Performing a Steam System Checkup: A Three-Step Checkup Identifies Potential Opportunities for Improvements

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Everyone knows the value of visiting the doctor for a yearly physical checkup. However, sometimes people put off this checkup – risking health problems.

To protect steam systems and ward off potential problems, operators and plant energy managers need to perform a "checkup" on their steam system. This checkup can improve the productivity and profitability of plant operations and/or assess the status of operations.

The Department of Energy (DOE) Office of Industrial Technology's (OIT) BestPractices Steam effort is developing a set of steam survey guidelines to help steam users evaluate and improve their steam systems. The guidelines focus on improvements steam users can make without relying on the help of outside consultants. Circumstances that warrant outside assistance are also identified.

Improvement opportunities in the areas of boiler efficiency, steam generation, steam distribution, steam utilization, steam losses, and heat and condensate recovery are discussed. Sample calculations and methods for estimating improvement opportunities are presented.

Plants can benefit from a three-step steam system checkup process that includes:

- Steam system profiling.
- Identifying potential opportunities for improvement.
- Reviewing maintenance practices.

The BestPractices guidelines discuss steam system profiling and identify opportunities for improvement. Maintenance practice review goes a step beyond the guidelines to ensure the plant retains any improvements.

Steam System Profiling

Profiling issues focus on utility/steam costs and calculating benefits of improvements. In steam system profiling, the first step involves a series of questions to gain a better understanding of the steam system:

- Is the fuel cost for generating steam in the system known and measured?
- Are steam/product benchmarks known and measured?
- Are critical steam system operational parameters measured?

Fuel Cost For Generating Steam

Determining the fuel cost to make steam at a facility can be an eye-opener. In many steam systems, the fuel cost can be 80% or more of the total cost to operate the steam system.

For example, if an industrial boiler generates 100,000 pounds (lb) of steam per hour, and the fuel cost to make steam is $4.00 per 1,000 lb., then the total cost for continuous steam generation for one year would be $3.5 million. If 10 percent of the fuel costs could be cut each year through operating improvements, $350,000 could be saved in energy costs.

Two methods can be used to calculate fuel costs to generate steam. The first entails calculating the fuel price, fuel energy content, steam production rate, steam energy addition and boiler efficiency. The second entails calculating the fuel feed rate per hour and the fuel price. Both methods provide a benchmark for the magnitude of energy savings possible in a steam system.

Steam/Product Benchmarking

Many industrial users measure and track steam/product benchmarks – for example, the pounds of steam needed to make a given unit of product – to benchmark their productivity. They track this benchmark with what other facilities in their company do, with what their competitors do, and with how the benchmark varies in a facility over time. Steam/product benchmarking is an excellent way to monitor productivity and the possible effect of steam system improvements on productivity.

Steam System Measurements

To monitor a steam system and diagnose potential problems, it is important to measure certain key parameters. These key parameters include boiler fuel flowrate; feedwater and makeup water flow rates; chemical input flow rates; steam flow rates (out of the boiler and at key locations in the steam system); blowdown; boiler flue gas temperature, O_2 content and CO content; boiler efficiency; steam quality out of the boiler, and condensate flow rate.

Remember, what is not measured cannot be managed.

Identifying Opportunities

This section of the checkup involves a review of some of the basic areas of steam system operation. This review can provide excellent opportunities for improving steam use and operations productivity. The opportunities discussed here fall into three areas: total steam system, boiler plant and steam distribution, and end use and recovery.

Total Steam System

The following questions will help identify operating practices and improvement opportunities for a total steam system:

- Are the steam traps in the steam system correctly selected, tested, and maintained?
- Is the effectiveness of the water treatment program reviewed?
- Are the steam system's major components well insulated?
- Are steam leaks quickly identified and repaired?
- Is water hammer in the steam system detected and eliminated?

Steam traps serve three important functions in steam systems: preventing steam from escaping from the system before its heat is used; removing condensate from the system; and venting noncondensable gases. Poor steam trap selection, testing, and maintenance can result in many system problems, including water hammer, ineffective process heat transfer, steam leakage, and system corrosion. An effective steam trap selection and maintenance program often offers paybacks in less than six months.

An effective steam system water treatment program reduces the potential for waterside fouling problems in boilers; is critical to minimizing boiler blowdown and resulting energy losses; can reduce the generation of wet steam; and greatly reduces the potential for corrosion problems throughout the steam system. Most effective water treatment programs include mechanical treatment such as filtration and deaeration, as well as chemical treatment. Problems in this area can lead to equipment failure and downtime – consultation with a chemical treatment specialist on an ongoing basis is advised.

Steam system insulation – on piping, valves, fittings, and vessels – also serves many important purposes. Insulation keeps steam energy within the system to be used effectively by processes. It can reduce temperature fluctuations in the system. Insulation also helps prevent burns to personnel.

Two main approaches are used to improve steam system insulation. The first approach is to determine the economic insulation thickness required for the operations. This can be done using a tool such as 3E-Plus software. The second approach involves system insulation surveys to identify exposed surfaces that should be insulated and/or removed, as well as any disturbed or damaged insulation.

Steam leaks can result from failures associated with improper piping design, corrosion problems, and valves. In high-pressure industrial steam systems, the energy costs associated with steam leaks can be substantial.

