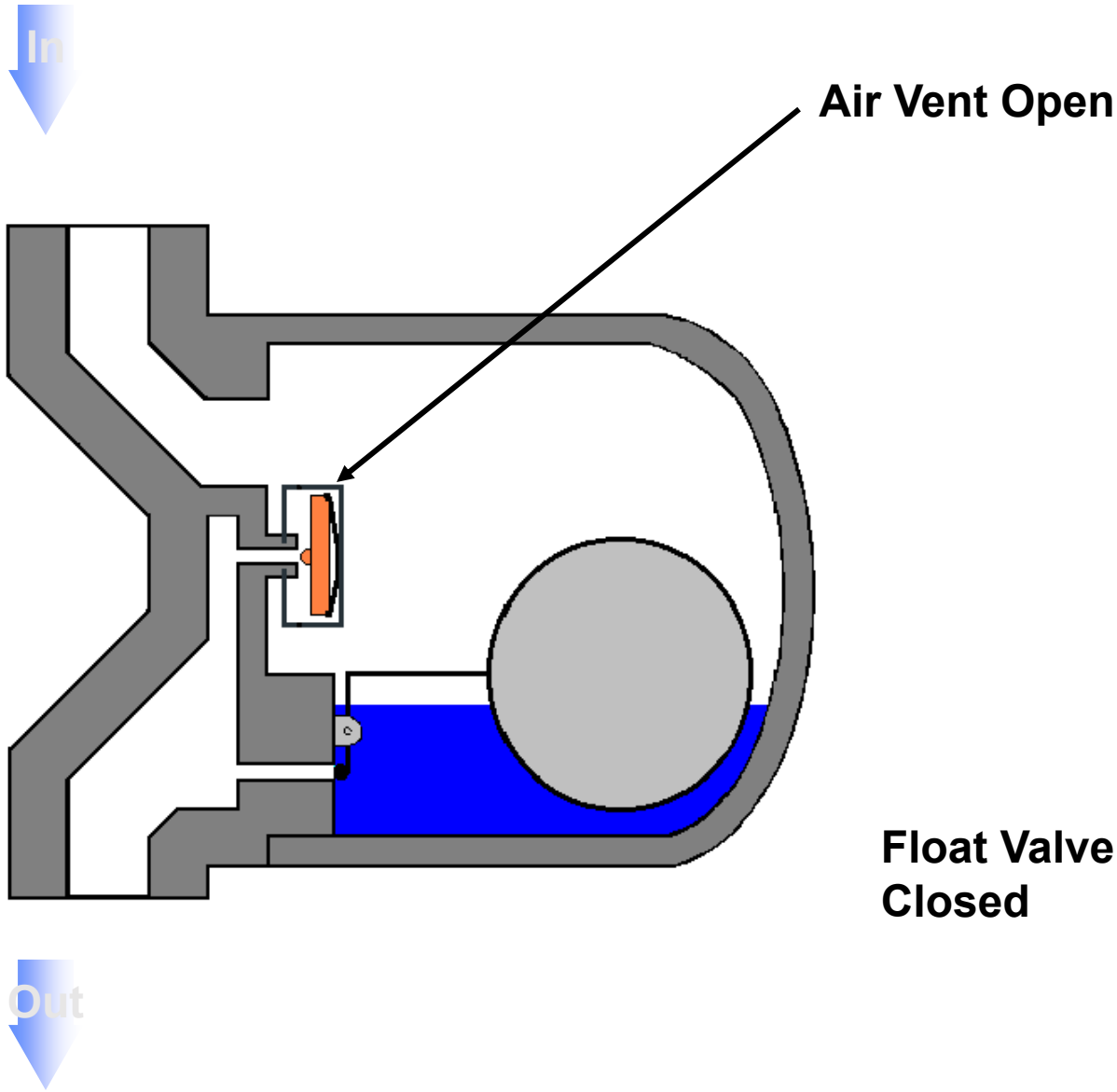
Inverted Bucket Steam Traps

- Made to withstand high pressure
- Good tolerance to waterhammer conditions
- Can be used on superheated steam lines
- Can handle a fair amount of scale or dirty
- Mechanical Failure - Open

