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Function of the FENIX Hydrodynamic Trap working on Variable Load Applications

The FENIX Trap and Variable Loads – how it works

The following is intended to give an explanation to a question that often perplexes people when considering using the FENIX Hydrodynamic Steam Trap with venturi technology– that is **‘how can trap that has a fixed diameter orifice with no moving parts operate on applications with a variable load?’**

The follow text attempts to explain the function of the FENIX Hydrodynamic Trap and in particular how the use of the flash steam in the venturi section of the FENIX Hydrodynamic Trap provides the FENIX Trap with a varying capacity.

Why use venturi technology

A simple orifice trap has a limited operating range on varying loads. It will work if the loads are relatively constant e.g. distribution systems. The FENIX Hydrodynamic Trap works by combing venturi technology with the orifice so part of the capacity of the FENIX Hydrodynamic Trap is related to the size of the orifice but part is also related to the back pressure that is generated inside the venturi. It is a combination of the pressure drop across the orifice and the back pressure generated in the venturi that gives the FENIX Hydrodynamic Trap its overall capacity.

As the condensate passes through the orifice of the FENIX Hydrodynamic Trap there is a pressure loss. On the upstream side of the orifice (the heat exchanger or steam line side) the condensate is at the same pressure and temperature as the steam and it contains a lot of energy (it’s hot). As it drops pressure across the orifice the temperature and pressure of the condensate reduces so it contains less energy.

However, energy cannot disappear. So the difference in energy between the high pressure/temperature upstream side and the low pressure/temperature downstream side (i.e. the condensate return system) is converted into steam. The higher the pressure difference across a trap (and it is the same for all traps) the more condensate has to be converted into ‘flash’ steam.

FENIX uses this flash steam to create a back pressure inside the venturi.

As the condensate is forced through the orifice of the FENIX Hydrodynamic Trap by the upstream pressure the resultant pressure drop generates flash steam. This flash steam is 1000 times the volume of the condensate so the sudden expansion results in the condensate being accelerated in the venturi of the FENIX Hydrodynamic Trap. This sudden acceleration creates and opposite and equal force or back pressure inside the venturi which acts to restrict the flow of condensate through the orifice.

Because the amount of flash steam changes depending upon the operating conditions then the resultant back pressure also changes. This is then regulating the flow of condensate through the trap and hence gives it is variable capacity characteristics.

Cold start up.

This will be situation when the plant has been down for some time. In this case all the pipework is cold including the reactor vessels and heat exchangers. When the steam is first 'switched on' there is a massive rush but this is to evacuate the air from system. The cold air is more dense than the steam so the lighter steam sits above the air and pushes it out through the trap. (Please note that under normal operating conditions when the air is the same temperature as the steam the air is lighter so the only way to eliminate air from a system is to install an air vent at the highest location).

Once the steam starts to come into contact with the cold walls of the vessels and heat exchanger surfaces it condenses. Because of the huge temperature difference between the steam and the surfaces the condensing load can be 2 to 3 times the normal operating load. However the condensate that forms is not at the saturation temperature of the steam. It is possible to run your hand through the condensate discharging from a trap at start up. Because the temperature is below the boiling point of water at atmospheric temperature i.e. below 212^oF, there is no flash steam being generated inside the venturi of the traps. Since there is no flash steam being generated there is no backpressure being generated either so the condensate can flow at a higher rate through the trap. The capacity of the FENIX Hydrodynamic Trap for cold start ups is typically 2 to 3 times 'normal' running conditions. This means that there is no need to use bypass valves for cold start up for either low load applications, drip legs and trace heating, or for larger process loads.

