The Case for Flash Separator Heat Recovery Equipment

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One of the advantages of a steam generator such as a boiler is that every time you generate a pound of steam at the operating pressure of the boiler you transfer with it the heat energy necessary to change this water into steam at that pressure. In the steam tables this is termed the Enthalphy of Evaporation (hfg)' For a boiler operating at 150 psig this amounts to 857.5 BTU's per pound of steam. While the heat of evaporation is an advantage in steam generation it works to the opposite advantage when hot water is taken from the boiler. Such a situation exists due to the continuous blowdown from a boiler. It has long been recognized the importance of continuous blowdown in controlling the amount of Total Dissolved Solids in the boiler. In the recent years substantial effort has been made to minimize and economize continuous blowdown with automatic blowdown controls. Nevertheless considerable amount of heat lost from continuous blowdown still occurs. We have set out in this article to show how the amount of heat energy lost can be calculated and further to show how this heat energy can be recovered by various types of heat recovery equipment.

On a 600 Hp., 20,700#/Hr. boiler, operating at 150 psig with 10% continuous blowdown (2,070#/Hr.) and a make-up water temperature of 60° F the total amount of heat lost is:

2070#/Hr. X 310.47 BTU's/# = 642,672.9 BTU's/Hr.

Where 310.47 BTU's/# represents the total amount of BTU's in the blowdown at 150 PSIG (338.535 BTU's/#) minus a make-up water temperature of 60° F (28.06 BTU's/#) with no heat recovery.

Let's take a look at one system for recovering the heat from continuous blowdown. This is the Shell and Tube Heat Exchanger System, which is the first type of system. In this system the heat exchanger is attached to the continuous blowdown line. The blowdown goes through the shell side of the heat exchanger. The continuous blowdown valve is located downstream of the heat exchanger to assure that no flashing occurs in the heat exchanger where the tubes would be damaged. With this system the heat exchanger has to be built to withstand full boiler pressure. The make-up (60°F) goes through the tube side of the exchanger and is preheated before it goes into the deaerator, feedwater heater or boiler as shown in Fig. 1.

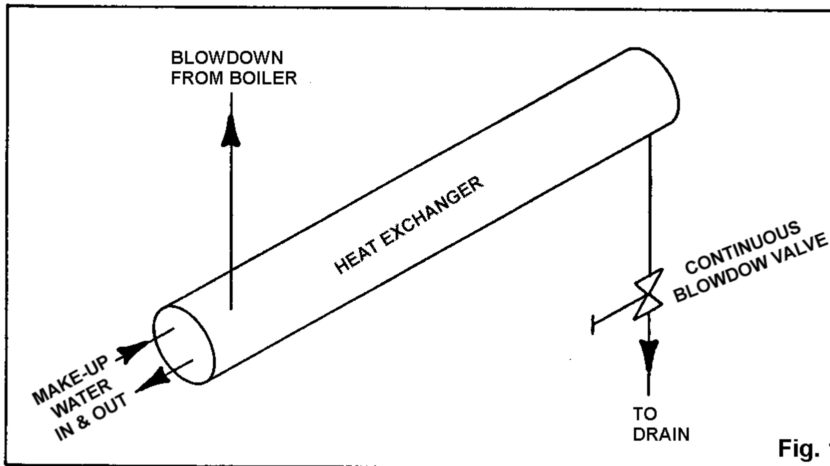


Fig. 1

Using a U-tube heat exchanger with 50% make-up, at 60°F the drain water from the heat exchanger (cooled continuous blowdown) can be reduced to 110° F. The amount of heat recovered with this type system then becomes:

2070#/Hr. X 260.595 BTU's/# = 539,431.65 BTU's recovered

Where 260.595 BTU's/# represents the total amount of BTU's in the blowdown at 150 PSIG (338.535 BTU's/#) minus a drain temperature of 110°F (77.94 BTU's/#). There BTU's are recovered by the heat exchanger. We have used a U-Tube heat exchanger because this is one of the most common type heat exchangers used for this application. Other heat exchangers can be used i.e. Single Pass and Plate and Frame heat exchangers should be given consideration as to effectiveness vs. cost and size.

Another system commonly used for continuous blowdown heat recovery is the Flash Separator/Shell and Tube Heat Exchanger System, which is the second type of system. In this system the continuous blowdown is taken into a flash separator where the steam is directed to the deaerator or feedwater heater to heat make-up (1st stage). The remaining continuous blowdown (Flash Separator Drain Water) passes into a heat exchanger (2nd stage) the same as discussed in the 1st System. The Flash Separator/Shell and Tube System is shown in Fig. 2.