For example, for a steam system operated continuously, a 1,000 lb-per-hour steam leak, at a steam cost of $4.00 per 1,000 lb, would mean a yearly energy loss of $35,000. This leak rate would be expected with a 3/8-inch-diameter hole in a 300-psig steam system, or a ½-inch-diameter hole in a 150-psig steam system. Steam leak repair is essential.

Water hammer in a steam system also is a serious concern. It can lead to failure and rupture of piping and valves and, in many cases, to significant injury to personnel from contact with steam and condensate.

There are two main types of water hammer. One is caused by condensate accumulation in steam distribution piping, followed by transport of this condensate by high-velocity steam. The other is caused by a pressure pulse resulting from steam collapse (rapid condensation) in condensate return lines and heat exchange equipment. Water hammer in a steam system always necessitates repair.

Boiler Plant

These questions can help identify operating practices and improvement opportunities:

- Is the boiler efficiency measured and are the trends charted?
- Is installation of heat recovery equipment on the boilers – feedwater economizers, combustion air preheaters, blowdown heat recovery – investigated?
- Is high-quality steam generated in the boilers?

First, the major sources of inefficiency in boiler operations must be identified. The major losses in a boiler are typically associated with combustion and flue gas energy losses, blowdown losses, and refractory insulation losses. Although an understanding of blowdown and refractory insulation losses is important, these losses are not as problematic as combustion and flue gas energy losses.

Second, the efficiency of the boilers must be measured, and flue gas temperature, flue gas O_2 content and flue gas CO content also must be measured regularly. Measurement and control of excess O_2 are critical to minimizing boiler combustion energy losses. Charting the flue gas temperature trends can indicate other potential problems in the boiler. For example, elevated flue gas temperatures might indicate waterside or fireside fouling problems.

Third, if the plant runs multiple boilers, it should operate them using a strategy that minimizes the total cost to generate steam for the facility. For example, one strategy would be to use the boiler that operates with the highest efficiency for the longest possible time.

In some boilers, high flue gas temperatures and high continuous blowdown rates can provide opportunities for installation of heat recovery equipment. Feedwater economizers and combustion air preheaters can be installed, under appropriate conditions, to extract excess flue gas energy and effectively increase the boiler efficiency. Blowdown heat recovery equipment can also be installed, for some systems, to extract heat from the blowdown stream that would be otherwise lost. An economic analysis is needed to determine the feasibility of the opportunity, and qualified professionals should design and install the equipment.

The quality of the boiler steam also is important. High-quality dry saturated steam has 100 percent quality (the amount of steam divided by the total water and steam, expressed as a percentage) and contains no water droplets. Wet steam has a lower quality and contains water droplets. Generating wet steam in your boiler can cause many system problems, including inefficient process heat transfer, steam trap failures, equipment failure by water hammer, corrosion, and deposits and erosion.

Some typical causes for creation of wet steam and boiler carryover are wide swings in boiler water level, reduced operating pressure, boiler overload and poor boiler total dissolved solids (TDS) control [1]. A critical step to ensuring generation of high-quality steam is to measure steam quality out of the boiler. This typically is done using a steam calorimeter.

Steam Distribution, End Use, and Recovery

These questions will help identify operating practices and improvement opportunities for steam distribution, end use, and recovery:

- Can pressure reducing valves (PRVs) be replaced with backpressure turbines in the steam system?
- Are steam end-user needs being considered?
- How much available condensate is recovered and used?
- Is high-pressure condensate being utilized to produce usable low-pressure steam?

In many steam systems, PRVs are used to provide steam at pressures lower than those generated from the boiler. A steam system potentially can be improved by minimizing the flow of steam through PRVs. One way to do this is to replace PRVs with backpressure turbines that provide low-pressure steam and generate electricity for use. Detailed economic and engineering feasibility analyses must be performed to evaluate this type of opportunity.

Steam end-user needs also must be considered. In many industrial steam systems, process steam users are being asked to handle different product parameters, including weights and dryness, process temperatures and process flows. At the same time, they are required to maintain safe and efficient operations. Steam process operators need to attend to proper equipment installation and process control, measurement of process inputs and outputs, and measurement of individual product metrics (unit of product per pound of steam needed).

Recovering and returning a substantial portion of your condensate to the boiler can have both energy and chemical treatment benefits. Condensate is hotter than makeup water, so less energy is required to convert condensate to steam. Condensate also requires significantly less chemical treatment than makeup water, so chemical treatment costs associated with returning condensate are reduced. Increased condensate return also can reduce boiler blowdown, because fewer impurities are resident in condensate, and minimize blowdown energy losses.

Reviewing Maintenance Practices

If an effective system maintenance program is in place, the operating practices and operational improvements discussed here can provide benefits to plant steam operations year after year. Major areas requiring maintenance include steam traps; boiler performance; water treatment; piping, heat exchangers, pumps, motors, and valves; and thermal insulation.

Conclusion

This article includes only some of the critical steam system areas that should be monitored and reviewed. Other important resources for improving operations include steam system consultants and service providers who can perform system assessments, troubleshoot performance problems and identify additional improvement opportunities. The DOE BestPractices Steam effort also offers tools and resources to assist steam users in improving their operations. These resources are available on DOE's website at www.oit.doe.gov/bestpractices/steam.

References

1. Glenn Hahn, October 1999. "Not-So-Candid Camera," *Engineered Systems*, pp. 80.

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