Section 11

Steam System Optimization – Conclusions

Conclusions
Tools & Resources

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Conclusions

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Key Points / Action Items - Fundamentals

1. *Use a Systems Approach to optimize steam systems*
2. *There are four major areas of a steam system – Generation, Distribution, End-Use & Recovery*
3. *An understanding of the laws of thermodynamics, heat transfer, fluid flow and steam properties is required for a steam system analysis*
4. *Use a systematic approach (gap analysis, comparison to BestPractices) to identify potential energy saving opportunities that may exist in steam systems*

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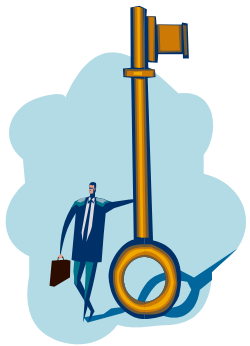
Key Points / Action Items – Boiler Efficiency



1. *Determine boiler plant operating cost*
2. *Determine unit cost of steam generation*
3. *Determine boiler operating efficiency*

$$\eta_{boiler} = \frac{m_{steam}\left(h_{steam} - h_{feedwater}\right)}{m_{fuel}\, HHV_{fuel}} \times 100$$

4. *There are three major losses in steam generation – shell loss, blowdown loss and stack loss*

$$\eta_{boiler} = 100 - \lambda_{shell} - \lambda_{blowdown} - \lambda_{stack} - \lambda_{other}$$

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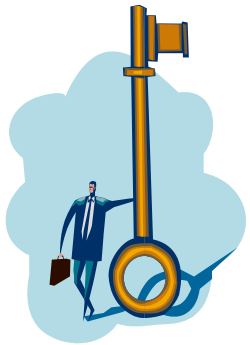
Key Points / Action Items – Shell Loss



1. *Search for "hot spots"*
2. *Measure boiler surface temperatures*
   - *Infrared thermography*
   - *Typical surface temperature should range between 55 ℃ and 70 ℃*
3. *Repair refractory*
4. *Monitor surface cladding integrity*
5. *Reduced boiler load can present an opportunity*
   - *Minimize number of operating boilers*

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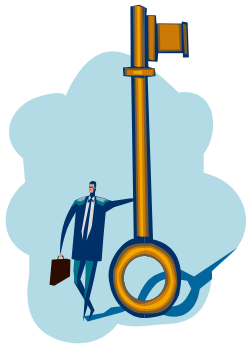
Key Points / Action Items – Blowdown Loss



1. *Estimate amount of blowdown using boiler and feedwater conductivities*
2. *Quantify the boiler and system-level energy loss due to blowdown*
3. *Evaluate installation of an automatic blowdown controller*
4. *Evaluate and install flash steam and heat recovery equipment*
5. *Work closely with plant's water chemists to maintain and manage appropriate blowdown*

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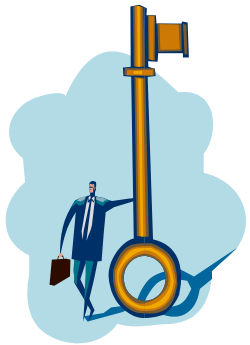
Key Points / Action Items – Stack Loss



1. *Monitor and record flue gas temperature with respect to:*
   - *Boiler load*
   - *Ambient temperature*
   - *Flue gas oxygen content*
2. *Compare flue gas temperature to previous, similar operating conditions*
3. *Maintain appropriate fire-side cleaning*
4. *Maintain appropriate water chemistry*
5. *Evaluate heat recovery component savings potential*

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Key Points / Action Items – Stack Loss

1. *Combustion management principles:*
   - *Add enough oxygen to react all of the fuel*
   - *Minimize the amount of extra air*
   - *Monitor combustibles to identify problems*
2. *Measure the oxygen content of boiler exhaust gas*
3. *Control oxygen content within a minimum and maximum range*
   - *Continuous - automatic O_2 trim control*
   - *Positioning control*
4. *Challenge the control range*
   - *Control upgrade*
   - *Combustion tuning*

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Key Points / Action Items – Boiler Plant Optimization

1. *Use a steam system model based on the laws of thermodynamics to quantify energy and cost savings opportunities*

2. *Fuel switching and boiler plant operations are excellent areas for optimization of steam systems – significant cost savings can be realized by applying optimal operating strategies*