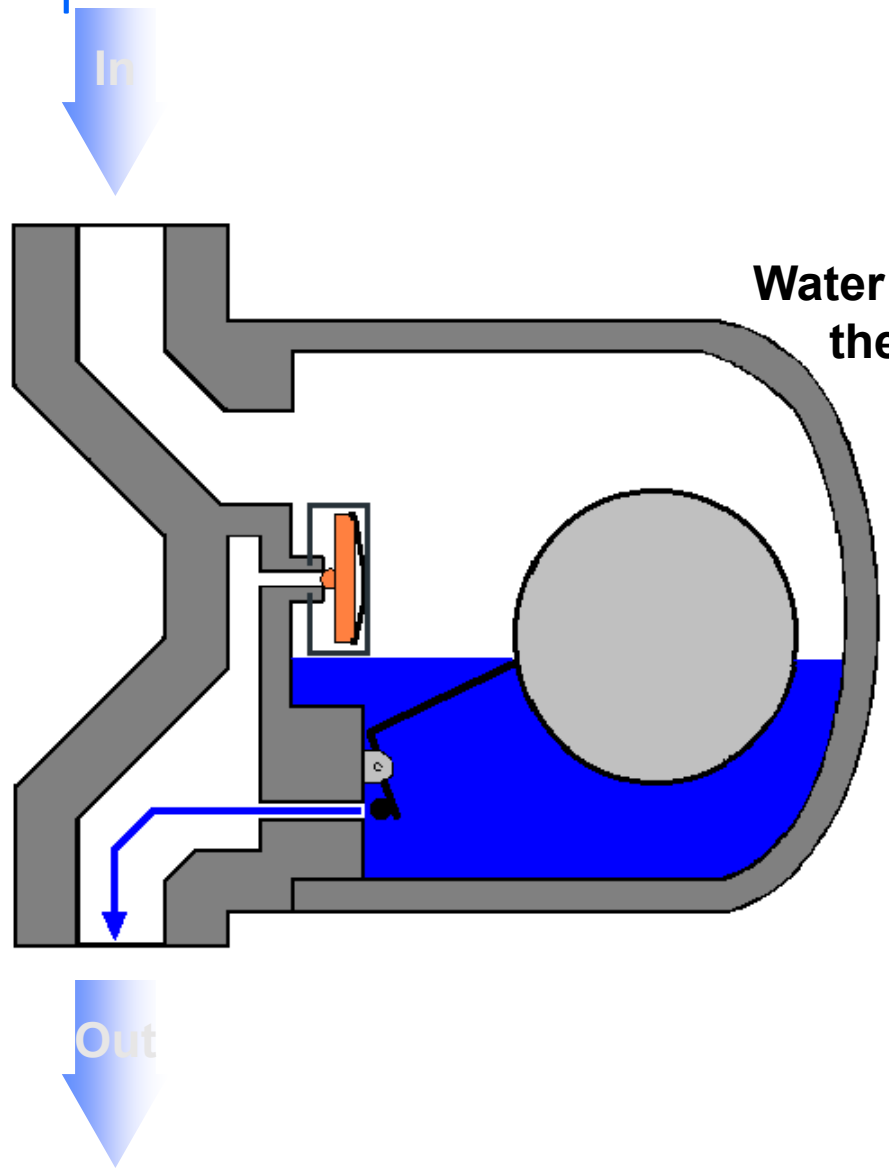
Float Trap with Thermostatic Air Vent



Float Trap with Thermostatic Air Vent

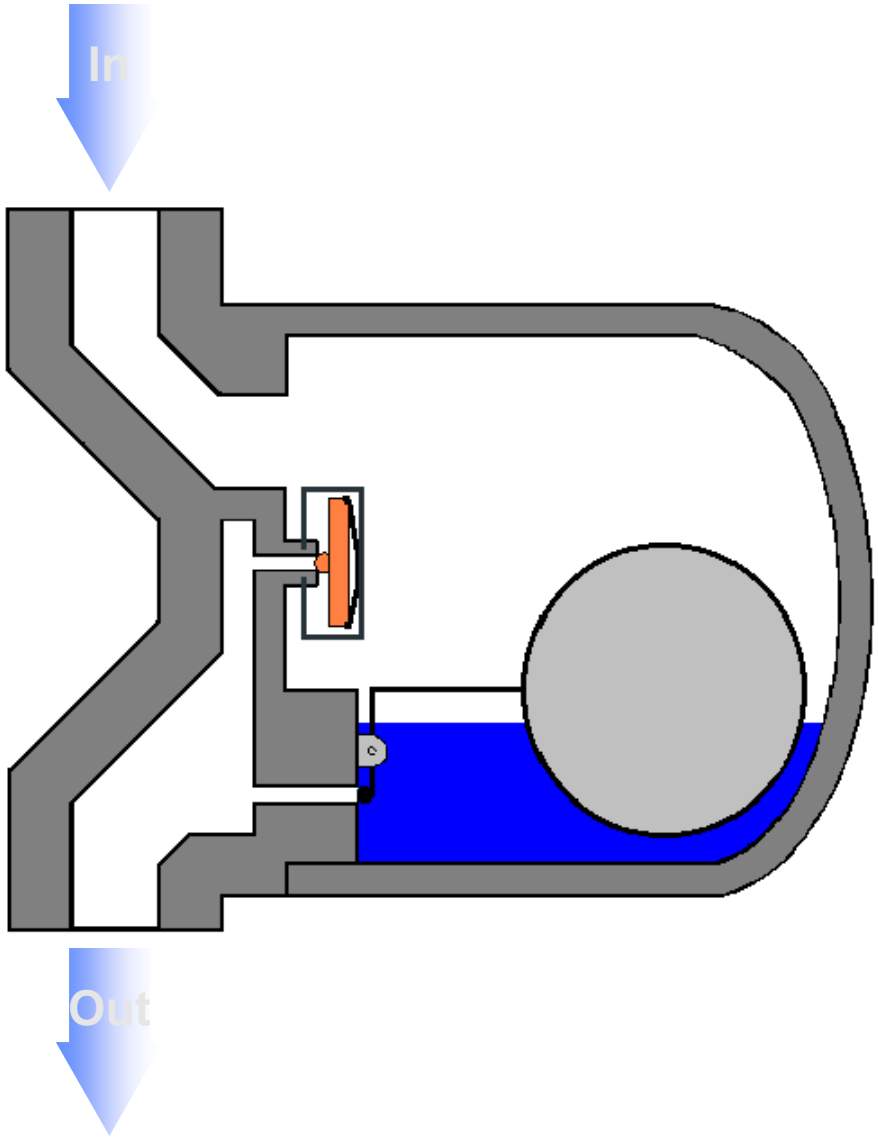


Float Trap with Thermostatic Air Vent



Water Level Increases, the Float Rises and the Valve Opens

Float Trap with Thermostatic Air Vent

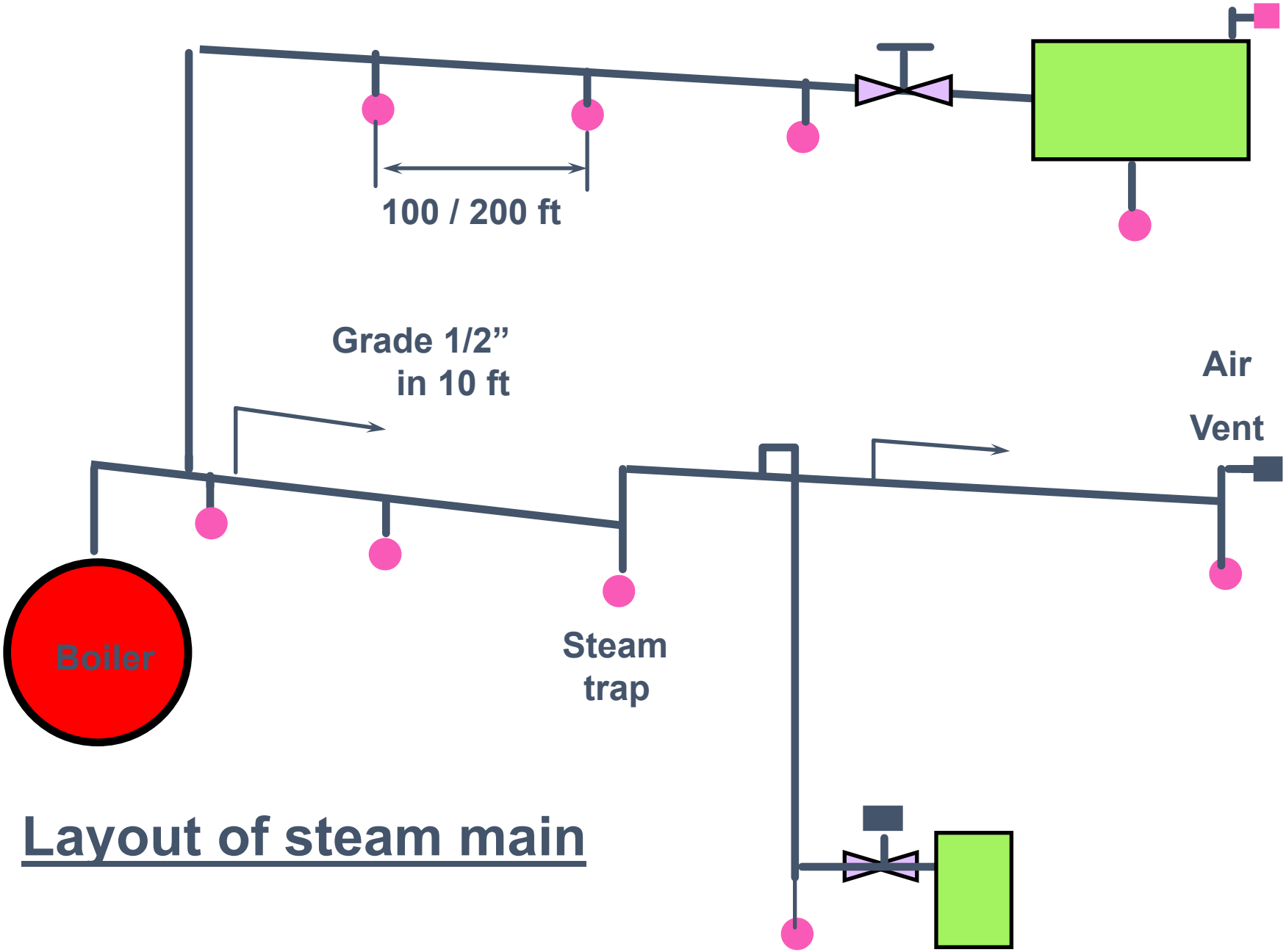


Float & Thermostatic Traps

- Continuously discharge condensate at steam temperature
- Handles heavy and light condensate loads equally well
- Ability to handle start up air loads freely
- Ideal for process application using a modulating Control Valve
- Mechanical Failure - Closed

