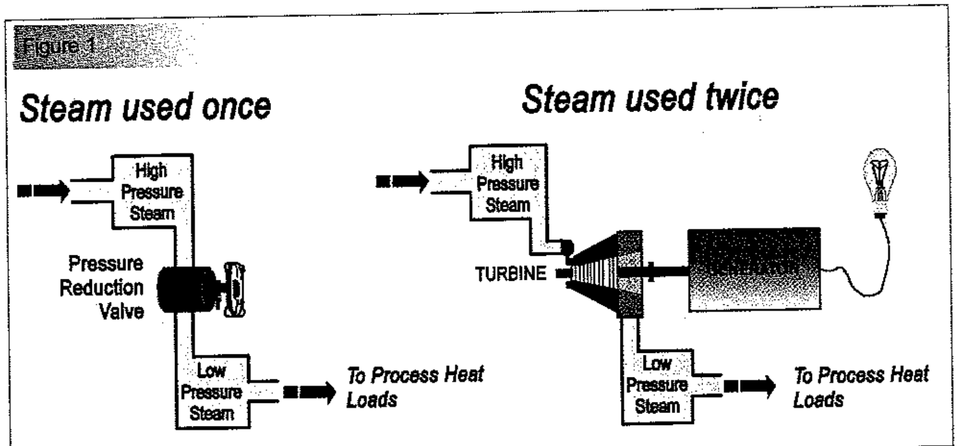
Maximizing plant profitability with steam turbine generators

By Sean Casten, Mark Heilman and Tom Pietsch

The history of the fuels industry is one of steady increases in raw material utilization and product diversity. The first oil refineries existed solely to produce lamp oil; leftover material was considered waste. Within a few decades, however, competitive pressures forced refiners to extract more value from each barrel of crude oil and today's modern refinery produces everything from "carbon black" to transportation fuels.

In many ways, wet mill ethanol plants have mirrored this trend. A single bushel of corn yields ethanol, animal feed, corn syrup and a slate of organic chemicals. In contrast, dry mill ethanol plants are less complex, depending largely on the price spread between corn and ethanol for their profitability. It is thus reasonable to assume that dry mills will face pressure to increase their processing efficiency—and the first mills to make these investments will realize "first mover" advantage, enjoying increased operating margins before competition drives ethanol prices down.

One of the simplest and most cost-effective ways to expand the dry mill product slate is to convert wasted energy into electric power. Such investments provide a hedge against commodity price volatility, boost plant profits, enhance local electricity reliability and reduce the environmental footprint of ethanol production.



Putting steam to work twice

Understanding this opportunity starts with a review of the pressure reduction valves (PRVs) that are typically installed between a steam boiler and low-pressure distribution headers. These valves convert high-pressure, high-value steam into low-pressure, low-value steam, presenting an opportunity to recycle the wasted value into electricity, as shown in Figure 1.

In addition to creating more revenue per pound of steam, an advantage of this approach is its low-tech design; turbine-driven pumps already installed in many mills are identical to the mechanical portion of the turbine-generator, and steam turbine generators have been—and continue to be—the workhorse of U.S. power generation. As a result, these systems can provide all of the benefits of on-site power generation without the technical and economic risk common to many other small generation technologies.

Ethanol dry milling from a power industry perspective

To better understand the opportunity that exists in today's ethanol plants, it is worth taking a moment to look at a typical ethanol mill from the perspective of the electricity industry.

In 1859, William Rankine invented a steam power cycle that sequentially pressurizes, evaporates, expands and condenses water to generate electricity (Fig. 2). Today, Rankine's invention is used to generate over 70 percent of U.S. electricity.

As is obvious by comparison with Figure 3, there are substantial similarities between this design and ethanol milling operations. However, while the power industry builds this capital to generate power (and thereby throws away the waste heat in a condenser), the ethanol industry builds this capital to produce heat (and throws away the value of high pressure steam in a PRV).

