# Replace Pressure-Reducing Valves with Backpressure Turbogenerators

Many industrial facilities produce steam at a higher pressure than is demanded by process requirements. Steam passes through pressure-reducing valves (PRVs, also known as letdown valves) at various locations in the steam distribution system to let down or reduce its pressure. A non-condensing or backpressure steam turbine can perform the same pressure-reducing function as a PRV, while converting steam energy into electrical energy.

In a backpressure steam turbogenerator, shaft power is produced when a nozzle directs jets of high-pressure steam against the blades of the turbine's rotor. The rotor is attached to a shaft that is coupled to an electrical generator. The steam turbine does not consume steam. It simply reduces the pressure of the steam that is subsequently exhausted into the process header.

## Cost-Effective Power Generation

In a conventional, power-only steam turbine installation, designers increase efficiency by maximizing the pressure drop across the turbine. Modern Rankine-cycle power plants with 1,800 psig superheated steam boilers and condensing turbines exhausting at near-vacuum pressures can generate electricity with efficiencies of approximately 40%.

Most steam users do not have the benefit of ultra-high-pressure boilers and cannot achieve such high levels of generation efficiency. However, by replacing a PRV with a backpressure steam turbine, where the exhaust steam is provided to a plant process, energy in the inlet steam can be effectively removed and converted into electricity. This means the exhaust steam has a lower temperature than it would have if its pressure was reduced through a PRV. In order to make up for this heat loss, steam plants with backpressure turbine installations increase their boiler steam throughput.

Thermodynamically, the steam turbine still behaves the same way as it would in a conventional Rankine power cycle, achieving isentropic efficiencies of 20 to 70 percent. Economically, however, the turbine generates power at the efficiency of your steam boiler (modern steam boilers operate at approximately 80 percent efficiency), which then must be replaced with an equivalent kWh of heat for downstream purposes. the resulting power generation efficiencies are well in excess of the average U.S. electricity grid generating efficiency of 33 percent. Greater efficiency means less fuel consumption; backpressure turbines can produce power at costs that are often less than 3 cents/kWh. Energy savings are often sufficient to completely recover the cost of the initial capital outlay in less than 2 years.

## Applicability

Packaged or "off-the-shelf" backpressure turbogenerators are now available in ratings as low as 50 kW. Backpressure turbogenerators should be considered when a PRV has constant steam flows of at least 3,000 lbs/hr, and when the steam pressure drop is at least 100 psi. The backpressure turbine is generally installed in parallel with the PRV.

## Estimating Your Savings

To make a preliminary estimate of the cost of producing electrical energy from a back-pressure steam turbine, divide your boiler fuel cost (in $/MMBtu) by your boiler efficiency. Then convert the resulting number into cost per kWh, as shown in the sample calculation on the next page:

## Life and Cost of Backpressure Turbogenerators

Turbogenerators with electrical switchgear cost about $700/kW for a 50 kW system to less than $200/kW for a 2,000 kW system. Installation costs varies, but typically averages 75 percent of equipment costs.

Backpressure steam turbines are designed for a 20-year minimum service life and are known for needing low maintenance.

## Suggested Actions

Consider replacing PRVs with backpressure turbogenerators when purchasing new boilers or if your boiler operates at a pressure of 150 psig or greater.

- Develop a current steam balance and actual process pressure requirements for your plant.
- Develop steam flow/duration curves for each PRV station.
- Determine plant electricity, fuel cost, and operating voltage.
- Consider either one centralized turbogenerator, or multiple turbogenerators at PRV stations.

*Steam Tip Sheet information adapted from material provided by the TurboSteam Corporation and reviewed by the DOE BestPractices Steam Technical Subcommittee. For additional information on steam system efficiency measures, contact the OIT Clearinghouse at (800) 862-2086.*

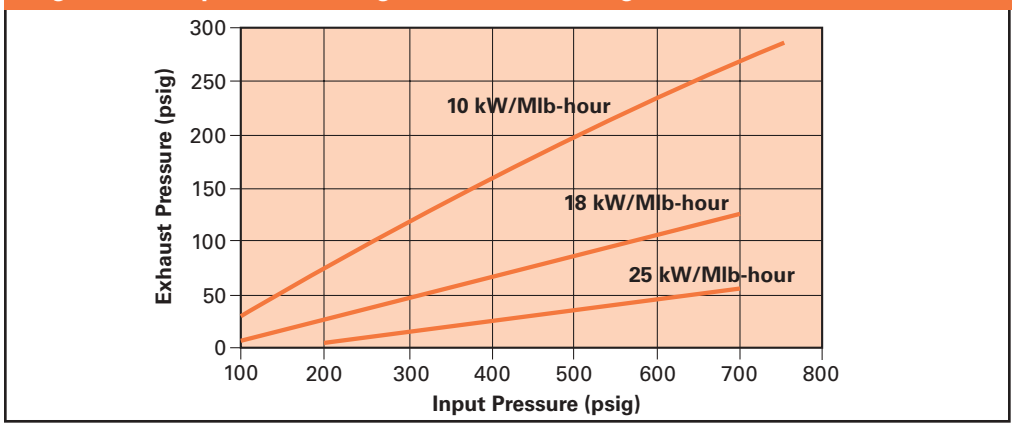
$$\text{Electricity cost} = \frac{\text{Fuel cost (\$/MMBtu)} \times 0.003412 \text{ MMBtu/kWh}}{\text{Boiler efficiency}}$$

$$\text{Example:} \quad \frac{\$5.00/\text{MMBtu} \times 0.003412 \text{ MMBtu/kWh}}{0.80} = \$0.021/\text{kWh}$$

To estimate the potential power output at a PRV, refer to Figure 1, which shows lines of constant power output (expressed in kW of electrical output per 1,000 pounds per hour of steam throughput) as a function of turbine inlet and exhaust pressures. Look up your input and output pressure on the horizontal and vertical axes, and then use the reference lines to estimate the backpressure turbogenerator power output per Mlb/hour of steam flow. Then estimate the total installed generating capacity (kW) by multiplying this number by your known steam flow rate. The annual cost savings from the backpressure turbine can then be estimated as:

Power output (kW) x Steam duty (hrs/year) x (Cost of grid power – cost of generated power, $/kWh)

**Figure 1. Backpressure Turbogenerator Generating Potential (kW/Mlb-hour)**




Note: Assumes a 50% isentropic turbine efficiency, a 96% efficient generator, and dry saturated inlet steam

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DOE/GO-102002-1476
January 2002
Steam Tip Sheet #20