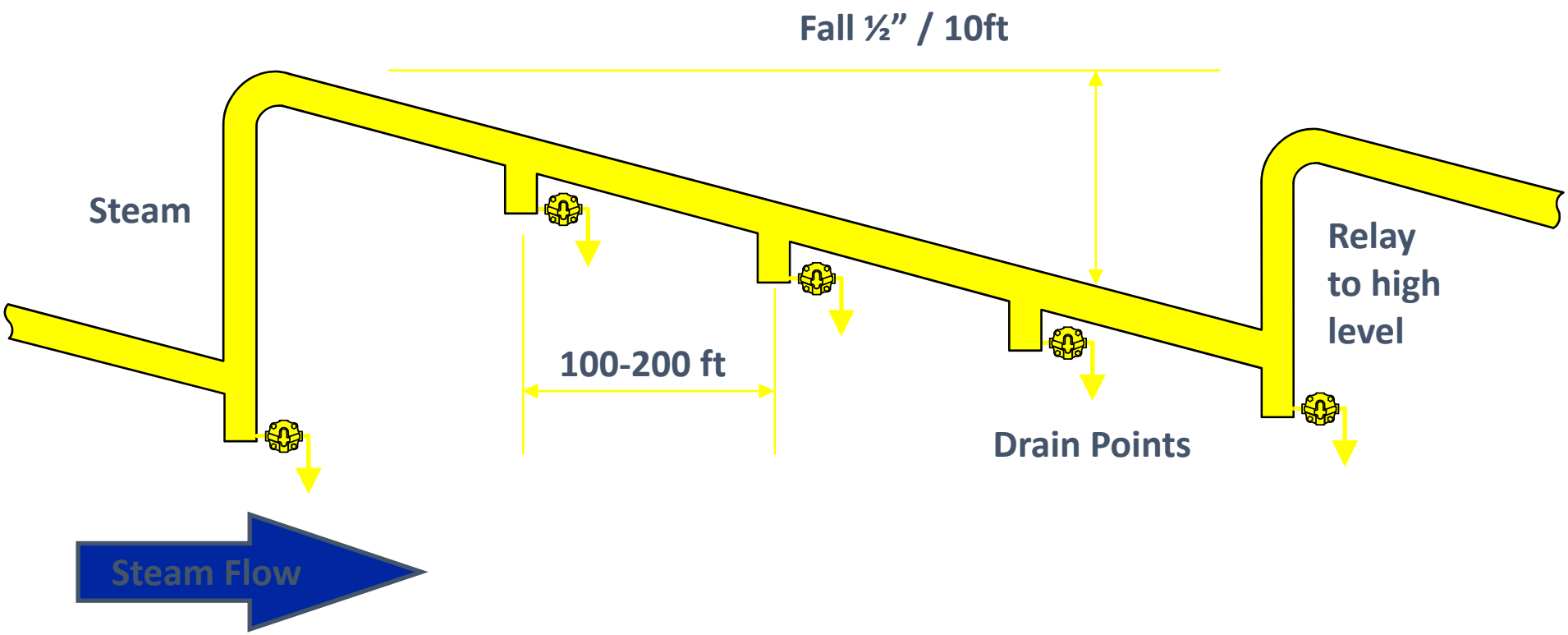
What locations do you need a Steam Trap?

- End of Steam Header
- 100/ 200 FT along horizontal runs
- At every change in elevation
- A head of Control Valves
- On Steam Equipment – Coils & Heat Exchangers

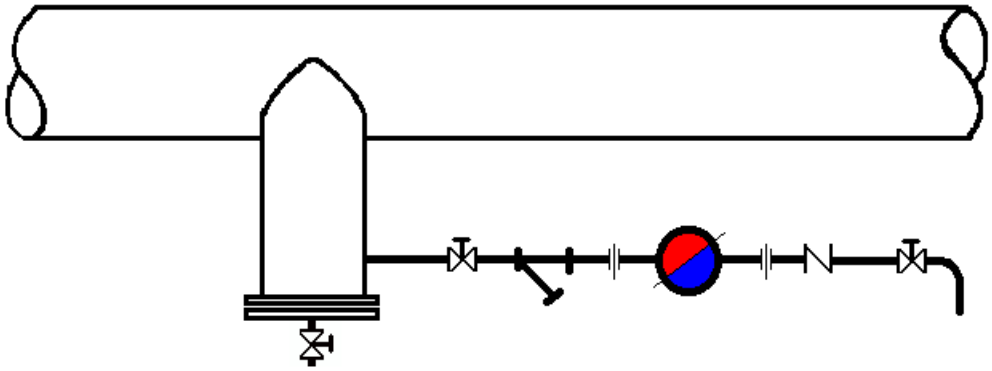


Layout of steam main

Steam Trap off of Main Steam Headers

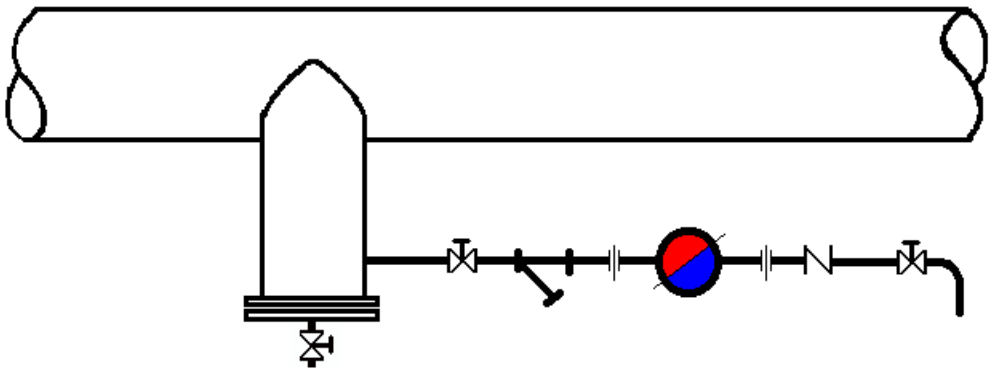


8” Steam Header at 125 psig



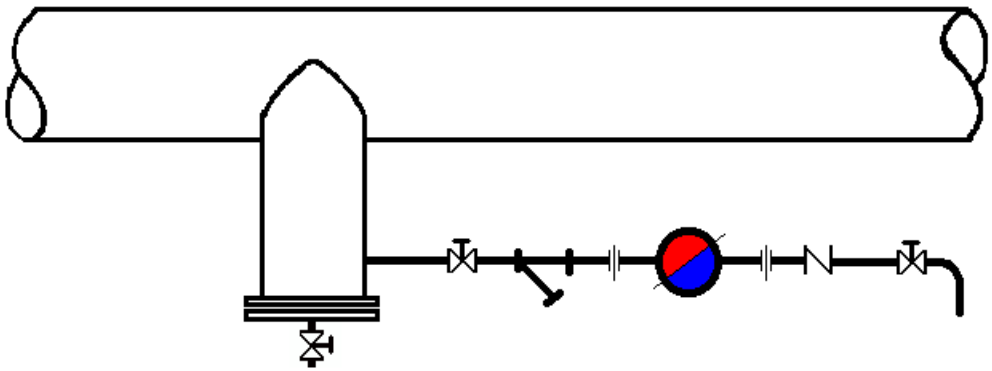
What size steam trap?

Trap Sizing for Steam Headers



• Operating Pressure	• 125 PSIG
• Return Back Pressure	• 0 PSIG
• Ambient Air Temperature	• 0 °F
• Feet of Steam Line Trapped	• 150 FT
• Steam Main Diameter	• 8 Inches
• Insulation Efficiency %	• 80%

Trap Sizing for Steam Headers



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Condensate Load Table

Table 5: Running Load in Pounds per Hour per 100 Ft of Insulated Steam Main

Ambient Temperature 70°F. Insulation 80% efficient. Load due to radiation and convection for saturated steam.

Steam Pressure psi	Main Size 2"	2½"	3"	4"	5"	6"	8"	10"	12"	14"	16"	18"	20"	24"	0°F Correction Factor†
10	6	7	9	11	13	16	20	24	29	32	36	39	44	53	1·58
30	8	9	11	14	17	20	26	32	38	42	48	51	57	68	1·50
60	10	12	14	18	24	27	33	41	49	54	62	67	74	89	1·45
100	12	15	18	22	28	33	41	51	61	67	77	83	93	111	1·41
125	13	16	20	24	30	36	45	56	66	73	84	90	101	121	1·39
175	16	19	23	26	33	38	53	66	78	86	98	107	119	142	1·38
250	18	22	27	34	42	50	62	77	92	101	116	126	140	168	1·36
300	20	25	30	37	46	54	68	85	101	111	126	138	154	184	1·35
400	23	28	34	43	53	63	80	99	118	130	148	162	180	216	1·33
500	27	33	39	49	61	73	91	114	135	148	170	185	206	246	1·32
600	30	37	44	55	68	82	103	128	152	167	191	208	232	277	1·31
800	36	44	53	69	85	101	131	164	194	214	244	274	305	365	1·30
1000	43	52	63	82	101	120	156	195	231	254	290	326	363	435	1·27
1200	51	62	75	97	119	142	185	230	274	301	343	386	430	515	1·26
1400	60	73	89	114	141	168	219	273	324	356	407	457	509	610	1·25
1600	69	85	103	132	163	195	253	315	375	412	470	529	588	704	1·22
1750	75	93	113	145	179	213	278	346	411	452	516	580	645	773	1·22
1800	79	96	117	150	185	221	288	358	425	467	534	600	667	800	1·21

†For outdoor temperature of 0°F, multiply load value in table for each main size by correction factor shown.