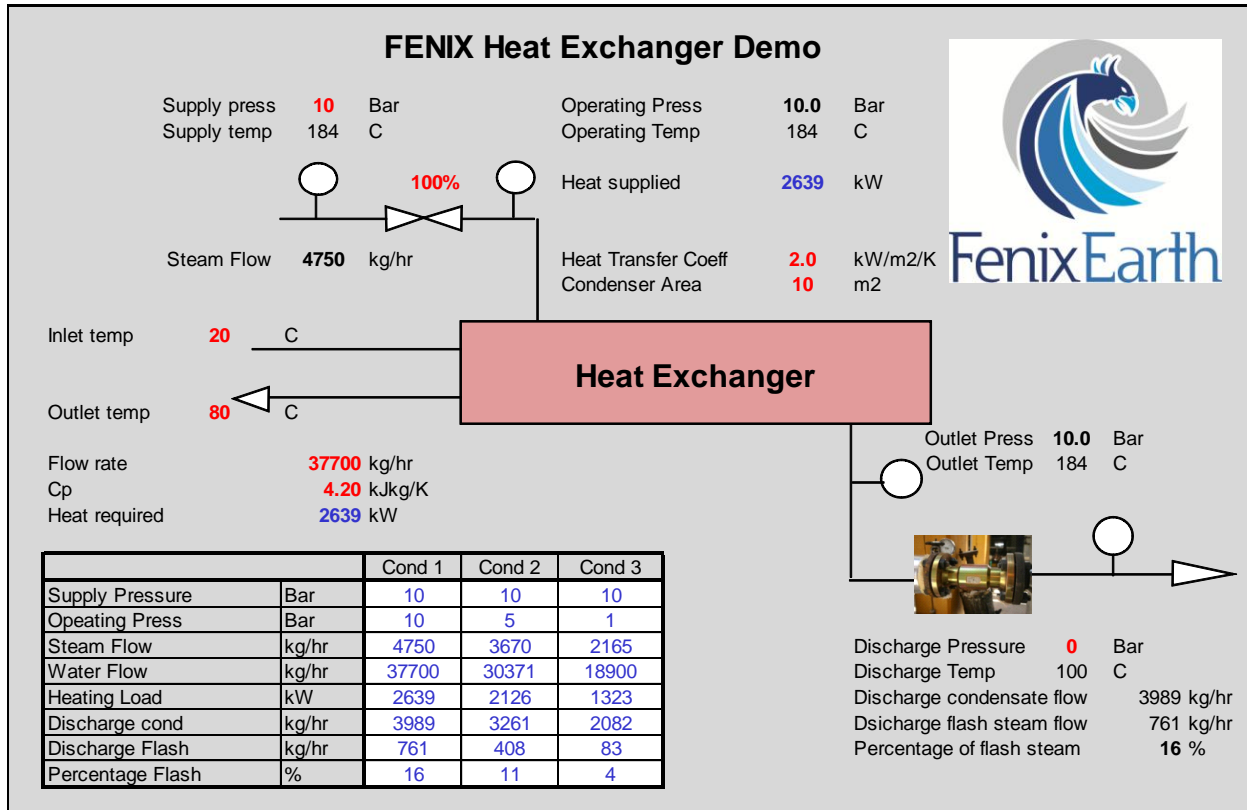
The second condition would be a normal on off start up such as a batch process. There will always be a small amount of preheating to get all the system back to temperature but if the batch process are frequent then the warm up is minimal. Also there is usually an ON/OFF valve rather than a modulating valve which will open 100% at the start of the batch. I believe this is the case in R-1801. In this situation there is an initial high load as the product heats up and then it will sit at maximum capacity until the end of the batch.

During the heat up phase the condensate rate is higher due to the higher temperature difference between the steam and the product. However the condensate formed be sub-cooled and so less the flash that is generated in the venturi. Once the product reaches steady state conditions then the condensate arriving at the trap will be at the saturation temperature there will be less condensate but it will be at saturation temperature. Therefore the resulting increase in flash steam will create an increased back pressure and 'hold back' the flow of condensate. This will be the design condition that the trap will be specified for.

The final condition is if an application that has a control valve that is regulating the flow of steam to a unit. Below is a model of the function of the steam trap operating on a heat exchanger.

The model simulates a heat exchanger with a 10m² surface area heating water from 20^oC to 80^oC (please excuse metric units). The model simulates how the change in the flash steam varies as the flow rate of water to be heated varies.

