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

100 psig
338°F

15 psig
249°F

Condensate
Steam
Vapor

PRV
Trap
Trap
Trap
Trap
Trap
Vent

100 psig
338°F

15 psig
249°F
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.
<table>
<thead>
<tr>
<th>GAUGE PRESSURE</th>
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<tbody>
<tr>
<td>PSIG</td>
</tr>
<tr>
<td>0</td>
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<tr>
<td>100</td>
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<tr>
<td>TEMP °F</td>
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<td>33</td>
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<td>212</td>
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<td>212</td>
</tr>
<tr>
<td>338</td>
</tr>
<tr>
<td>HEAT IN BTU /LB</td>
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<tr>
<td>SENSIBLE</td>
</tr>
<tr>
<td>0</td>
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<td>970</td>
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<td>0</td>
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<tr>
<td>1</td>
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<tr>
<td>180</td>
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<tr>
<td>1150</td>
</tr>
<tr>
<td>1189</td>
</tr>
<tr>
<td>SPECIFIC VOLUME</td>
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<tr>
<td>CU. FT/LB</td>
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STEAM CURVE

TEMPERATURE

PRESSURE

STEAM

CONDENSATE
## 150 PSIG vs 15 PSIG

<table>
<thead>
<tr>
<th>Gauge Pressure</th>
<th>Steam Temp F</th>
<th>Sensible Heat</th>
<th>Latent Heat</th>
<th>Total Heat</th>
<th>Specific Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td>150</td>
<td>365</td>
<td>338</td>
<td>857</td>
<td>1195</td>
<td>2.75</td>
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<tr>
<td>15</td>
<td>250</td>
<td>218</td>
<td>945</td>
<td>1164</td>
<td>13.75</td>
</tr>
</tbody>
</table>
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

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</table>
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

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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 @ 287°F

@ 100% Dry (saturated) steam supplies 919 Btu / lb.
   \[\therefore\] process requires 5,054 lb/hr.

@ 90% Dryness Fraction, steam supplies 827 Btu/lb.
   \[\therefore\] process now requires 5616 lb/hr. A 11% Increase

@ 80% Dryness Fraction, steam supplies 735 Btu/lb
   \[\therefore\] process now requires 6319 lb/hr. A 25% increase
Drain Separator Cut Away
Drain Separator

Designed to eliminate 98% of entrained liquids

Steam

Condensate

Dirt

Dry Steam Outlet

Drain Separator Operation

Drain for condensate and dirt
Drain Separators

Note:
1. Safety Relief Valve to be set at 10 psi higher or 10x higher than the downstream pressure, whichever is greater.
2. It is suggested that the inlet "Y" type strainer be installed on its 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

Steam

Condensate

Incorrect

Correct
Concentric Vs. Eccentric Reducers
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**

<table>
<thead>
<tr>
<th>Size of Main ‘D’</th>
<th>Collection Leg Diameter</th>
<th>Length of Collection Leg ‘H’</th>
</tr>
</thead>
<tbody>
<tr>
<td>1/2” to 4”</td>
<td>Same dia. as main ‘D’</td>
<td>Automatic Start up: ‘H’ to be 28” or more</td>
</tr>
<tr>
<td>5” &amp; larger</td>
<td>2 to 3 Pipe Sizes Smaller than Main, But Never Smaller than 4”</td>
<td>Supervised Start up: Length to be 1.1/2 times steam Main Diameter, but never shorter than 8”</td>
</tr>
</tbody>
</table>
20” Header with 1” Drip Pocket
Waterhammer
Waterhammer
Waterhammer

SAGGING STEAM HEADER

Condensate

Slug of water from condensate

Vibration and noise caused by waterhammer
New York Steam Explosion

Steampipe test shows safety valve was faulty

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

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 the trap, saving it will record the tests 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."
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

- **Air Vent Open**
- **Float Valve Closed**

Diagram showing the flow from In to Out with the air vent open and the float valve closed.
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

- Boiler
- Steam trap
- Air Vent

100 / 200 ft

Grade 1/2” in 10 ft
Steam Trap off of Main Steam Headers

Steam Flow

Steam

Fall \( \frac{1}{2}'' / 10\text{ft} \)

