Federal Energy Management Program

Fact Sheet

A product of the FEMP O&M Center of Excellence

Leading by example, saving energy and taxpayer dollars in federal facilities

O&M First!

Actions You Can Take to Reduce Heating Costs

Heating accounts for a significant energy load and usually presents a number of opportunities to improve performance and save money. It's a good idea to make sure these systems are operating efficiently and effectively. While we recommend taking a long-term approach to solving your operations and maintenance (O&M) problems, there may be some actions you can take now to further reduce the burden of heating fuel costs. This FEMP O&M tutorial calls out some of the most likely opportunities for reducing heating costs for your facilities. While most of these opportunities are expressed for steam and hot-water boilers, many are also applicable to furnaces. Available opportunities and potential savings will vary by site.

Opportunity 1: Optimize Air-to-Fuel Ratio for Fired Systems

Fuel needs oxygen to burn. In fuel-fired systems, excess air is provided to ensure complete and safe combustion. However, too much excess air will reduce combustion efficiency by increasing heat losses carried away by the exhaust gases. *Solution*: Test the amount of excess oxygen and carbon monoxide in the exhaust gases using an electronic combustion (flue) gas analyzer. Modify the air-to-fuel ratio to provide sufficient air for complete combustion but minimize the amount of excess air. Ensure that carbon monoxide levels in the exhaust gas do not reach excessive levels. If carbon monoxide levels exceed 100 ppm (parts per million), it could mean the boiler has insufficient air for complete combustion or has improper air/fuel mixing. Small boilers can be checked periodically with portable combustion analyzers. Optimizing combustion efficiency can reduce fuel costs by 3 to 10%. *Remember*: Excess air levels will be different for different firing rates and for different boilers. For natural-gas boilers, high-firing rates may require less than 2% excess oxygen (10% excess air), while low-firing rates may require more than 6% excess oxygen to ensure complete combustion. Oil-fired systems will require more excess air than gas-fired systems. Also remember that colder supply air will result in an increased level of excess air because colder air is denser than warmer air.


1


2


3

Don't have a combustion gas analyzer? Base models start as low as $1,500. If you can't afford one, then consider renting the equipment or service.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

---

1 Reproduced with permission of M.A. Selmon Co., LLC, Stratford, CT.
2 Reproduced with permission of Bacharach, Inc., New Kensington, PA.
3 Reproduced with permission of Bell Combustion, Mississauga, Ontario, Canada.

Excess Air

The use of Figure 1 is illustrated through the following example. Inspection and testing using a portable combustion analyzer led to the observation that a boiler is currently operating at 9% oxygen (~65% excess air) in the exhaust gases. It is believed that the burner can be adjusted to operate at 2% oxygen (~10% excess air). The exhaust gases leaving the boiler are 570°F. The air at the combustion inlet is 70°F. Assuming the historical boiler fuel consumption (while operating at 9% excess oxygen) is 40,000 million Btu/yr at $6.00/million Btu, determining the potential energy and cost savings through improving the air-to-fuel ratio of the boiler (reducing excess air) are illustrated below.

Determining the boiler's combustion efficiency using the figure

Relevant data:

- Existing level of oxygen in the exhaust gases is 9%
- Target level of oxygen in the exhaust gases is 2%
- Stack temperature rise is 500°F (stack temperature, 570°F-combustion air inlet temperature, 70°F)
- Using Figure 1, Step 1, existing combustion efficiency is 76.5% (or 0.765)
- Using Figure 1, Step 2, target combustion efficiency is 81.5% (or 0.815)
- Historical boiler fuel consumption is 40,000 million Btu/yr
- Marginal boiler fuel cost is $6.00/million Btu

Potential energy savings:

= [(0.815-0.765)/(0.815)] x (40,000 million Btu/yr)

= 2,454 million Btu/yr

Potential energy cost reduction:

= (2,454 million Btu/yr) x ($6.00/million Btu)

= $14,724/yr

For larger systems, continuous and automatic trim-control systems should be considered.

