Steam Balancing: The First Step in Steam Optimization

The ability to achieve an optimal steam balance can help to improve the overall thermal cycle efficiency of any steam-production system

Kelly Paffel
Inveno Engineering, LLC

IN BRIEF

THE CHALLENGE AT HAND

ACHIEVING A STEAM BALANCE

END RESULTS OF A STEAM BALANCE

WHAT A STEAM BALANCE PROVIDES

STEPS FOR A STEAM BALANCE

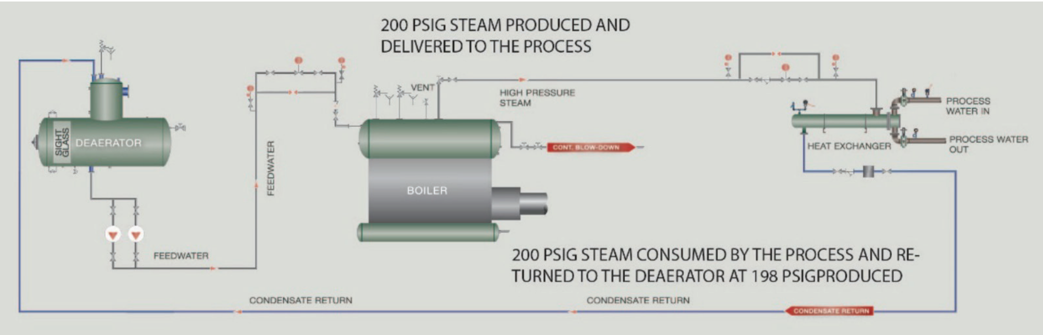

FIGURE 1. Shown here is a perfect steam balance. This scenario is an aspirational goal for process operators

In any chemical process plant that produces steam, carrying out a steam balance is the most efficient way to improve knowledge of all aspects of the overall steam system, including steam generation, distribution, end users and condensate-recovery systems. Carrying out a steam balance is a necessary first step in any effort to optimize and manage overall steam generation.

For instance, the valuable knowledge gained from developing or updating a steam balance can help process engineers to develop a road map that will allow the steam system to be used in the most efficient way. Such an effort also provides essential insight that can increase the overall thermal-cycle efficiency of the steam-generation system. Ideally, every plant should strive to achieve the highest possible thermal-cycle efficiency; the steam balance provides the information needed to achieve this objective.

An optimal steam balance ensures that the end users — that is, the steam-consuming processes — can consume the correct amount of energy at the correct steam pressure and temperature, with the required steam quality. A system that has achieved an optimal steam balance has no energy losses that might otherwise occur from steam leakage, excessive low-pressure steam venting, flash steam venting and condensate loss.

Establishing the correct steam balance can be very challenging because so many different dynamics are at work in any given steam system. These include modulating steam loads, variable production times, unaccountable losses, insulation inefficiencies, turbine operation and more.

Figure 1 shows a nearly perfect steam balance, which produces steam at 200 psig and delivers it to the process. The process consumes the entire 200 psig (latent energy) of the steam while the condensate (sensible energy) is removed from the process. The end user's process requires the latent energy contained in the steam. When that latent steam is released, there is no temperature or pressure variance, and the condensate that contains the sensible energy is returned to the deaerator operation at a pressure of 30 psig or higher. The condensate system that is operating at 198 psig returns the condensate (using a high-pressure return system)

