Steam Fundamentals
(in heating & processing applications)
Introduction
Common Heat Energy conveyers:

• Thermal Oil
• Hot water
• Steam
• Electrical
  – Electric Heaters
  – Electrodes (High Current)
Steam Fundamentals

Why using steam?

- **Steam is efficient & economic to generate**
  - Water is inexpensive, non hazardous to health and environment
  - Steam can hold 5~6 times as much potential energy as an equivalent mass of water
  - It can be generated at high pressure to give high temperature
  - Lower capital cost and running cost
• **Steam can easily and cost effectively be distributed to the point of use**
  – Steam is one of the most widely used media to convey heat over distances
  – No circulation pumps are needed to move steam in the network
  – Due to high heat content, relatively small pipe size is required to carry the steam at high pressure.
• **Steam is easy to control**
  – Temperature can be easily and accurately controlled by controlling the steam pressure
  – Only 2 port control valve is needed to control the steam line
• Energy is easily transferred to the process
  – Steam provides excellent heat transfer properties
  – Steam can surround or be injected into the product being heated
  – Because of high heat transfer properties, the required heat transfer area is relatively small
• **Steam is flexible**
  – It is used for sterilization in food and pharmaceutical industries
  – It is also used in humidification
# Comparison of common heating media with steam

<table>
<thead>
<tr>
<th>Steam</th>
<th>Hot water</th>
<th>High temperature oils</th>
</tr>
</thead>
</table>
| High heat content  
Latent heat approximately 2.100 kJ/kg | Moderate heat content  
Specific heat  
4.19 kJ/kg°C | Poor heat content  
Specific heat often 1.69-2.93 kJ/kg°C |
| Inexpensive  
Some water treatment costs | Inexpensive  
Only occasional dosing | Expensive |
| Good heat transfer coefficients | Moderate coefficients | Relatively poor coefficients |
| High pressure required for high temperatures | High pressure needed for high temperatures | Low pressures only to get high temperatures |
| No circulating pumps required  
Small pipes | Circulating pumps required  
Large pipes | Circulating pumps required  
Even larger pipes |
<p>| Easy to control with two way valves | More complex to control - three way valves or differential pressure valves may be required | More complex to control - three way valves or differential pressure valves may be required. |</p>
<table>
<thead>
<tr>
<th>Temperature breakdown is easy through a reducing valve</th>
<th>Temperature breakdown more difficult</th>
<th>Temperature breakdown more difficult</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam traps required</td>
<td>No steam traps required</td>
<td>No steam traps required</td>
</tr>
<tr>
<td>Condensate to be handled</td>
<td>No condensate handling</td>
<td>No condensate handling</td>
</tr>
<tr>
<td>Flash steam available</td>
<td>No flash steam</td>
<td>No flash steam</td>
</tr>
<tr>
<td>Boiler blowdown necessary</td>
<td>No blowdown necessary</td>
<td>No blowdown necessary</td>
</tr>
<tr>
<td>Water treatment required to prevent corrosion</td>
<td>Less corrosion</td>
<td>Negligible corrosion</td>
</tr>
<tr>
<td>Reasonable pipework required</td>
<td>Searching medium, welded or flanged joints usual</td>
<td>Very searching medium, welded or flanged joints usual</td>
</tr>
<tr>
<td>No fire risk</td>
<td>No fire risk</td>
<td>Fire risk</td>
</tr>
<tr>
<td>System very flexible</td>
<td>System less flexible</td>
<td>System inflexible</td>
</tr>
</tbody>
</table>
Typical Steam Circuit

- Pan
- Process Vessel
- Space Heating System
- Vat
- Make-up Water
- Condensate
- Condensate
- Feed Tank
- Feed Pump
- Boiler
Barriers to Heat Transfer:
Air film, condensate, scale, on the steam side, plus heat exchanger wall, and stagnant film of product to be heated are the common heat transfer barriers.
Temperature gradients across heat transfer layers
Layers That Reduce Heat Transfer Efficiency

- Steam: 4 bar, 151°C
- Water: 93°C
- Metal Wall
- Condensate Film
- Scale Film
- Stagnant Water

- Fouling layers 0.25 mm thick

- 125°C
- 121°C
- 116°C
- 120°C
Steam Boiler Types

• Packaged Boilers
Packaged boilers are limited to 25Ton/Hr capacity and 17Bar pressure. Mainly there are 3 types of packaged boilers: fire tube boilers, vertical boilers, and reverse flame boiler.

