

# Condensate recovery in industrial systems

## Addressing water scarcity

SUPPLIED BY SPIRAX SARCO

### 1. EXECUTIVE SUMMARY

Steam is a popular and efficient medium for moving heat around a wide variety of processes and premises. Formed by condensed steam, liquid condensate needs to be drained from pipelines and equipment on a continuous basis to avoid the risk of water hammer and to maintain heat exchange efficiencies in processes. Although condensate is effectively removed from many steam plants the condensate is not always returned back to the boiler feedback to form a closed circuit. In today's cost-conscious environment, it's vital for steam users to make the best possible use of the energy and hot water in steam. Pressure on our natural water resources is also mounting, so effective condensate recovery is essential. Condensate is the hot, treated water produced as steam releases its heat energy. It's a valuable resource that contains around 25% of the useful energy in the original steam. It makes sense to return it to the boiler, instead of dumping it to drain. It may be impractical to return all the condensate to the boiler for various reasons, but in most applications a goal of 75-80% condensate return is reasonable. Condensate recovery offers several benefits. It saves energy and reduces fuel costs, reduces water charges and chemical treatment costs and brings down effluent charges. This combination leads to a typical payback for new condensate recovery systems of between one and two years. So it's perhaps unsurprising that most steam users already have some form of condensate recovery system in place, although most of them could be improved using the latest techniques and systems.

### 2. CONDENSATE RECOVERY SAVES MONEY

#### Reduced fuel costs:

Normally, condensate will contain around 25% of the usable energy of the steam from which it came. Returning this to the boiler feedtank can save hundreds of thousands of Rands

per year in energy alone. Using condensate to heat the boiler feedwater leaves the boiler with less to do in converting the water to steam. In other words, less fuel is needed to produce steam from hot water rather than cold water. As a rule of thumb: every 6°C rise in feedwater temperature achieved by using "free" energy from hot condensate equates approximately to a 1% fuel saving.

#### Energy saving:

Condensate is distilled water with little total dissolved solids (TDS). More condensate returned to the feedtank reduces the need for boiler blowdown, which is used to reduce the concentration of dissolved solids in the boiler. This therefore reduces the energy lost from the boiler during the blowdown process.

#### Reduced water charges:

Any condensate that is not returned and re-used must be replaced by fresh water in the boiler feedtank.

#### Reduced chemical treatment costs:

Re-using as much condensate as possible minimises the need for costly chemicals to treat raw water in the boiler feedtank.

#### Reduced effluent costs:

Besides municipal water charges consumers are also charged for effluent. Certain municipal by-laws prohibits the discharge of hot effluent into the public sewer because it is detrimental to the environment and may damage earthenware pipes. In these cases hot effluent must be cooled, which could incur extra costs, as well as potential fines for non-compliance.

#### Eliminated steam plumes:

Steam systems that allow hot condensate to flash to steam in receiver tanks can create plumes that, as well as wasting energy and water, are visible. This potentially presents a poor image of an organisation that is not environmentally friendly.

FIGURE 1: Graph showing the heat content of steam and condensate at the same pressure reveals that condensate contains around a quarter of the energy of the steam from which it came.

