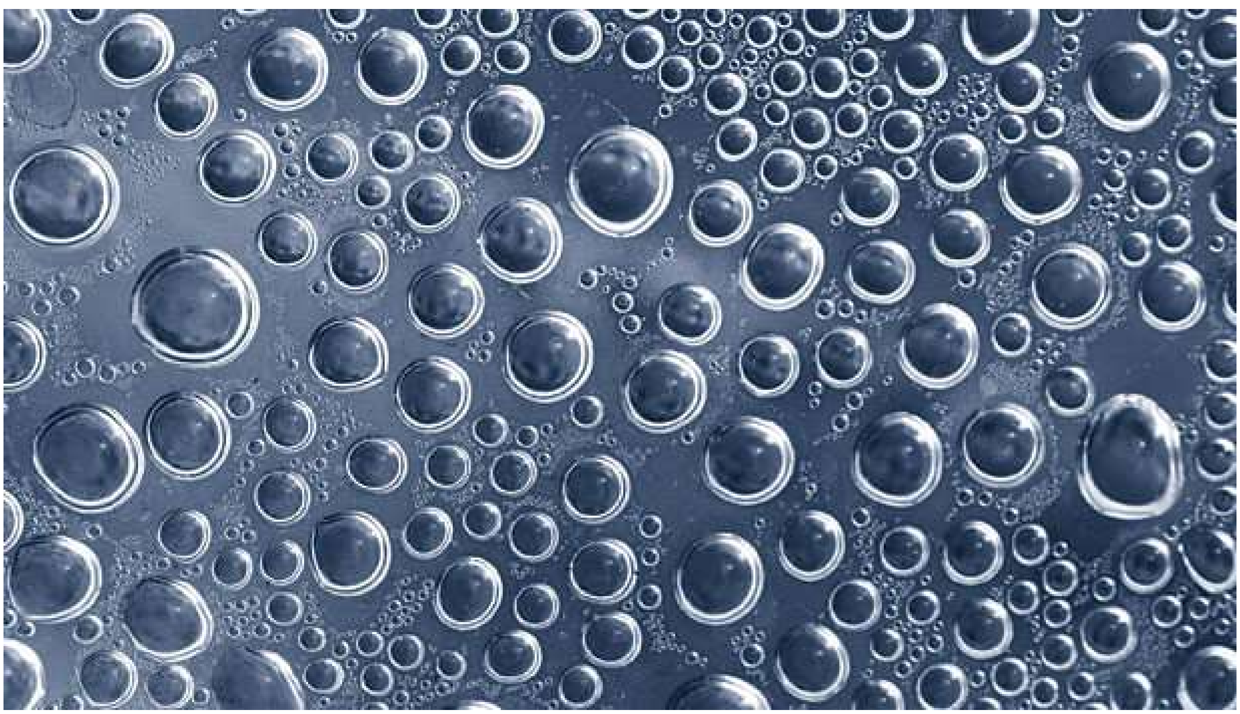
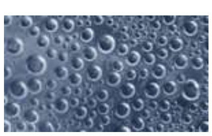
process HEATING

Knowing the Cost of Steam

How well do you know your steam costs? Is that an unloaded, modified unloaded or loaded calculation? The true cost of steam may be much more than you think.





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

- 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; alternately, unfeasible projects may be approved for implementation.
- To serve as a basis for optimizing the steam generation system and minimizing costs.
- 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 do not have steam cost benchmarked. Knowing the loaded steam cost is the most important steam cost for any steam system management program.

Many factors in the steam system will affect the cost of steam. A large percentage of the varying factors can be changed or improved based on a proactive steam management program. Some of the factors that can affect steam cost are:

- **Fuel Cost.** Lower cost fuels will provide a lower steam cost.
- **Operating Steam Pressure.** Lower operating steam pressures will provide a lower steam cost. Higher operating steam pressures will require more energy to produce the steam. Steam pressures should be reviewed to ensure the steam pressure is at the optimum pressure to meet the plant's process requirements.
- **Percentage of Makeup Water or Percentage of Condensate Return.** Normal condensate return will have a higher BTU content than makeup water. Modern plants use 90 percent as the industrial benchmark for condensate return if the plant is not injecting steam for the process.
- 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 the ASME boiler performance test code (PTC 4.1).

Unloaded Steam Cost vs. Loaded Steam Cost

Two methods can be used to calculate steam cost: unloaded or loaded. The unloaded steam cost, which only reviews the boiler operation — steam BTU, feedwater BTU, boiler efficiency and fuel cost — is the simplest steam cost method to calculate. By contrast, loaded steam cost takes into account 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 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 unloaded steam costs (SC):

$$SC = \frac{a_F \times (H_G - H_F)}{1{,}000 - \eta_B}$$

where:

SC is the unloaded steam cost.

a_F is the fuel cost in dollars per thousand BTU ($/MMBTU).

H_G is the enthalpy of steam in BTU/lb.

H_F is the enthalpy of boiler feedwater in BTU/lb.

h_B is the true boiler efficiency (ASME PTC 4.1) percentage.

1,000 is included because steam cost is measured in units of 1,000 lb/hr.

True boiler efficiency (h_B) takes into consideration all aspects that influence boiler efficiency, including:

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

ASME PTC 4.1 provides additional calculation details (figure 1).

A few examples will help illustrate how to calculate the cost of steam.

The first steam cost example will use one steam generator (boiler), a single fuel and one steam pressure. In the example, for the unloaded steam cost calculation, I will use the deaerator feedwater BTU content, which does not consider makeup water or condensate return. Also, the calculation only will use one boiler efficiency.

For the example, assume 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 percent. Under those conditions:

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

$$SC = \$11.67 \text{ per } 1{,}000 \text{ lb}$$

Of course, that cost is the unloaded cost. Now I will look at ways to improve it.

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 it should be considered when calculating the unloaded steam cost.

The limitation to the unloaded steam cost calculation is the fact that 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 vs. using makeup 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:

- **Gravity or Atmospheric (GR).** The condensate return pressure is maintained at or close to 0 psig.
- **Low Pressure (LP).** Condensate return pressure is between 1 to 15 psig.
- **Medium Pressure (MP).** Condensate return pressure is being returned between 16 to 99 psig.
- **High Pressure (HP).** Condensate return pressure is returned at 100 psig or higher.
- **Makeup Water (MW).** Water is 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 with a better understanding 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

In this second example, assume steam again is being generated at 100 psig. Furthermore, assume 60 percent of the condensate is being returned through an atmospheric return system, 20 percent is being returned through a 10 psig return system, and the remaining 20 percent is using makeup water at 60°F (15.5°C). Again, the fuel cost is $9.50/MMBTU, and boiler efficiency is 80 percent.

First, begin by calculating a modified enthalpy of the boiler water:

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

$h_f = 155.2$ BTU/lb

Now that more accurate enthalpy value has been calculated, we can use that to calculate steam cost:

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

SC = $12.29 per 1,000 lb

Using the calculated enthalpy value for boiler water better reflects the actual costs for this plant than the unloaded calculation could (figure 2).

Loaded Cost of Steam

Ultimately, a loaded steam cost is the preferred method for plant accountability with today's energy costs. The loaded cost of steam takes into account many different factors related to steam generation. The fees and costs include:

- Electrical power.
- Chemicals.
- Water and sewer.
- Emissions payments.
- Labor.
- Management.
- Operations.
- Maintenance.
- Waste disposal.
- New projects.

The loaded cost of steam provides a much more accurate cost for steam production, and the loaded steam cost value will provide more clarity when evaluating production costs, utility billing issues and energy-efficiency projects.

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

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