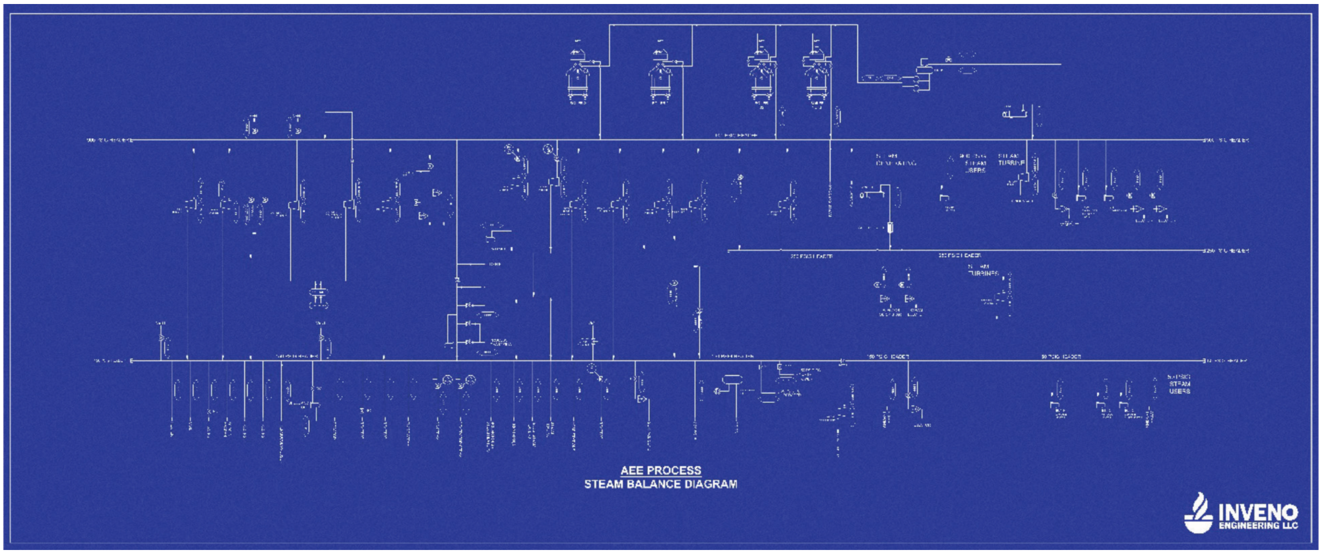

FIGURE 2. In the steam balance shown here, a few minor changes to the steam piping allowed low-pressure steam to be consumed by the end users, thereby reducing the flash steam losses, improving condensate drainage and further reducing the flash steam venting

back to a high-pressure deaerator system. This dearator system delivers the feedwater at an elevated temperature (198 psig = 387°F) into the boiler

An optimal steam balance can achieve the following objectives:

1. Ensure high sensible energy content in the condensate
2. Reduce flash steam
   a. Eliminate the need for flash steam recovery (The deaerator will consume the small percentage of flash steam)
3. Allow for smaller-diameter condensate piping
4. Enable higher feedwater temperatures, and thus a higher boiler efficiency
5. Yield higher thermal-cycle efficiency for the steam system

The ideal system shown in Figure 1 example is hard to achieve due to the actual process conditions and the design of the condensate-drainage system (using steam traps or condensate control valves), which