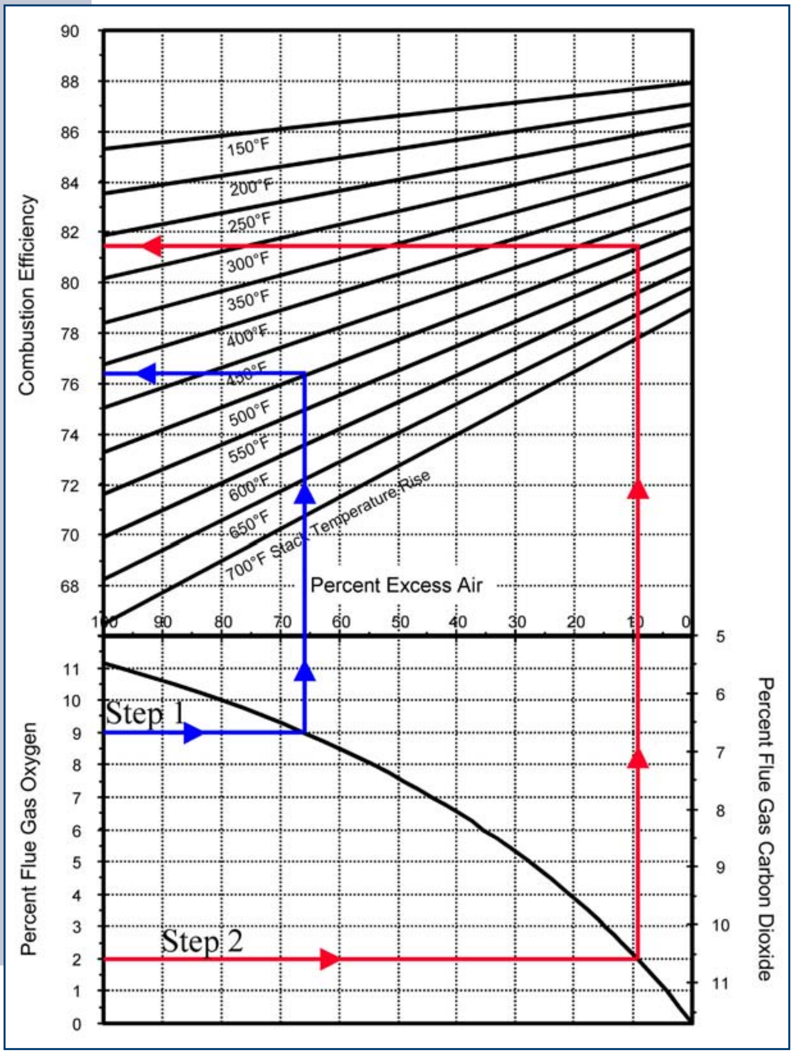

Figure 1. Combustion efficiency chart for natural gas.

Opportunity 2: Inspect and Repair Burner Systems

Look at the combustion flame through an access port—does it look uniform, or irregular? Use the combustion gas analyzer to test for excess air and carbon monoxide—do both show high levels? These are some of the signs that the burner systems may be in need of repair or replacement. *Solution*: Regularly inspect and maintain burner systems. This should include the combustion air duct, gas delivery system, oil delivery system, strainers, fuel and air linkages, mixers, burner nozzles and the fuel atomizing system. Once the burners are functioning properly, optimal combustion control can be achieved and maintained. Your boiler and burner manufacturer will recommend a regular inspection cycle. Keep notes and observations in your daily boiler log.