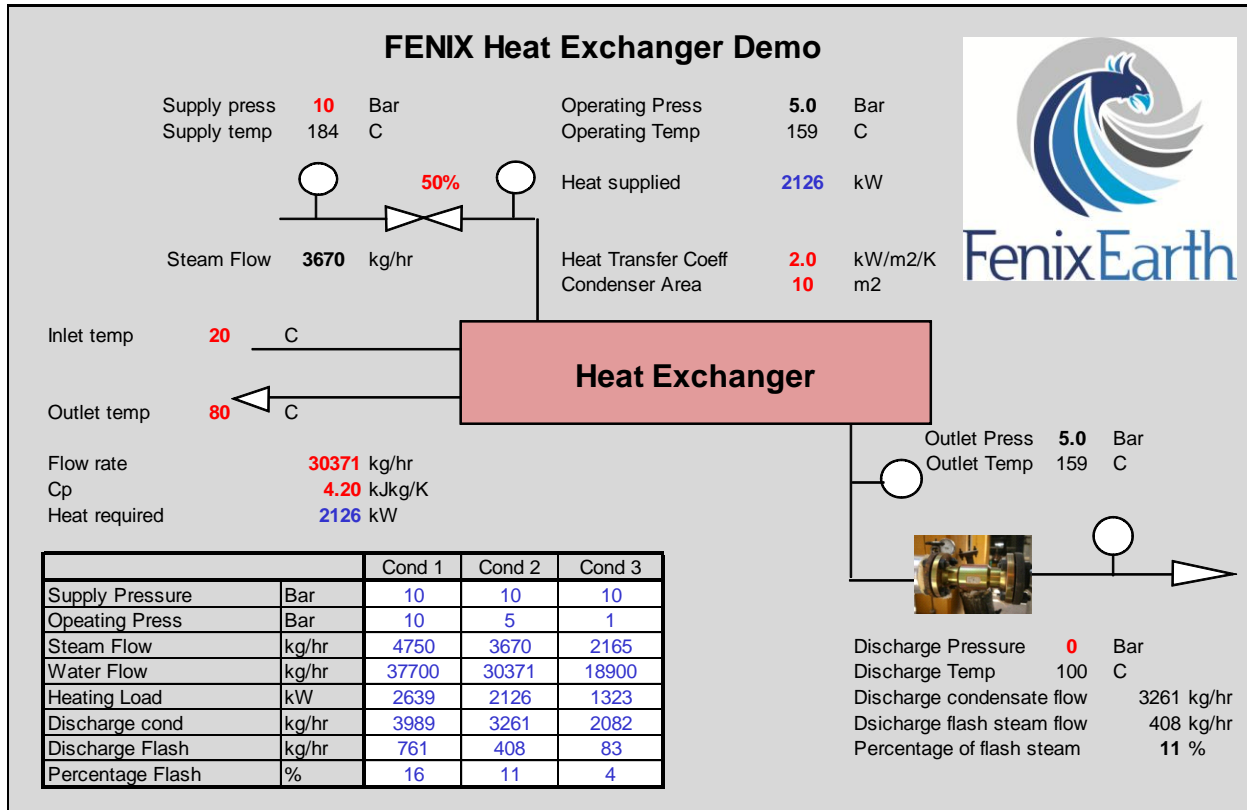
Cond 1 – Full load operation



This is the maximum output condition for the application. The water flow rate is 37700 kg/hr and at this flow rate it is necessary to supply 2639 kW of energy which requires a steam flow rate of 4750 kg/hr at 10 Bar. Hence the control valve is fully open. This is the maximum output that this unit is capable of and is the ideal design point for the FENIX Hydrodynamic Trap. This will be the design specification that will be stated in the O&M manuals.

Under these conditions the flash steam generated will be 16% of the condensate flow rate, so by mass this will equate to a flash steam flow of 761 kg/hr. This will be the maximum flash steam and will generate the maximum back pressure in venturi of the trap.

