PRESSURIZED CONDENSATE RETURN SYSTEMS

NOT A NEW CONCEPT, BUT A CONCEPT TO BE ADDRESSED TODAY DUE TO THE INCREASINGLY HIGH ENERGY COSTS IN STEAM SYSTEM OPERATIONS

Pressurized condensate systems can provide plants with a minimum of 15% to 35% savings in fuel costs when compared to a conventional atmospherically vented condensate system. That is a tremendous opportunity for facilities since fuel prices have quadrupled recently and are expected to increase even further. The pressurized condensate system is not a luxury, but a necessary component to maximize and increase the steam system efficiency. Unfortunately, not all steam plants or steam applications can implement a high pressure return system. Therefore, proper preliminary assessment, design review and knowledge of the application are necessary to insure a successful condensate system.

What is a Pressurized Condensate System?

Pressurized condensate systems operate continuously at a pressure above 15 psig and the condensate return system is not vented to atmosphere. The pressure in the condensate system is sustained by the dynamics of the system or a systematic control process loop. Typical condensate systems operate with *some* backpressure due to condensate line under-sizing and neglect of steam traps blowing steam into the condensate line. These items alone can cause pressure in the condensate system. A pressurized condensate system differs in that the condensate return pressure is systematically controlled to a predetermined set point which is matched to the process' peak performance level.

There are four (4) classifications of a condensate system used in plants today.
- o Gravity or atmospheric (condensate line pressure maintained at or close to zero psig)
- o Low pressure (1 to 15 psig)

- o   Medium pressure (16 to 99 psig)
- o   High pressure (100 psig or higher)

Pressurized condensate technology is not new since these systems can be documented back to 1941. Though the technology may be considered old, it has been overlooked over the years due to relatively inexpensive fuel prices. As fuel prices have risen, new attention toward these systems is increasing as they have proven to be a significant way to decrease operational costs in industry.

Why Maintain a Pressurized Condensate System? "Increase Efficiency – Reduce Energy Cost"

The best reason to use a pressurized condensate system is the dramatic energy savings that can be achieved by implementing a pressurized condensate system. The condensate that is not contaminated in a process should be returned to the boiler room for reuse. Condensate contains sensible energy and if not properly return to the boiler operation, a large portion of the sensible energy is loss. To prevent the sensible energy loss, the condensate that is recovered must have its temperature raised to the saturated temperature of the steam boiler operating pressure. To accomplish this task, energy is introduced at the deaerator or high pressure condensate vessel and at the boiler.

The higher the temperature or pressure (direct relationship in steam) of the condensate being returned to the boiler plant, the less energy required to raise the temperature of the condensate back to saturated temperature of the boiler operating pressure. The most efficient system will be a condensate return system that is controlled at a pressure as close to the boiler operating pressure as possible. In a perfect system; the steam system for example, would operate at 150 psig and the pressurized condensate system would operate 149 psig, but system elements such as line sizes, distances, steam trap differential and elevations must be taken into consideration. With these variables in the system, a typical target for pressure differential between the steam supply and condensate return is 30-45%. All pressurized condensate systems must be thoroughly evaluated before selecting the condensate return line pressure.

What are the Savings?

High Pressure Return System Savings vs. Standard Condensate Return System	
Flash Steam Losses	149,235.84
Heating the condensate from 212°F (atmosphere conditions) to 240 F (deaerator conditions)	19,618.56
Make-up Water (heating to atmosphere conditions)	20,067.84
Approximate Chemical loss or cost	
Chemical loss or cost	5,000.00
Higher condensate temperatures	73,382.40
Total Savings	**267,304.64**

