BEST PRACTICE NO. 16

INVENO ENGINEERING LLC

KNOWING THE COST OF STEAM

1. COST OF STEAM

Knowing the correct cost of steam is very important for many reasons, and all of them have to do with improving the company's bottom line:

1. To properly evaluate the economics of proposed steam system efficiency improvement projects. If the calculated steam cost is not accurate, many feasible energy projects may be missed or rejected, while infeasible projects may be approved for implementation
2. To serve as a basis for optimizing the steam generation system and minimizing costs
3. To provide a true cost for the production areas for accountability in energy consumption

Steam cost is the first benchmark of any steam system management program. Unfortunately, a high percentage of industrial plants have not benchmarked the cost of steam. A **loaded** steam cost is the most important steam cost for any steam system management program.

1.1. What Affects the Cost of Steam?

Many factors in the steam system affect the cost of steam. A large percentage of the varying factors can be changed or improved based on a proactive steam management program. Examples of a few of the factors that can affect steam cost include the following:

- Fuel cost: Lower cost fuels will provide a lower steam cost.
- Operating steam pressure: Is not a major factor and must be reviewed carefully for each boiler before implementing.
- Percentage of make-up water or percentage of condensate return: Normal condensate return will 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.
- Boiler efficiency: A higher boiler efficiency will provide a lower steam cost. Boiler efficiency will vary depending on the boiler operation firing rate or load demand. Lower firing rates or steam load demand will have lower boiler efficiency. Understanding and documenting the fuel-air ratio is extremely important. Boiler efficiency is calculated by using PTC 4.1.

1.2. Unloaded Steam Cost vs. Loaded Steam Cost

There are two methods to calculate steam cost (unloaded or loaded). The simplest method to determine the cost of steam is to calculate the unloaded steam cost, which only requires reviewing the boiler operation (steam Btu, feedwater Btu, boiler efficiency, and fuel cost). The loaded steam cost takes into account all aspects and costs of producing steam, which provides a more accurate steam cost.

1.2.1. Unloaded Steam Cost

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

Here is the equation to calculate an **unloaded** steam cost:

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

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)
o Percentage
1,000 = Steam cost is measured in 1,000 lbs. per hour

True boiler efficiency (ηB) takes into consideration all aspects that influence boiler efficiency, including the following:

- Moisture content in the fuel
- Combustion air temperature
- Radiation losses
- Flue gas losses
- Blowdown losses
- Etc.

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

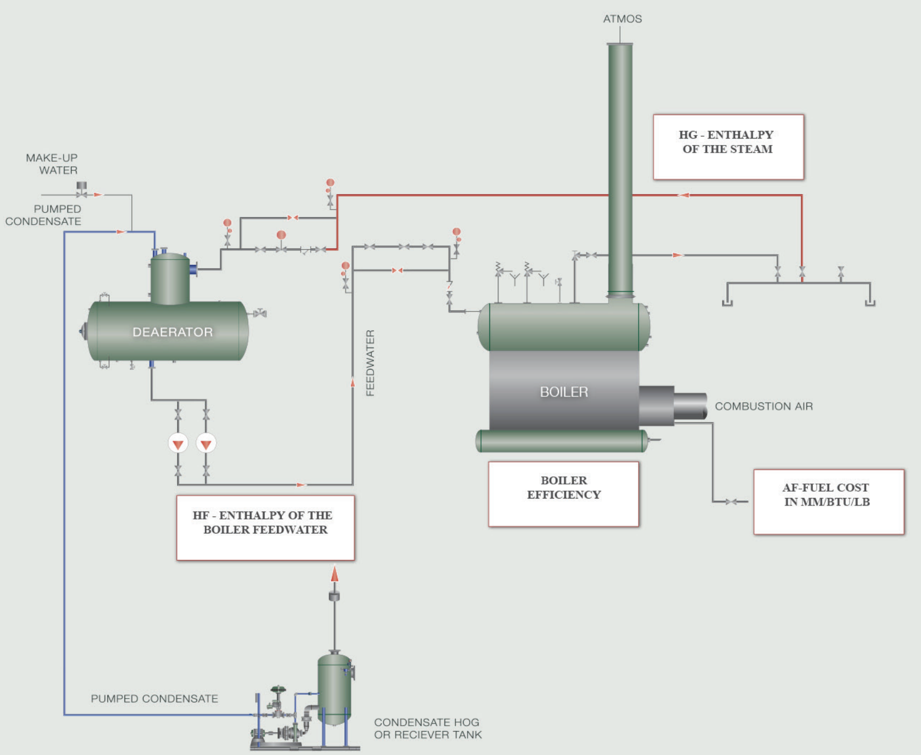

Figure 1: Steam Cost Print

Example I

The outlined steam cost example uses one steam generator (boiler), a single fuel, and one steam pressure. The example of unloaded steam cost calculation uses the deaerator feedwater Btu content, which does not take into consideration make-up water or condensate return. Also, the calculation uses only one boiler efficiency.