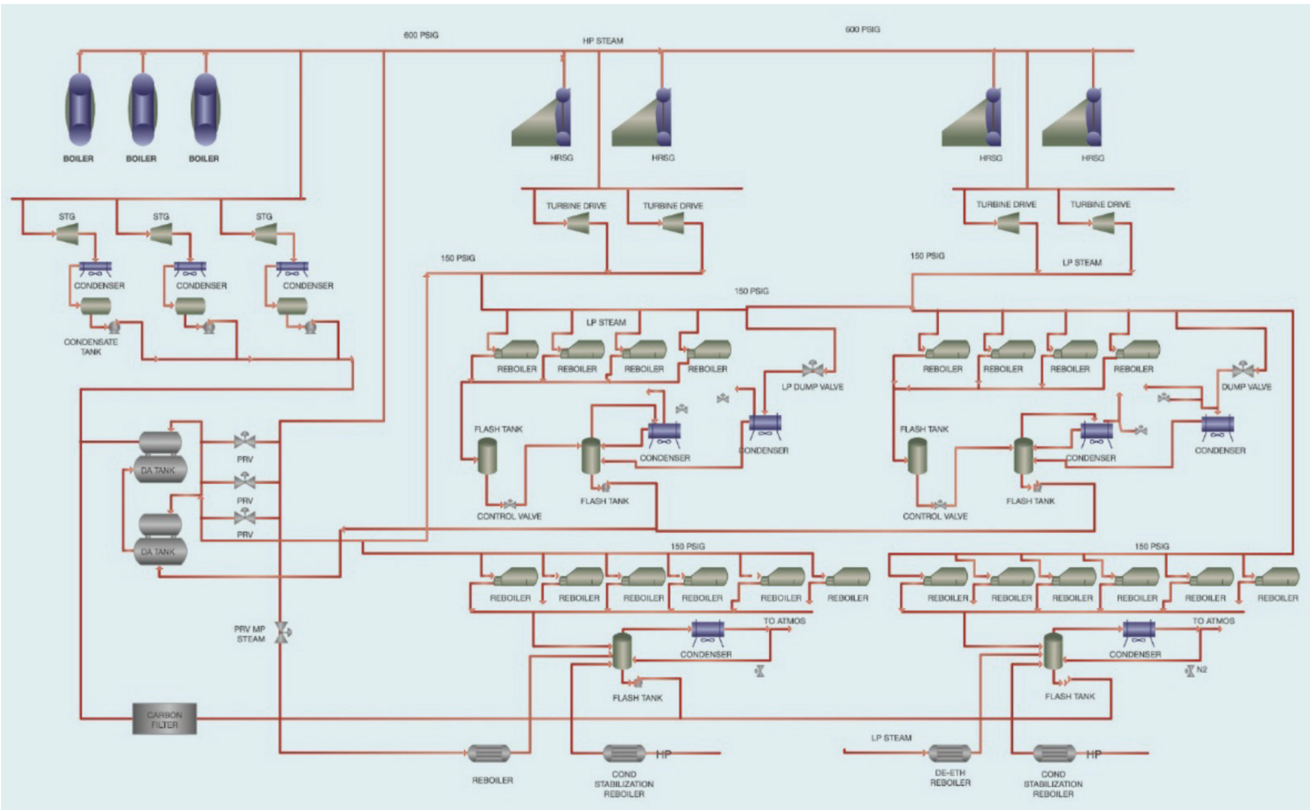

FIGURE 3. Different methods can be used to recover the condensate under pressure, thus saving energy and reducing emissions for the plant operation. For instance, switching from a low-pressure deaerator to a high-pressure deaerator, with some changes to the condensate line, allowed the return of condensate from non-modulating processes to the high-pressure deaerator, resulting in higher thermal-cycle efficiency for the steam system

