BEST PRACTICE NO. 66

» STEAM SYSTEM THERMAL CYCLE EFFICIENCY

1. WHAT IS THERMAL CYCLE EFFICIENCY AND WHERE DO LOSSES HAPPEN?

A question that all steam system managers need to answer is what variables affect the efficiency of their steam systems. The average steam system thermal cycle efficiency is 56.3%, which means that 43.7% of the energy that is consumed in the boilers is wasted or lost. Every operation will have a few acceptable losses, but a high percentage of losses can be prevented or eliminated. Some plants maybe more efficient and some plants may be less efficient. Not until the steam system is bench-marked will the plant management know how much is being lost in the steam system.

1. When benchmarking the thermal cycle, the sensible energy in the condensate and quantity that is delivered back to the boiler is considered the recovered energy.

2. The deaerator uses steam from the main steam line to maintain pressure and temperature on the deaerator, therefore it cannot be the benchmark for recovered condensate.

Total fuel energy or BTUs input into the boiler to generate the steam – BTUs that are recovered and delivered back to the boiler plant = **Thermal Cycle Efficiency**

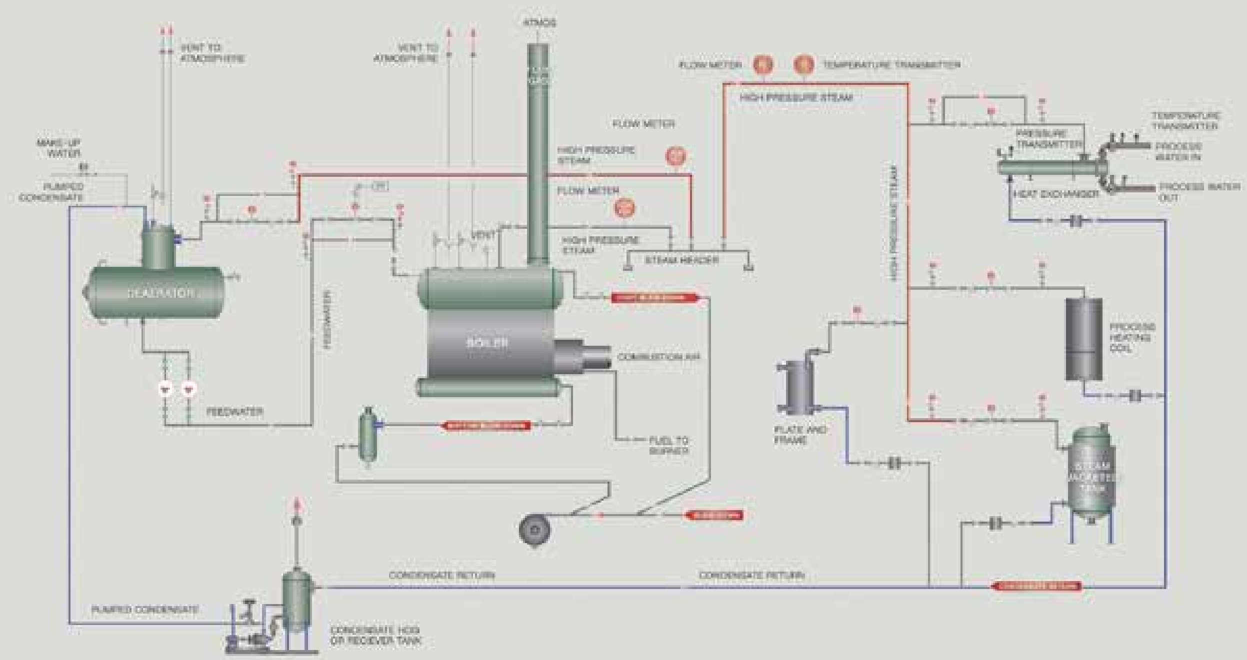

Figure 1: Total Steam System

2. STEAM SYSTEM ITEMS THAT CAN AFFECT THE THERMAL CYCLE EFFICIENCY

The steam system components that can affect the steam system thermal cycle efficiency need to be reviewed and no item can be overlooked. Each item can contribute significant losses if not properly managed.

