# Heat Balance Review for Double-digit Savings

## Boiler/steam/condensate cycle holds key to energy savings

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The days of passing on to customers the cost of now seemingly negligible fuel price increases are but a distant memory. To remain competitive in this age of record high fuel costs, energy users must take a hard look at their fuel consumption and find ways to optimize it.

Although economizers, heat exchangers, low-oxygen burners, insulation, and the like are excellent means of reducing fuel consumption and worthy of consideration, without a doubt the most productive place to start looking for maximum fuel/energy savings – the one offering the greatest return on investment – is the boiler/steam/condensate cycle. Unless plant heat balance is correct, unreclaimed flash steam and hot condensate represent significant – in fact, the greatest – heat loss. Consider that fuel loss from a 15 pounds per square inch gauge (psig) open condensate system can amount to six percent of the fuel required to produce steam. In a 100 psig system, the fuel loss is 19 percent. With a well-designed closed condensate system, payback can be a matter of months, if not less.

### Energy Requirements

The easiest and most logical way to review plant heat balance is to observe plant operation. Go to the roof and see if steam is being wasted to the atmosphere; if it is, determine the source. Check the process(es) for the loss of potentially recoverable condensate.

While the observation of plant operation may reveal large "holes," it does not tell the entire story. For instance, consider a paper corrugation plant in which steam is utilized at 175 psig by a machine operating in a closed cycle. Live steam is consumed for the plasticization of paper prior to corrugation, but the heat balance is such that considerable positive pressure is left over. It is not unusual to see a plant of this type blasting steam into the atmosphere to keep production processes in motion.

Another example is a canning plant, where food is prepared inside of large atmospheric hot water cookers. Prior to 1980, water for the cookers was heated through the direct injection of steam. With the introduction of heat exchangers and the return of condensate in a trapless closed-loop system, a savings of 18 percent could be realized. When fuel costs 3.5 cents per therm, such a conversion was difficult to justify for a seasonal operation, but with impending fuel costs of 70 cents or more per therm, payback can be a matter of weeks.

Having failed to review their energy requirements, many industries now are realizing the fuel dollars they throw away (condensate to drain) or let go up in smoke (flash steam).

### Actual Losses

Table 1 shows actual volume, total heat, and fuel losses at various pressures. The "Total heat lost to flashing" column indicates heat loss attributable to the need to replace lost flash steam with makeup at 60 degrees Fahrenheit (F). The real eye opener, though, is the fuel required to regenerate this lost heat in a boiler operating at 80 percent efficiency ("Fuel lost in replacement of lost heat" column). With a closed-loop system, these fuel loss percentages are direct fuel savings.

Table 1 is not entirely accurate because it fails to take into account such uncalculable losses as increased blowdown, increased chemical use, cost of makeup water, sewer cost, and water required by some municipalities to cool blowdown.

**Table 1. Volume, Total Heat, and Fuel Losses at Various Pressures**

| System pressure, psig | Volume lost to flashing, percent | Total heat lost to flashing, percent* | Fuel lost in replacement of lost heat, percent** |
|---|---|---|---|
| 15 | 4 | 5 | 6 |
| 50 | 9 | 10 | 13 |
| 100 | 13 | 15 | 19 |
| 150 | 16 | 18 | 23 |
| 200 | 18 | 21 | 26 |
| 250 | 20 | 23 | 29 |

*Based on the replacement of lost flash steam with makeup at 60˚F.
**Based on the regeneration of lost heat in a boiler operating at 80-percent efficiency.

## Heat Balance Categories

There are two types of heat balance: one based on a plant's current operating condition, and the other based on a plant's optimum energy use. Most plants fall into one of three basic categories:

- Category 1: All steam is used by the process and is unrecoverable because of direct injection, contamination, or impracticality. An aggregate plant, a steam vacuum jet, and a pressure cooker with potentially contaminated steam are good examples.
- Category 2: Most or all condensate is recoverable, and the average feedwater temperature is considerably higher than the feedwater system operating pressure. Rendering plants, plywood plants, corrugators, and rubber plants are good examples.
- Category 3: Only a portion of the condensate is recoverable, and the heat balance is less than 212 degrees F. Canneries, chemical plants, and paper mills are examples.