A typical example of an industrial application is highlighted below.
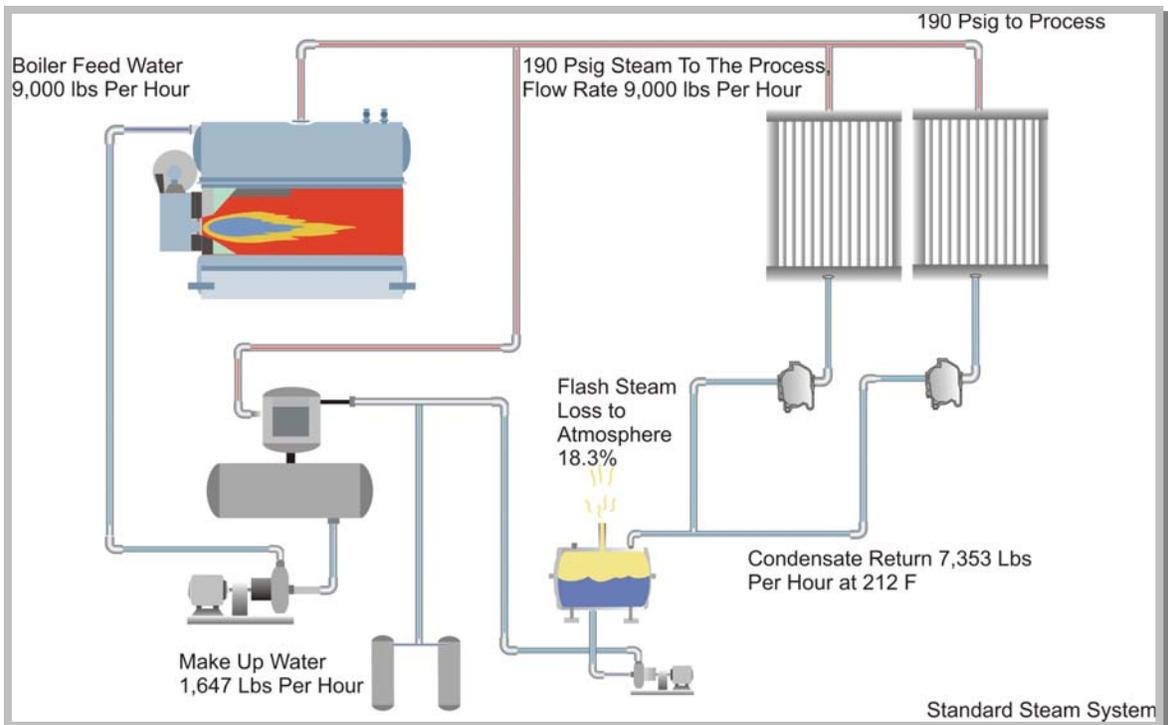
Typical details of one steam application in a process plant:

Application:	Steam Press
Steam pressure supplied to the press:	190 psig (before a control valve)
Equivalent Steam Temperature:	384°F
Steam pressure at the press:	150 psig (lowest process steam pressure)
Steam flow rate:	9,000 lbs per hour (minimum)
Operation:	7 days a week; 24 hours per day
Number of days per year:	312 (excludes preventive maintenance days)
Condensate line pressure:	Zero (vented to atmosphere and mechanical pumped back to the boiler plant)
Cost of steam (per thousand lbs):	$ 12.10 (December 2005 pricing, expected to increase)
Boiler operating pressure:	190 psig

Current operating steam press conditions

A minimum steam requirement for the press of 9,000 lbs per hour provides 9,000 lbs per hour of condensate at 384° F (the saturated temperature for the given pressure).

Condensate is drained from the steam process through a steam trap. The steam trap discharges to a vented condensate receiver system. When condensate is drained from the process at a given pressure (150 psig) and passes through a steam trap to a lower pressure (0 psig @ 212°F), then a percentage of the condensate will flash to steam. The vented condensate receiver allows the flash steam to be vented to the atmosphere and ultimately lost from the system.

The percentage of flash steam loss that will occur is calculated as;

$$\frac{357.698 \text{ (sensible heat at the higher pressure)} - 180 \text{ (sensible heat at the lower pressure)}}{970 \text{ (latent heat at the lower pressure)}}$$

= 18.3 %

Using this percentage we can calculate the loss of flash steam from the system as

(9,000 lbs x .183) = 1,647 lbs of flash steam will be created and vented to atmosphere

If the cost of steam is $12.10 per thousand pounds, then

1647 / 1000 x $ 12.10 = $ 19.93 per hour loss

Using the operational data, a total loss can be calculated due to flash steam alone.

$ 19.93 x 24 hours = $ 478.32 loss each day of steam system operation and ultimately, over the course of 312 days per year accounting for preventive maintenance days when the system will be down,

$149, 235.84 losses per year because of flash steam.