Steam Generation

1. Boilers
2. Steam turbines

Steam Distribution

1. Insulation
2. Steam leaks

End Users

1. Shell and tube heat exchangers
2. Plate and frame
3. Steam trap stations

Condensate Systems

1. Condensate lines
2. Flash steam losses
3. Pumps
4. Condensate leaks
5. Condensate losses
6. Tanks

3. STEAM GENERATION LOSS?

The first area that needs to reviewed is steam generation, which can contribute a significant energy loss even before the steam is distributed into the steam system.

Boiler Flue Gas

The boiler has on average 16.4% energy loss due to the flue gas volume and the elevated temperature of the gases from the combustion process. The boiler can have several devices to lower the flue gas losses which will be discussed later on.

Boiler Outer Shell or Casing

The outer shell or casing of the boiler will contribute a low loss percentage (0.5%), which is an acceptable loss as long as the boiler casing does not have hot spots or above normal temperatures. The plant should have an infrared camera scan of the casing at least once a year.

The data is used to benchmark the detected fatigue of the boiler's internal insulation.

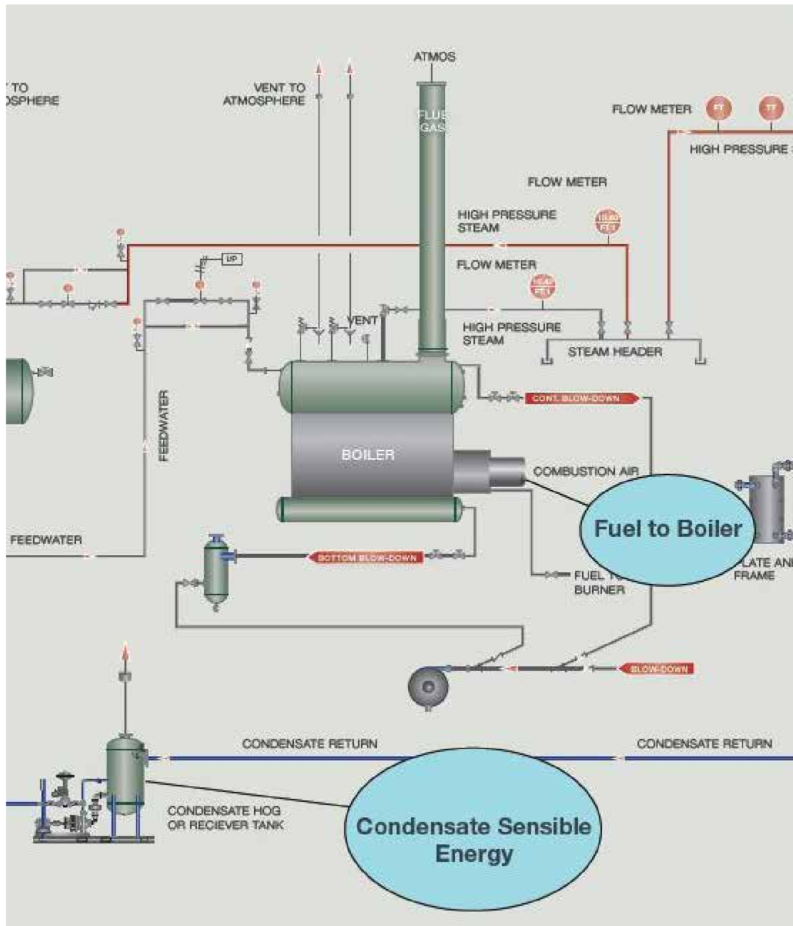

Figure 2: Energy in and Returned

Boiler Continous Blowdown

The continuous blowdown is continually skimming the boiler water for impurities slightly below the water level, and discharging boiler water to a blow- down tank. The estimated energy loss from the continuous blowdown is 1.5% which is caused by a number of factors that are discussed in other SEA Best Practices.

