Knowing the Cost of Steam

COST OF STEAM

Knowing the correct cost of steam offers important insight on improving a company's bottom line by:

A. Allowing for accurate evaluation of the economics of proposed steam system efficiency improvement projects. Inaccurate or incomplete steam costs may result in many feasible energy projects being missed or rejected, while unfeasible projects may be approved for implementation

B. Assisting in optimization of the steam generation system and reducing costs

C. Providing a true cost to the production areas for accountability of energy consumption.

Steam cost is the first benchmark of any steam system management program. Unfortunately, a high percentage of industrial plants do not benchmark their steam costs. A loaded steam cost is the most important variable for any steam system management program because it captures all aspects and costs for producing steam.

What Affects the Cost of Steam?

Many factors in the steam system affect the cost of steam. They include:

A. *Fuel cost*
Lower-cost fuels result in lower steam cost.

B. *Operating steam pressure*
Lower operating steam pressure results in lower steam cost. Higher operating steam pressure requires more energy to produce the steam. Steam pressure should be reviewed to ensure that it is at the optimum pressure to meet the plant's process requirements.

C. *Percentage of make-up water or percentage of condensate return*
Normal condensate returns have a higher Btu content than make-up water. Today's industrial benchmark for condensate return is 90% if the plant is not injecting steam for the process.

D. *Boiler efficiency*
Higher boiler efficiency lowers steam cost. Boiler efficiency varies depending on the boiler operation firing rate or load demand. Lower firing rates or steam load demand lower boiler efficiency. Understanding and documenting the fuel-air ratio is extremely important. Boiler efficiency is calculated by using PTC 4.1.

A proactive steam management program can improve a large percentage of the above factors.

Unloaded Steam Cost versus Loaded Steam Cost

There are two methods to calculate steam cost: unloaded and loaded. The simplest steam cost method calculates the unloaded steam cost, which only reviews the boiler operation; steam Btu, feedwater Btu, boiler efficiency, and fuel cost. Loaded steam cost captures all aspects and costs for producing steam which provides a truer steam cost.

Unloaded Steam Cost

The unloaded cost is a basic comparison between the amount of steam produced and the cost of fuel required to produce it. The basic equation for calculating unloaded steam cost includes the cost of fuel, operating steam pressure, feedwater Btu, and boiler efficiency.

Here is the equation to calculate unloaded steam cost:

$$S_C = \frac{a_F \times (H_g - h_f)}{1{,}000 \cdot \eta_B}$$

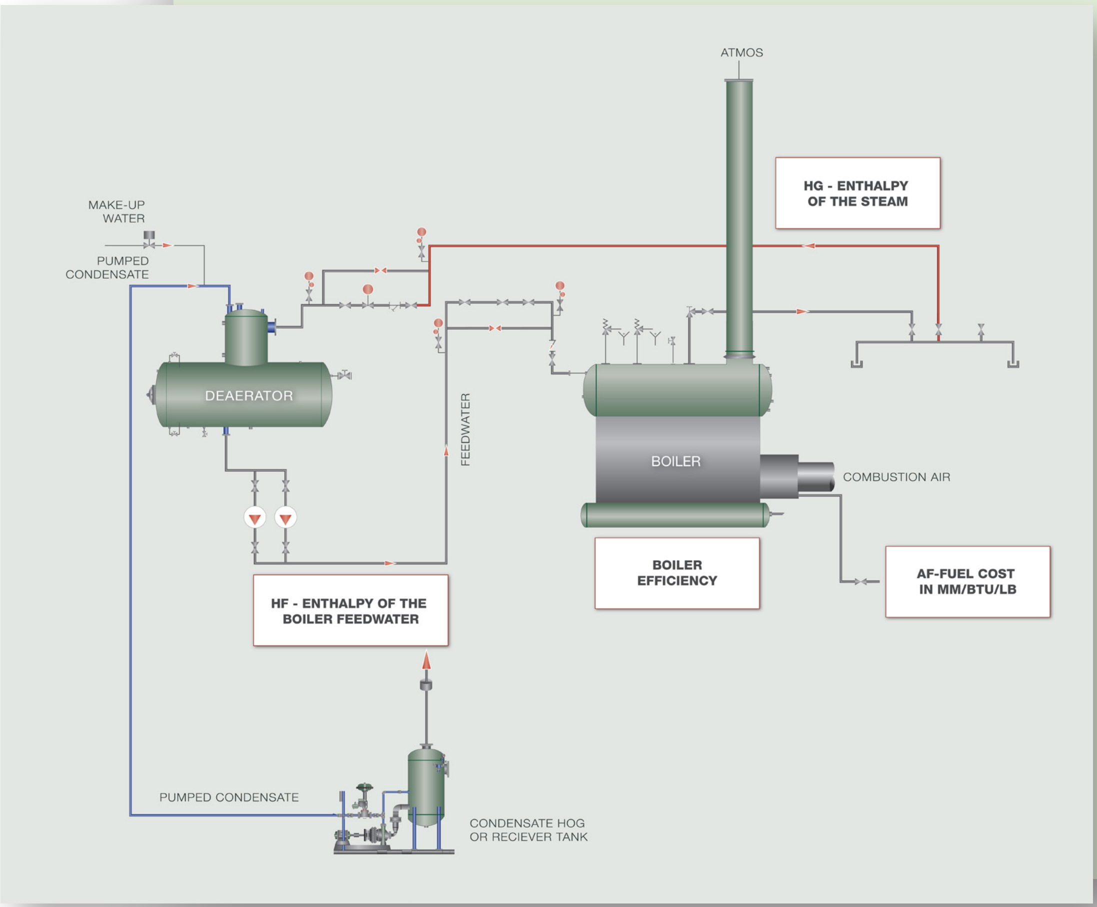
Where:

- S_C = steam cost, unloaded
- a_F = fuel cost in $/MMBtu
- H_g = enthalpy of steam, in Btu/lb.
- h_f = enthalpy of boiler feedwater in Btu/lb.
- η_B = true boiler efficiency (ASME PTC 4.1)
- 1,000 = steam cost is measured in units of 1,000 lbs. per hour

True boiler efficiency (η_B) considers all aspects that influence boiler efficiency, including:

- fuel moisture content
- combustion air temperature
- radiation losses
- flue gas losses
- blowdown losses

(Refer to ASME PTC 4.1 for additional calculation details.)



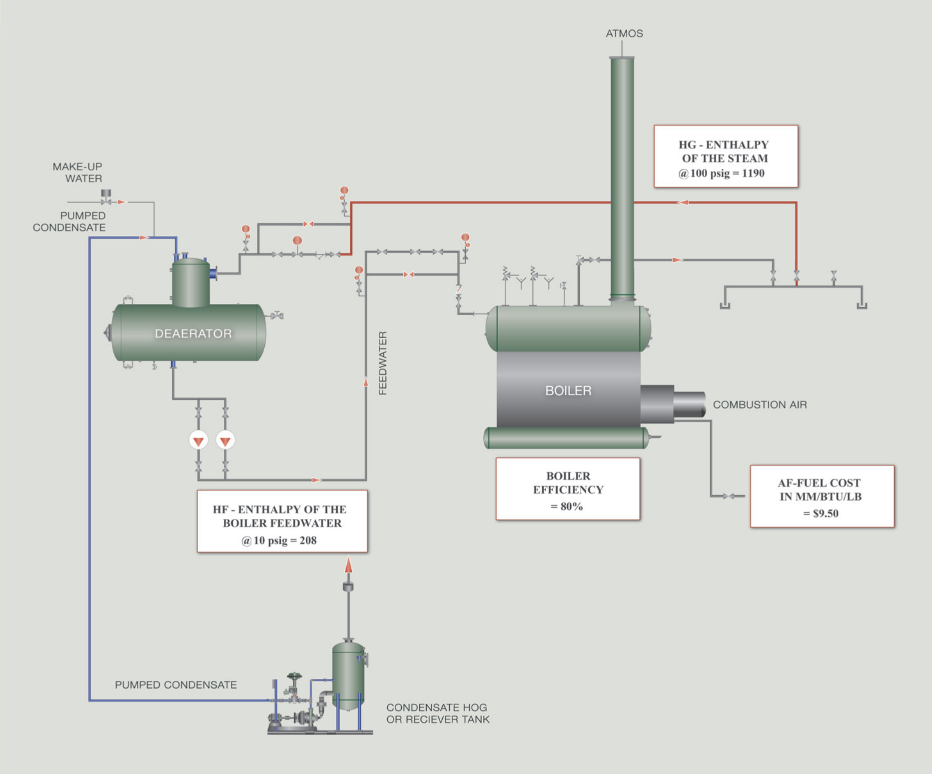
Example I

The steam cost example outline below assumes use of one steam generator (boiler), a single fuel, and one steam pressure. The unloaded steam cost example calculation factors in deaerator feedwater Btu content, which does not consider make-up water or condensate return. Also, the calculation uses only one boiler efficiency.

Steam is being generated at 100 psig and is being returned to a deaerator tank operating at 10 psig. Fuel cost is $9.50/MMBtu, and boiler efficiency is 80%.

$$S_c = \frac{\$9.50(1190 - 208)}{1000(0.80)}$$

$$S_c = \$11.67 \text{ per } 1{,}000 \text{ lbs.}$$



IMPROVING THE CALCULATION OF THE UNLOADED COST OF STEAM

Condensate Return to the Boiler Operation

The amount of condensate being returned has a significant effect on the cost of steam and should be considered when calculating the unloaded steam cost. The limitation to the **unloaded steam cost** calculation is the fact the calculation has the deaerator feedwater Btu content as the Btu input parameter for the calculation. The deaerator uses steam from the boiler operation to heat the feedwater to an operational pressure/temperature. Therefore, the deaerator prevents an understanding of the benefits of condensate return at various pressures versus using make-up water. Condensate that is being returned to the deaerator tank can be from several different return systems, and a percentage of condensate flow must be used based on a measurement or an estimated amount.

The condensate return systems are classified as follows:

1. GR: *Gravity or atmospheric* — condensate return pressure maintained at or close to 0 psig
2. LP: *Low pressure* — condensate being returned between 1 to 15 psig