3. *Each application will need an independent evaluation – there are NO thumb rules!*

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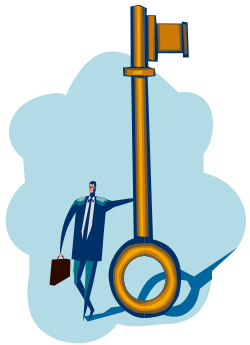
Key Points / Action Items – Leaks



1. *Steam leaks occur in all plants and a continuous improvement type steam leak management program should be implemented in industrial plants*

2. *An "order of magnitude" steam loss estimate can provide enough information to determine if the repair must be made immediately, during a future shutdown, or online*

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Key Points / Action Items - Insulation

1. *There are several reasons for damaged or missing insulation*
2. *These areas result in significant energy losses and a continuous improvement type insulation appraisal (audit) program should be implemented in industrial plants*
3. *Some basic instruments, heat transfer models and process data are required to quantify the economic impact of missing or damaged insulation*

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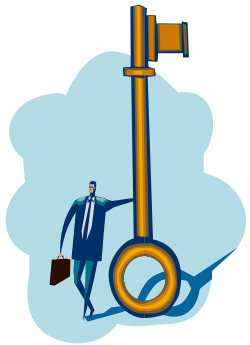
Key Points / Action Items – End Use



1. *There are several end-uses of steam in industrial plants*
2. *Do a steam end-use balance in an industrial plant and identify the largest steam end-users in a plant*
3. *Reduce steam end-use by*
   - *Improving the efficiency of the process*
   - *Shifting steam demand to a waste heat source or lower pressure steam available in the plant*

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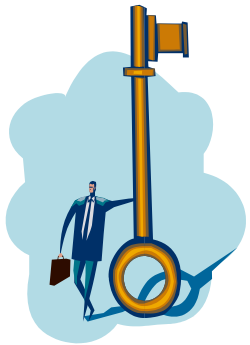
Key Points / Action Items – Heat Exchangers



1. *Heat exchangers have a 1st Law efficiency of ~100%*
2. *Heat exchanger InEffectiveness leads to significant system level energy loss*
3. *Monitor and trend heat exchanger effectiveness by measuring inlet and outlet temperatures and calculating U-values*
4. *Clean heat exchangers on a periodic basis to minimize fouling build-up*

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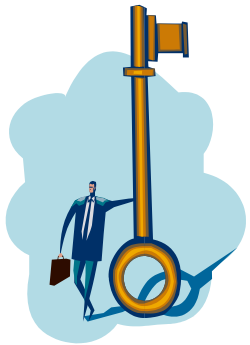
Key Points / Action Items – Process/Utility Integration



1. *Upgrade low pressure (or waste) steam to supply process demands*
2. *Several plants need heating and cooling for process*
3. *Process integration can lead to significant energy savings opportunities and plant optimization*
4. *These opportunities will need significantly higher amounts of due-diligence*

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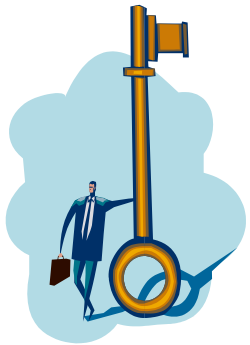
Key Points / Action Items – Steam Traps



1. *There are different kinds of steam traps and hence, functionality and principles of operation must be understood*
2. *Major steam trap failure modes - open / closed*
3. *An effective steam trap management program must be in place*
4. *There are several commercially available tools for steam trap investigations*
5. *Conduct a steam trap audit at least once a year and repair/replace defective traps*
6. *Steam trap manufacturers are a valuable resource*

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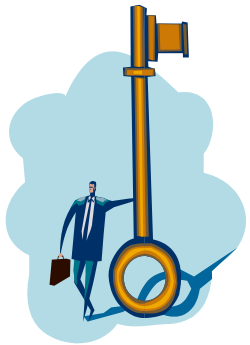
Key Points / Action Items – Condensate Recovery



1. *Returning condensate*
   - *Reduces energy*
   - *Reduces make-up water*
   - *Reduces chemicals for water treatment*
   - *Reduces quenching water*
   - *May reduce blowdown*
2. *Condensate recovery is often neglected but it can provide significant energy savings*
3. *Quantify the amount of condensate being recovered in a plant using a simple mass balance on the entire steam system*
4. *Identify potential areas of condensate recovery*