Opportunity 3: Implement an Effective Steam Trap Maintenance Program

When steam vapor gives up its heat energy, such as through a heat exchanger, it condenses into liquid called condensate. Steam traps are specialty valves used to let condensate pass while holding back steam. Steam traps exist in a harsh environment and therefore will eventually fail. When steam traps fail open, useful steam energy is lost. For a facility without a regular steam trap maintenance program, it is not uncommon to find a 25 to

Failed Steam Trap

The use of Figure 2 is illustrated through the following example. Inspection and observation of a steam trap led to the judgment that the trap had failed open and was passing live steam to the condensate receiver tank. Manufacturer data indicated the steam trap's orifice to be 1/4 inch diameter. The steam system operates at 110 psia (~95 psig). Assuming the average steam system efficiency is 75%; the steam system is active (pressurized) 50% of the year; and steam costs $10/million Btu), determining the associated energy loss and cost are illustrated below.

Estimating steam loss using the figure

Relevant data:

- 1/4-inch-diameter orifice in steam trap
- Steam pressure is 110 psia (~95 psig)
- Operating hours are 50% of 8,760 h/yr (figure assumes continuous operation)
- Steam system efficiency is 75%
- Steam cost is $10/million Btu
- Using Figure 2, base steam loss is 2,000 million Btu/yr

Energy loss through failed steam trap:

= (2,000 million Btu/yr) x (50%) / (75%)
= 1,333 million Btu/yr

Cost of energy loss through failed steam trap:

= (1,333 million Btu/yr) x ($10/million Btu/yr)
= $13,330/yr

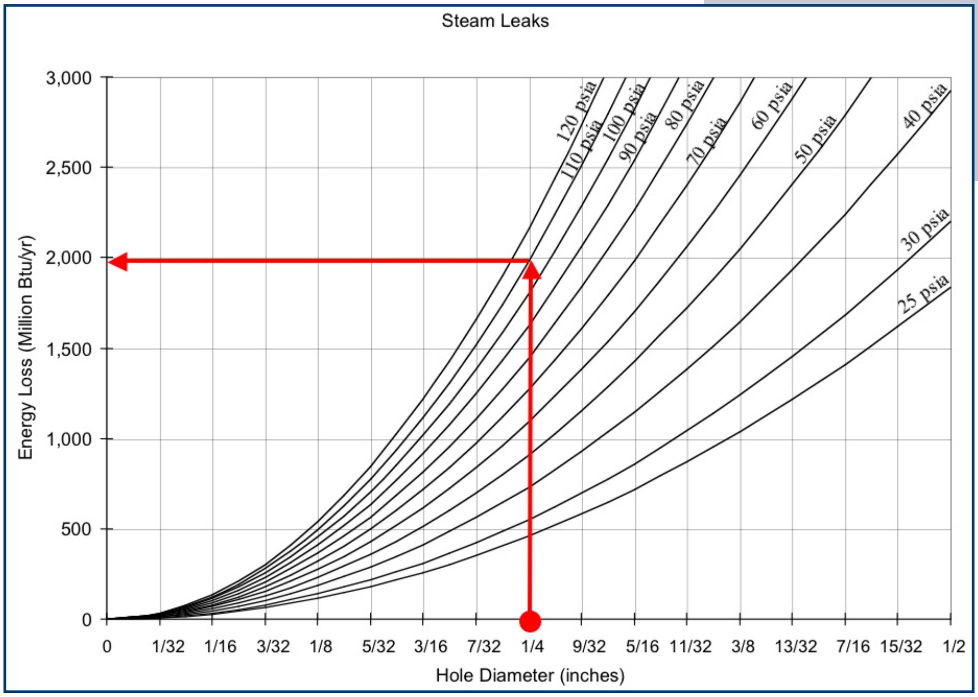

Figure 2. Estimating steam loss through leaks and failed-open traps.

Checklist Indicating Possible Steam Trap Failure

Signs Indicating Steam Traps Failed Open

- Condensate receiver tank venting steam
- Abnormally warm boiler room
- Condensate pump water seal failing prematurely
- Boiler operating pressure difficult to maintain
- Steam in condensate return lines
- Steam trap abnormally noisy
- Inlet and outlet lines to steam trap nearly the same temperature
- Higher than normal energy bill

Signs Indicating Steam Traps Failed Closed

- Underheating conditioned space
- Water hammer in steam lines
- Steam trap not warm

A failed-open steam trap can waste considerable steam.