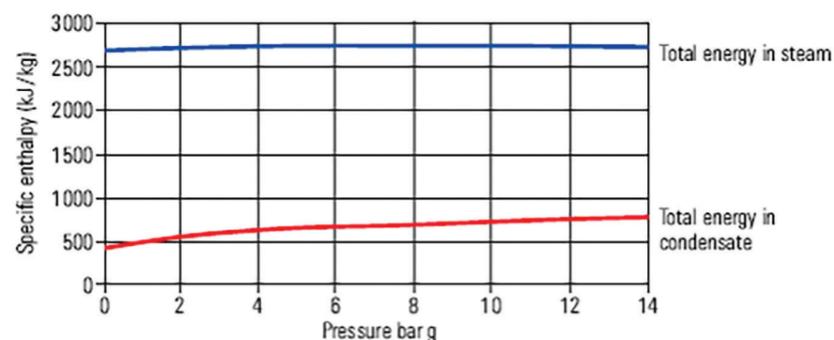
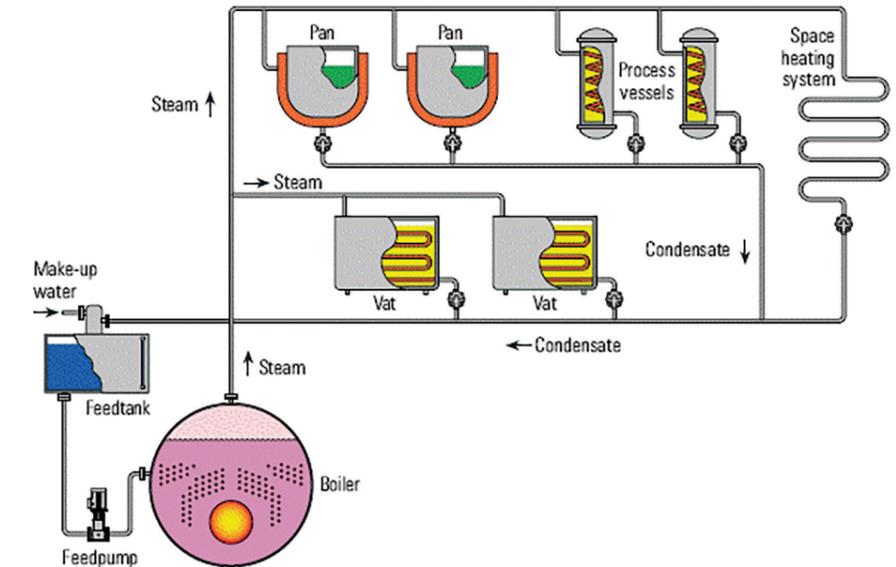


FIGURE 2: Schematic showing the steam and condensate loop with condensate being recovered and returned to the boiler feedtank.



### 3. CONDENSATE RECOVERY PAYBACK PERIOD

There is no doubt that an effective condensate recovery system can pay for itself very quickly when compared to a system where all the condensate is sent to drain. Each system is different and only a technical assessment and cost saving calculation can determine the payback of a particular project. Below is a typical example of a real site:

- Steam supply:** 10 000kg/h boiler
- Condensate recovery potential:** 75% @ 7500kg/h
- Hours of operation** = 24 hours x 5.5 days/week x 50 weeks = 6,600 hours
- Boiler efficiency:** 75%
- HFO cost:** R10/litre

The potential cost savings of installing condensate recovery equipment:

#### Fuel savings

The rate of energy saved by re-using condensate at 85°C, replacing cold feedwater at 15°C =  $(7500 \times 4.186 \times (85-15))/3600 = 610.4\text{kW}$ , which equates to 71.1 litres/hr of HFO  
 Fuel saved per annum =  $(71.1 \times 6600 \times 10) = \text{R}4,690,715$

#### Water savings

Water and effluent costs = R20/m<sup>3</sup>  
 Annual water cost savings =  $(7500 \times 6600 \times 20)/1000 = \text{R}990,000$   
 Total cost savings per annum: R5,680,715  
 (Not including boiler blowdown and additional savings in water treatment chemicals.)

### 4. THE TECHNOLOGY OF CONDENSATE RECOVERY

#### 4.1 Steam traps to remove condensate from the steam system

In order to recover and re-use condensate it is first necessary to remove it from the steam system. The steam trap is the most important link in the condensate loop because it

connects steam usage with condensate return by retaining steam within the process for maximum utilisation of heat, while releasing condensate and incondensable gases at the appropriate time. Steam condenses as it gives up its heat. The resulting condensate must be purged from the system or it will lead to poor heat transfer and possible problems with water hammer. Air and other non-condensable gases must also be purged or they can lead to poor heat transfer and corrosion problems.

A good start point in any project to improve condensate recovery, and one of the most cost effective measures, is to commission a professional steam trap survey to identify where improvements could be achieved.

#### 4.2 Using pumps to return condensate to the boiler feedtank

Condensate should ideally run away from a steam trap by gravity. In some cases this is not possible and it has to be lifted to a higher level. Lifting condensate from the traps requires sufficient steam pressure in the system to overcome the lift. However, sufficient steam pressure may not always be available to clear the condensate. In this case, some form of pumping equipment may be required.