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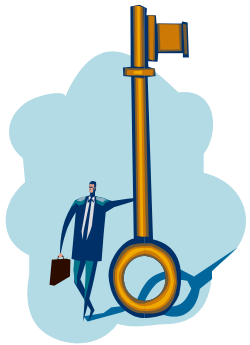
Key Points / Action Items – Backpressure Turbines



1. *Backpressure turbines are used instead of pressure letdown stations*
2. *Turbine efficiency is NOT 1st law efficiency but a comparison of actual turbine versus an ideal turbine*
3. *Continuous operations with a simultaneous thermal and electric demand are good candidates for backpressure turbines*
4. *Each facility analysis is unique and will depend on several economic as well as operating factors*
5. *Turbine analysis will need a solid thermodynamic steam system model*

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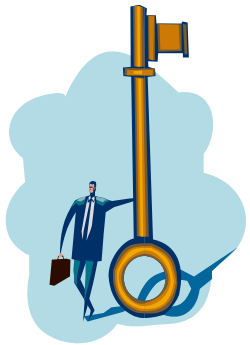
Key Points / Action Items – Condensing Turbines



1. *Condensing turbines are used strictly for power generation or driving large mechanical equipment*
2. *They serve niche applications in the industry*
3. *Condensing turbines provide maximum shaft power per unit of steam flow*
4. *Each facility analysis is unique and will depend on several economic as well as operating factors*
5. *Turbine analysis will need a solid thermodynamic steam system model*

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Tools & Resources

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Tools

- In order to properly evaluate steam systems the physics of each process must be understood
  - Thermodynamics
  - Heat transfer
  - Fluid flow
- US DOE Tools Suite
  - Steam System Survey Guide
  - Steam System Scoping Tool (SSST)
  - Steam System Assessment Tool (SSAT)
  - Insulation evaluation software – 3E-Plus
- Several other commercially available software tools for steam systems
- Process measurements

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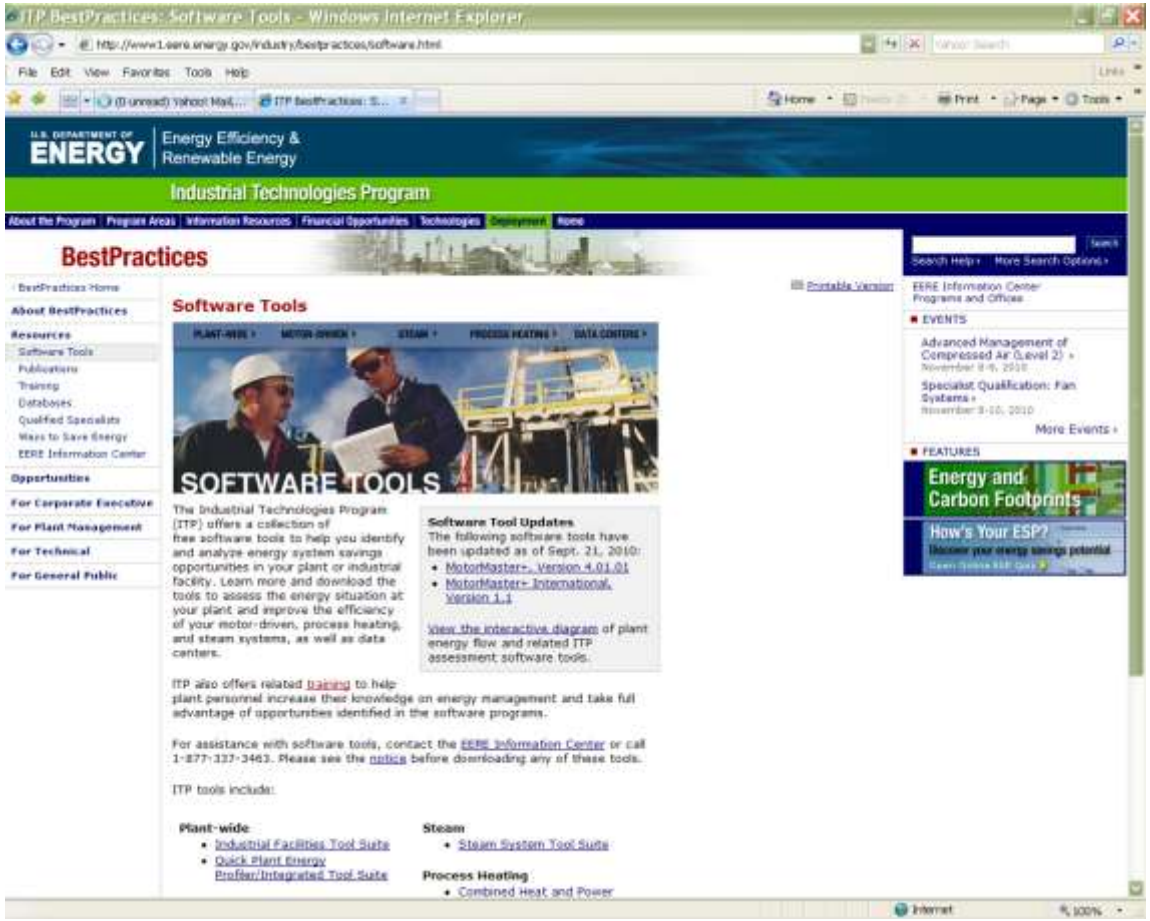
Where to Download the Tools