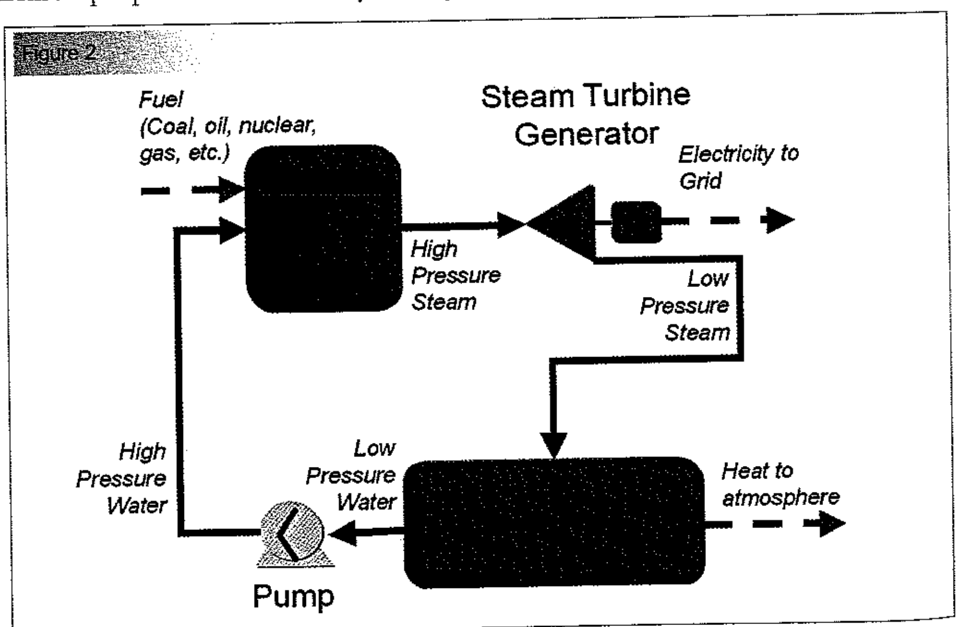
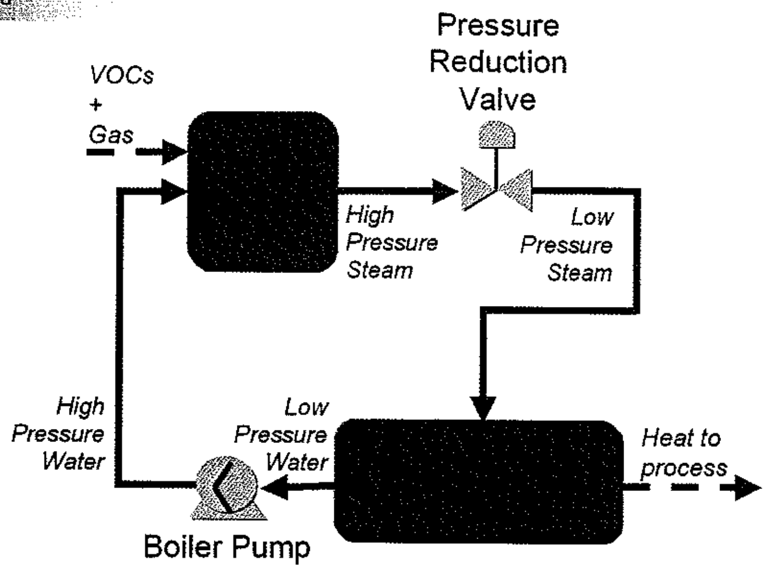


Figure 3



The opportunity for the ethanol industry is thus one of leveraging existing capital. In essence, every ethanol plant contains a 75 percent complete steam power plant that is generating no power. The addition of a steam turbine-generator thus produces the revenue stream of a power plant with a fraction of the capital outlay that would otherwise be required.