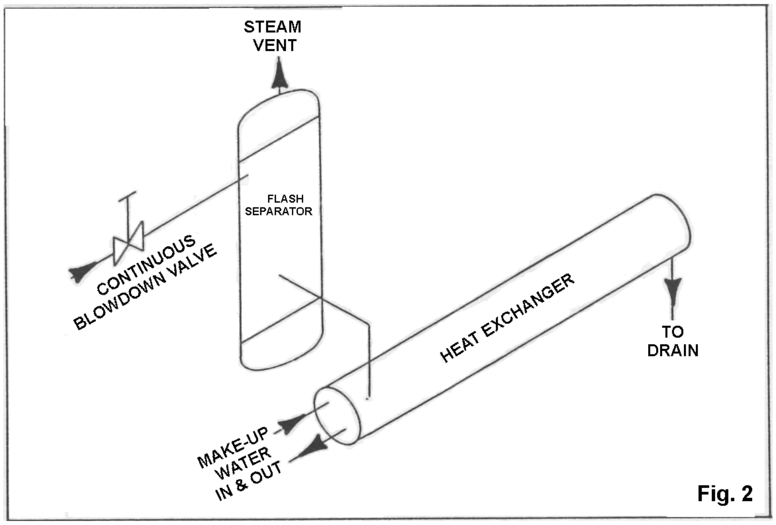


Fig. 2

The amount of heat recovered in the 1st Stage is a function of the drop in pressure on the blowdown water. For our consideration let's use the 150 PSIG boiler going to a 5 PSIG deaerator. At these pressures a percentage of the blowdown flashes to steam. This percent is determined by the following formula:

$$\text{\% of Flash Steam} = \frac{\text{Heat Content of Water @ higher Pressure} - \text{Heat Content of Water @ lower Pressure}}{\text{Latent heat of Evaporation @ lower pressure}}$$

If our 2070#/Hr. of blowdown is taken into a flash tank with the steam qutlet hooked to the deaerator this formula becomes:

$$\text{\% of Flash Steam} = \frac{338.535 - 195.271}{961.05} = 14.907\text{\% Flash Steam}$$

Thus, 14.907 of the 2070#/Hr. or 308.57#/Hr. Blowdown will flash into steam. This flash steam has all of the heat of the saturated vapor (h_g) in it or 1155.8 BTU's/# of flash steam. Therefore, the heat recovered in the 1st Stage becomes:

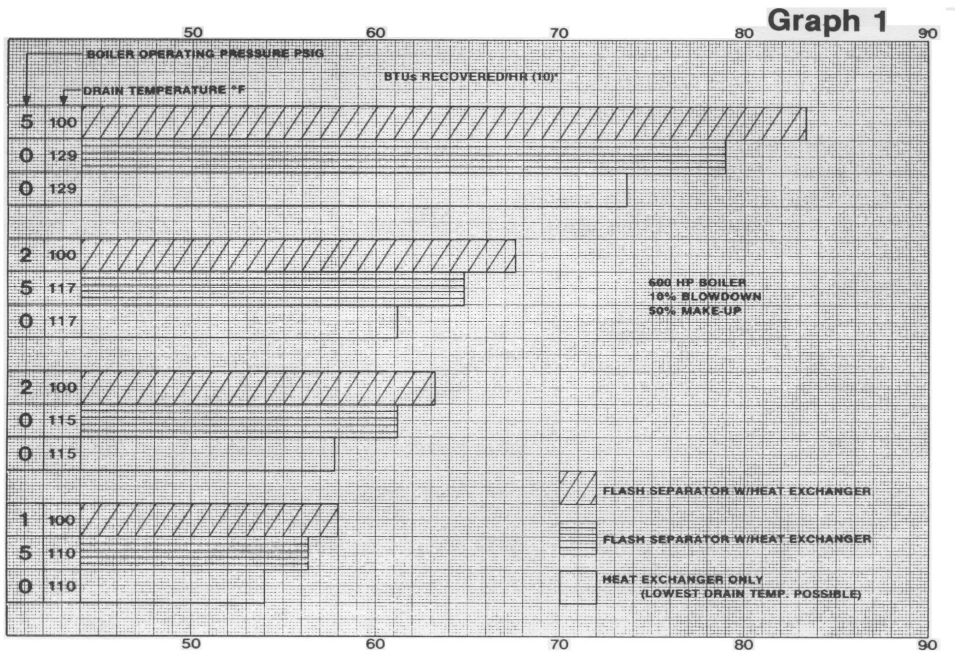
$$\text{1st Stage Recovery} = 308.57\text{\#/Hr.} \times 1155.996\ \text{BTU's/\#} = 356{,}705.69\ \frac{\text{BTU's}}{\text{Hr.}}$$

This brings out several advantages of flashing the continuous blowdown in the 1st stage.

1. All of the BTU's in the flash steam are recovered in the Deaerator or feed water heater - 100% Recovery.
2. A percentage of the blowdown water is returned to the boiler. In the case above, 14.907% or 308.57#/Hr. of blowdown water is returned. With todays costs of treating water this can become a factor, and becomes even more of a factor as the operating pressure of the Boiler increases. Recovering this blowdown water can increase boiler efficiency as much as one percent.