US DOE website -http://www1.eere.energy.gov/industry/bestpractices/software.html

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Technical Publications & Resources

http://www1.eere.energy.gov/industry/bestpractices/publications.asp

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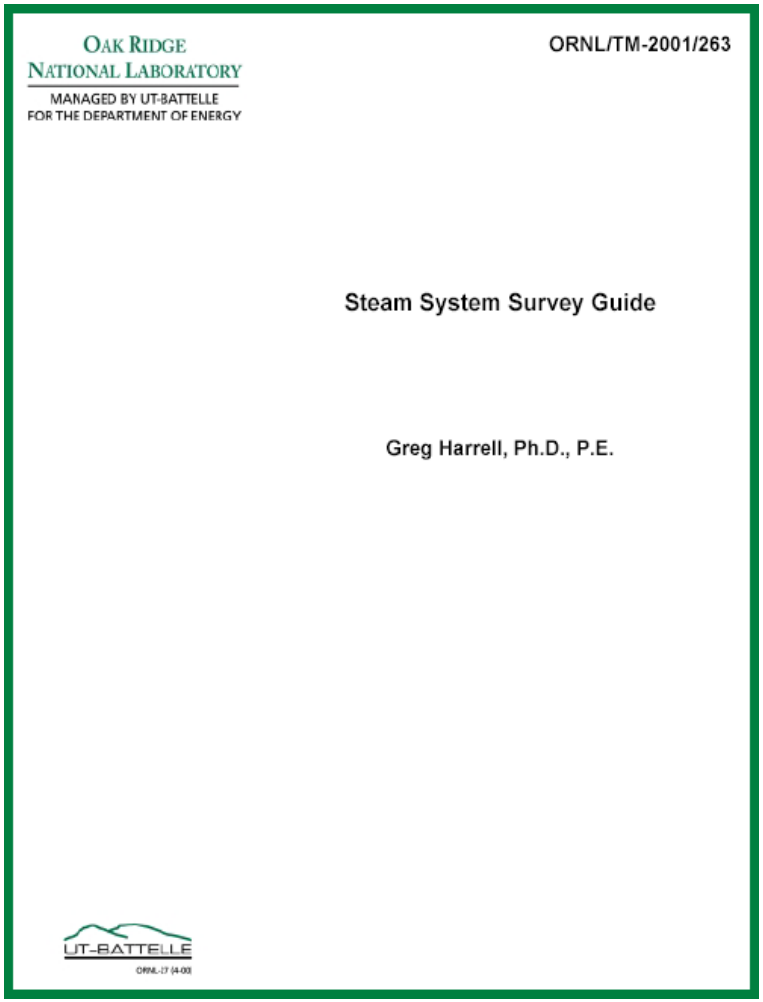
Steam System Survey Guide

- Technical Guide
- Covers 5 Areas:
  - Steam system profiling
  - Identifying steam properties
  - Improving boiler operations
  - Improving resource utilization
  - Improving steam distribution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ORNL/TM-2001/263

Steam System Survey Guide

Greg Harrell, Ph.D., P.E.

