Steam Systems 101
Understanding Your Energy Systems Better

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CONSULTING SOLUTIONS / TECHNICAL SOLUTIONS / CONSTRUCTION SOLUTIONS
• Background in Heating/Power plants associated with large industrial and central plants associated with campus distribution systems.
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• From a project delivery perspective, have sat in every chair around the project members table.
Agenda

- Steam Systems 101
- Boiler Room Concerns
- System Concerns
  - Distribution Issues
  - End Users
  - Return System
- Preventative Maintenance Practices
- Start-up / Commissioning
Steam Systems 101
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Donald E. Tanner, Executive Director,
National Board - NB Bulletin/Fall 2002
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• In one day, more people come in close proximity to a boiler or pressure vessel than the number of people who fly each year in the United States.”
Laws of the Boiler Room

- Mother Nature always wins.
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- **Steam, chilled water and electricity are generated on demand and cannot be stored.** Requires plant operations to “swing” immediately and constantly with system demands.

- **You can’t get something for nothing.** Thermodynamics and efficiency vs. operating costs.
System Forces

- Boiler at 15 psi – “Low Pressure”
  - 8.5” by 11” = 93.5 IN²
  - 93.5 IN² x 15 LBS/IN² =
  - 1,402.5 pounds force or ~ ¾ of a ton
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• Boiler at 100 psi
  • 8.5” by 11” = 93.5 IN²
  • 93.5 IN² x 100 LBS/IN² =
  • 9,350 pounds force or ~ 4.75 tons
Potential Energy

It is a known engineering fact that a given volume of water, under pressure at or above 212 degrees will instantaneously flash and grow in volume to occupy a space greater than \textbf{1,600 times} its original volume.

- Dynamite expands \textgreater900 times in volume

- Where would we encounter water above atmospheric pressure?
It is a known engineering fact that a given volume of water, under pressure at or above 212 degrees will instantaneously flash and grow in volume to occupy a space greater than 1,600 times its original volume.

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- Where would we encounter water above atmospheric pressure?
Boiler Room Concerns
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Total Cost Factors For 1,000 Pounds of Steam

Fuel, 74%
Electricity, 2.50%
Equipment, 9.75%
Labor, 10%
Sewer, 1.50%
Water, 0.75%
Chemicals, 0.50%
Boiler Room Concerns

Definitions:

- **Efficiency**: “The ratio of the effective or useful output to the total input of any system”
- **Combustion Efficiency**: The effective use of fuel to the burner.
- **Boiler Efficiency**: The effective use of heat to the boiler.
- **Boiler Room Efficiency**: The effective use of steam in the boiler room.
- **System Efficiency**: The effective use of steam from the time it leaves the boiler room and until it returns to the boiler room.
Boiler Room Concerns

- **Burner Zone:**
  - Tune burner
  - Boiler controls
  - Oxygen trim ($O_2$)

- **Boiler Zone:**
  - Casing leaks, refractory
  - Efficient dispatching
  - Feedwater economizer
  - Water treatment
  - Soot blowing

- **Boiler Room Zone:**
  - DA tank operation
  - Feedwater pump recirculation
  - Blowdown heat recovery
  - Combustion air make-up
  - Compressed air system
## Boiler Room Concerns

<table>
<thead>
<tr>
<th>Item</th>
<th>Principle of Operation</th>
<th>Efficiency Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economizer</td>
<td>Transfer energy from flue gas to feedwater</td>
<td>1% for each 40°F decrease in stack gas temperatures or 1% for each 10°F increase in feedwater temperature</td>
</tr>
<tr>
<td>Firetube Turbulators</td>
<td>Increase turbulence in secondary passes.</td>
<td>Same as economizer</td>
</tr>
<tr>
<td>Combustion Controls</td>
<td>Improve fuel/air ratio and $O_2$</td>
<td>0.25% increase for each 1% decrease in $O_2$</td>
</tr>
<tr>
<td>Oil &amp; Gas Burners</td>
<td>Improve fuel/air ratio and $O_2$</td>
<td>0.25% increase for each 1% decrease in $O_2$</td>
</tr>
<tr>
<td>Insulation</td>
<td>Reduce heat transfer</td>
<td>Dependent on surface temperatures</td>
</tr>
<tr>
<td>Blowdown System</td>
<td>Transfer waste heat and/or reduce flow</td>
<td>1-3% dependent on blowdown quantity and operating temperatures</td>
</tr>
<tr>
<td>Condensate Return</td>
<td>Reduce make-up water</td>
<td>12 – 15%</td>
</tr>
</tbody>
</table>
System Concerns
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Figure 1. Steam System Schematic
System Concerns - Distribution
Distribution Issues