50% failure rate. *Solution*: It is important to regularly inspect and replace or repair failed steam traps. Even a small steam trap can cost thousands of dollars per year in lost steam. Steam traps should be checked once or twice per year in smaller or simpler steam distribution systems. In larger, more complex systems, consider installing a continuous monitoring steam trap program.

Opportunity 4: Repair Steam and Condensate Leaks and Return Condensate to the Boiler

In a perfect system, all condensate could be returned to the boiler for reuse in steam generation. Condensate is distilled water and, therefore, is extremely clean. Leaks in the steam system, condensate system and vent lines result in some of the condensate being lost. Therefore, make-up water is required to be added to the boiler feedwater system. Increased use of make-up water results in increased energy, water and chemical costs. *Solution*: Repair leaks in the steam, as well as, condensate system. Repairing steam leaks should be a very high priority. Besides costing a lot of money, steam leaks are also a safety hazard. In addition, return as much condensate as possible back to the boiler for use as feedwater by repairing leaks or through other means. Returning condensate to the boiler makes sense for several reasons. As more condensate is returned, less make-up water is required, saving fuel, make-up water chemicals, and treatment costs. Less condensate discharge to the sewer system reduces disposal costs. Return of high purity condensate also reduces energy losses through boiler blowdown. Significant fuel savings can occur if the condensate is returned at a higher temperature than the off setting make-up water.

Steam leaks can be dangerous, as well as energy wasters. This uninsulated pressure-reducing station should also be insulated.

Opportunity 5: Inspect and Improve Insulation of Heated Pipes and Equipment

Insulation around steam and hot water lines, storage tanks, heat exchangers, and steam traps frequently becomes damaged or is removed and never replaced during system repairs. While insulation is inexpensive and fairly durable, it can become damaged over time or with excessive abuse. Inspection may also reveal uninsulated piping and equipment. *Solution*: Missing, damaged, compressed, or wet insulation should be replaced immediately.

Insulation

As a rule-of-thumb, if the surface is too hot to hold with your bare hand, it will likely be cost-effective to add insulation.

If the system requires frequent access, consider special removable insulation blankets, especially for valves and fittings. In general, if the surface temperature exceeds 130°F, it is likely cost-effective to add insulation.

Opportunity 6: Reducing Boiler Cycling Losses

Smaller boilers cycle on and off to meet varying heat load requirements. Boiler short cycling can occur when the boiler meets the load too quickly or is off for only a brief period before being required to come on again. A boiler cycle consists of a pre-purge, a firing interval, and a postpurge, followed by an idle (off) period. While necessary to ensure a safe burn cycle, the pre- and post-purge cycles result in heat loss up the exhaust stack. Short cycling results in excessive heat loss. *Solution*: The combustion control system is equipped with a "differential" control to determine when the system cycles "on" and when it cycles "off." Increasing the differential will reduce the amount of short cycling. When adjusting the differential, however, be sure not to exceed critical process temperature control requirements. For example, if your steam system supplies a sterilization process, don't let the steam pressure drop below the point necessary to supply the minimum temperature requirement.

Scale

Scale deposits on the water side and soot deposits on the fire side of a boiler not only act as insulators that reduce efficiency, but also cause damage to the tube structure because of overheating and corrosion.