Cond 2 – Part Load

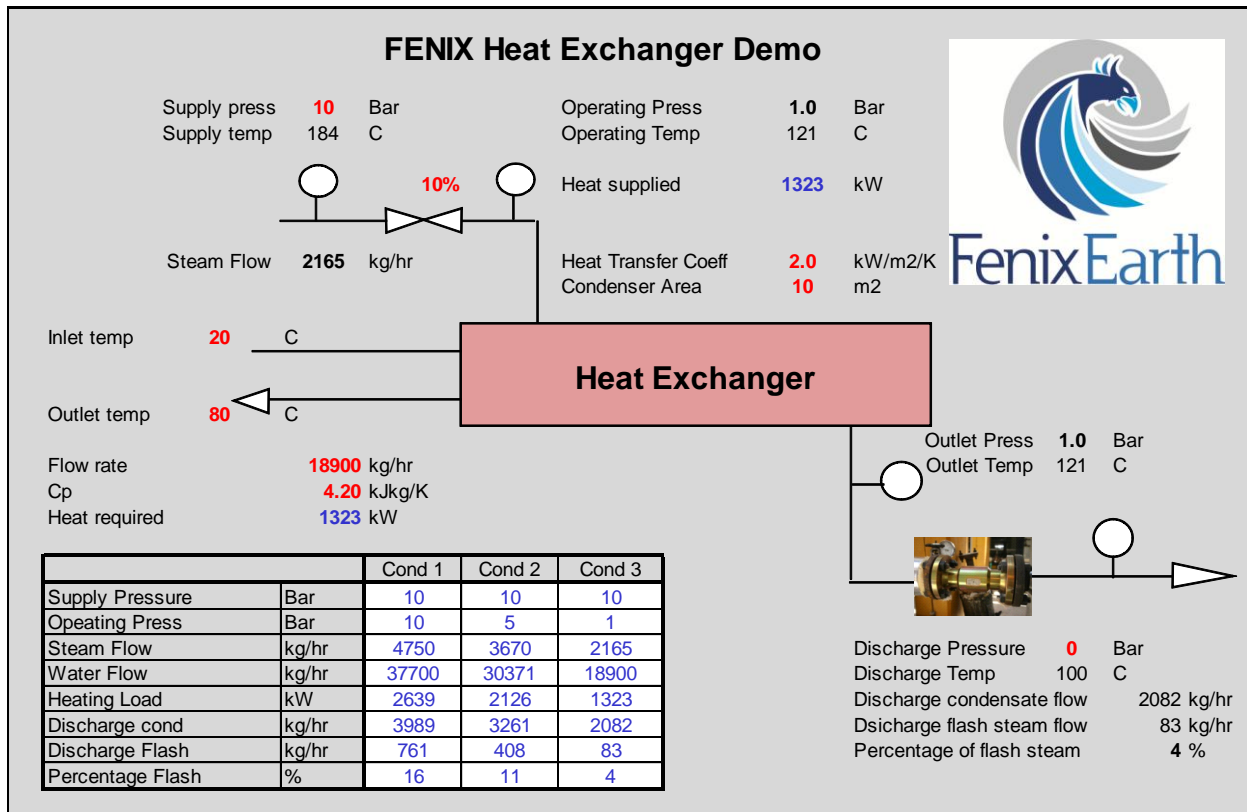


If the flow rate of water now reduces to 30371 kg/hr (to simulate a reduced load) then the heat demand reduces to 2126 kW. To meet this demand it is only necessary for the unit to operate at 5 Bar and the flow rate of steam will reduce to 3670 kg/hr.

So now you have less condensate arriving at the trap (3670 kg/hr instead of 4750 kg/hr) but there is less pressure forcing it through (5 Bar instead of 10 Bar). But because the temperature of the condensate has reduced there is less flash steam generated. The percentage drops (now 11% instead of 16%) but also the mass flow reduces (now 406 kg/hr instead of 761 kg/hr).

The reduction in the flash steam being generated means that there is less back pressure generated so even though there is less pressure forcing the condensate through the orifice of the trap there is less back pressure holding it back.

Cond 3 – Low load



If the water flow to the heat exchanger is reduced even further to 18900 kg/hr then the heat exchanger will only have to operate at 1 Bar to maintain the required 80°C.

The steam flow rate will now be 2165 kg/hr to meet the reduced heat demand of 1323 kW. Under these conditions only 4% of the condensate will flash off and the total flash flow will have reduced to 83 kg/hr. So although there is very little pressure forcing the condensate through the trap there is very little backpressure being generated in the venturi section.

The net result of all this is that as the process conditions change the capacity of the FENIX Hydrodynamic Trap changes accordingly.