Calculating Condensate Loads

8” Header at 125 psig	45 #/HR per 100 FT
150 FT Header	45 x 1.5 = 67.5 #/HR
0 F Correction Factor	67.5 x 1.41 = 95 #/HR
2:1 Safety Factor	190 Total #/HR

We need to select a steam at 125 PSIG that can pass 190 #/hr of Condensate

Steam Trap Selection

- Steam Trap size based upon 125 PSIG Pressure Differential across the Trap

✓½ - ¾" Inverted Bucket has a capacity of 600 #/HR @125 PSIG

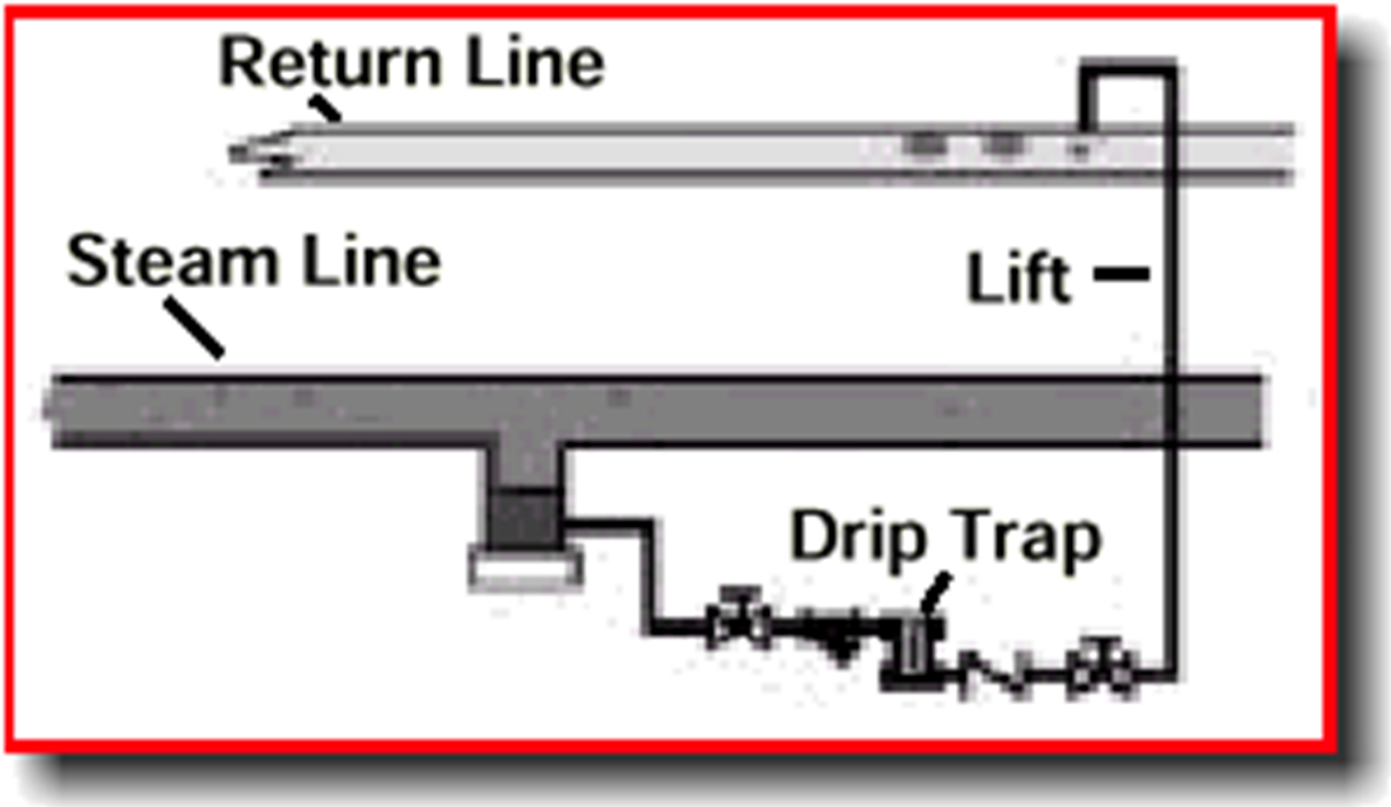
X 1 1/4" Inverted Bucket has a capacity of 3,500 #/HR @ 125 PSIG

X 2" Inverted Bucket has a capacity of 10,000 #/HR @ 125 PSIG

❖ Steam Header (24") can be drained with a ½ - ¾" steam trap!

Lifting Condensate

What lift condensate from a lower elevation to a higher elevation?

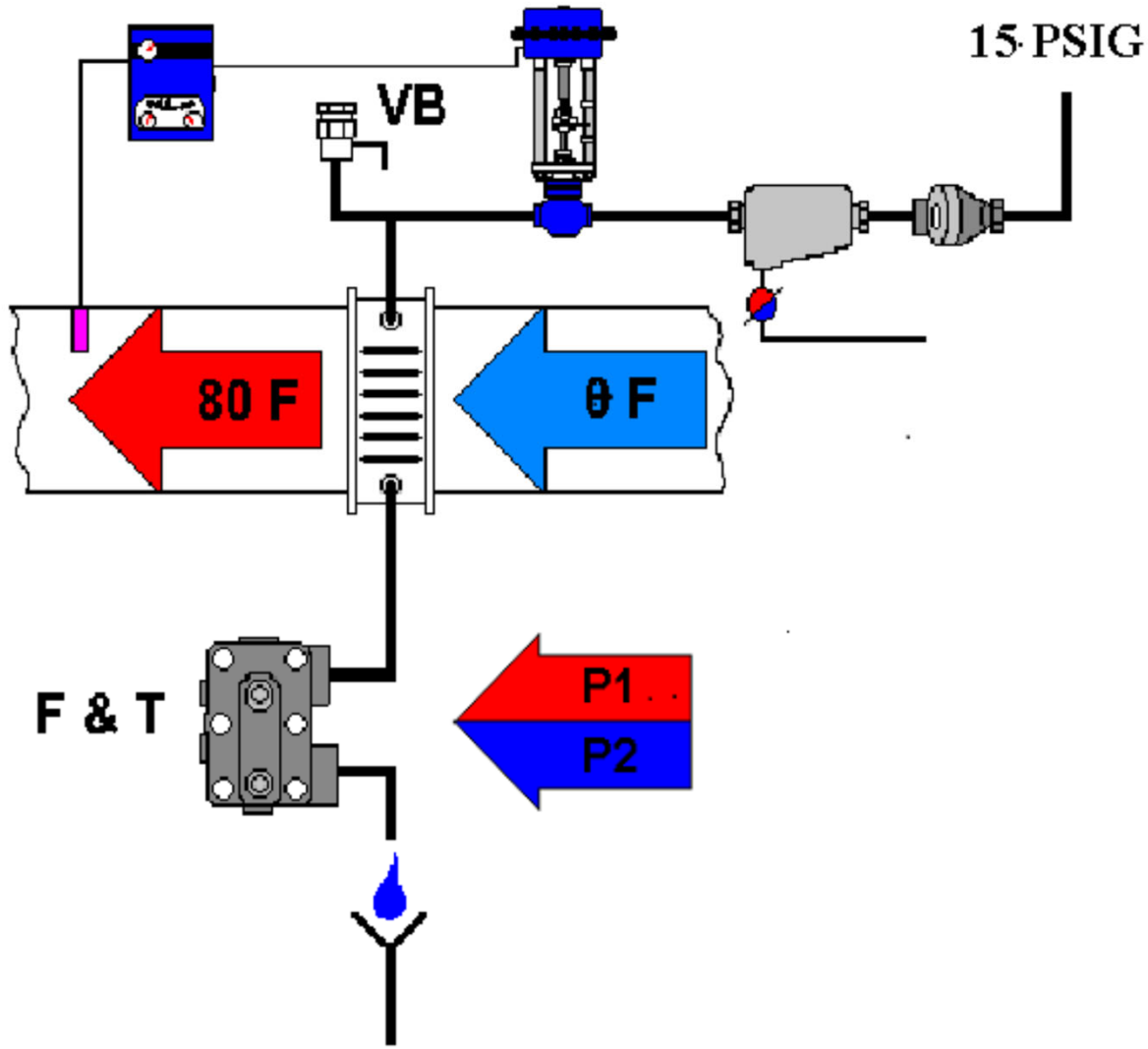


1 PSIG for every 2 feet of **condensate lift**

15 Psig Steam Pressure at the inlet of the steam trap = 30 feet of lift

The Proper Drainage of Steam Equipment such as Heat Exchangers and Heating Coils

Heating Air with a Steam Coil
What size trap?