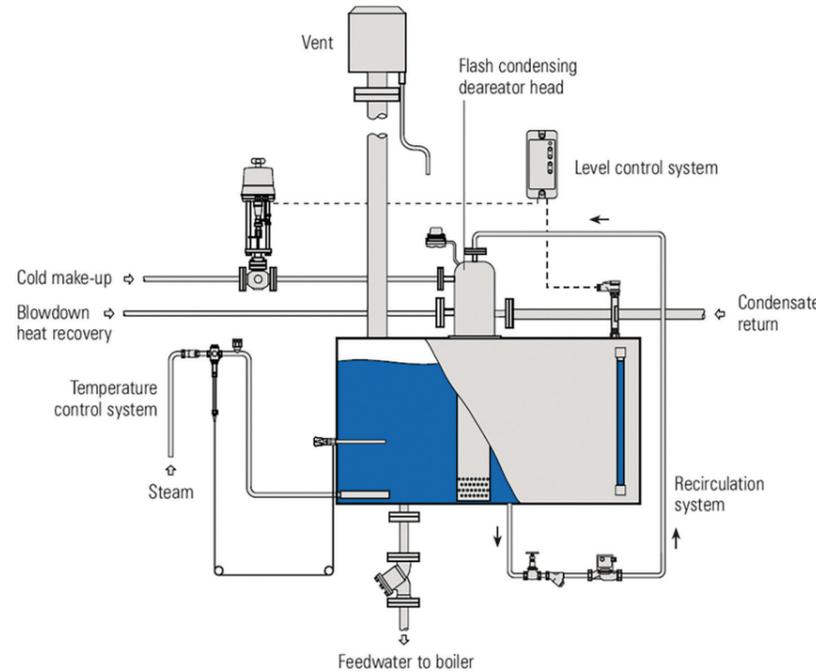
##### 4.2.1 Electrical condensate pumps

Electrical pumping is well suited to applications where large volumes of liquid need to be moved and are usually built into a Condensate Recovery Unit (CRU). CRUs typically include a receiver, a control system operated by probes or floats and one or two pumps. Electrical pumps need to be designed and selected so that they can handle hot condensate without the risk of cavitation and pump damage. Pumps for this application should be able to operate with a low Nett Positive Suction Head (NPSH) when handling hot flashing condensate.

##### 4.2.2 Mechanical condensate pumps

Mechanical pumps are often a better option for removing condensate than electrically-driven centrifugal pumps for several reasons, both practical and economic. First,

FIGURE 3: A flash condensing deaerator head ensures that returned condensate fed into the boiler feedtank efficiently and without operational problems.



centrifugal electric pumps cause mechanical stresses and peaks in electrical demand when they start up. Second, the motive power for a mechanical pump comes from steam that can be returned to the system, so it incurs minimal energy costs. In addition, the high temperature of the condensate that needs to be pumped away can cause problems for a centrifugal pump. Since the condensate is drawn into a centrifugal pump's inlet at a lower pressure it produces flash steam in the pump, which severely reduces pumping capacity. Cavitation, caused by collapsing steam bubbles within the pump's impeller, can also erode the pump and reduce its life. Mechanical pumps require a receiver to be used because when the pump is discharging, it is not filling. This means that there needs to be somewhere for the condensate to be stored between pumping cycles.

**4.2.3 Automatic pump traps**

Conventional steam traps need an upstream steam pressure that is higher than the downstream pressure to enable them to remove condensate from pipelines and heating equipment. Yet in plate heat exchangers commonly used in processing applications, when heating demand falls, so does the upstream pressure, and steam traps can fail to clear condensate. The consequences can be a slowing of the process, a drop in energy efficiency, noise and vibration within the heat exchanger, burst pipes, higher maintenance requirements and even a totally stalled process.

The most effective way to clear condensate from heat exchangers in this situation, as well as in other applications where there is insufficient pressure to clear condensate, is to fit an automatic pump trap. Under normal operating conditions, these act as conventional steam traps. But in conditions where back pressure would cause a normal trap to stall and flood the system, pump traps automatically switch to pumping mode to ensure condensate is removed.