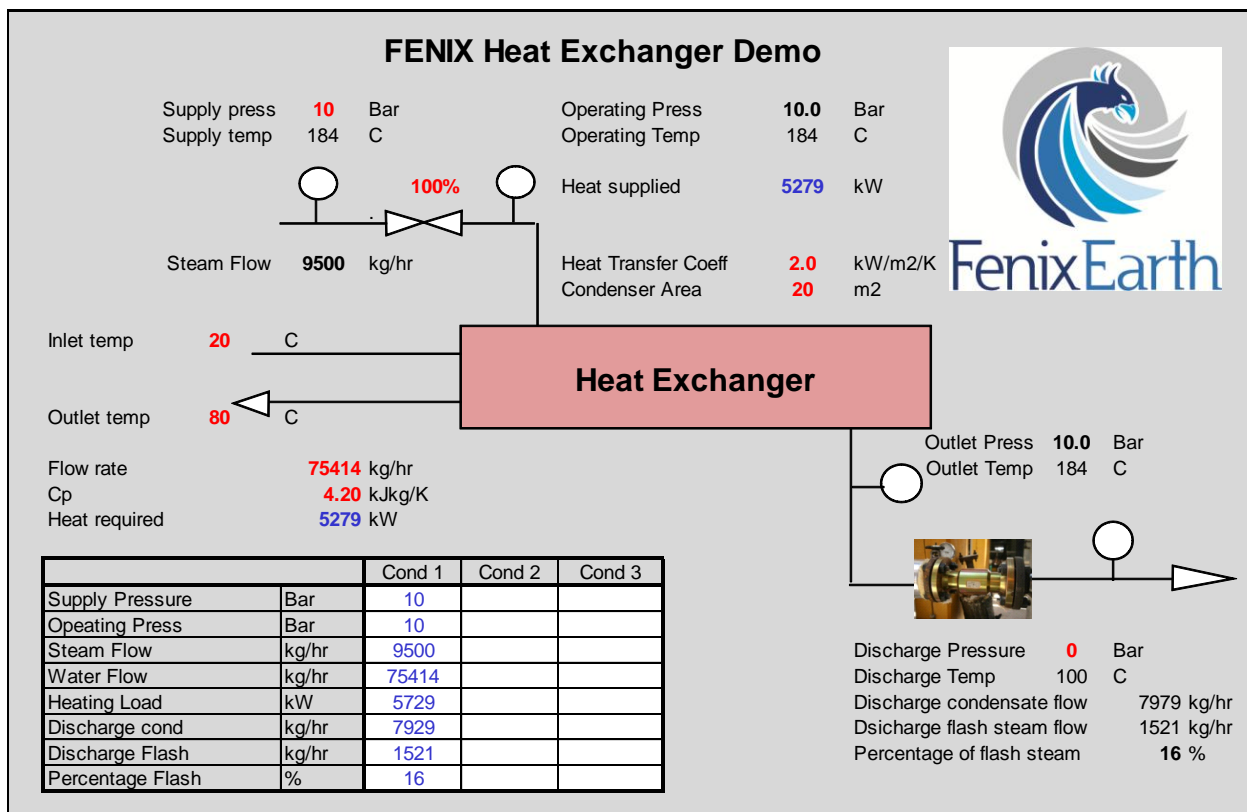
The output characteristics of a heat exchanger is not linear but a curve which starts at the maximum condition i.e. the maximum flow and maximum pressure, and regulates down to zero as the control valve closes completely.

The capacity of the FENIX Trap is a function of the nozzle size and the dimensions of the venturi section. By utilising the natural laws of physics, i.e. the change in the flash steam with change in pressure, the capacity of the FENIX Hydrodynamic Trap can vary with the changes in process conditions. The internal dimensions of the FENIX Hydrodynamic Trap are designed in such a way that the capacity of the FENIX Trap changes with the changing capacity of the application.

Hence the FENIX Hydrodynamic Trap works on varying loads from minimum through to maximum capacity.

The only point of issue is that it is necessary to know at least one point on the process curve of the application to be able to size the FENIX Hydrodynamic Trap. As a general guide we need to know the design specification of an application to within around 20%.

If in the above example it was a plate heat exchanger and the number of plates was doubled to increase the capacity then the surface area would be 20m² instead of 10m².



Now it is possible to heat 75414 k/hr of water to 80°C but the steam consumption has increased to 9500 kg/hr.

But if this scenario happened then it would be necessary to change the FENIX Hydrodynamic Trap plus it would also be necessary to change the control valves, pipework sizes, etc. We only get issues with the sizing if we don't have accurate design information. But if we get it wrong first time we just change the size until we have success. In more than 90% of the applications we have sufficient information to size the FENIX Hydrodynamic Traps accurately first time.

And once in and operating correctly – they cannot fail!