Condensate recovery in industrial steam systems
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Please note that all the applications illustrated within this White Paper are diagrammatic representations and are not detailed enough for safe working practice.
Steam is a popular and efficient medium for moving heat around a wide variety of processes and premises. 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, 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 British 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.

Spirax Sarco offers a full portfolio of the latest condensate recovery solutions that will help steam users reduce their utility bills and optimise their systems.

For organisations struggling to find the capital budget to invest in energy-saving measures, rental-style finance arrangements can help them upgrade their condensate recovery systems sooner rather than later, so they can start to benefit immediately.
2.0 Rising pressures of using natural resources

Drought or the threat of it across large swathes of the UK appears commonly in the headlines. Low rainfall levels in successive years can quickly deplete water reserves, creating a risk of restrictions and contributing to rising water costs for industry.

A study by the UK’s Environment Agency concludes that: “All of the scenarios predicted a future with less water available for people, businesses and the environment.” The agency also says that: “Future pressures will not be limited to the south and east of England. Under many of the scenarios, the south west and northern England will see significant unmet demand.”

Running in parallel is the ever-present pressure on energy costs as oil prices fluctuate, yet remain on an upward trend. According to the UK’s Department of Energy and Climate Change, gas consumers generally saw prices, excluding the Climate Change Levy (CCL), increase between Q3 2010 and Q3 2011 by an average of 25%.

The impact of future green policies is also uncertain. For example, the 21 March 2012 Budget statement by the Chancellor of the Exchequer indicated that the Carbon Reduction Commitment (CRC) could be replaced by an alternative environmental tax, but no details were given.

These developments clearly impact steam users because water and energy are the two key resources used to create steam for process and hot water heating. There are a variety of ways that steam-using organisations can reduce their water and energy consumption, ranging from using the latest boiler control technology to ensuring that pipework systems are insulated fully.

Yet one of the most effective resource-saving measures for most steam system sites is condensate recovery – installing recovery systems if they are not already present, or enhancing existing systems to improve their effectiveness.

Given the pressures on our water resources it is crucial that businesses manage their water use, and adopt new technologies over time to improve their water efficiency and cut costs.

Water and the green economy fact sheet, DEFRA (Department for Environment, Food and Rural Affairs).
3.0 The importance of effective condensate recovery

The return of condensate to the boiler feedtank is commonly recognised as a highly effective way to improve the efficiency of steam plant. Formed by condensed steam, liquid condensate needs to be drained from pipelines and equipment to avoid the risk of waterhammer.

Waterhammer is a risk in a poorly drained steam main, where condensate collects and forms a slug of water. This water is incompressible - unlike steam - and can cause damage when carried along by the high-speed steam.

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.
Condensate also contains around one-quarter of the energy of the steam from which it came. Allowing condensate to pass to drain wastes valuable energy and water, and most steam system sites recognise that condensate is a valuable resource. There are only a few sites in the UK without any form of condensate recovery system, but many sites could do more.

There are applications in which condensate is not returned to the boilerhouse for operational reasons – either the steam is injected into the end product, for example in animal feed mills or direct steam injection in food processing, or because there is a risk that the condensate is contaminated and could damage the boiler. Typical examples include chemical processing, dyeing and food processing, where food particles could enter the condensate recovery system. However, even these systems could potentially recover condensate by installing contamination detection systems or heat exchange systems to avoid boiler contamination.

Figure 2: Schematic showing the steam and condensate loop with condensate being recovered and returned to the boiler feedtank.
3.1 Condensate recovery saves money
Condensate is a valuable resource and the recovery of even small quantities is often economically justifiable.

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 thousands of pounds 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. Every 6°C rise in feedwater temperature achieved by using “free” energy 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. This top up will incur additional water charges.

Reduced chemical treatment chemical costs:
Re-using as much condensate as possible minimises the need for costly chemicals to treat raw water.

Reduced effluent costs:
In the UK, trade effluent above 43°C cannot be returned to the public sewer because it is detrimental to the environment and may damage earthenware pipes. Condensate above this temperature must be cooled if discharged, which could incur extra costs. Similar restrictions apply in most countries and effluent charges and fines may be imposed by water suppliers for non-compliance.