Plant reliability

Even before the 2003 northeast blackout, it was widely considered good practice to install backup electrical generation in the event of a disruption to the local grid. Most commonly, backup generation is provided by reciprocating engines that are quick to start and relatively low-cost. However, their high operating costs and emissions usually make them inappropriate for everyday operation. This places plant operators in a risky position when outages occur as their plant's reliability is suddenly dependent on the successful operation of an otherwise idle generator. Many facilities are now realizing that it is much better to use a cost-effective, clean, base-loaded generator that operates at all times and simply "rides through" a utility outage, which is exactly what one achieves from the approach described herein.

We have found that modern dry mill steam systems can implement this approach to generate 15 percent to 50 percent of their total electric load. Since such installations reduce—or eliminate—the need for diesel generators, they displace alternative capital investments and require little to no marginal investment in a green-field ethanol plant.

Rules of thumb

The power output from a steam turbine generator is a function of four variables: steam flow rate, inlet pressure, inlet temperature and exhaust pressure. Raise any of the first three and the power output will increase. Raise the final variable (exhaust pressure) and the power output will decrease. While a turbine can be designed to virtually any set of flow conditions, higher power outputs generally cost less per kilowatt of output, thus putting a practical floor on the types of opportunities worthy of consideration. Generally speaking, it is worth considering this approach if a steam facility satisfies the following criteria:

- The pressure drop across an existing PRV should be at least 100 psi
- The pressure ratio (psia inlet/psia outlet) should be at least 2.0
- The steam flow through the PRV should be at least 10,000 pounds per hour

The fact that these criteria apply to just about any ethanol plant PRV gives an indication of the magnitude of the opportunity for this approach.

Business considerations

So why hasn't the power industry already stepped up to the plate to invest in this opportunity? In a word, size.

Most electric power companies avoid projects smaller than 50 megawatts (50,000 kilowatts), and only then if they sell to the grid. Thus, a generator designed for ethanol plant loads gets ignored by the power industry, leaving the responsibility for project execution squarely with ethanol plant owners.

This is unfortunate from the ethanol industry's perspective, since plants cannot rely on their utility to assume project technical and financial risk. However, that simply means that the ethanol plant can earn a greater share of the opportunity—power that is guaranteed to be cheaper and cleaner than that from the grid. Consider the following examples:

- A 1,000 kilowatt steam-turbine generator of the type described herein can be fully installed for $300 to $600 per kilowatt. According to the Federal Energy Regulatory Commission, utilities invest $1,300 per kilowatt just for the transmission and distribution infrastructure to transmit electricity to the point of use, with another $500 per kilowatt or greater for the central power station. On-site steam turbine generation thus starts with a substantial capital cost advantage relative to power purchased from the grid, even before operating costs are taken into consideration.
- According to the U.S. DOE, the average central power plant operates at 33 percent efficiency, and thus must recover every $1 of fuel expense with at least $3 of electricity revenue. By contrast, the technologies described herein have efficiencies of *at least* 80 percent. All else equal, this means that a $1 rise in natural gas prices must lead to a $3 rise in retail electric rates, but only leads to $1.25 rise in the cost of locally-generated electricity. This $1.75 savings falls straight to the bottom line when fuel prices rise.

Taken collectively, our experience is that the integration of this design into conventional dry mills can increase plant operating profits by 0.5 to 2 cents per gallon.

Design considerations

As a final thought, we offer a few general recommendations to maximize the value created by this approach:

1) Design the system to existing steam flows, not to electric power loads.

2) Maximize boiler operating pressure and minimize process supply pressure, to the extent possible.

3) Minimize the "number of cooks in the kitchen." A common mistake is to hire one firm to design your power island, another to manufacture it, a third to install it and a fourth to finance it. Instead, find a single organization to take complete responsibility, so that you can focus on making ethanol rather than contract administration.

4) Design for your energy rate structure and steam load profile. The structure of an electric rate ultimately sets the most optimal operating mode, but a steam turbine will only operate economically if there is a need for low-pressure steam. Both need to be considered to achieve the optimal generating size and operating profile.

5) Make the most of regulatory incentives. Like ethanol, there are a host of regulatory incentives for clean, on-site power generation. Depending on your location, these can provide significant capital offsets and/or additional annual revenue streams to enhance project economics. EP

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