Sizing Steam Traps for Coils

Heating :	**50,000 CFM**
Inlet Temperature:	**20°F**
Outlet Temperature:	**80°F**
Steam Pressure:	**15 PSIG Saturated**

By General Usage Formula:

lb/hr Steam = (CFM/900) X Temp. Rise

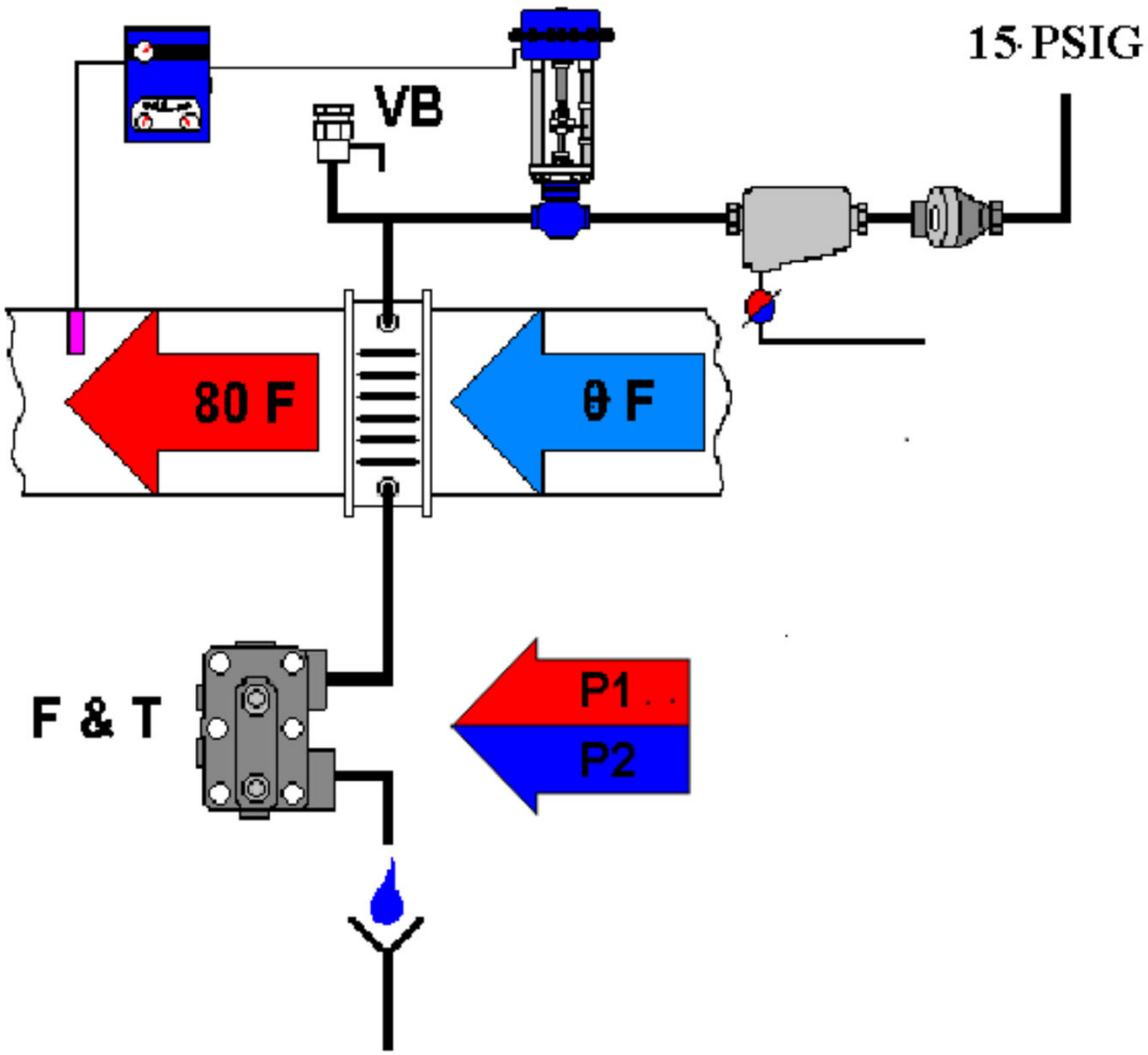
= (50,000/900) X 60 = 3,300 lb/hr

Safety Factor = No S.F.

Size using ½ psi pressure to size the steam trap

2" Float & Thermostatic Trap

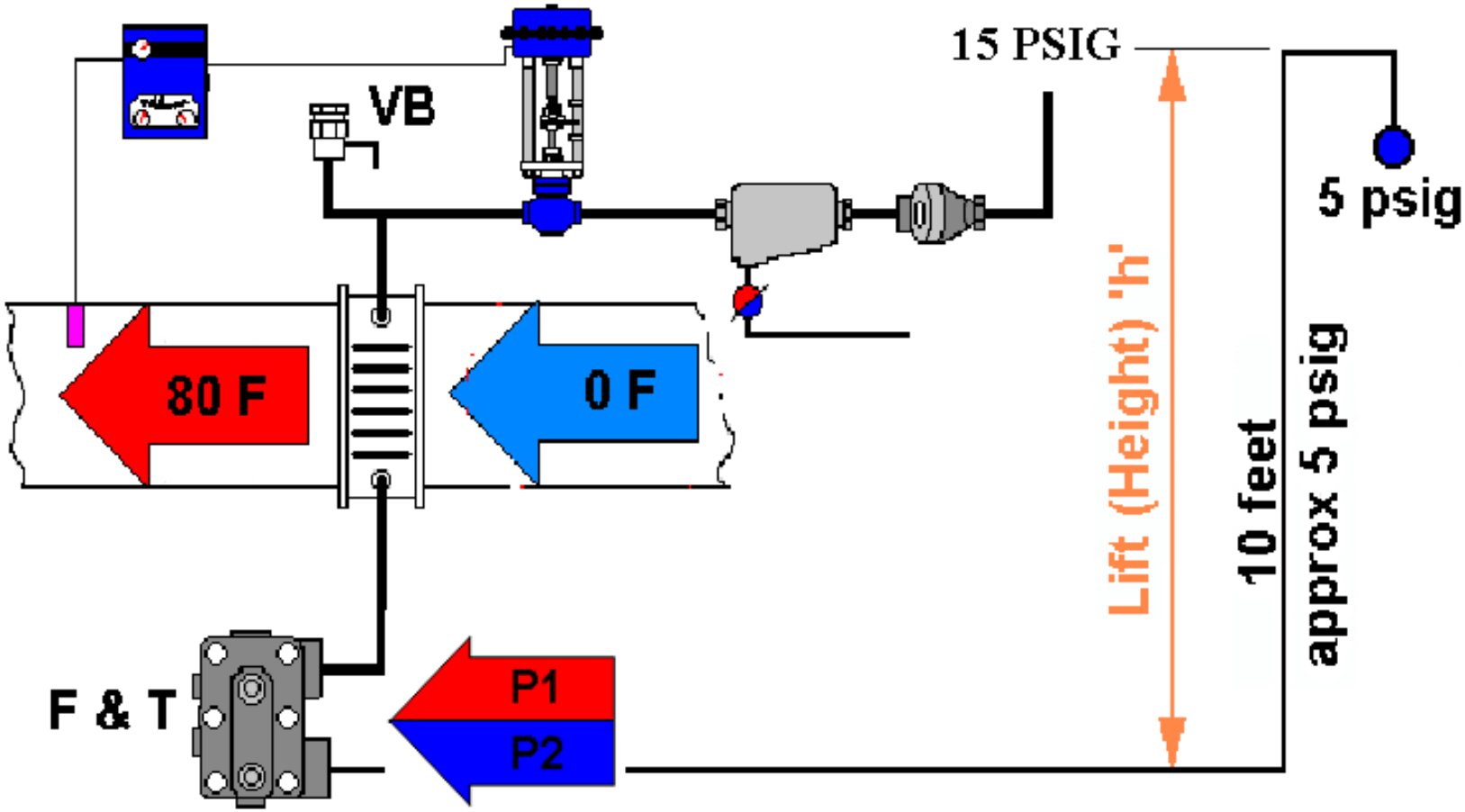
Heat Air to 80 Degrees – What pressure steam?



