PG&E's Energy Management Solutions for

BOILERS

CONDENSING BOILERS – When sufficient heat is removed, one of the by-products of combustion is the vapor condensed to a liquid. The typical dewpoint temperature at which this starts to occur for a natural gas boiler is 130°F. In addition to water vapor there are other compounds present in the exhaust stream, which makes the condensate highly corrosive to carbon steel or cast-iron. Modern condensing boilers use high grades of stainless steel or electroplated coatings to eliminate corrosion. Most boilers currently installed have been designed to not produce condensation.

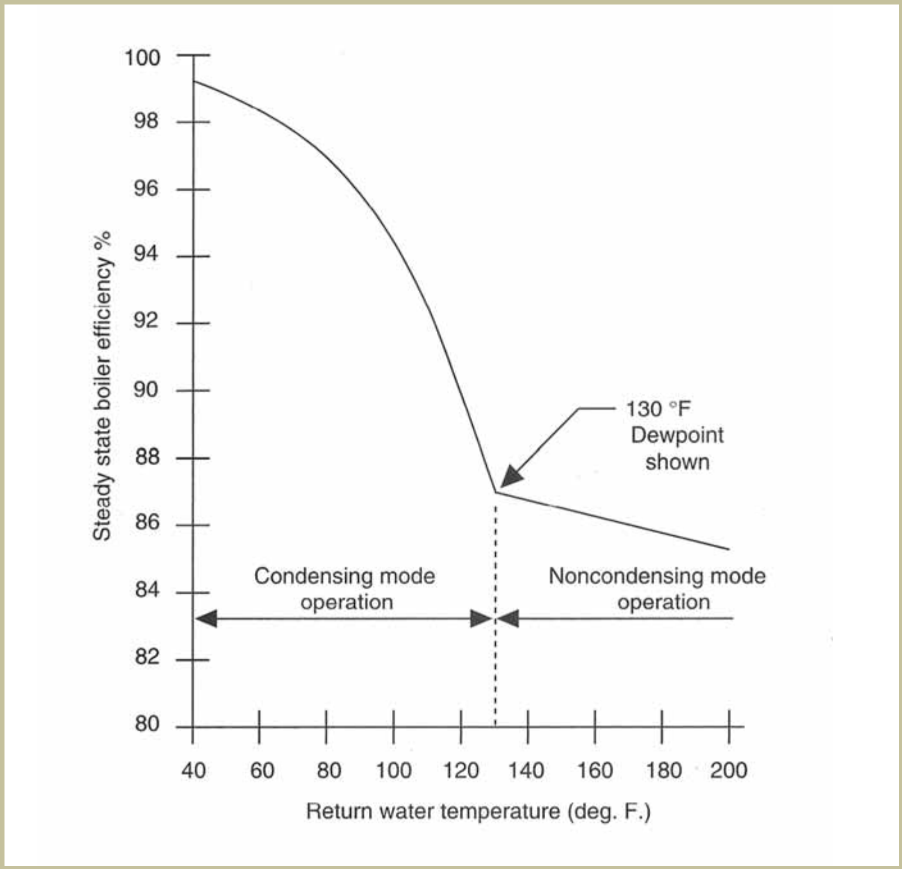

Figure 1. Boiler efficiency in both condensing and non-condensing modes. Source: Siegenthaler, Modern Hydronic Heating.

Figure 1 illustrates the relationship between the return water temperature to the boiler and the efficiency. The lower the return water temperature, the more efficient the operation of the boiler. In order to take advantage of the potential efficiency of a condensing boiler the return water temperature needs to be approximately 130°F or lower, otherwise the condensing boiler operates at an efficiency comparable to a conventional boiler. The return water can be cold boiler makeup or other cold water streams that require heating to the 80-120°F range.

Condensing boilers can achieve thermal efficiencies of 90 – 95%; recent case study data from several manufacturers indicated that condensing boilers are commonly available and cost-effective. This same case study analyzed replacing the conventional boiler with a 93% efficient condensing boiler, resulting in a 13% saving in space heating energy. If the system is not designed to provide inlet temperatures low enough for a condensing boiler to actually condense, the potential efficiencies will not be realized.

