DRYTECH 2008
1st and 2nd December 2008

Condensate Removal from Steam Heated Coils to Reduce Energy Use in Drying

spirax/sarco
• Ball Float Steam Traps are used to remove condensate from the steam coil.
• Each coil should be individually trapped (no group trapping).
• Steam pressure in the coil provides the motive force to drive the condensate through the trap and back through the condensate return system.
Ball Float Trap

- High Capacity
- Built-in Air Vent
- Continuous modulating action
- Able to handle high and low flows
• The trap must operate against the combined Lift and Backpressure.
• Lift is simply how high the condensate must rise up.
• Backpressure is due to flow related pressure drop in the return system and is influenced by flow rate and diameter & length of the return piping.
Flash Steam Formation

Flash Steam forms as the condensate pressure is dropped through the trap

Example – 5,000 kg/hr of condensate discharged from a coil running at 8 bar and with condensate return backpressure at 1 bar g:

• Condensate formed at 8 bar g, \( h_f = 743.1 \text{ kJ/kg} \)
• Condensate at 1 bar g, \( h_f = 505.6 \text{ kJ/kg} \)
• 10.8% of the condensate Flashes off
• Volume of Flash Steam at 1 bar g = 0.881 \( \text{m}^3/\text{kg} \)
• Volume of Flash Steam = 475 \( \text{m}^3/\text{hr} \)
• Volume of Condensate = 4.6 \( \text{m}^3/\text{hr} \)
• Velocity of Flash steam in 2.1/2” pipe = 40 m/s
• Pressure Drop approximately 0.3 bar per 100m
**Flash Steam in the Condensate System**

- Flash Steam forms most of the volume in the condensate return system.
- The high volume of Flash Steam flow has a major influence on the flow related drop that causes backpressure.
- To keep flash steam velocity to below 15 to 20m/s requires very large condensate lines – not always practical.
- Condensate lines that are too small and/or very long can have high backpressure.
- Flash Steam flow can vary causing changes in condensate backpressure.

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**Flash Steam**
- 10% of mass
- 99% of Volume

**Condensate**
- 90% of mass
- 1% of Volume
If there is insufficient steam pressure in the coil to return the condensate then Stall and Flooding will occur.

\[ P_c < (P_{bp} + \text{Trap delta } P) \]
Heat Energy Transfer Equation

\[ Q = U \times A \times \Delta t_{\text{lmtd}} \]

Where:
- \( Q \) = Heat transfer rate (W)
- \( U \) = Overall coefficient of heat transfer (W/m\(^2\)°C)
- \( A \) = Heat transfer area (m\(^2\))
- \( \Delta t_{\text{lmtd}} \) = Logarithmic mean temperature difference (°C)
Steam gives up heat energy, causing phase change. Temperature remains constant.

Secondary temperature rises

Steam as a Heating Medium
Heating Load Turndown

\[ Q = U \times A \times \Delta T_{\text{lmtd}} \]

- \( A \) is fixed
- \( U \) will vary slightly, but can be assumed to be fixed
- \( Q \) is proportional to Talmud
- As load turns down, \( Q \) reduces, requiring lower Talmud
- Lower Talmud is achieved by lower steam pressure
- Running the kiln at lower temperature is in effect turning down the load

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Steam Pressure Drop with Load Turndown

Steam Pressure reduces as heating load turns down

Start-up (slow, controlled pressure rise)

Coil steam pressure as heat load turns down

Time

Coil Steam Pressure
What happens when a Coil Floods

- $P_c < (P_{bp} + \text{Trap delta } P)$
- Condensate builds up and begins to flood the coil
- The flooding results in less heat transfer area $(A)$
- $Q$ is reduced and air temp off coil falls below set point
- Control system reacts and opens control valve to increase coil steam pressure $(P_c)$
- Pressure quickly builds up increasing Talmud and air temp off coil comes back to set point
- At the same time the increased pressure $(P_c)$ overcomes backpressure and condensate is drained from coil, exposing more area $(A)$ to steam
- $Q$ is increased and air temp off coil overshoots
- Control system reacts and closes control valve (sometimes control valve closes completely)
- Pressure in coil decays and flooding begins again
**Stall and Flooding - Affect**