With category 1 plants, it is important that the possibility of the conversion of unrecoverable cycles to recoverable ones be considered. For instance, a vacuum pump may pay for itself by eliminating a wasteful steam jet. Heat exchangers can be used in place of the direct injection of steam. Lost condensate attributable to impracticality suddenly may become cost-effective.

A category 2 plant calls for a closed condensate system. This type of plant usually produces a large amount of flash steam that, unless utilized, results in a high degree of inefficiency. The utmost care is required not only to select components suitable for the pressures and temperatures involved, but to tailor the system to the plant. It is important that systems personnel be familiar with the process and production equipment involved. Sometimes, the increased production possible with a closed-loop system can exceed the fuel savings.

Although there appears to be no savings potential with category 3 plants, close scrutiny reveals hard-to-detect losses, such as condensate coolers and atmospheric trapped condensate systems, which can be closed for better heat utilization. Furthermore, a well-designed trapless closed-loop system can increase production significantly by enabling unrestricted drainage and continuous removal of non-condensable gases for maximum heat transfer.

## Types of Systems

With so many processes employing steam, no single system can be expected to handle every variable. Six fairly basic systems that can be used individually or in combination to close a steam/condensate loop and save all of the available flash steam and British thermal units (Btus) lost to the atmosphere are shown in Figures 1 through 6.

Figure 1 illustrates an approach to saving heat by which condensate is pumped directly back to a boiler. This approach is not responsive to gas removal, which is extremely important for maximum heat transfer. The pump operates continuously in a semi-steam binding condition, which usually results in considerable maintenance.

Figure 2 illustrates a variation of the direct pumping concept, with pump discharge modulated in exact proportion to condensate flow and operating with a flooded suction at all times. Excellent gas removal maximizes production, while the absence of traps enhances condensate flow and speeds startup. Selection of a pump with an extremely low net positive suction head is critical.

Figures 3 through 6 illustrate pressurized boiler feedwater systems, which consist of a receiver operating at a controlled pressure usually at or slightly higher than the plant heat balance. These systems save energy by not only conserving all high-pressure condensate, but reducing pump horsepower requirements with their additional suction pressure. Annual savings per horsepower are at or near $500. Because makeup is minimal in a properly designed closed-loop condensate system utilizing a pressurized boiler feedwater system, a smaller deaerator, one sized for actual requirements, usually is incorporated. Often, existing feedwater systems can be used.

*Continued on page 12*

**Figure 1. Direct Pumping System Augmenting Boiler Feed System**

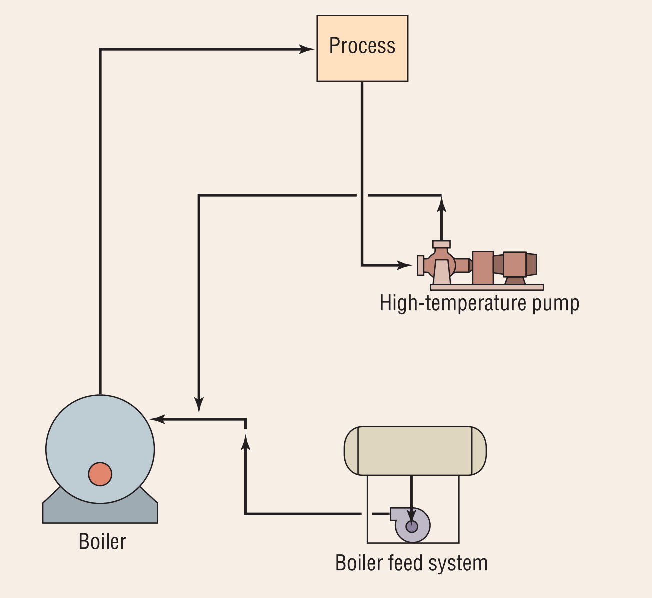
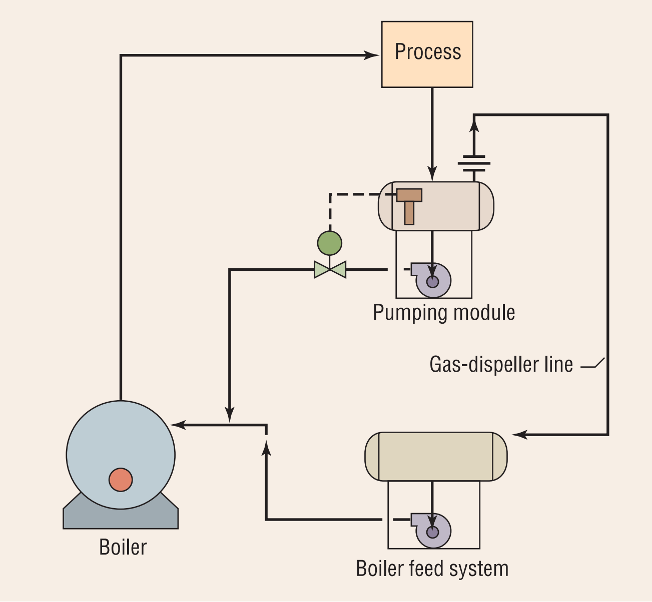