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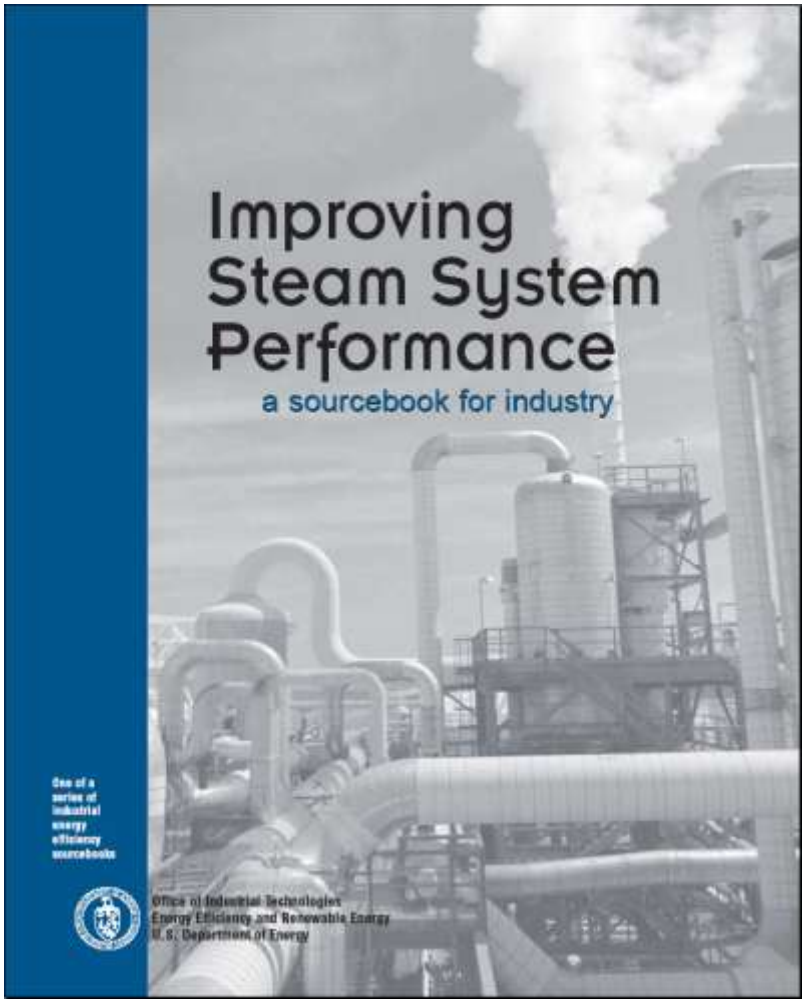
Steam System Sourcebook

- Includes Three Main Sections:
  - Steam System Basics
  - Performance Improvement Opportunities
  - Programs, Contacts, and Resources



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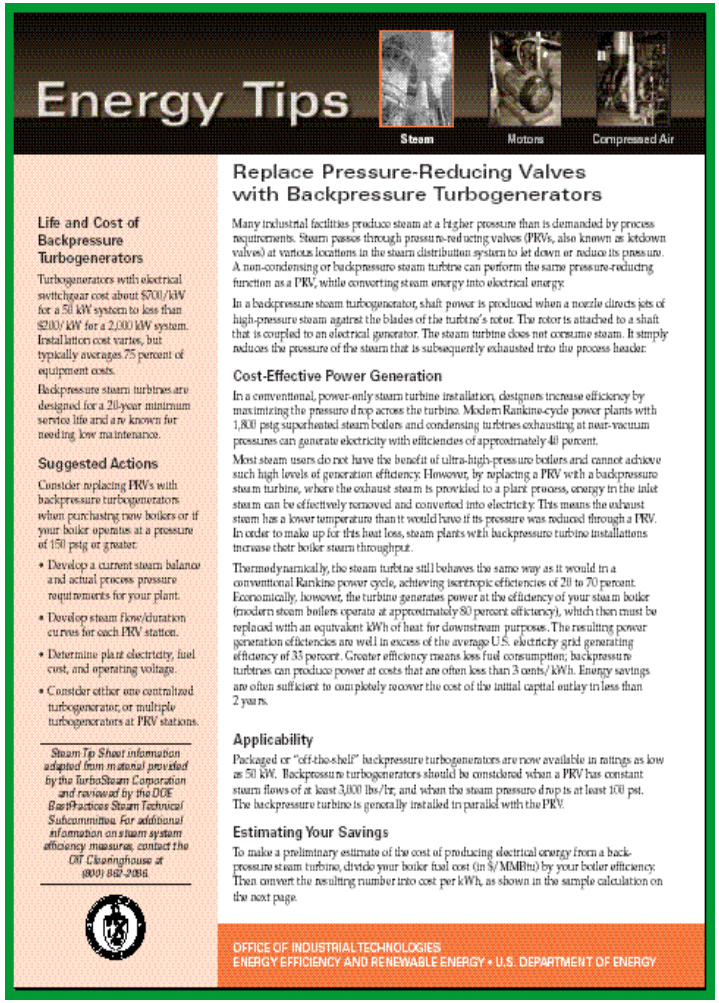
Steam Energy Tips