3. MP: *Medium pressure* — condensate being returned between 16 to 99 psig
4. HP: *High pressure* — condensate being returned at 100 psig or higher
5. MW: *Make-up water* — water added to the steam system to offset any condensate lost in the system that is not being returned to the boiler operation.

Using the equation below will provide the plant operator with a better understanding of the value of condensate recovery in the plant operation. A "modified" enthalpy of the boiler feedwater can be calculated as follows:

$$h_f = \%(GR) + \%(LP) + \%(MP) + \%(HP) + \%(MW)$$

Example II

Steam is being generated at 100 psig; 60% of the condensate is being returned through an atmospheric return system, 20% is being returned through a 10 psig return system, and the remaining 20% is using make-up water at 60°F. Fuel cost is $9.50/MMBtu, and boiler efficiency is 80%.

$$h_f = \%(GR) + \%(LP) + \%(MP) + \%(HP) + \%(MW)$$

$$h_f = 0.60(180) + 0.20(208) + 0.0(MP) + 0.0(HP) + 0.20(28)$$

$$h_f = 155.2 \text{ Btu/lb.}$$

$$S_c = \frac{\$9.50(1190 - 155.2)}{1000(0.80)}$$

$$S_c = \$12.29 \text{ per 1,000 lbs.}$$

LOADED COST OF STEAM

A loaded steam cost is the preferred method for plant accountability. The loaded cost of steam captures many different factors related to steam generation and provides a more accurate cost for steam production. The loaded steam cost value provides more clarity when evaluating production costs, utility billing issues, as well as energy efficiency projects. Below are factors that need to be included in the calculation of a loaded steam cost:

- electrical power
- chemical costs
- water and sewer
- emissions payments
- labor costs
  - management
  - operations
  - maintenance
- waste disposal
- maintenance costs
- new projects

The true cost of steam **can easily be one and a half to two times** the value of the unloaded steam cost and can make a dramatic difference in the evaluation of different energy, efficiency, and emission projects.

Road Map:

1. Determine unloaded cost of steam.
2. Determine unloaded cost of steam using the calculations for the condensate return systems.
3. Determine loaded cost of steam.

Swagelok

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