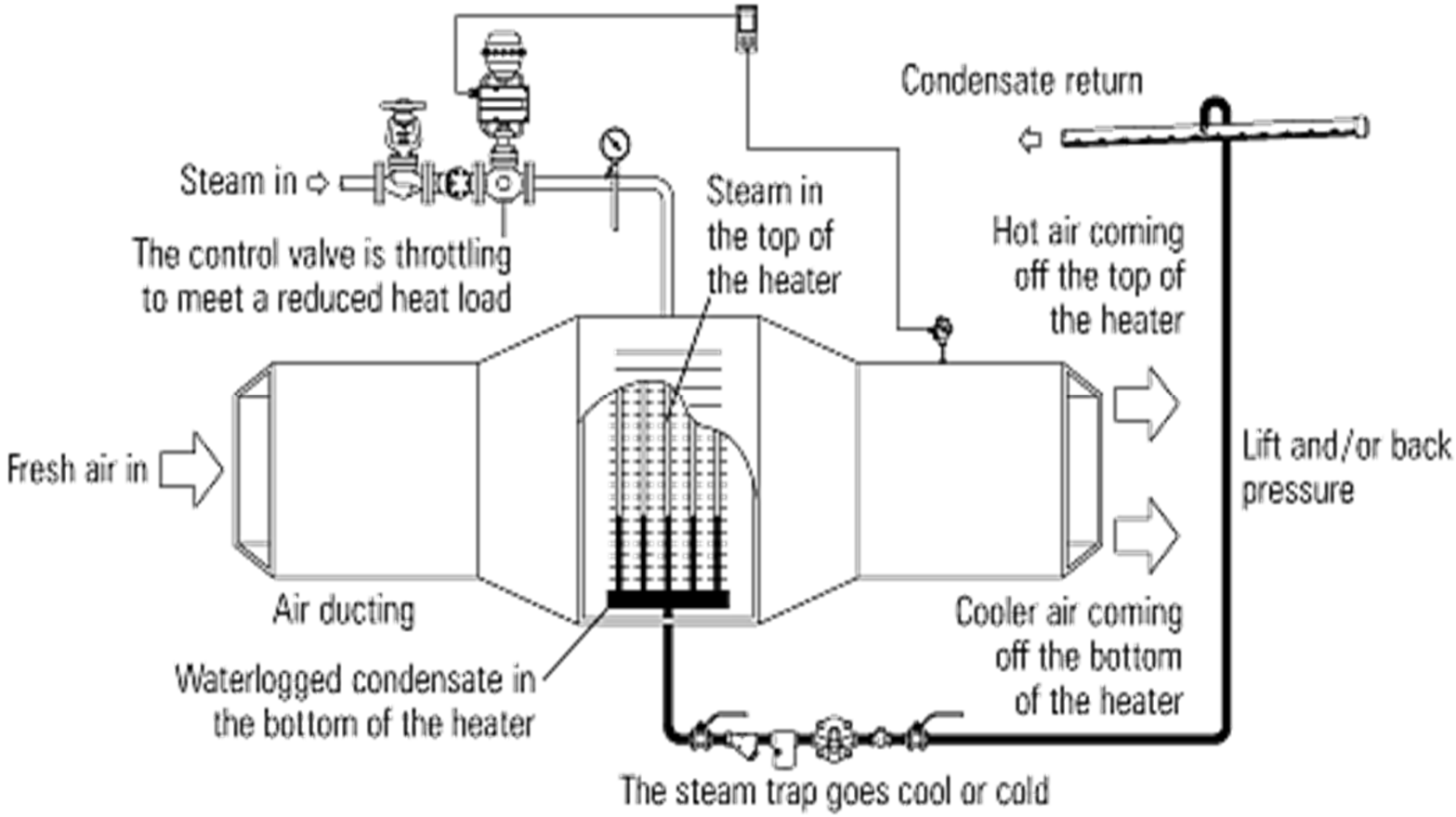
Vacuum Steam

Gauge Pressure	Steam Temp F	Sensible Heat	Latent Heat	Total Heat	Specific Volume
300	421	398	805	1203	1.47
150	365	338	857	1195	2.75
40	287	256	919	1175	7.79
15	250	218	945	1164	13.75
28 Inches of Vacuum	80	69	1036	1106	333.60

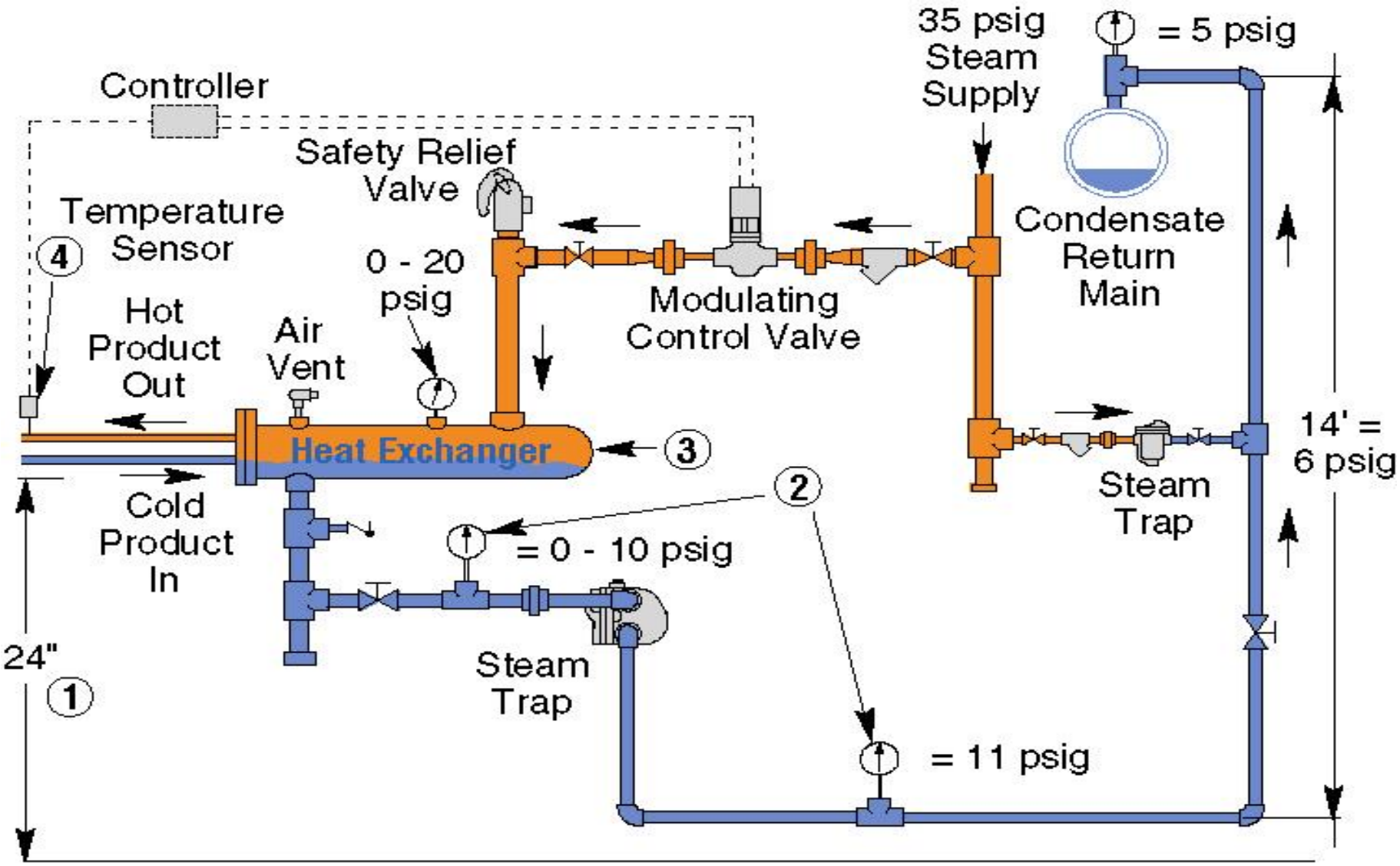
Lifting condensate to the over head return line