- 1- Page Tips For Improving Steam System Areas
- Available On BestPractices Web Site and in Steam Sourcebook



Energy Tips

Steam | Motors | Compressed Air

Replace Pressure-Reducing Valves with Backpressure Turbogenerators

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 cost 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.

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 percent.

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.

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ENERGY EFFICIENCY AND RENEWABLE ENERGY • U.S. DEPARTMENT OF ENERGY

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US DOE Tip Sheets

- Benchmark the Fuel Cost of Steam Generation
- Clean Boiler Water-side Heat Transfer Surfaces
- Consider Installing a Condensing Economizer
- Consider Installing High-Pressure Boilers with Backpressure Turbine-Generators
- Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers
- Consider Steam Turbine Drives for Rotating Equipment
- Considerations When Selecting a Condensing Economizer
- Cover Heated, Open Vessels
- Deaerators in Industrial Steam Systems
- Flash High-Pressure Condensate to Regenerate Low-Pressure Steam
- Inspect and Repair Steam Traps
- Install an Automatic Blowdown Control System
- Install Removable Insulation on Valves and Fittings
- Insulate Steam Distribution and Condensate Return Lines

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US DOE Tip Sheets

- Improve Your Boiler's Combustion Efficiency
- Minimize Boiler Blowdown
- Minimize Boiler Short Cycling Losses
- Recover Heat from Boiler Blowdown
- Replace Pressure-Reducing Valves with Backpressure Turbogenerators
- Return Condensate to the Boiler
- Upgrade Boilers with Energy-Efficient Burners
- Use Feedwater Economizers for Waste Heat Recovery
- Use Low Grade Waste Steam to Power Absorption Chillers
- Use Steam Jet Ejectors or Thermocompressors to Reduce Venting of Low-Pressure Steam
- Use Vapor Recompression to Recover Low-Pressure Waste Steam
- Use a Vent Condenser to Recover Flash Steam Energy

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US DOE Technical Documents

- Improving Steam System Performance: A Sourcebook for Industry
- Achieve Steam System Excellence: Industrial Technologies Program BestPractices Steam Overview Fact Sheet
- BestPractices Steam Technical Brief: Steam Pressure Reduction-Opportunities and Issues
- BestPractices Steam Technical Brief: How to Calculate the True Cost of Steam
- BestPractices Steam Technical Brief: Industrial Heat Pumps for Steam and Fuel Savings
- BestPractices Steam Technical Brief: Industrial Steam System Heat-Transfer Solutions

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US DOE Technical Documents

- BestPractices Steam Technical Brief: Industrial Steam System Process-Control Schemes
- Guide to Combined Heat and Power Systems for Boiler Owners and Operators
- Guide to Low-Emission Boiler and Combustion Equipment Selection
- Review of Orifice Plate Steam Traps
- Save Energy Now in Your Steam Systems
- Steam Digest: Volume IV (2003)
- Steam Digest 2002
- Steam Digest 2001
- Steam Systems Energy Efficiency Handbook
- Steam Systems Survey Guide

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Course Evaluation & Feedback

Your input is greatly appreciated and it will be acted upon to refine this training program as well as better tailor further complementary technical assistance to be offered by the UNIDO project to South African enterprises

THANK YOU !

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