**Figure 2. Direct Pumping System with Modulated Discharge and Gas-dispeller Line**



**Heat Balance** *Continued from page 11*

Figure 3 illustrates a drainage module used for a typical process. The module incorporates a pressure insensitive system that senses inflow and automatically adjusts outflow to match. Because the module does not have a fixed orifice, such as a trap, high-pressure drops are not necessary for good drainage. The module can drain to a pressurized feedwater system with very little differential. Depending on the processes involved and the plant's configuration, several modules may be used in conjunction with the system.

The system in Figure 4 is similar to the one in Figure 3, except the modules are equipped with pumps (for processes with variable pressures) or temperature controls. The pumps continuously evacuate process condensate, regardless of pressure.

In the system illustrated in Figure 5, several processes operate at a common pressure. Process equipment is drained first to a common receiver, then in a single line to a remotely located pressurized feedwater system. Good pressure control enables this single line to operate overhead and drain to a receiver located above grade. Excellent non-condensable gas removal is characteristic of this type of system.

Figure 6 illustrates a typical process that uses steam at several pressures. The cascading of flash steam from the high-pressure process to the low-pressure process enables the use of a less expensive type of pump at the condensate system. Flash steam from the high-pressure process often provides a significant portion of the steam for the low-pressure process.

The systems in Figures 1 through 6 are merely the tip of the iceberg. Variations and combinations are innumerable and impossible to apply without a good plant survey.

## Needed Information

A plant survey requires information in two basic areas: plant operation and boiler room.

Detailed information on plant operation is needed to determine heat balance and required equipment. Particularly difficult to obtain is the actual operating pressure of process equipment. If, for instance, a boiler operating at 150 psig supplies steam to a process with no pressure reduction or temperature control, the operating pressure is 150 psig. If a pressure reducing valve is included, the operating pressure will be the downstream pressure relief valve set pressure. A temperature control located at the steam inlet of the process equipment functions as a variable pressure-control system. Process pressure can vary between full line pressure and negative pressure, depending on the process load, temperature, etc. Sometimes, the only way to determine the average operating pressure of a temperature controlled process is to log the pressure at the inlet to the trap on the equipment in question.

Also important to know when performing a plant survey is where components are located in relation to one another and the boiler room, the steam consumption of each piece of equipment, and the height of the condensate outlet above the floor. Boiler room information is a must if new condensate equipment is to be incorporated into an existing operation. Boiler operating pressure, feedwater regulation, hours of operation, and cost of fuel is other information necessary for proper planning of an integrated closed boiler feedwater system.

## Determining Heat Balance

Heat balance is not difficult to determine. What one needs to know is the average steam load and the percentage distributed to the various users.