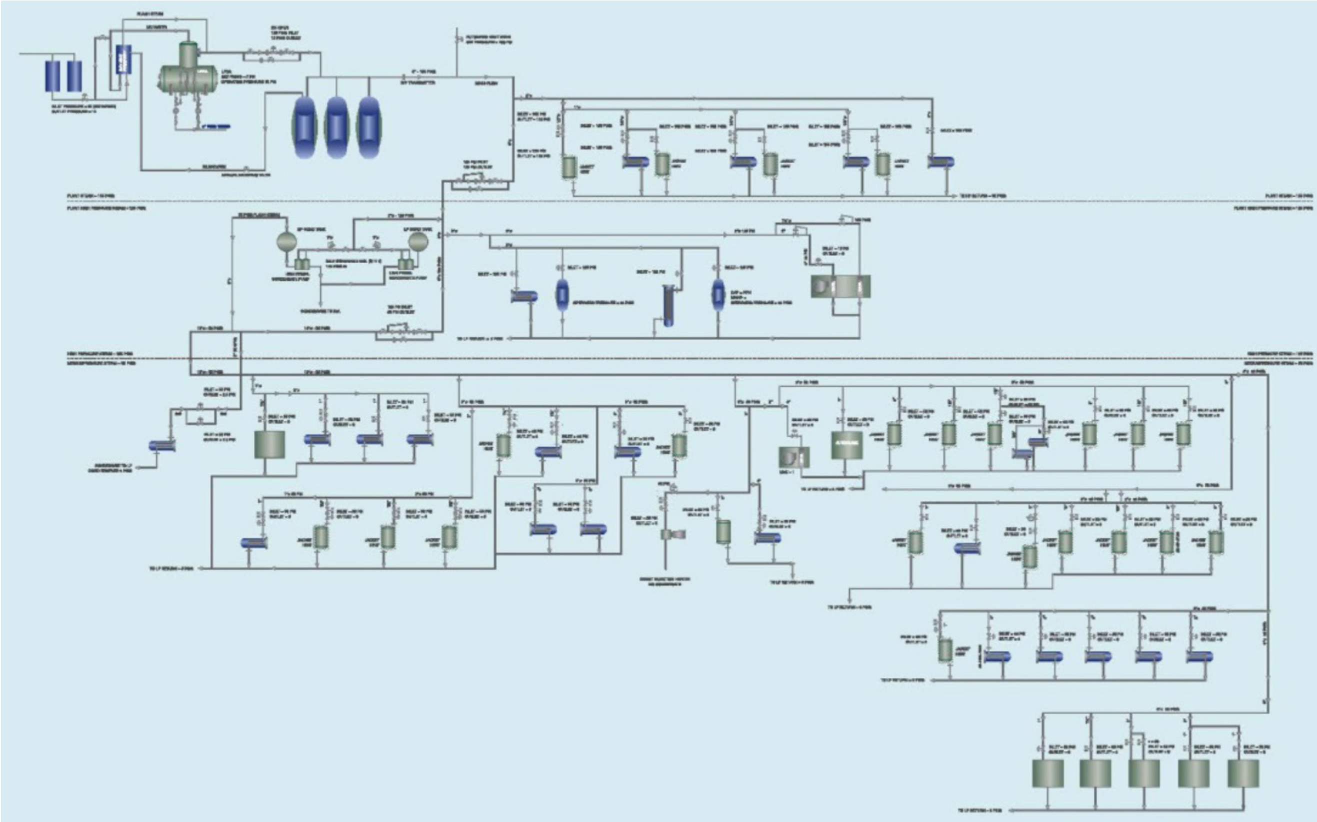

FIGURE 4. A steam-balance flow document provides all the required steam and condensate information, capturing relevant information about the steam flows, pressures, end users, pressure-reduction stations, turbines, boilers, condensate tanks and more

need different pressures to remove the condensate from the process devices. To achieve a high thermal-cycle efficiency for the steam system, the plant should strive to achieve a steam system with a condensate system that operates at a high elevated pressure (as shown in Figure 1).

In reality, a perfect steam balance cannot really exist for several reasons. First, modulated steam pressures or steam flows to the process will reduce the differential pressures for the devices in the condensate drain (such as the steam trap stations or condensate control valve). Also, the economics of such condensate-drain devices will change (in terms of an increase in size and cost) at lower operating pressure differentials. For example, the condensate system dynamics can limit the plant in terms of how