Eliminated steam plumes:
Steam systems that allow condensate to flash to steam can create plumes that, as well as wasting energy and water, are visible. This potentially presents a poor image to the outside world of an organisation that is not environmentally friendly.
3.2 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.

In reality, many sites in the UK already have condensate recovery systems in place, although nearly all could be enhanced by the latest techniques. For non-steam-sparge applications, a good benchmark to aim for is a condensate recovery rate of 75-80%.

Each system is different and only a technical assessment and cost saving calculation can determine the payback of a particular project. However, typically the payback is between one and two years, making it an attractive proposition for organisations.

At sites where the payback is longer than two years, it may still be a worthwhile project offering substantial cost savings in the longer term. But in today’s uncertain economic climate, capital budgets are being squeezed, making it difficult for many steam-using organisations to invest upfront in these projects, even though they could be saving money. However, the rising availability of rental options can help organisations carry out projects sooner and reap the benefits of eliminating wasted energy immediately. The resulting savings effectively make many projects self-funding.

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The potential cost savings of condensate recovery: a worked example based on a real site

The following example is based on a real site in the UK with no condensate return.

Steam supply: Two 454 kg/h boilers delivering up to 908 kg/h of steam
Condensate recovery potential: 400 kg/h (a conservative estimate)

The potential cost savings of installing condensate recovery equipment:

**Fuel savings**

The rate of energy saved by re-using condensate at 95°C, replacing cold feedwater at 10°C (based on a specific heat capacity of water of 4.186 kJ/kg) = (400 x 4.186 x (95-10))/3600(seconds) = 39.53 kW

Assuming 75% boiler efficiency, generating 39.53 kW would require gas equivalent to 52.71 kW.

Hours of operation = 24 hours x 5.5 days/week x 50 weeks = 6,600 hours
Gas price = 2.3 p/kWh
Cost of gas saved per year = (52.71 x 6600 x 2.3)/100 = £8,001.38

**Water savings**

Water and effluent costs = £2.00 per m3
Annual water cost savings = (400 x 6600)/1000 = 2640 kg x £2.00 = £5,280.00

**Total cost savings: £13,281.38 per year**

(Not including boiler blowdown and additional savings in water treatment chemicals.)
3.3 Dealing with condensate contamination

One of the major reasons for not re-using condensate is the risk of contamination from the process or end product finding its way into the boiler. Contaminated condensate can cause both corrosion in boilers and carryover (where droplets of liquid water are entrained in the steam emerging from the boiler) and must therefore be avoided.

There are two common ways of overcoming this risk.

An existing hotwell installation can be fitted with conductivity and turbidity meters to detect contamination. When detected, controls automatically trigger dumping of the contaminated condensate before it reaches the boiler. The monitors should be sited so that only the contaminated condensate supply is dumped and not the whole of the condensate stream. It may be necessary to monitor and dump each condensate source independently.

Another solution is to use heat exchangers to extract energy from contaminated condensate. This recovers a major portion of the energy, although the treated, contaminated condensate itself is lost.
4.0 The technology of condensate recovery

There are several essential steps in any effective condensate recovery system. The ultimate goal is to re-use this valuable source of hot, treated water.

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 waterhammer. 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. Such a survey will also give an estimate of the potential financial gains through upgrades – providing information to help justify maintenance expenditure.

Rapid payback from steam trap surveys

A steam trap survey will help to keep a system running smoothly and will almost certainly reveal impressive savings through reduced fuel consumption, fuel emissions, water and effluent charges. For example, an analysis of 50 Spirax Sarco steam trap surveys revealed potential annual energy savings of £28,400 per survey on average.

The average payback time on each survey, including the cost of replacement products and their installation, is about two months, when all upgrade work is completed.
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

These pumps use centrifugal force to speed up the flow of the liquid being pumped. Liquid enters the pump and is directed to the centre of a rotating impeller. 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 Net Positive Suction Head (NPSH) when handling hot flashing condensate.