• Site assembled boilers. (Or water tubes Boiler)
water tube boilers are used mainly in power generation or wherever high pressure and/or high steam capacity is required.
Typical Packaged Steam Boiler
3 Pass Steam Boiler

1st Pass (Furnace Tube(s))

2nd Pass (Tubes)

3rd Pass (Tubes)

Steam at 150°C

1600°C

250°C

400°C

200°C
### Typical Heat Transfer Data for a 3 Pass Boiler

- For 100 m² Heating Surface (Total)

<table>
<thead>
<tr>
<th>Pass</th>
<th>Area (m²)</th>
<th>Temperature (°C)</th>
<th>Heat Transfer (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st Pass - Furnace</td>
<td>11</td>
<td>1,600</td>
<td>65</td>
</tr>
<tr>
<td>1st Pass - Combustion chamber</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2nd Pass</td>
<td>43</td>
<td>400</td>
<td>25</td>
</tr>
<tr>
<td>3rd Pass</td>
<td>46</td>
<td>250</td>
<td>10</td>
</tr>
</tbody>
</table>
Reverse flame or thimble boiler

Water

Steam

Chimney

Furnace back wall

Tubes around furnace

Burner

Thimble furnace

Steam Space
Steam Generator (Vertical Boiler)

- Burner
- Steam Outlet
- Water
- Combustion Chamber
  - 1st Pass, Downward
- Finned Convection
  - 2nd Pass, Upward
Coil Boiler

Q kg/h Dry saturated steam to plant
10% water with impurities to waste/recycle

Q kg/h + 10%
Boiler Fittings
Boiler Fittings

- There are a number of attachments and fitting on a boiler.
- The objectives of these fittings include:
  - Operation.
  - Safety.
  - Efficiency.
  - Compliance with laws, regulations and guidance notes.
Feed Water System
Feed Tank Purposes:
• Receives condensate from the network
• Storage reasonable amount of water to cover boiler feed demand
• Remove oxygen and incondensable gasses
• Preheat the feed water to prevent thermal shock
Feed Tank Components
Deaerator Head
Boiler Inside Video
Boiler Control & Burner Management
Burner Requirements:

- provide high combustion efficiency
- follow steam demand load
- Easy to start
- Simple and easy to maintain
- Provide highest safety level
Burner Components

- Blower Motor, Blower
- Air Damper and Turbulator
- Oil Pumps, Oil Valves, Metering Valve, Nozzles (For Oil Burner)
- Gas Train, Gas Solenoid Valve, Butterfly metering valve, and Gas nozzles (for gas burners)
- Ignition Transformer and Electrodes
- Pilot assembly
- Flame Scanner and Burner Controller
- Modulation Motor and Linkages
Burner Controller

• **Burner Management**
  – Sequencing of StartUp
  – Sequencing of Shutdown
  – Monitoring of Interlocks
    • Fuel Pressure/Temperature
    • Air Pressure

• **Flame Safeguard**
  – Monitoring of the Flame presence/absence
Flame Scanners

- Photo cell (visible light scanner)
- Ultra-Violet (UV)
- Infrared (IR)
- IR + UV
Millimeter waves, telemetry

Infrared

Visible light

Ultraviolet

X-rays, Gamma rays

Hz
Oil Burner Flow Diagram
Burner Sequence

- Initialization: 5 secs, self test
- Purge
  - High Fire Purge 30 sec
  - Low Fire Purge 30 sec
- PTFI (Pilot Trial For Ignition)
  - Ignition spark (5 sec)
  - Oil Valve (10 sec)
- MTFI: 10 sec (Main Trial For Ignition)
- AUTO
- Post-Purge: 15 sec
- Standby

One CYCLE!
Burner Firing Sequence

1- On/Off
2- low, high, off system
3- Full Modulation