BOILER STACK ECONOMIZERS recover flue gas heat for re-use, such as pre-heating boiler feedwater. Stack Economizers should be considered as an efficiency measure for almost all applications, as simple payback is usually 6 months to 2 years. The savings potential is based on the existing stack temperature, the average percent boiler load, and the hours of operation. Economizers are available in a wide range of sizes, from small coil-like units to very large waste heat recovery economizers. Larger economizers are often located between the boiler outlet and stack. A generally accepted "rule of thumb" is that about 5% of boiler energy input can be recovered with a properly sized economizer (relative to 80% economizer).

FLUE GAS CONDENSERS – These condensers are designed to reduce flue gas temperature below the dew point, which results in recovering the sensible heat in the flue gas and also the heat of condensation from the water vapor in the flue gas when it condenses to a liquid. Condensers are worth considering as a measure in cases where large amounts of cold water make-up are needed, or if there is an accompanying need for large quantities of 100–120°F hot water. The primary differences between flue gas condensers and economizers is that condensers heat large amounts of water to a lower temperature, while economizers are designed to heat smaller volumes of water to a higher temperature. Condensers have the potential for greater efficiency than economizers because of their lower outlet exhaust temperature and potential energy available in the condensed flue gases. Condensers are available as small as 50 hp or a single condenser can be used on multiple boilers.

TURBULATORS – Install turbulators in the boiler tubes of fire tube boilers to increase heat transfer between the combustion gases and the water. The result is a relatively modest improved boiler efficiency. Turbulators are an option to a more costly economizer or air-preheater, but energy savings are less. They are simple, easy to install, and low cost. Their installed cost is about $10 to $15 per boiler tube.

BOILER RESET CONTROL – For hot water boilers used for space heating, they reduce the water temperature to the lowest temperature that will met the demand. For example, setting the water temperatures cooler during warmer months and a little hotter during the coldest parts of the winter will provide a better match between boiler output and space heating needs, resulting in improved boiler efficiency and indoor comfort. To avoid unnecessary corrosion of the equipment, care must be taken to avoid a lowered temperature that could cause condensation in a non-condensing boiler.

BLOWDOWN CONTROL – The right amount of blowdown is critical: too much results in energy loss and excessive chemical treatment cost; too little and excessive concentrations of impurities build up. An automatic Blowdown Control device will measure the build up of total dissolved solids (TDS) in boiler water, and blowdown only when required to maintain acceptable water quality.

BLOWDOWN HEAT RECOVERY – Blowdown Heat Recovery systems can recover up to 90% of the heat energy losses incurred during blowdown. The recovered heat is use to pre-heat boiler make-up water.

The following table shows boiler minimal efficiency requirements, recommendations, and best efficiencies available.

Product Type (Fuel/Heat Medium)	Rated Capacity (Btu/h)	California Standards Minimum Thermal Efficiency (e_t)[b]	Recommended Minimum Thermal Efficiency (e_t)[b]	Best Available Conventional Boiler Thermal Efficiency (e_t)[c]	Best Available Condensing Boiler Thermal Efficiency (e_t)
Natural Gas Water	<300,000	80% AFUE[e]	85% AFUE		93% AFUE
	300,000 - 2,500,000	75% e_t[d] (80% combustion efficiency[e])	80% e_t	86.7% e_t	98% e_t
	2,500,001 - 10,000,000	80% combustion efficiency[e]	80% e_c	83.2% e_c	95% e_t
Natural Gas Steam	<300,000	75% AFUE[e]	85% AFUE		83% AFUE
	300,000 - 2,500,000	75% e_t[d]	79% e_t	81.9% e_t	89.3% e_t
	2,500,001 - 10,000,000	80% combustion efficiency[e]	80% e_c	81.2% e_c	85% e_t

Table 1. Boiler Efficiency Requirements, Recommendations, and Best Efficiencies Available. (Sources: California Energy Commission and the Department of Energy)

a This recommendation covers low- and medium-pressure boilers used primarily in commercial space heating applications. It does not apply to high-pressure boilers used in industrial processing and cogeneration applications.

b Thermal efficiency (e_t), also known as “boiler efficiency” or “overall efficiency,” is the boiler's energy output divided by energy input, as defined by ANSI Z21.13. In contrast to combustion efficiency (e_c), e_t accounts for radiation and convection losses through the boiler's shell.

c These “best available” efficiencies do not consider condensing boilers, which are generally more efficient but are not readily ratable with ANSI Z21.13.

d Title 24 Standards.

e Title 20 Standards. The Title 20 definition of AFUE is “Annual fuel utilization efficiency (AFUE) of a space heater means a measure of the percentage of heat from the combustion of gas or oil that is transferred to the space being heated during a year.”

f With an economizer, efficiency can approach 86%.