Opportunity 7: Consider Installing Turbulators in Two- and Three-Pass Firetube Boilers

In firetube boilers, the flow of combustion gases through the boiler tubes may not maximize overall heat transfer. Turbulators can be a cost-effective way to improve the heat transfer process, balance gas flow through the boiler tubes, reduce stack temperature and increase the overall fuel-to-steam efficiency of firetube boilers. *Solution*: The efficiency of two- and three-pass firetube boilers can be improved through the addition of turbulators. Turbulators can consist of small baffles, angular metal strips, spiral blades, or coiled wire. They are inserted into the last boiler tube pass to increase the effectiveness of heat transfer, resulting in a lower exhaust stack temperature, and thus increasing combustion efficiency. Consider installing turbulators in your boiler if the stack temperature 100°F or more above your steam or hot water supply temperature. Installing turbulators in two- or three-pass firetube boilers can reduce fuel costs by 2 to 5%. *Remember*: To avoid combustion problems, the combustion efficiency and excess air should be checked and adjusted as necessary after the turbulators have been installed. Do not install turbulators in natural draft or solid fuel boilers without first consulting the boiler manufacturer.

Opportunity 8: Minimize Boiler Blowdown

As water evaporates into steam, solids present in the feedwater are left to accumulate in the boiler drum. The suspended solids form sludge or sediments in the boiler, which can degrade heat transfer. Dissolved solids promote foaming and carryover of boiler water into the steam. High levels of total dissolved solids also promote scaling. Your boiler manufacturer and the American Boiler Manufacturers Association have recommended upper limits for total dissolved solids and other impurities. To reduce the levels of suspended, total dissolved solids, or other impurities to acceptable limits, water is periodically discharged, or blown down, from the boiler. Bottom blowdown is usually a short and infrequent procedure performed manually and used to reduce the sediments. Total dissolved solids and other impurities are usually controlled using surface or skimming blowdown. Surface blowdown is a more frequent, sometimes continuous process. While insufficient blowdown will lead to some problems, excessive blowdown can be very costly in terms of energy, water, and chemical treatment. *Solution*: Reduce skimming blowdown to maintain close to, but below, upper limits on total dissolved solids and other impurities. Continuous skimming blowdown can be more effective and less costly than periodic blowdown when performed correctly. Therefore, if you use periodic blowdown to maintain impurity levels in the boiler drum water, consider using a continuous skimming blowdown process instead. *Remember*: Continuous skimming blowdown is also more effective for installing an automatic blowdown control system or a waste-heat recovery project, such as preheating make-up water with the blowdown, both of which could be considered later as potential capital projects.

Additional Opportunities

There are many more opportunities that will cost-effectively improve heating operations, save energy, and reduce winter fuel costs. Examples include:

- For oil-fired systems, inspect oil pressure, temperature, strainers and burner nozzles
- Clean boiler waterside heat transfer surfaces
- Remove ash accumulation on heat transfer surfaces
- Optimize load sharing between multiple boilers
- Eliminate hot standby
- Add or restore boiler refractory
- Don't heat unnecessary space
- Isolate unused steam lines
- Lower steam pressure or hot water supply temperature, if possible
- Seal leaking ducts in air distribution systems
- Inspect and reduce obstructions in space heating delivery systems
- Reduce thermostat settings, if appropriate.

Continuous attention to these types of issues is a critical component to an effective O&M program as presented in FEMP's *O&M Best Practices: A Guide to Achieving Operational Efficiency, Release 2.0.*

For Additional Information

DOE, ***"Check Burner Air to Fuel Ratios,*** **Tip Sheet #2,"** **Energy Tips**, DOE/GO-102002-1552, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, May 2002.

DOE, ***"Clean Boiler Waterside Heat Transfer Surfaces,*** **Tip Sheet #7,"** **Energy Tips**, DOE/GO-10099-952, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, June 2001.

DOE, ***"Consider Installing Turbulators on Two- and Three-Pass Firetube Boilers,*** **Steam Tip Sheet #25,"** **Energy Tips–Steam**, DOE/GO-102004-1709, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, April 2004.

DOE, ***"Improve Your Boiler's Combustion Efficiency,*** **Tip Sheet #4,"** **Energy Tips**, DOE/GO-102002-1506, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, March 2002.

DOE, **Improving Steam System Performance**. DOE/GO-102004-1868, Office of Industrial Technologies, U.S. Department of Energy, Washington DC. October 2004.