- Poor Control (air temperature overshoot & undershoot)
- Cycling/hunting control valves (wear + energy usage)
- Condensate dumped to drain (energy loss, 10%)
- Thermal cycling (distortion & thermal fatigue)
- Hammer in coil and condensate system (vibration & stress can result in cracking and failure)

- Hammer is often evident at start-up as well, when the coil is flooded with cold condensate
A Condensate Pumping Station will reduce the possibility of stall and flooding by minimising backpressure and lift

- Located near Kilns – short pipe runs to pumping station means less backpressure
- Flash steam is vented at receiver
- Low profile – reduces condensate lift
- Low profile – may allow free draining of coil at shutdown

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Steam-Powered Pump Package

The Steam-Powered Pump Package is ideally suited for the Condensate Pumping Station

- Small filling head required – gives low profile with minimal lift from trap.
- No cavitation issues – able to pump boiling condensate without considering NPSH
- No level controls or electrical power
- Pump starts per hour not an issue - allows small receiver
- Pump counter available for monitoring
Recent Developments

The use of Float Traps and Steam-Powered Condensate Pumping Stations are a proven & effective method of removing condensate from steam heated coils.

However with increased energy costs and the introduction of carbon tax is there a better way to manage condensate removal and improve energy efficiency?

Recent developments in High Capacity Automatic Pump Traps (APT’s) offer a new way to approach condensate management.
What is an APT?

APT – Automatic Pump Trap

An APT combines the operation of a float trap and steam-powered pump into one device.
APT 14 rear view

- Motive steam
- Exhaust
- Inlet port
- Outlet porting
- Two stage valve
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APT features

• Removes condensate under all load conditions, including vacuum and shut-down
• Removes condensate against backpressure

• Self contained compact unit
• As little as 200mm installation head required
• Positive snap action pump mechanism
• High capacity two stage trap module
• Requires no electrical power
• SG iron body with stainless steel internals
• Innovative, patent applied for low profile mechanism
• Low resistance swing type inlet check valve
Condensate enters the body through the inlet swing check valve causing the float to rise.

The float is connected to the trap mechanism via a multi-link pivot.

If the upstream system pressure (P_c) is sufficient to overcome the back pressure (P_bp), the condensate will be discharged through the opening two stage trap mechanism.

In this way, the float will automatically modulate according to the rate of condensate entering the APT, controlling the rate of opening and closure of the trap.

\[ P_c > P_bp \]
How the APT operates (2)

As load turns down the coil steam pressure ($P_c$) will drop and may become lower than the back pressure at ($P_{bp}$).

If this occurs a standard trap will ‘stall’, allowing the condensate to flood the coil being drained.
How the APT operates (3)

However, with the APT, the condensate simply fills the main chamber - lifting the float until the changeover linkage is engaged, opening the motive inlet and closing the exhaust valve.
The snap action mechanism ensures a rapid change from the trapping mode to the active pumping mode.

With the motive inlet valve open, the pressure in the APT increases above the total back pressure and the condensate is forced out through the trap seat into the plant’s return system.
How the APT operates (5)

As the condensate level falls within the main chamber, the float re-engages the change over linkage, causing the motive inlet to close and the exhaust valve to open.
As the pressure inside the APT equalises with the condensate inlet pressure through the open exhaust valve, condensate re-enters via the inlet swing check valve.