INSTALL INSULATION – All hot surfaces should be insulated for both worker safety and energy efficiency. Insulation must be in good condition to provide any benefits, for instance wet insulation is worse than no insulation. In general, any surface above 120°F should be insulated, including boiler surfaces, piping and fittings. Removable insulating jackets are available for many fittings to allow easy access for maintenance.

CONSIDER MULTIPLE SMALL BOILERS INSTEAD OF ONE LARGE UNIT – Installing multiple boilers in hotels and motels, and multi-family facilities provides redundancy and allows staging, which can meet loads more efficiently than a single large boiler. The Department of Energy states that efficiency loss can vary as much as 10% when operations change from the maximum continuous output to a reduced boiler output (30 to 40% of capacity).

BOILER SEQUENCE CONTROL – When multiple boilers are in use, install an automated boiler sequence control to achieve the best combination of boiler run efficiency.

EXHAUST DRAFT CONTROL – It is important to maintain a proper flue draft to optimize combustion: too little draft leads to problems such as CO formation, condensation, soot, and flue gas spillage; on the other hand too much draft leads to inefficient operation of the boiler. Exhaust draft controls can increase energy efficiency, however the systems must be designed with safety features that will deactivate the boiler if the draft falls below a certain setpoint.

UPGRADE BOILERS WITH ENERGY EFFICIENT BURNERS – According to the Department of Energy, a poorly designed boiler with an efficient burner may perform better than a well designed boiler with a poor burner. Even small improvements in burner efficiency can result in significant energy savings, for example, a boiler that consumes 250,000 MMBTU (2,500,000 therms) of natural gas with a 1% burner combustion efficiency improvement can save 3,120 MMBtu (31,200 therms) annually. Assuming a gas rate of $0.90 per therm, the savings would amount to $28,080 annually.

COMBUSTION AIR CONTROL SYSTEM – To reduce excess air flow through the boiler and boiler room, install a combustion air control system. Operating a boiler with an optimal amount of excess air will improve combustion efficiency, which is a measure of how effectively the heat content of a fuel is transferred into usable heat. The Department of Energy indicates that as a rule of thumb, boiler efficiency can be increased by 1% for each 15% reduction in excess air or 40°F reduction in stack gas temperature. For example, for a boiler operating 8,000 hours annually and consuming 500,000 million btu (MMBtu or 5,000,000 therms), reducing the excess air from 44.9% to 9.5% effectively increases the combustion efficiency from 78.3% to 80.9%, resulting in a savings of 16,069 MMBtu (160,689 therms) annually. Assuming a gas rate of $0.90 per therm, the savings would amount to $144,620 annually.

EFFICIENCY TERMINOLOGY – According to the Boiler Burner Consortium, there are many ways of measuring the efficiency of a boiler and it is important to know which type of efficiency is being used when comparing boilers.

- **Combustion Efficiency** is a measure of the burner's ability to burn fuel. Efficient burners using gaseous or liquid fuels operate at excess air levels of 15% or less and leave negligible amounts of unburned fuel.

- **Thermal Efficiency** is an indication of the ability of the boiler's heat exchanger to transfer heat from the combustion process to the water or steam in the boiler. Thermal efficiency is exclusively a measurement of the effectiveness of the heat exchanger of the boiler and it does not include radiation and convection losses; therefore thermal efficiency is not a true measure of the boilers fuel usage.

- **AFUE or Annual Fuel Utilization Efficiency** measures the amount of fuel converted to space heat in proportion to the amount of fuel entering the boiler. This is commonly expressed as a percentage. For example, an AFUE of 90% indicates that 90% of the energy in the fuel becomes heat and the remaining 10% is lost. AFUE ratings do not include the heat losses of the duct system or piping.

- **Boiler Efficiency** is a term often used interchangeably with the thermal efficiency.