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

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

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

2. IMPROVING THE CALCULATION OF THE UNLOADED COST OF STEAM

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

Using the equation below will provide the plant 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:

hf = % (GR) + %(LP) + %(MP) + %(HP) + %(MW)

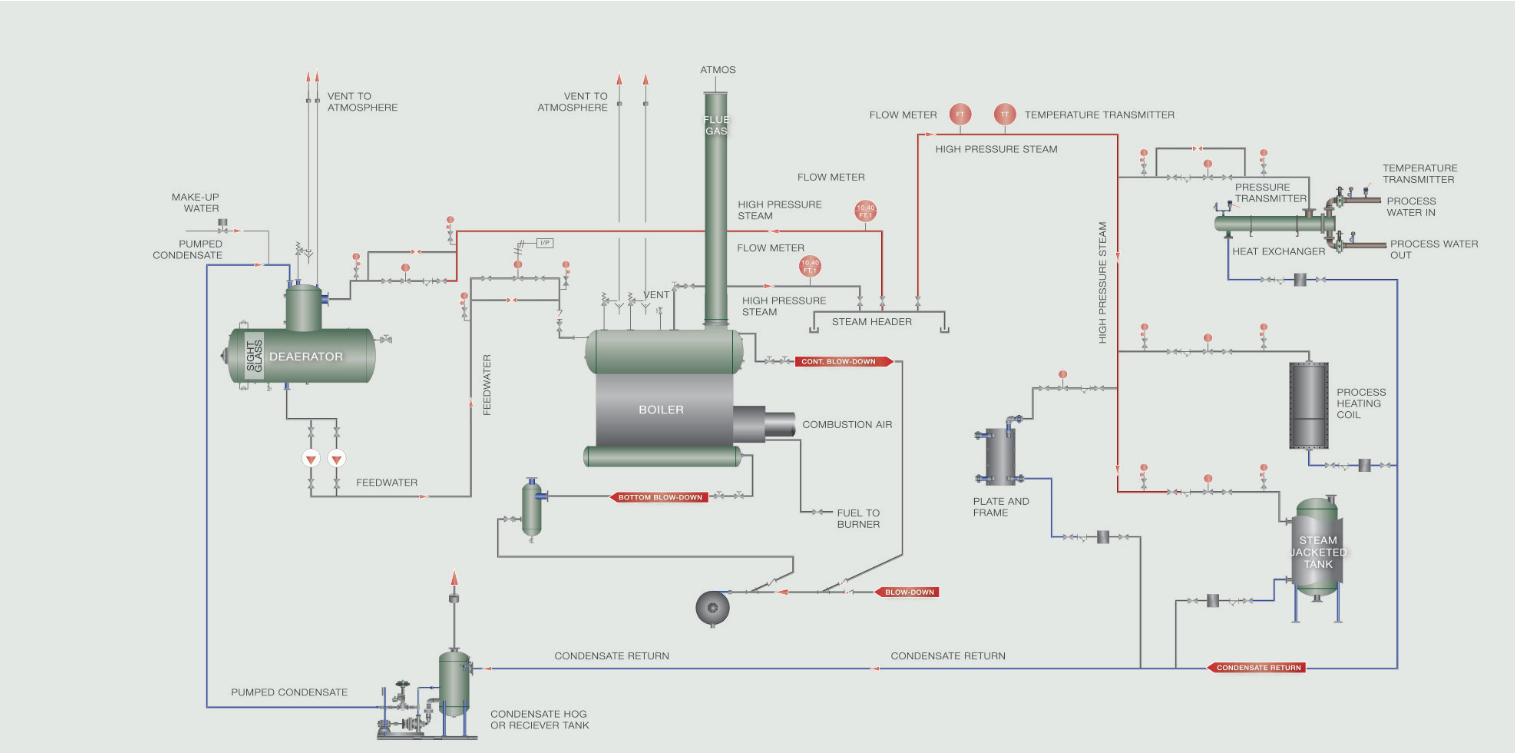

Figure 2: Steam System Layout

Example II

Steam is being generated @ 100 psig, and 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 @ 60°F. Fuel cost is $9.50/MMBtu, and boiler efficiency is 80%.

hf = %(GR) + %(LP) + %(MP) + %(HP) + %(MW)
hf = 0.60(180) + 0.20(208) + 0.0(MP) + 0.0(HP) + 0.20(28)
hf = **155.2** Btu/lb.

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

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

2.2. Loaded Cost of Steam

The **loaded steam** cost is the preferred method for plant accountability with today's high energy costs. Load Coast takes into account many different factors related to steam generation. Therefore, the loaded cost of steam provides a much more accurate cost for steam production. This value will also provide more clarity when evaluating production costs, utility billing issues, as well as energy efficiency projects. Below are some of the factors that need to be included in the calculation of a loaded steam cost:

- Electrical power
- Chemical cost
- Water and sewer
- Emissions payments
- Labor cost
  - o Management
  - o Operations
  - o Maintenance
- Waste disposal
- Maintenance cost
- New projects
- Etc.

The true cost of steam ***can easily be 2 to 3 times*** the value of the unloaded steam cost. This will make a dramatic difference in evaluating the different energy, efficiency, and emission projects.

Road Map

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