At the same time the outlet ball check valve ensures no condensate can drain back into the main chamber and the trapping or pumping cycle begins again.
APT Selection and Sizing
Spirax Sarco APT Pump Trap Sizing and Selection Program v.6.0

**Input Customer & Spirax Details:**

<table>
<thead>
<tr>
<th>Customer: -------</th>
<th>APT10 - 4.5</th>
<th>APT14</th>
<th>APT14HC</th>
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<tbody>
<tr>
<td>Application:</td>
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**Spirax Contact:**

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**Input Units, Process Type and APT14HC Operating Conditions:**

<table>
<thead>
<tr>
<th>HOW DOES THE PROCESS LOAD CHANGE?</th>
<th>APT14HC OPERATING CONDITIONS?</th>
<th>PROCESS FULL LOAD CONDITIONS?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Variable Secondary Inlet Temperature.</td>
<td>No. of APT14HCs in Parallel: 1</td>
<td>Steam Pressure (P): 8.8 bar g</td>
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<td>2) Variable Secondary Outlet Temperature.</td>
<td>Installation Head (H): 600 mm</td>
<td>Steam Load (B): 5000 hp</td>
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<td>Input 1, 2 or 3: 1</td>
<td>Condensate Pressure (C): 3.5 bar g</td>
<td>Secondary Outlet Temp (B): 140 deg C</td>
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<td>Lift (L): 5 m</td>
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<td>Discharge Pipe Length: 150 m</td>
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<td>APT Discharge Connection: 40 mm</td>
<td>Frictional Loss (gL): 0.03 bar g</td>
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<td>Considered Discharge Pipe: 80 mm</td>
<td>Prop. of pipe carrying flash</td>
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<tr>
<td></td>
<td>Eff. Back Press. (C x D + F): 4.03 bar g</td>
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**Optimum pumping capacity will be achieved with a differential pressure of 2 - 4 bar.**
APT14HC Sizing Chart

Receiver Volume Required is 5.13 Litres
Condensate removal using APT

Installation Includes:
- Reservoir Pipe
- Exhaust & Balance Line
- Air Vent
- Motive Steam Supply

CONDENSATE RETURN TO BOILER HOUSE
Returning Condensate to the Boiler Feed Tank

APT’s allow condensate to be returned directly to the Boiler Feed Tank.

Returning all condensate represents more than 10% of energy usage.

Flash steam will still be vented and thus lost (equivalent to between 10 and 15% of energy usage – depends on operating pressure of coil).
Can Flash Steam be used at the Feed Tank?

For kilns it is normal for most of the condensate to be returned, so there is minimal requirement to pre-heat cold make-up water.

As the condensate in the feed tank is usually already close to 100°C it is not possible to heat it further. Indeed if the condensate and flash steam is sparged into the tank it usually causes boiling and shaking of the feed tank.

As there is not much potential to use the flash steam energy at the feed tank what are the alternatives?
Condensate is maintained at a constant backpressure and is passed through a Heat Exchanger.

The backpressure determines the temperature of the condensate (e.g. 3.5 bar = 148ºC).

Pressurised boiler feed water is passed through the other side of the heat exchanger.

Condensate loses latent heat and sensible heat to feed water, which is heated above 100ºC.

Assumes modulating boiler level control and that feed water flow and condensate return rate are relatively balanced (not too much lag).
Energy Transfer

Not all the available energy can be removed from the condensate. How much will depend on:

• Backpressure of condensate system
• Size of heat exchanger
• The lag between steam consumption, feed water flow and condensate return

Typically it would be expected to get a 5 to 10°C differential between Condensate and Feed Water temperatures.

The small amount of heat still left in the condensate can be recovered by passing through a combustion air heater before returning to the feed tank.
Summary

• Combined lift and backpressure can cause stall and flooding of steam coils at start-up and as load turns down.
• Stall and Flooding causes hammer, which can damage steam coils and the condensate return system.
• Using ball float traps combined with a steam-powered condensate pumping unit is an effective means of returning hot condensate to the feed tank and also reduce the risk of stall and flooding.
Summary

• Returning all condensate will save approximately 10% of the energy required to raise steam.

• Recently developed High Capacity Automatic Pump Traps (APT’s) can be used to actively remove and return condensate to the boiler house under all load conditions.

• Using APT’s to close the condensate thermal loop with a heat exchanger and pressurised condensate return system allows almost all the condensate energy to be recovered and will save approximately 20% of the energy required to raise steam (10% from returned of condensate and a further 10% from recovering energy normally lost as flash steam).