Consider, for example, a typical steam load of 50,000 pounds (lb.) per hour (1,500 horsepower) at an operating pressure of 150 psig, of which 20 percent is lost to process or flashing, 60 percent is returned at full pressure, and 20

**Figure 3. Pressurized Boiler Feedwater System with Process Operating at Boiler Pressure**

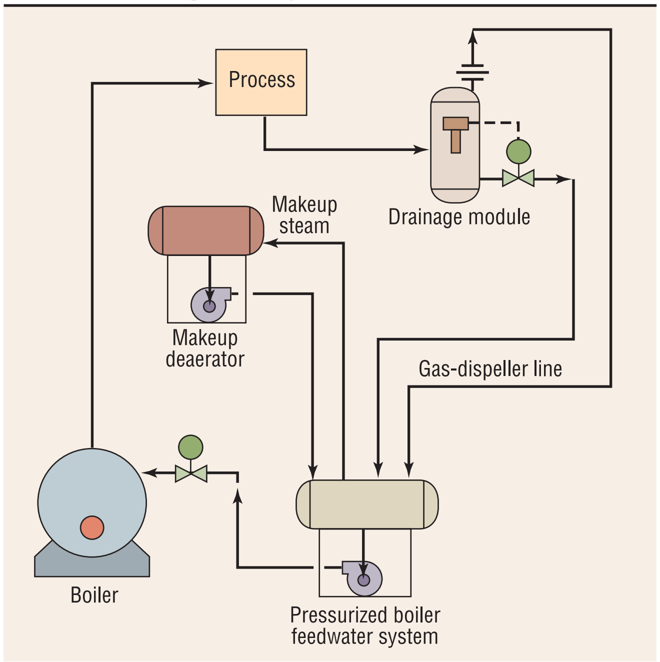
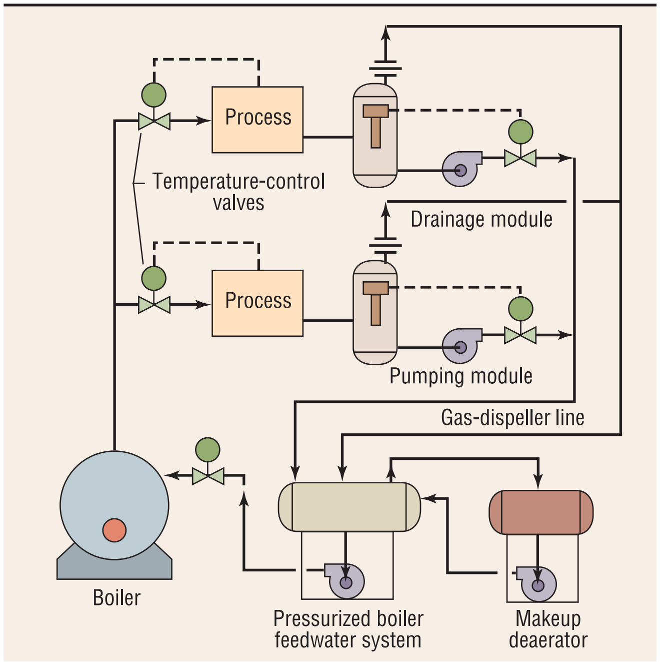


**Figure 4. Pressurized Boiler Feedwater System with Pumping Modules for Temperature Controlled Systems Operating at Variable Pressures**



percent is returned from a temperature controlled system with an average pressure of 65 psig. Suppose that all condensate is being saved.

As can be seen in Table 2, the average feedwater temperature is 181.6 degrees F. After the cycle is closed, it is 328.3 degrees F. An increase in feedwater temperature of approximately 10 degrees F results in fuel savings of one percent. This can be taken as an increase in boiler capacity or a reduction in firing. For instance, the calculation in Table 2 indicates:

- a nearly 15 percent savings in fuel at 50,000 lb. per hour, or, in other words, that the same amount of production could be accomplished at 42,500 lb. per hour;
- an increase in boiler capacity to nearly 59,000 lb. per hour.

If the plant wasted all of its condensate to drain (no returns), the total heat lost would be 31.5 percent instead of 15 percent.