DOE, ***"Inspect and Repair Steam Traps,*** **Steam Tip Sheet #1,"** **Energy Tips**, DOE/GO-102002-1503.

DOE, ***"Install an Automatic Blowdown Control System,*** **Steam Tip Sheet #23,"** **Energy Tips–Steam**, DOE/ GO-102004-1711, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, April 2004.

DOE, ***"Install Removable Insulation on Valves and Fittings,*** **Steam Tip Sheet #17,"** **Energy Tips–Steam**, DOE/GO-102004-1802, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, April 2004.

DOE, ***"Insulate Steam Distribution and Condensate Return Lines,*** **Tip Sheet #2"** **Energy Tips**, DOE/GO-102002-1504, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, March 2002.

DOE, ***"Minimize Boiler Blowdown,*** **Tip Sheet #9,"** **Energy Tips**, DOE/GO-10099-954, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, October 2003.

DOE, ***"Minimize Boiler Short Cycling Losses,*** **Tip Sheet #16,"** **Energy Tips**, DOE/GO-1002000-1116, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, December 2000.

DOE, **O&M Best Practices: A Guide to Achieving Operational Efficiency,** Release 2.0, Office of Federal Energy Management Programs, U.S. Department of Energy, Washington DC, July 2004.

DOE, ***"Return Condensate to the Boiler,*** **Tip Sheet #8,"** **Energy Tips**, DOE/GO-10099-953, Office of Industrial Technologies, U.S. Department of Energy, Washington DC, June 2001.

Payne, F. William. **Efficient Boiler Operations Source Book,** Third Edition. Fairmont Press, Lilburn, GA, 1991.

Turner, Wayne C. **Energy Management Handbook, Fifth Edition**. Fairmont Press, Lilburn, GA, 2004.

Zeitz, Ronald A., **Council of Industrial Boiler Owners (CIBO) Energy Efficiency Handbook.** CIBO, Burke, VA, November 1997.

O&M First!—FEMP is pleased to present this series of fact sheets as a way to promote energy efficiency by first applying O&M best practices. It is our hope that the experiences shared will provide federal facility managers with strategies they can apply to their own facilities, as well as introduce the FEMP O&M program to federal site staff.

A copy of the FEMP O&M Best Practices Guide can be downloaded at www.eere.energy.gov/femp/operations_maintenance/om_best_practices_guidebook.cfm. This guide, which covers a full range of facilities O&M topics, provides the rationale for a proactive O&M program; identifies O&M management issues and their importance; explains the various O&M program approaches; introduces maintenance technologies; and explores O&M procedures for the predominant equipment found at most federal sites.

U.S. Department of Energy
Energy Efficiency and Renewable Energy
Bringing you a prosperous future where energy is clean, abundant, reliable, and affordable

A Strong Energy Portfolio for a Strong America

Energy efficiency and clean, renewable energy will mean a stronger economy, cleaner environment, and greater energy independence for America. Working with a wide array of state, community, industry, and university partners, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy invests in a diverse portfolio of energy technologies.

For More Information

EERE Information Center
1-877-EERE-INF or
1-877-337-3463
www.eere.energy.gov/femp

FEMP O&M Program Manager

Ab Ream
Ab.ream@ee.doe.gov
(202) 586-7230

O&M Program Technical Support

Dave Hunt
dave.hunt@pnl.gov
(202) 646-7867

FEMP O&M Resources

FEMP is committed to providing federal facility staff tools and knowledge to help optimize their O&M programs. Visit the FEMP homepage for information on O&M and other FEMP programs and activities at www.eere.energy.gov/femp.

FEMP also offers the workshop Operations and Maintenance Management. To find out more about this course, visit www.eere.energy.gov/femp/services/training_om.cfm.

Produced for the U.S. Department of Energy, Energy Efficiency and Renewable Energy, by the Pacific Northwest National Laboratory

January 2005

PNNL-SA-43825