Additional Energy Input

Low temperature or pressure condensate returning from a conventional vented condensate system has to be heated to 240°F in the deaerator process. Boiler plant operation steam is used to heat the returning condensate. The deaerator process is receiving make-up water that has to be heated to 240°F in the deaerator. The make-up water is required largely because of the flash steam losses.

The specific enthalpy of the condensate returning from the process is 180 BTU/lb. Additional steam will be added to the condensate to raise the temperature from 212 °F to the deaerator operating temperature of 240°F. The BTU content of condensate at 240°F is 208 BTU/lb. Therefore, 28 BTU/lb (208-180 BTU/lb) are added to the condensate to increase the temperature.

So, 7,353 lbs per hour of returning condensate at 212 °F with 180 BTU/lb is changed to the deaerator operating conditions of 10 psig and 240°F by adding 28 BTUs / lb or a total of 205,884 BTU per hour.

At 10 psig, the BTU content in steam is 952 BTU / lb. Steam costs were $12.10 per thousand pounds. So the system requires 205,884 BTU/hour, the steam contains 952 BTU per pound and costs $12.10 for each 1000 pounds. This results in a cost of $2.62 per hour to heat the returning condensate.

> 208 – 180 = 28 BTU's per lb required to increase temperature to 240°F
> 28 BTU's x 7,353 lbs = 205,884 BTU's per hour
> (205,884 BTU/ hour) * (1lb/952 BTU) * ($12.10/1000 lb)
> = $2.62 cost of energy per hour.
> Over 24 hours and 312 days this results in an additional energy input to system of
> **$ 19,618.56 per year**

Calculating the annual costs given the operational conditions results in **$19,618.56 loss per year** to heat the returning condensate at the lower pressure.

Other losses in the system

The flash steam loss will cause of loss of condensate, which will have to be replenished with the use of make-up water at a lower temperature and BTU content. In the first segment of the calculations, there was 18.3% of the condensate flashed as a result of the atmospheric vessel. This loss is replaced with make-up water and requires 1,647 pounds per hour.

Make-up water BTU content:	80
Condensate temperature:	$240^{o}F$
Condensate BTU content:	208

208 – 80 = 128 BTU's per lb required to increase temperature to 240°F

128 BTU's x 1,647 lbs (make-up required) = 210,816 BTU's per hour

(210,816 BTU/ hour) * (1lb/952 BTU) * ($12.10/1000 lb)

= $2.68 loss per hour.

Over 24 hours and 312 days this results in an additional loss of

$ 20,067.84 per year loss in make-up water

Summary of Energy Losses with a Typical Vented Condensate Return System

Summarizing all the losses, the atmospheric return system in this example will cost a facility $193,922.24.

o	Flash steam loss to atmosphere	$ 149,235.84
o	Heating the condensate from $212^{o}F$ (atmosphere conditions) to $240^{o}F$ (deaerator conditions)	$ 19,618.56
o	Make-up Water (heating to atmosphere conditions)	$ 20,067.84
o	Approximate Chemical loss or cost	$ 5,000.00

Total loss from a vented system   **$ 193,922.24**

Identifying the loss in a monetary figure is the first step to developing an improvement plan. Pressurized condensate systems are an excellent method for reducing these losses by 90% or more.

Results Implementing a High Pressure Condensate System and instituting the New Operating Conditions