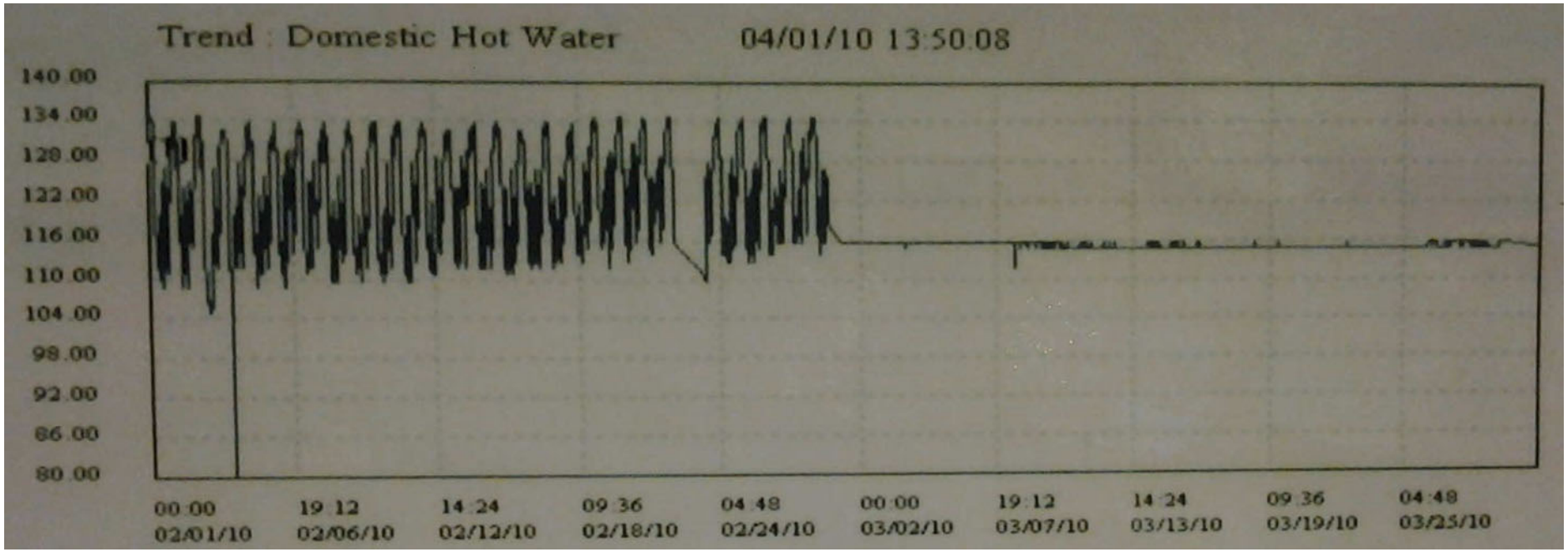
Steam System Stall – Water Logging Coils



“Steam System Stall”



Poor Temperature Curve



Effects of Steam System Stall

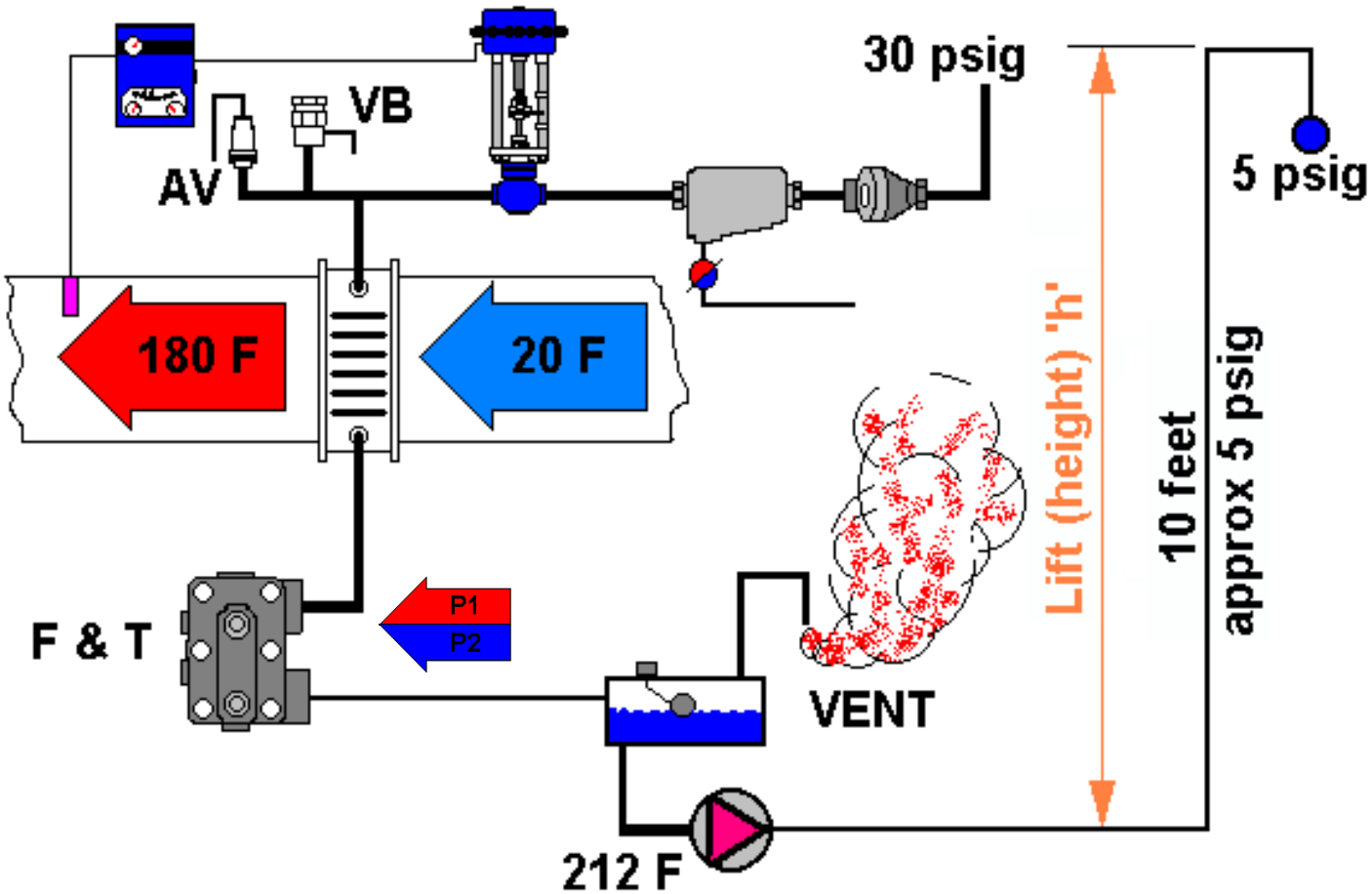
- Inadequate condensate drainage
- Water hammer
- Frozen coils
- Corrosion due to Carbonic Acid formation
- Poor temperature control
- Control valve hunting (system cycling)
- Reduction of heat transfer capacity