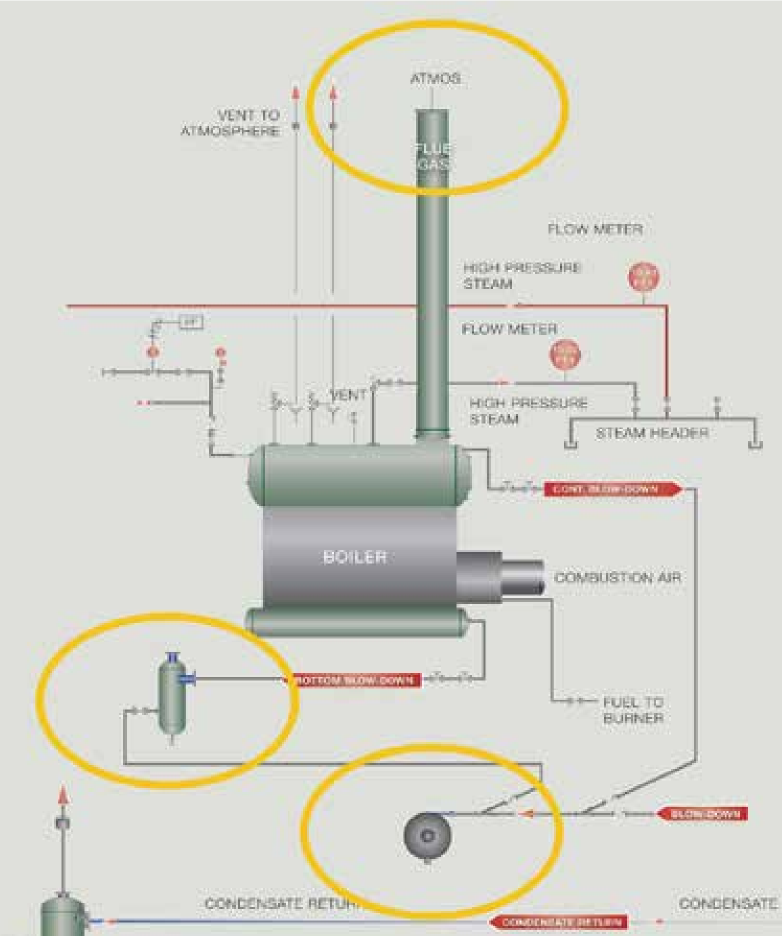

Figure 3: Losses in the Steam Generation Area

Figure 4: Small Steam Turbine Installation

Total Steam Generation Losses Due to:

Boiler flue gases	16.4%
Boiler outer surface shell or casing	0.5%
Continuous blowdown	1.5%
Bottom blowdown	0.2%
Total	**18.6 %**

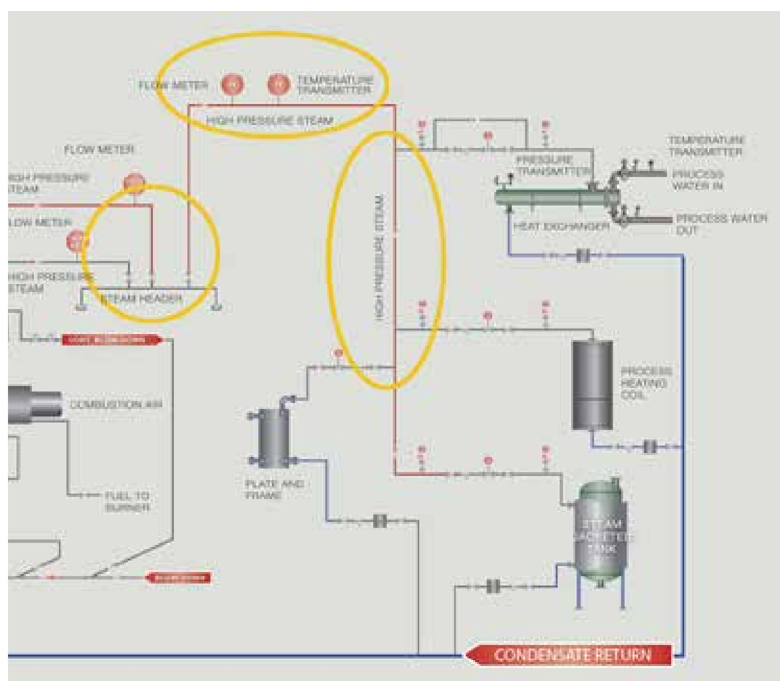

Figure 5: Steam Distribution Losses

Boiler Bottom Blowdown

The boiler has a bottom blow down system which is activated periodically from the lowest water containment area of the boiler. The periodic bottom blowdown removes the sludge found at the bottom of the boiler, and discharges the water and materials to a blowdown tank. The estimated energy loss from the bottom blowdown is 0.2% which is caused by a number of factors that are discussed in other SEA Best Practices.