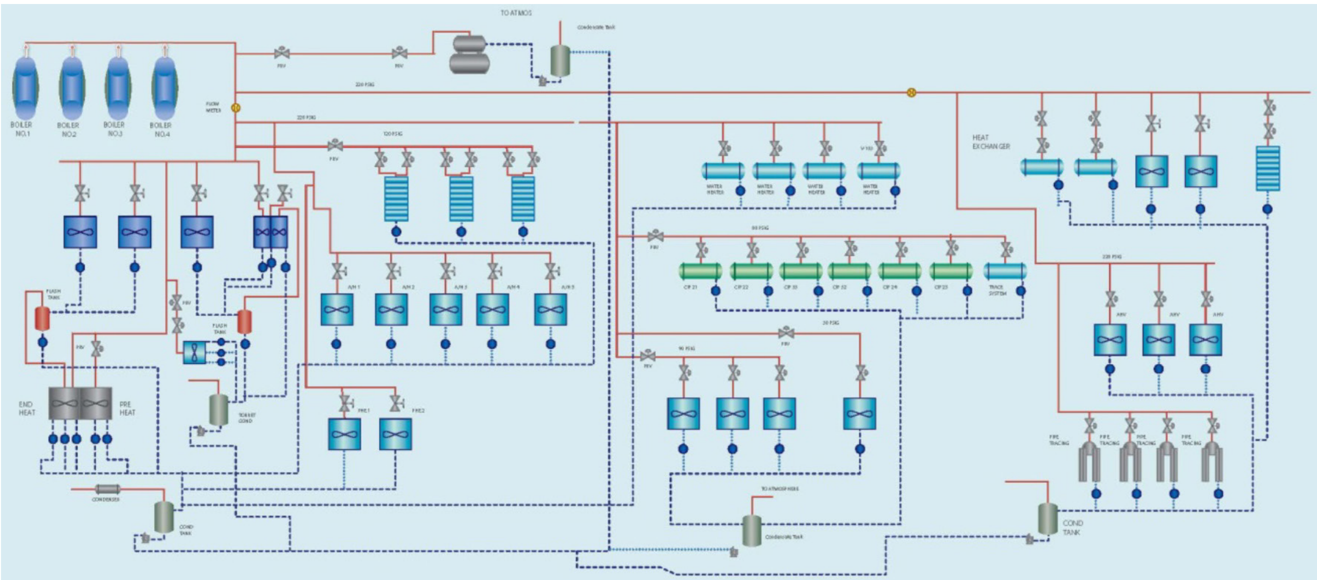

FIGURE 5. A system that has achieved an optimal steam balance has no energy losses that might otherwise occur from steam leakage, excessive low-pressure steam venting, flash steam venting, condensate loss and more

high the condensate pressure can be maintained in the condensate-return system.

The consumers (end users) of the steam have their own demand for the required quantity and they expect 100% steam quality at a given specific pressure and temperature. It is up to the plant to manage the steam balance in a way that meets end users' requirements. However, that is easier said than done, because the end users' steam demand constantly varies during operation of the steam system. Achieving high thermal-cycle efficiency for the steam system requires that operators develop a well-documented steam balance.

The challenge at hand

Too often, knowledge of the steam system gets segmented. For instance, the boiler plant personnel have deep knowledge of how to operate the boiler plant, while process personnel have a deep understanding of the how to operate the process steam system. Sometimes, the steam distribution and condensate system are not considered a focus area in the steam-system operation. Similarly, too often, the condensate system is omitted from the total steam-system balance, even though this part of the system accounts for roughly 16% of the overall energy in the steam vapor. Striving to achieve a proper steam balance allows process operators to understand and recover the flash steam by some means, to ensure a high steam thermal cycle efficiency.

The typical steam system has a large number of different piping and instrumentation diagrams (P&ID) prints, which are often located somewhere in the facility (but not necessarily stored in a centralized or organized fashion). For many facilities, such diagrams are often established over many years, by many different engineers, with different formats, thus making it difficult to establish a single or dual set of prints. Computer-aided drawing (CAD) prints are generally not kept updated, which makes the task even more difficult to accomplish. Nonetheless, the effort to develop and maintain a current steam balance print can provide significant payback.

Achieving a steam balance

In general, it is impossible to optimize a steam and condensate system without a steam balance, and this requires a complete understanding of the system. The easiest and best way to truly understand the steam system is to create a steam balance flow diagram.

The steam-balance flow diagram can be accomplished in many different ways, such as a fully devolved document completed in different technical software systems, or a simple flow diagram completed with a basic graphics program. The key point is to develop a steam-balance document that plant personnel can use, such as that shown in Figure 2.

End results of a steam balance

Implementing a perfect steam balance — one that accounts for steam generation, distribution, end-user requirements and condensate recovery — can be an extremely challenging goal in any industrial steam plant operation. An industrial plant can have several different steam-generating sources and a multitude of end users with varying steam pressure and steam flow demands. The steam turbine operation for electrical generation or drive units play an important part of the balance, and the operation of the steam-pressure-letdown valves (pressure-reducing valves) needs to be minimized to ensure maximum steam flow to the steam turbine operation.

Four types of condensate-recovery systems are typically added into the balance, making the system dynamics even more complex. To meet production requirements, plants typically continue to update and make process changes over time, and all such changes will affect the steam balance. Therefore, steam balancing must be viewed as a continuous program — not a one-time effort.