You will have “Steam System Stall” when …

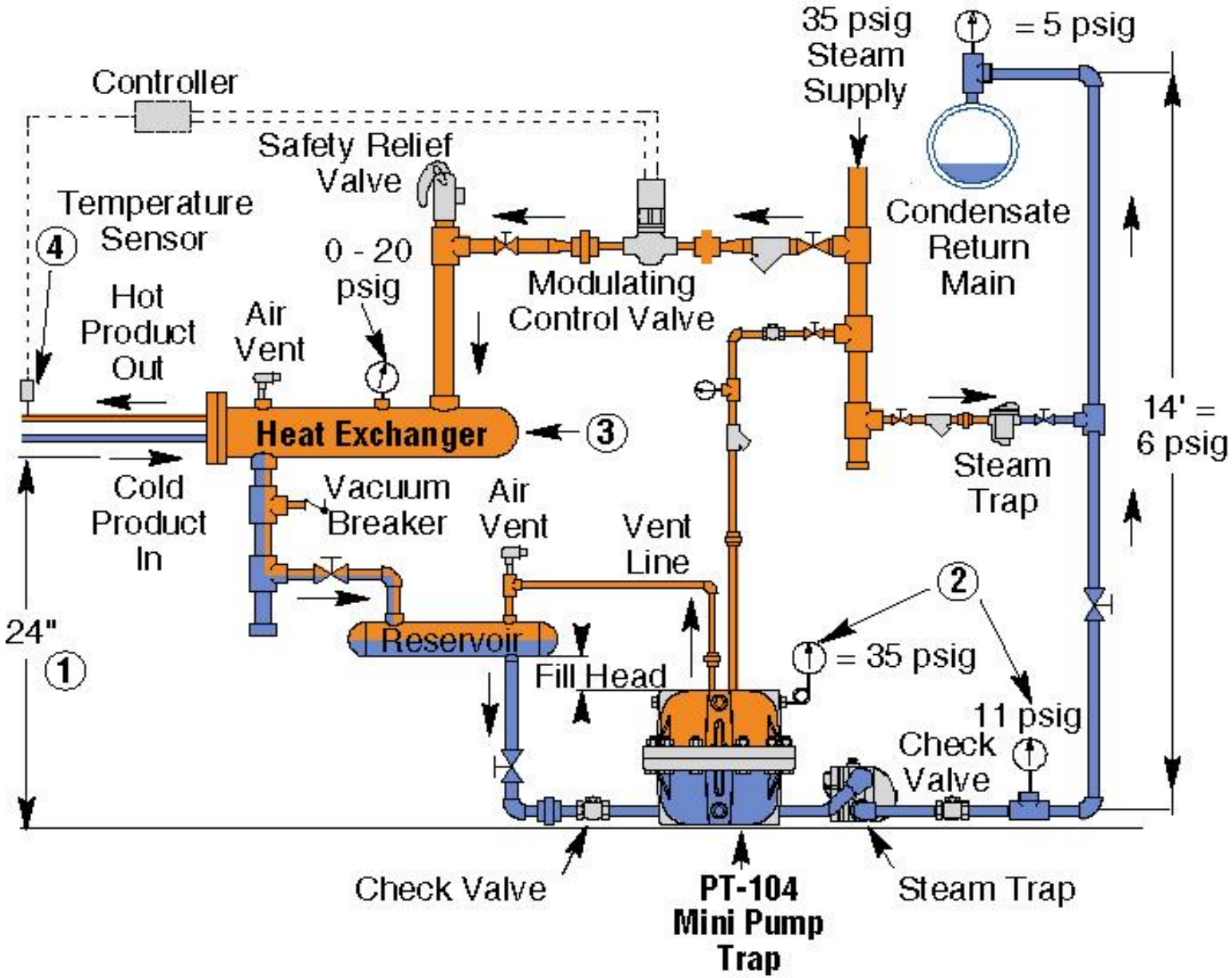
- P1 is less than P2.
- Inlet Pressure at the Steam Trap is less than the Back Pressure at the steam trap.

✓ Steam Modulating Control Valve feeding the heat transfer equipment and lifting the condensate to the overhead return.

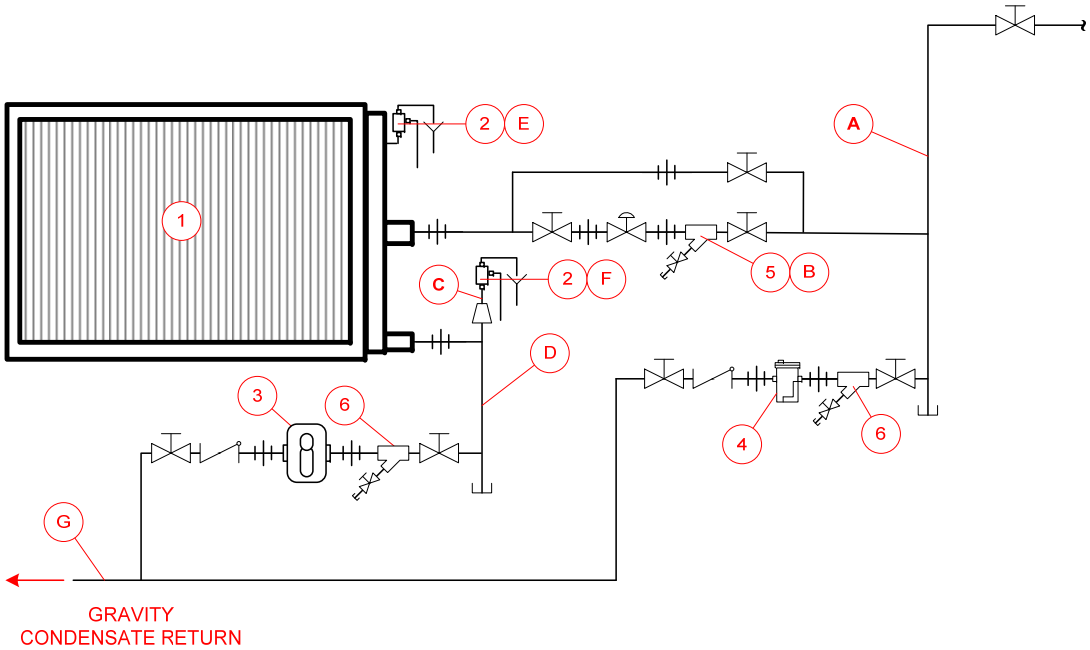
Electric Condensate Pumps



Closed-Loop Solution to Steam System Stall



Proper Steam Coil Piping for Modulated Control



ITEM	DESCRIPTION	BRAND	MODEL
1	CENTIFEED STEAM COIL	ARMSTRONG	PER APPLICATION
2	AIR VENT/VACUUM BREAKER COMBINATION	ARMSTRONG	TAV-B
3	FLOAT & THERMOSTATIC STEAM TRAP	ARMSTRONG	PER APPLICATION
4	INVERTED BUCKET STEAM TRAP	ARMSTRONG	PER APPLICATION
5	STRAINER	ARMSTRONG	PER APPLICATION
6	STRAINER	ARMSTRONG	PER APPLICATION

NOTES:

A) STEAM SUPPLY PIPED WITH DRIP LEG AND TRAP AS SHOWN UNLESS RUNOUT IS LESS THAN 10FT. AND CAN BE PITCHED BACK TO MAIN AT ½" PER FT.

B) INSTALL 100X100 MESH STRAINER (ITEM 5) AHEAD OF CONTROL VALVES.

C) UNINSULATED PIPE RISER TO AIR VENT (ITEM 2) 18" MINIMUM ELEVATION ABOVE COIL OUTLET CONNECTION

D) PIPE DRIP LEG TO TRAP FULL DIAMETER OF COIL CONDENSATE OUTLET CONNECTION. PROVIDE MINIMUM OF 10-12" DROP FROM COIL CONDENSATE OUTLET TO TRAP INLET ELEVATION.

E) INSTALL AIR VENT/VACUUM BREAKER COMBINATION (ITEM 2) AT THIS LOCATION WHEN COIL MANUFACTURER PROVIDES AN AIR VENT CONNECTION ON RETURN SIDE HEADER

F) INSTALL AIR VENT/VACUUM BREAKER COMBINATION (ITEM 2) AT THIS LOCATION WHEN NO COIL VENT CONNECTION IS PROVIDED

G) COILS WITH MODULATED CONTROL REQUIRE ALL CONDENSATE PIPING DRAIN BY GRAVITY, WITH NO RISE IN ELEVATION, TERMINATING TO A VENTED RECIEVER.

Steam 101 Summary

- High Pressure and Low Pressure (latent heat & specific volume)
- Steam Velocity
- Proper locations for steam traps
- Importance of steam quality
- Proper Size Drip Legs
- Waterhammer
- Steam trap sizing for main headers (1/2” to ¾”)
- Do not lift condensate on H*eat Transfer* applications that use a Modulating Control Valve (gravity drain or use a pump trap)

Thank you!