Steam Turbine

Steam turbines are often used to reduce steam system pressure and generate energy you can use elsewhere. A rule of thumb is 75 lbs. of steam per hour is equal to one horsepower of work from a steam turbine. The energy loss from reducing steam pressure with a control valve instead of a steam turbine is not included as a thermal cycle loss.

4. STEAM DISTRIBUTION

The energy loss is already at 18.6% and the steam vapor has yet to perform any usable work. In order to best release the contained energy in the steam to the process, the next step is to safely distribute the steam to the end user. We will primarily focus on insulation and steam leaks with the piping, valves, and expansion devices.

Insulation

Insulation is the most overlooked item that provides energy savings, with an estimated average energy loss of 6.4%. According to the United States Department of Energy (DOE) Best Practices Steam program, mechanical insulation should be used on any surface over 120°F (49°C). Therefore, all steam and condensate components need to be insulated, and that insulation protected to ensure long operational life.

Figure 6

Steam Leaks

Steam and condensate leaks cost industrial plants millions of dollars in lost latent and sensible energy. These leaks will also increase your system emissions, create safety hazards, and lower the reliability of plant operations.

While plant personnel would be well advised to pay attention to all utility losses, greater attention should be paid to the costs and problems associated with those losses related to steam. An estimated energy loss from the steam and condensate leakage is 7.5%.

Summary of the Energy Losses to this Point Due to:

Insulation	6.4%
Steam leaks	7.5%
Steam Distribution Subtotal	**13.9%**
+ **Steam Generator**	**18.6%**
Total Energy Loss	***32.5%***

The energy loss is now at 32.5% and the steam vapor has not performed any usable work.

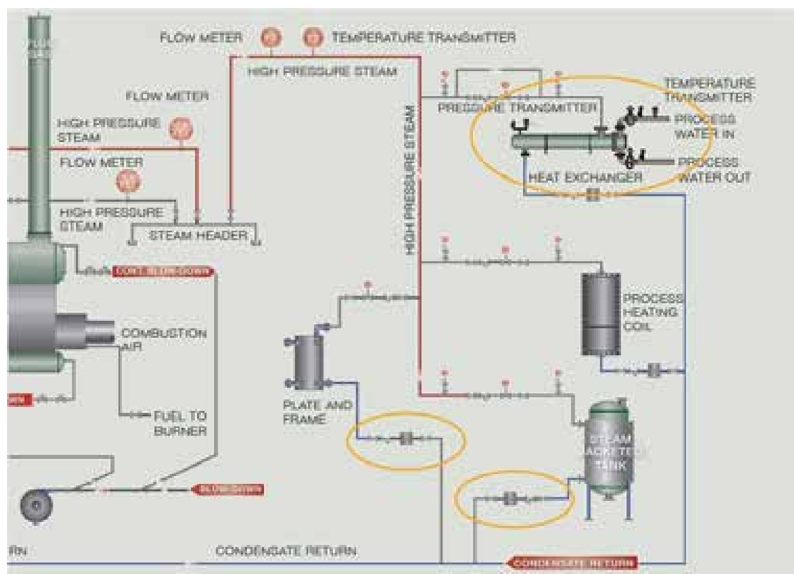

Figure 7: Steam End Users Thermal Losses

5. END USERS

Finally the steam has reached the intended objective which is to provide the latent energy to the process. The insulation losses from not insulating the heat exchangers, tracer lines, jacket tank heaters, etc., have already been included in the insulation estimate. The steam leaks from flanges, threaded connections, valves, etc., have already been added into the previous estimation. The next areas to look at are the steam trap stations.

Steam Trap Stations

The average performance level of a steam trap station should be a failure rate below 3%. The energy loss from failed steam trap stations is estimated at 3.6%.

Summary of the End Users' Loss Points:

	Insulation (already added in the totals)	6.4%
+	Steam leaks (already added in the totals)	7.5%
	Steam trap station failures	3.6%
	Total	***3.6%***

6. CONDENSATE SYSTEMS

The steam has released the latent energy to the process and now the sensible energy is in the condensate.

Condensate losses

Condensate contains 16% of the energy in the steam vapor (sensible energy), and by not recovering this condensate can result in a significant loss. The estimated energy loss from loss condensate is 3.8%.