Figure 4: A typical electrical Condensate Recovery Unit (CRU).
4.2.2 Mechanical condensate pumps

Mechanical condensate pumps consist of a body, into which condensate flows by gravity, containing a float and an automatic mechanism, operating at a set of changeover valves. Condensate is allowed to build up inside the body, which raises a float. When the float reaches a certain level, it triggers a vent valve to close and an inlet valve to open to allow steam to enter and pressurise the body to push out the condensate. The condensate level and the float both fall. The steam inlet valve then shuts and the vent valve opens allowing the pump body to refill. Check valves are fitted to the condensate ports to ensure correct directional flow.

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.

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

Figure 5: A typical arrangement using a mechanical pump and receiver tank to return condensate back to the boiler feedtank.
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.

Two automatic pump traps helped solve a control issue for Sembcorp, a leading UK industrial utilities and services companies which heats its gas supply to 40°C to prevent it freezing as it enters lower pressure lines downstream. A variable load on the gas heater can cause a pressure drop or even a vacuum forming inside the heat exchanger, which used to prevent condensate escaping, leading to stalling and temperature fluctuations in the gas.

The two Spirax Sarco automatic pump traps remove condensate in a controlled way, regardless of back pressure. Previously, the gas temperature varied widely, but the temperature control is now within 2°C of the set point. Together with a new control system, they have solved the problem.

Automatic pump traps - a success story

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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, vapour and energy can be lost and 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. The deaerator head mixes the cold feedtank make-up water with its high oxygen content with the flash steam from the condensate and blowdown heat recovery.

Figure 7: A flash condensing deaerator head ensures that returned condensate is fed into the boiler feedtank efficiently and without operational problems.
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.

Flash steam can be collected using a flash vessel. Condensate from steam traps enters the vessel. Inside the vessel’s chamber, flash steam separates from the condensate and passes out of the vessel to supply the low pressure process or heating equipment in which the flash steam is to be used.

The remaining condensate inside the chamber is discharged through a steam trap and is passed to the condensate recovery system where it is piped away to the boiler feedtank.

4.4.1 Flash steam vent condenser

Condensate recovery units and other condensate receivers are typically fitted with a vent to atmosphere to ensure they do not become pressurized. The flash steam from this discharge and exhaust vent pipework can be recovered and used for heating duties such as pre-heating make-up or process water. This is typically achieved by fitting a heat exchanger, or flash steam vent condenser, to the receiver vent line. Depending on the installation costs, plants will typically recover the cost of a flash steam vent condenser within a year.

Figure 8: A heat exchanger fitted to a condensate recovery unit to extract heat from vented flash steam.
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 as bubbles form and collapse on the low-pressure (upstream) side of the pump, which can quickly damage the 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.

Huge savings in annual fuel and water costs, estimated to range from £17,000 for a small system, to £160,000 for larger systems, are possible. Significant savings in CO₂ emissions are also being achieved in real deployments, as high as 2,000 tonnes per year. Payback times for the system investments have sometimes been less than 12 months.

Pressurised low loss condensate recovery - a success story

The success of closed loop condensate recovery technology is well illustrated by a project at Abbey Corrugated, which commissioned Spirax Sarco to design and install a system as part of a major energy saving campaign. The installation proved to be the most valuable project in the scheme and helped it to become one of just 12 organisations across England and Scotland to be awarded the "Carbon Trust Standard".

Before the project, water entered the boiler at around 70°C. It now arrives at around 140°C, according to Abbey Corrugated’s Facilities Manager, Paul Gale: “There was a lot of work going on at the time, but it’s fair to say that the savings from this project were in the region of 25% of the gas used by the boiler.”
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 boilerhouses, 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.

Figure 9: Typical heat recovery from boiler breakdown.

Boiler blowdown heat recovery - a success story

British Bakels has knocked almost 6.5% off the combined cost of energy and water to its boiler, thanks to a flash steam recovery system from Spirax Sarco. The system recovers the flash steam generated by blowdown from the main boiler at the company’s site in Bicester. Previously, this flash steam was being discharged, rather than recycled.