A proper steam balance will also eliminate the waste associated with venting "unusable" low-pressure steam to the atmosphere, by instead balancing the steam flow more effectively to the end users (steam turbines, heat exchangers, reboilers) and then discharging the condensate/flash steam to the downstream steam cascade systems. This results in a final steam process that has the correct amount of low-pressure steam. If such a cascade system cannot be accomplished, then the operator may opt to use a thermocompressor to upgrade the low-pressure steam to medium-steam-pressure grids until the desired balance is achieved in the system.

Steam balance example 1. The following steam balance (Figure 1) was accomplished in a simple software graphics program format, but it resulted in a substantial reduction in energy and emissions. The steam balance indicated that a pressurized condensate system could easily be instituted into segments of the process system using the current condensate system, incurring relatively minor capital costs but saving millions of dollars per year over the long run.

Steam balance example 2. The second example steam balance, shown in Figure 2, determined that a few minor steam-piping changes allowed low steam pressures to be consumed by end users, thus reducing the flash steam losses. The changes improved condensate drainage and further reduced the flash steam venting. The result was increased steam system thermal-cycle efficiency with a reduction in energy and emissions and increased overall reliability.

Steam balance example 3. Figure 3 shows different methods to recover the condensate under pressure, which can help save energy and reduce emissions for the plant operation. Switching from a low-pressure deaerator to a high-pressure deaerator, with some changes to the condensate line, allowed the return of condensate from non-modulating processes to the high-pressure deaerator, resulting in higher steam system cycle efficiency.

What a steam balance provides

1. Improved knowledge of the steam

and condensate system
2. Ability to set a roadmap for change to improve system performance
3. Increased energy efficiency
4. Reduced emissions
5. Increased reliability

Steps for a steam balance

A steam-balance flow document (such as those shown in Figures 4 and 5) provides all the required steam and condensate information, capturing relevant information about the steam flows, pressures, end users, pressure-reduction stations, turbines, boilers, condensate tanks and more. The more detail added into a steam-balance flow diagram, the more important and valuable the document becomes to the plant operation.

Shown below are some of the essential items that should be properly documented during the process:

1. All boilers or steam generators
   a. Steam output
   b. Operating steam pressures
   c. Safety valve set pressures
2. Deaerator system details
   a. Operating pressures
   b. Steam flows
3. Makeup water system for the deaerator
   a. Flowrates
   b. Average temperatures
4. Steam turbines
   a. Supply pressures
   b. Extraction pressures
   c. Electrical or drive output
5. Steam headers by operating pressure
6. Steam pressure-letdown stations
   a. Inlet and outlet pressures
   b. Maximum and minimum flowrates
7. End users or consumers
   a. Energy requirements (Maximum and minimum)
8. Condensate headers
   a. Operating pressures
   b. Flowrates
9. Flash tanks
   a. Integration into the system
   b. ASME stamping
10. Condensate tanks
   a. Venting or not venting
   b. Pressure ratings
11. Other site-specific details that can help support the project

The list will grow as the steam balance process continues.

Closing thoughts

Every plant, regardless of size, from a small food processing plant to a large petroleum refinery, needs to prepare a steam balance in a format that works to support the plant's operation. Conducting a steam balance does not necessarily require a complex software system in order to be beneficial to the steam system manager; rather, it can be accomplished using a simple graphic software package. Whatever method is selected, carrying out a steam balance is the first step in increasing overall steam system thermal-cycle efficiency, which will reduce energy use and emissions and increase overall system efficiency. ■

Edited by Suzanne Shelley

Author

Kelly Paffel currently serves as technical manager at steam engineering firm Inveno Engineering, LLC (7320 East Fletcher Ave, Tampa, FL 33637; Phone: 239-289-3667; Email: kelly.paffel@invenoeng.com). Paffel has 41 years of experience in steam and power operations and is an experienced lecturer who has published many technical papers on the topics of steam system design and operation. He is known for writing "Steam System Best Practices," which are used by plants and engineers globally to ensure proper operation of steam and condensate systems.