Once a new high pressure condensate system is installed, typical losses will be greatly reduced and the high pressure condensate from the steam press will operate nominally at 125 psig @ 353°F.
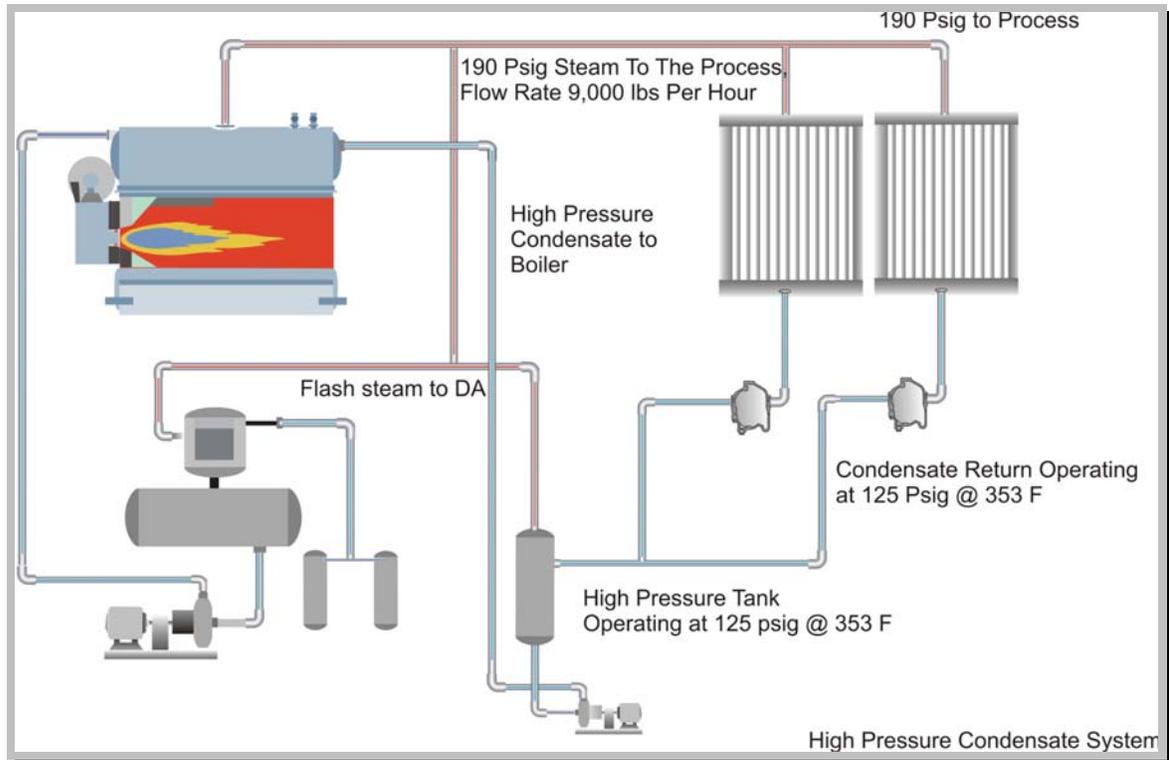
High pressure condensate vessel (tank or deaerator) will maintain the condensate temperatures at 125 psig @ 353 °F and the condensate will now be pumped directly back into the operating boiler. The condensate was not exposed to the atmosphere and does not have to go through the deaeration process. The returning high pressure condensate can then be delivered to a high pressure condensate tank system or a high pressure deaerator process, depending on the plant steam system configuration.

The same process conditions as noted in the typical vented system in a process plant where now a pressurized return system is used:

Application: Steam Press
Steam pressure supplied to the press: 190 psig (before a control valve)

Equivalent Steam Temperature:	384°F
Steam pressure at the press:	150 psig (lowest steam pressure to press)
Flow rate:	9,000 lbs per hour (minimum)
Operation:	7 days a week; 24 hours per day
Number of days per year:	312 (excludes preventive maintenance days)
Condensate line pressure:	125 psig
Cost of steam (per thousand lbs):	$ 12.10 (December 2005 pricing, expected to increase)
Boiler operating pressure:	190 psig

New Operating Conditions Energy Savings

Flash steam

Flash steam from the process is greatly reduced, and the new smaller percentage of flash steam is contained at a higher pressure (125 psig), which allows the plant to use the flash steam for other applications, such as the deaerator process. The end result is no flash steam loss to atmosphere

The percentage of flash steam that will occur is calculated as;

$$\frac{357.698 \text{ (sensible heat at the higher pressure)} - 324.913 \text{ (sensible heat at the lower pressure)}}{868.686 \text{ (latent heat at the lower pressure)}}$$

= 3.8 %

Vented System = $149, 235.84 (loss)   Pressurized Condensate System = 0 (loss)

Make-up water

With the flash steam being recovered, there is no flash steam loss, thus only need for make up water is to replenish the deaerator non-condensable vent losses. The makeup costs are negligible in this example.

Condensate temperature

The condensate temperature is now higher than the deaerator, therefore the deaerator is not required to heat the condensate and a steam *savings* actually occurs.
325 Btu's (new condensate BTU content) – 208 BTU's (deaerator condensate or feed water BTU content) = 117 BTU savings in Boiler Fuel

117 Btu's x 9,000 lbs = 972,000 BTU's

$ 9.80 per hour savings in boiler fuel

$ 9.80 x 24 = $ 235.20 per day

$ 235.20 x 312 = $ 73,382.40 per year steam *savings*

Savings based on high temperature condensate vs. low temperature deaerator feedwater = $ 73,382.40 savings in steam.