Initial calculations predicted that British Bakels would save 5% of its boiler costs by installing 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 feedtank is maintained at 85°C by injecting live steam, and is fed by a mixture of returning condensate and cold make-up water. The new system offsets the need for both steam injection and make-up water.
Spirax Sarco offers a full range of condensate recovery and management products and services.

**Steam traps**
Each steam application has its own requirements - it is impossible to meet all needs with just one type of steam trap. Spirax Sarco offers a wide choice of different steam traps under three categories:

- **Thermostatic steam traps** do not discharge until the condensate temperature has dropped below steam saturation temperature. These traps are widely used in applications where it is acceptable to utilise some of the sensible heat in the condensate and reduce flash steam losses, such as non-critical tracing.
- **Mechanical steam traps** discharge condensate at steam temperature. This makes them the first choice for applications where the rate of heat transfer is high for a given heat transfer area, such as heat exchanger applications.
- **Thermodynamic steam traps** are compact, simple, lightweight and not affected by waterhammer or vibration. Thermodynamic traps discharge condensate close to steam saturation temperature. This makes them the first choice for steam mains drainage and critical tracing.

**Steam trap station**
The STS17.2 Steam Trap Station comprises all the components needed for a steam trap installation in one easy-to-fit package. By improving energy efficiency and reducing maintenance costs, the station lowers the total cost of ownership of steam plant and can help companies to reduce their carbon emissions. The whole package is supported by a 10-year warranty.

**Electric condensate pumps**
Electric condensate recovery units handle flashing condensate and return it for use as boiler feedwater to improve plant energy efficiency. Units are available with galvanised, copper, and stainless steel receivers capable of handling capacities up to 30,000 kg/h. Units outside this range are also available.

**Mechanical condensate pumps**
MFP14 automatic pumps recover condensate under all operating conditions. They are self-contained, using steam or other pressurised gas as motive power. There are no electric motors or level switches, simplifying installation and making them ideal for hazardous areas. MFP14 automatic pumps can pump high temperature fluids without cavitation, reducing plant maintenance.
Automatic pump traps
The APT range removes condensate from steam heat exchangers and process plant under all operating conditions, and forms an integral part of the condensate removal process. These compact, fully automatic pump traps will ensure process plant or equipment remains totally drained of condensate under all operating conditions – even vacuum - optimising thermal efficiency of the heat exchange interface.

Flash steam recovery
Spirax Sarco designs and specifies a full range of flash steam and heat recovery systems incorporating products from its extensive range of products including flash vessels, heat exchangers, controls, feedtank systems and more.

Closed loop condensate recovery
The FREME (Flash Recovery Energy Management Equipment) is a packaged system that can recover all the energy in condensate and flash steam and use it to preheat the feedwater to the boiler. FREME is a closed, pressurised system that enables returned condensate to be fed into the boiler at much higher temperatures than a conventional system that is open to atmosphere. This reduces the amount of work the boiler needs to do to raise steam, reducing energy costs considerably.

Services
Spirax Sarco offers technical support, knowledge and services, and works with steam system operators to identify, design and implement improvements to their systems, and then help to maintain the resulting system efficiency gains.

Surveys cover a wide range of equipment including steam traps, high limit control equipment and condensate pumps. The most popular survey is the steam trap survey. Once the survey is complete and the steam trap population is brought up to peak operating efficiency, Spirax Sarco’s steam trap management service can save money and effort by taking responsibility for keeping steam traps running at maximum efficiency year after year.

Financing condensate recovery investments
Spirax Sarco offers a bespoke finance facility that will allow organisations to invest in energy efficient steam systems and meet carbon reduction targets, without tapping into capital budgets. Spirax Rental enables steam system operators to reap the benefits of energy efficient plant and equipment with no up-front cost and pay for it from the money saved.

In many cases the fuel cost savings from new energy efficient equipment will more than cover the monthly payments, delivering cash benefits from day one. Financing can encompass the design and specification of new plant, its purchase and installation costs, as well as the removal of old equipment.