- Proper insulation
- Lines properly pitched and dripped
- Steam trap surveys
- Hangers adequately installed and maintained
- Anchors still in fixed position
- Expansion still compensated for
- Tightness of flanges and gaskets
- Lines properly sized
  - Facility expansion turned branch into main
- Pressure reducing valve stations and safety relief valves
System Concerns – End User
System Concerns – End Users

End Users

- Pressure reducing valve stations and superheated steam
- Proper operation of desuperheating valves
- Control valve operation
- Proper dripping and trap selection
- Inactive equipment
- Coil or heat exchangers – yellow metals
- Water treatment – neutralizing amines
- Proper freeze protection – vacuum breaker
System Concerns - Recovery

Figure 1. Steam System Schematic
Return System

- Return temperatures and entrained air
- Water treatment chemicals
- Steam trap discharging and gravity flow
- Condensate receivers and full return
- Proper insulation practices
- Piping materials
- Iron and copper returned to boiler system
- Corrosion coupons
Preventative Maintenance Practices
Preventative maintenance practices

**Mechanical Integrity**

- Identify equipment covered
  - Relief and venting system/devices
  - Emergency systems
  - Controls(sensors, alarms, interlocks)

- Written maintenance procedures

- Maintenance training
  - Overview of systems and hazards
  - Procedures perform task in a safe manner
    - Lockout/Tagout
    - Confined space

- Inspection and testing
  - Required by Insurance Carrier
  - Required by Code
  - Recommended by equipment supplier

- Quality assurance
  - Close the loop
Preventative maintenance practices

Good monitoring and testing

- Monitoring is:
  - Tools (automated or manual)
  - DCS trending
  - Operational rounds
  - Log sheets
  - Benchmarking

- Testing is:
  - Tools (online or off line collection)
  - Sampling
  - Destructive and non-destructive examination
Preventative maintenance practices

Benchmarking

- Heat changing equipment
  - Inlet/outlet temperatures and flows
- Prime movers
  - Differential pressures
  - Amp draw
  - Any throttling devices
- Boilers and pressure vessels
  - Metal thickness
  - Visual wear/fatigue
  - Deposits
Preventative maintenance practices

Boiler - Pressure Vessel Inspections

- Three most important people
  - Authorized Inspector
  - Person in charge of physical plant
  - Water treatment salesperson
Start-up / Commissioning
Boilers and support equipment operate at pressures and temperatures that are inherently dangerous.
  - Valve operation
  - Thermo-expansion

Steam has a large amount of potential and kinetic energy.
  - Any compressible gas

Understand where a vacuum can develop in the system

Hydro’s have limits – follow them
Start-up / Commissioning

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Start-up / Commissioning

- Valve = 8” Dia
- Gate area = 50.3 SQ IN
- System pressure = 600 psi
- Force = 30,180 lbs
- Roughly 15 tons

In a tug-of-war, as long as the forces are in equilibrium, both groups will remain on their feet. Once unbalanced, motion occurs.
Start-up / Commissioning
Start-up / Commissioning

Pipe support

Rigid design

Butt-welded 90° elbow

Flexible design

Expansion loop

Pipe
Start-up / Commissioning

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When the can is open to atmosphere, pressure acts on both inside and outside surfaces.

When evacuated of atmospheric air, the outside pressure acts upon the surface area to crush the can.

Atmospheric pressure

14.7 psi

To vacuum pump

Atmospheric pressure

14.7 psi

Vacuum 0 psi
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LP Gas storage sphere collapsed while being filled for a hydrostatic pressure test killing a worker underneath. Support legs had corroded due to water trapped between insulation and support column.
This is an example of brittle fracture caused by using cold water for a hydrostatic pressure test and then pressurizing vessel. The temperature of the water caused the metal to become brittle.
It's QUESTION TIME!!