Chemical cost

With no flash steam loss or make-up water there is no need for chemicals.

(No chemical cost)

Estimated at $ 5,000.00

Summary of Energy Savings Using a Medium or High Pressure Condensate System

- o Flash steam loss to atmosphere — $ 149,235.84
- o Make-up Water (heating to atmosphere conditions) — $ 20,067.84
- o Approximate Chemical loss or cost — $ 5,000.00
- o Higher condensate temperatures — $ 73,382.40

Annual total losses from a vented system when compared to a pressurized system operating at 110 psig.   **$ 267,304.64**

What are the Components Required?

Before changing everything to a medium or high pressure condensate system, the first step is to insure the steam system and the steam processes will be able to operate with the desired system.

Flash Steam Recovery Systems (Non-modulating steam conditions)

Condensate and flash steam (two-phase flow) discharging from a "non-modulating" steam system process can operate with a medium or high pressure condensate system.

(1) A non-modulating steam condition refers to a system where there is no control valve modulating the steam flow into the process to maintain a desired temperature or pressure. A process steam system that does not have a modulating steam control scheme for the process provides a constant steam pressure to the process. Therefore, if the return pressure is constant, there is a constant pressure differential across the steam traps or condensate discharge control valve.

(2) Additionally, a non-modulating steam condition may also refer to a system where a steam control valve supplying the process will not modulate the steam pressure below a predetermined step point. This type of process arrangement will provide a variable pressure differential across the steam traps or condensate discharge control valve. However, the lower limit of the set point fixes a boundary on the variable of modulation.

Examples of Non-Modulating Steam Processes:

➢ Steam Tracing

➢ Drip Leg Steam Traps

➢ Unit Heaters

➢ Process Heaters

➢ Re-boilers

➢ Corrugators
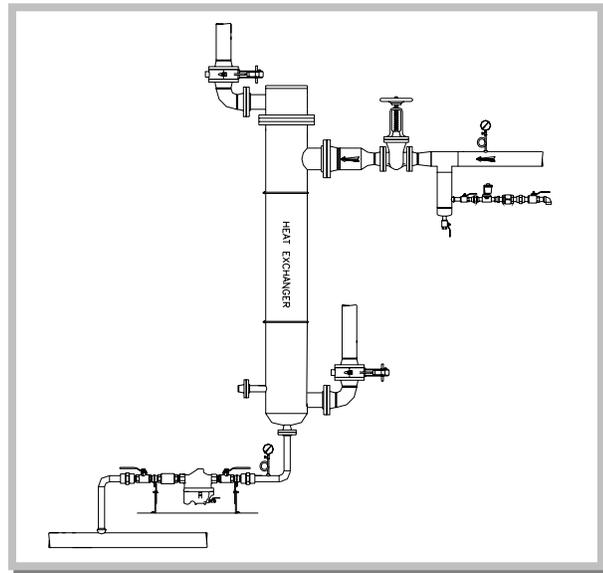
Flash Steam Recovery Systems (Modulating Steam Conditions)

A process with a steam supply modulating valve will result in the condensate and flash steam (two-phase flow) being discharged as a modulating load. This means the process has a steam control valve modulating throughout a full range from zero (closed) to 100% (full open) and any location in between. There is no limit on variability. The flash steam cannot be recovered in a pressurized flash tank or high pressure condensate return system. The condensate flow from the process has to be discharged into a vented condensate receiver and then the flash must be recovered by an external heat exchanger

or vent condenser. The vent condenser will consume the flash steam by heating air, water, or some other process.

A vent condenser typically will have a simple payback of 12 months or less depending on the installation cost.

In the case of a modulating steam process, it is best for the process steam system to use the lowest possible steam pressure for the application, therefore producing the least amount of flash steam.

All process applications that have a modulating steam control valves must have condensate drainage at or close to 0 psig or atmospheric pressure.

How To Get Started?

The first step is to have a steam and condensate audit conducted by plant personnel, or have an outside firm experienced in Steam and Condensate Drainage Systems assist with an audit.

Today is a great day to get started with the current energy situation, tomorrow might be too late…..