## Fuel Savings

From the above results, calculating actual dollar savings is easy. Assuming a cost of 80 cents per therm ($8 per million Btu), the savings per hour would be:

- Input (Btu per hour) × percent savings × cost per therm ÷ 100,000 Btu per therm
- Input = output ÷ boiler efficiency
  (50,000,000 ÷ 0.80) × 0.15 × 0.80 ÷ 100,000 = $75

Assuming the average 3,000 hours of operation per year, annual savings amount to $225,000.

## Summary

Closing a condensate cycle to capture every available Btu typically results in double-digit fuel savings. Proper selection of condensate system components is vital to the maximization of savings. If applied properly, efficient condensate drainage, along with the continuous removal of gases, can increase production and result in savings beyond calculable fuel savings. Good trapless systems result in faster startup, reduced batch times, hotter surfaces, and measurably improved heat transfer. Review plant heat balance first, as it holds the greatest potential for double-digit fuel savings. **R**

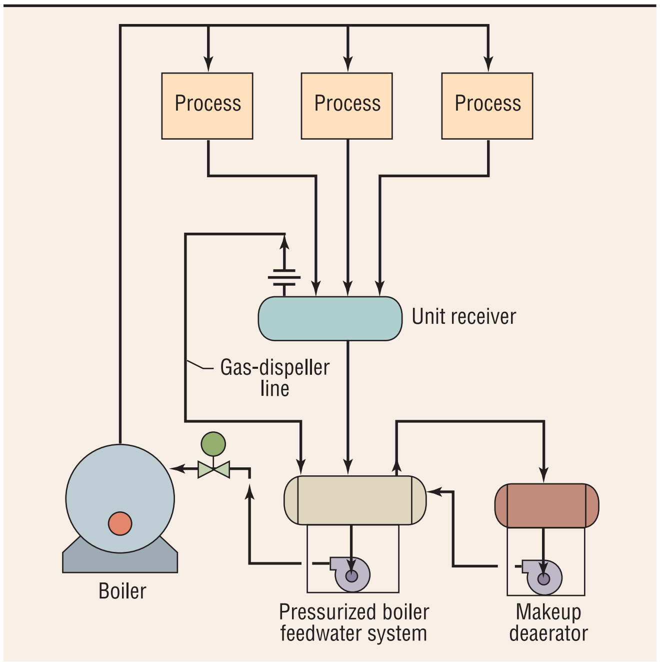
*Martin "Mike" Bekedam founded Industrial Steam in 1952. Soon after, he was joined by James F. Williams. Bekedam died March 16, 2008, at the age of 94. Williams remains with Industrial Steam, playing an integral role in mentoring and teaching.*

## Table 2. Calculations for a Typical Steam System

| Current average feedwater temperature | | | | | |
|---|---|---|---|---|---|
| Percent | × | water temperature, ˚F | = | accrued Btus | Volume lost to flashing, percent |
| 0.20 | × | 60 (makeup) | = | 12.00 | 0 |
| 0.60 | × | 212 (150 psig) | = | 127.20 | 9.60 = (0.16 × 0.60) |
| 0.20 | × | 212 (65 psig) | = | 42.40 | 2.00 = (0.10 × 0.20) |
| Average feedwater temperature | | | = | 181.60 | 11.60 |
| Average feedwater temperature after closing cycle | | | | | |
| 0.084* | × | 60 (makeup) | = | 5.00 | 0 |
| 0.696 | × | 366 (150 psig) | = | 254.70 | 0 |
| 0.220 | × | 312 (65 psig) | = | 68.60 | 0 |
| Average feedwater temperature | | | = | 328.30 | 0 |
| Minus previous feedwater temperature | | | = | – 181.60 | |
| | | | | 146.70 increase in feedwater temperature | |

*Makeup percent is reduced because of the saving of flash steam.
For simplicity and clarity, degrees Fahrenheit was used in lieu of heat of liquid.

### Figure 5. Pressurized Boiler Feedwater System with Unit Receiver for Processes Operating at Common Pressures



### Figure 6. Pressurized Boiler Feedwater System Using Cascading Flash Steam for Low-pressure Process