Second stage recovery with a U-tube heat exchanger is very similar to the first system, however, one must deduct the flash steam from the total blowdown to get the amount of water going to the heat exchanger, therefore,

2070#/Hr. blowdown - 308.57#/Hr. flash steam = 1761.43#/Hr. blowdown remaining The major difference now, however, with the flash steam removed and the different ratio of make-up to blowdown is that in the heat exchanger the drain water temperature can now be reduced to 100°F instead of 110°F for a boiler operating at 150 psig.
This factor becomes even more significant as the boiler operating pressure becomes higher. See graph 1.



The head recovery in the 2nd stage then becomes enthalpy of water 226.6ºF at 5 psig (195.33) - enthalpy at 100º (67.97) = 127.36 BTU's/# recovered with the heat exchanger. Therefore, 1761.43#/Hr. X 127.36 BTU's/# = 224,335.72 BTU's/Hr. recovered in the 2nd Stage. To get the total BTU's recovered add the 1st Stage and the 2nd Stage together. This gives a total of 581,041.41 BTU's/Hr. recovered from the continuous blowdown.

The two Systems U-Tube Heat Exchanger and Flash System can now be compared to the total blowdown lost to get a figure showing the % of heat recovered.

Percent for U-Tube Heat Exchanger

$$\frac{\text{539,431.65 BTU's Recovered}}{\text{642,672.9 BTU's Recoverable}} = \text{83.94\% Percent of BTU's recovered}$$

Percent for the Flash Separator/Shell and Tube System

$$\frac{\text{581,041.41 BTU's Recovered}}{\text{642,672.9 BTU's Recoverable}} = \text{90.41\% Percent of BTU's recovered}$$

Let's take a good honest look at the amount of BTU's recovered, and the amount of money saved in fuel costs with the Flash Separator/Shell and Tube Heat Exchanger versus the shell and tube heat exchanger.
In Graph 1 one can easily see the BTU's/Hr. recovered by each System. The 1st line in the Graph shows a Flash Separator/Shell and Tube Recovery System reducing the drain temperature to as low as it can possibly go with a Shell and Tube heat exchanger. The 3rd line on the Graph shows the number of BTU's recovered with just a heat exchanger—lowering the drain water to the lowest possible temperature a shell and tube heat exchanger can reduce the drain temperature to using 60ºF make-up water. The middle line in the Graph represents the amount of BTU's/Hr. that can be recovered by a Flash

Separator/Shell and Tube Heat Recovery System reducing the drain water from the heat Exchanger to the same temperature that you get with just the heat exchanger.

Several things become apparent from this Graph:

1. The Flash Separator/Shell and Tube System recovers more BTU's/Hr. than the other systems.
2. As the boiler pressure increases the Flash Separator/Shell and Tube System becomes more efficient recovering more BTU's.
3. Even when the Flash Separator/Shell and Tube System is limited to the same drain temperature as a Heat Exchanger it is more efficient in recovering heating dollars.

The reason why the Flash Separator/Shell and Tube System is so effective is that when you take the blowdown into a Flash Separator in the 1st Stage all of the heat that is flashed in the steam goes over to the deaerator or feedwater heater. This is why as the boiler pressure goes up since there is more flash steam the system becomes even more effective.

Chart 1

BOILER OPERATING PRESSURE	AMOUNT OF MONEY SAVED PER/WEEK: FLASH SEPARATOR/ HEAT EXCHANGER	AMOUNT OF MONEY SAVED PER/WEEK: (SHELL & TUBE)	AMOUNT OF MONEY SAVED PER/WEEK: OVER HEAT EXCHANGER	WEEKS TO PAY OFF FLASH SEPARATOR/ HEAT EXCHANGER
150	780.46 $/Week	724.55 $/Week	55.91 $/Week	11.5 Weeks
200	850.15 $/Week	775.75 $/Week	74.40 $/Week	10.5 Weeks
250	908.89 $/Week	825.05 $/Week	83.84 $/Week	9.8 Weeks
500	1,121.58 $/Week	990.28 $/Week	131.20 $/Week	7.8 Weeks

FUEL COST: $8.00 /MILLION BTU'S

Chart 1 shows the $ pay off period for the Flash Separator/Shell and Tube System using a fuel cost $8.00/million BTU's with blowdown operating 24 hrs./day. A look at column four shows that if a Flash Separator/Shell and Tube System is installed not only will you have a fast pay off period but over the entire life of the system you will get an additional savings over just a heat exchanger. For a 150 psig boiler this would be $2,907.32 extra for a total savings of $40,583.92 per year.

In summary then, the Flash Separator/Shell and Tube Heat Recovery System returns more heat to the boiler because first of all every BTU is reclaimed in the flash system going to the Deaerator or feedwater heater and secondly because you have taken a considerable percentage of the heat out of the blowdown in the 1st Stage Flash Sep. the drain temperature with the shell and tube heat exchanger can be reduced even more to reclaim more BTU's.

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