Steam loss to atmosphere

The flash and live steam loss to atmosphere represents the last of the energy losses in the thermal cycle. Venting steam to atmosphere reduces the thermal cycle efficiency and contributes to an increase in emissions. The benchmark in today's industrial plants is having no steam to atmosphere, and where it occurs you can expect an average loss of 7.4%. The steam components that allow steam to be vented to atmosphere are as follows:

1. Vented condensate tanks
2. Vented flash tanks
3. Automatic steam vents
4. Deaerator vent

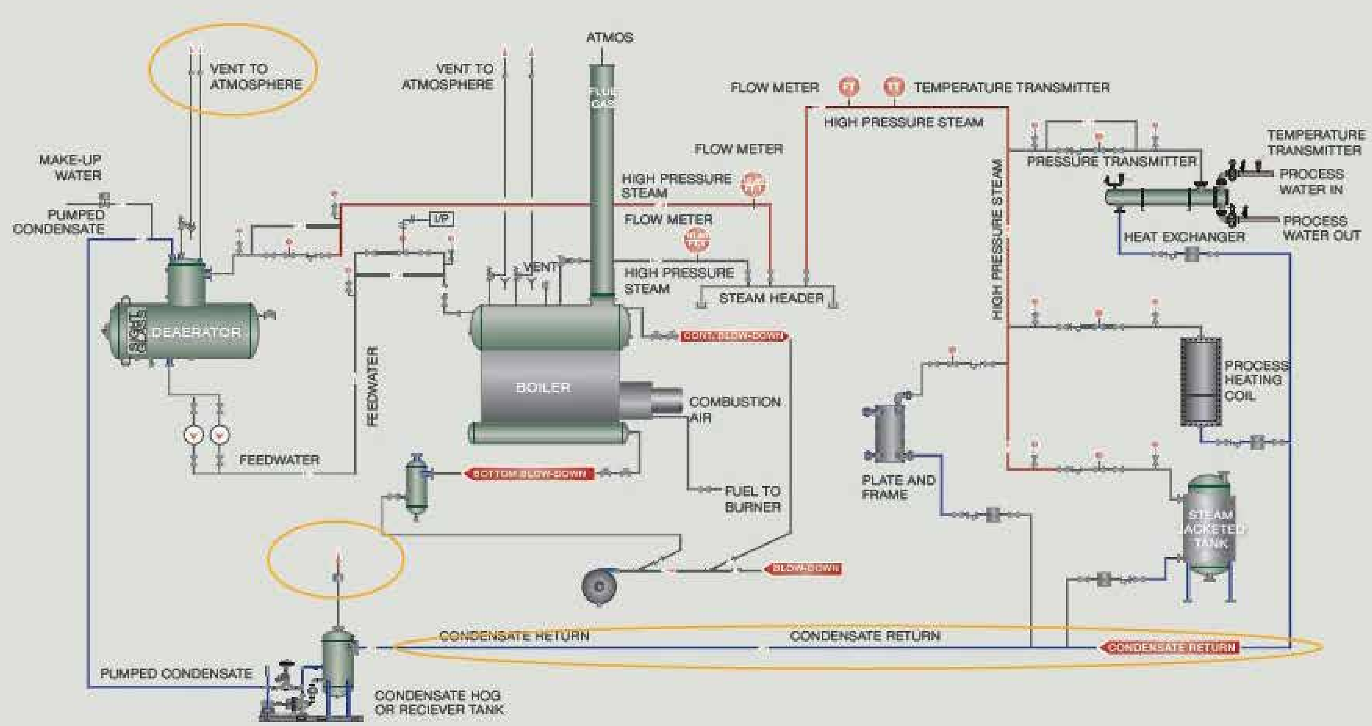

Figure 8

Summary of the Condensate System Losses Due to:

Condensate	3.8%
Steam loss to atmosphere	7.4%
Insulation (already added in our totals)	6.4%
Total	***11.2%***

7. STEAM THERMAL CYCLE SUMMARY

Steam losses equal the following:

Boiler flue gasses	16.4%
Boiler outer shell or casing	0.5%
Continuous blow down (boiler)	1.5%
Bottom blowdown (boiler)	0.2%
Insulation (steam and condensate)	6.4%
Steam leaks	7.5%
Steam trap station failures	3.6%
Condensate losses	3.8%
Steam loss to atmosphere	7.4%
Total	***47.3%***

The steam system cycle is complete, and only 52.7% of the steam energy was used successfully. A steam optimization program will definitely improve the company's bottom line, while reducing your emissions.