100-200 ft

Drain Points

Relay to high level
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**

<table>
<thead>
<tr>
<th>Steam Pressure</th>
<th>2''</th>
<th>2½''</th>
<th>3''</th>
<th>4''</th>
<th>5''</th>
<th>6''</th>
<th>8''</th>
<th>10''</th>
<th>12''</th>
<th>14''</th>
<th>16''</th>
<th>18''</th>
<th>20''</th>
<th>24''</th>
<th>0°F Correction Factor†</th>
</tr>
</thead>
<tbody>
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<td>psi</td>
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<tr>
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<tr>
<td>125</td>
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<td>16</td>
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<td>125</td>
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<td>534</td>
<td>600</td>
<td>667</td>
<td>800</td>
<td>1.21</td>
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</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Description</th>
<th>Calculation</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>8” Header at 125 psig</td>
<td>45 #/HR per 100 FT</td>
<td></td>
</tr>
<tr>
<td>150 FT Header</td>
<td>45 x 1.5 = 67.5 #/HR</td>
<td></td>
</tr>
<tr>
<td>0 F Correction Factor</td>
<td>67.5 x 1.41 = 95 #/HR</td>
<td></td>
</tr>
<tr>
<td>2:1 Safety Factor</td>
<td>190 Total #/HR</td>
<td></td>
</tr>
</tbody>
</table>

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

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

✗ 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:

\[
\text{lb/hr Steam} = \left(\frac{\text{CFM}}{900}\right) \times \text{Temp. Rise}
\]

\[
= \left(\frac{50,000}{900}\right) \times 60 = 3,300 \text{ lb/hr}
\]

Safety Factor = No S.F.

Size using \(\frac{1}{2}\) psi pressure to size the steam trap

2” Float & Thermostatic Trap
Heat Air to 80 Degrees – What pressure steam?
# Vacuum Steam

<table>
<thead>
<tr>
<th>Gauge Pressure</th>
<th>Steam Temp F</th>
<th>Sensible Heat</th>
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<td>287</td>
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<td>919</td>
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<td>945</td>
<td>1164</td>
<td>13.75</td>
</tr>
<tr>
<td>28 Inches of Vacuum</td>
<td>80</td>
<td>69</td>
<td>1036</td>
<td>1106</td>
<td>333.60</td>
</tr>
</tbody>
</table>
Lifting condensate to the overhead return line.
Steam System Stall – Water Logging Coils

The control valve is throttling to meet a reduced heat load.

Air ducting

Waterlogged condensate in the bottom of the heater

The steam trap goes cool or cold.

Condensate return

Hot air coming off the top of the heater

Lift and/or back pressure

Cooler air coming off the bottom of the heater
“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

- AV
- VB
- 30 psig
- 180 F
- 20 F
- Lift (height) 'h'
- 10 feet
- 5 psig approx 5 psig
- F & T
- VENT
- P1
- P2
- 212 F
Closed-Loop Solution to Steam System Stall

Diagram showing a steam system with various components such as a controller, temperature sensor, heat exchanger, safety relief valve, modulating control valve, vacuum breaker, vent line, reservoir, fill head, check valve, PT-104 mini pump trap, and steam trap. The system is labeled with pressures and flow directions, indicating the closed-loop solution for steam system stall.
Proper Steam Coil Piping for Modulated Control

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 ¼" 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.

<table>
<thead>
<tr>
<th>ITEM</th>
<th>DESCRIPTION</th>
<th>BRAND</th>
<th>MODEL</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>CENTIFEED STEAM COIL</td>
<td>ARMSTRONG</td>
<td>PER APPLICATION</td>
</tr>
<tr>
<td>2</td>
<td>AIR VENT/VACUUM BREAKER COMBINATION</td>
<td>ARMSTRONG</td>
<td>TAV-B</td>
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<tr>
<td>3</td>
<td>FLOAT &amp; THERMOSTATIC STEAM TRAP</td>
<td>ARMSTRONG</td>
<td>PER APPLICATION</td>
</tr>
<tr>
<td>4</td>
<td>INVERTED BUCKET STEAM TRAP</td>
<td>ARMSTRONG</td>
<td>PER APPLICATION</td>
</tr>
<tr>
<td>5</td>
<td>STRAINER</td>
<td>ARMSTRONG</td>
<td>PER APPLICATION</td>
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<tr>
<td>6</td>
<td>STRAINER</td>
<td>ARMSTRONG</td>
<td>PER APPLICATION</td>
</tr>
</tbody>
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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 Heat Transfer applications that use a Modulating Control Valve (gravity drain or use a pump trap)
Thank you!