Like mechanical condensate pumps, automatic pump traps are self-contained and use plant steam to provide the motive power to pump out condensate, even under vacuum. In operation, condensate enters the trapping chamber through the inlet. Normally, the condensate flows freely through the chamber into the condensate return system. However, if back pressure prevents the condensate from leaving normally, the pump trap's condensate outlet closes. Condensate continues to flow into and fill the chamber and is then pumped out using the same principle as a conventional mechanical condensate pump.

**4.3 Feedtank heating and deaeration**

Once the condensate is returned to the feedtank, it needs to be mixed with the existing feedwater to raise the temperature.

However, simply feeding condensate into the top of the feedwater tank can be inefficient. As it falls through the space above the water, flashing occurs with vapour and energy being lost in the process. Just as importantly air will be admitted, which could lead to corrosion of the boiler and steam plant. Oxygen in feedwater can be dispersed by heating and absorbed by chemical treatment. By heating the feedwater typically to 85°C to remove the bulk of the oxygen, the amount of scavenging chemicals required can be reduced by up to 75%. Heating and deaeration is most efficiently achieved by using a deaerator head, which mixes returned condensate, flash steam and cold make up water as they are fed into the feedwater tank.

**4.4 Flash steam and its recovery**

One of the most energy efficient ways of extracting heat from condensate before returning it to the feedwater tank is in a flash steam system. Flash steam is released from hot condensate when its pressure is lowered. When steam traps discharge condensate, they always do so from a higher to a lower pressure. The greater the difference between the initial pressure and the pressure after discharge, the greater will be the proportion of flash steam. Flash steam is the same kind of steam as that generated in a boiler. It has the same heat content as boiler steam. Flash steam is just as valuable as boiler steam for use in low pressure steam heated process plant and for space heating. In any steam system seeking to maximise efficiency, flash steam will be separated from the condensate, where it can be used to supplement any low pressure load. Every kilogram of flash steam used in this way is a kilogram of live steam which does not need to be supplied by the boiler.

**4.5 Pressurised low loss condensate recovery**

Conventional condensate recovery systems running at atmospheric pressure pose a natural barrier to how much of the recovered energy from condensate can be used. Typically the boiler feedtank is at atmospheric pressure with the feedwater being maintained at 85°C to 90°C. Any hotter than this can cause cavitation in the boiler feed pump. This clearly limits the amount of heat that can be fed into the feedtank from recovered condensate. If the amount of heat available from the condensate recovery system exceeds this, it is often wasted.

Implementing a pressurised low loss condensate recovery system overcomes this restriction by allowing virtually all the energy from both the condensate and its flash steam to be used, reducing steam-raising costs and increasing boiler efficiency. Such a system solves the boiler feed pump cavitation problem by creating a completely sealed steam system and transferring the heat from the flash steam and recovered condensate into the high pressure side of the boiler feed pumps. Therefore the water entering the boiler can be raised to well above 100°C without causing pump cavitation. Payback times for the system investments have sometimes been less than 12 months.

**4.6 Boiler blowdown heat recovery applications**

Tremendous cost savings can be achieved by improving the boiler water blowdown systems that control boiler contamination.

In many boiler houses, the blowdown valve is manually opened at regular intervals by the boiler operator and the water removed is just dumped to drain. Boiler blowdown contains massive quantities of heat which can be easily recovered as flash steam. After it passes through the blowdown control valve, the lower pressure water flows to a flash recovery vessel. At the vessel, the contaminant-free flash steam is separated from the condensate and becomes available for heating the boiler feedtank. Even greater savings can be made by passing the remaining blowdown through a heat exchanger to heat the make-up water coming into the boiler feedtank.

**BOILER BLOWDOWN HEAT RECOVERY - A SUCCESS STORY**

A site has knocked almost 6.5% off the combined cost of energy and water to its boiler, thanks to a new flash vessel and associated equipment that would enable the company to condense the flash steam and return it to the boiler feedtank. The system recovers the flash steam generated by blowdown from the main boiler. Previously, this flash steam was being discharged, rather than recycled, and the feedtank was maintained at 85°C by injecting live steam from the boiler. The new system offsets the need for both steam injection and excessive make-up water. ■