SECTION III. OPTIMIZING CENTRAL PLANT EFFICIENCY

3-34. OPTIMIZING COMBUSTION EFFICIENCY

With the cost of fuel continuously increasing, the need to operate central boiler plants efficiently becomes more important all the time. Procedures for optimizing operating efficiencies are discussed in this section. An operator should review the Elementary Combustion Principles and Principles of Steam and Hot Water Generation found in chapter 1. To optimize boiler efficiency the combustion efficiency must first be optimized. We have seen in paragraph 1-11 and tables 1-4, 1-5, 1-6, 1-7, and 1-8 that combustion efficiency is a function of the type of fuel burned, the flue gas temperature, and the amount of excess air in the flue gas. For a given fuel, the operator must take action to optimize combustion efficiency by maintaining as low a flue gas temperature and excess air level as is possible.

a. Sootblowing/Cleaning to Reduce Flue Gas Temperatures. On all boilers equipped with sootblowers, they should be operated as needed to maintain clean heat transfer surfaces. Once a shift is the recommended internal when oil or coal is being fired although experience may dictate a different interval for a particular unit. Note the flue gas temperature before and after scootblowing. A reduction in temperature of 35° F to 40° F corresponds to an efficiency improvement of one percent. Reference tables 1-5 through 1-8 for the specific improvement at the actual temperatures and excess air levels at which you are operating. For fire tube boilers not equipped with sootblowers, a record of flue gas temperatures at the normal firing rate of the boiler should be kept. When the flue gas temperature exceeds the clean boiler flue gas temperature by more than 70° F, the boiler should be taken out of service and cleaned. Fire-tube boilers should, as a minimum, be cleaned during the quarterly inspection.

b. Water Side Cleaning. Maintaining the water side of a boiler is equally as important as maintaining the fire side. Scale on the water side reduces heat transfer just as soot does, and thereby increases flue gas temperature and reduces efficiency. Maintain aproper water treatment program as described in chapter 4. Quarterly inspection and mechanical cleaning may be required. Chemical cleaning may be required occasionally. The operator should know the flue gas temperature of the boiler at its normal firing rate and excess air level, with the gas and water side clean. Any major change in temperature at those firing conditions indicates a problem, typically dirty gas or water side heat transfer surfaces.

c. Setting Leaks. Air leakage into the boiler system increases excess air levels and reduces efficiency. Any air drawn into the boiler through leaks in the furnace setting, casing, or flues must be heated from room temperature to the flue gas temperature, using heat that could otherwise be transferred to the steam. Normal maintenance should greatly reduce the number and size of leaks. Reference paragraph 5-11. The operator should ensure that all doors, ports, and openings into the furnace are closed tightly. The furnace draft should be maintained at a slightly negative level of -0.03s to -0.10 inches of water. This practice helps to minimize air leaks. When the draft is increased for sootblowing, take care to return it to its normal level after sootblowing is complete. The use of a continuous oxygen analyzer to traverse the stack or flue can sometimes help to locate an air leak by showing a higher than normal excess air level.

d. Baffles. To obtain maximum heat absorption, baffles are often used to help direct the hot gases over the tubes. Arrangements vary widely, depending upon tube arrangement. The baffles restrict the flow of gases and affect draft flow required by the boiler. Defective baffles allow gases to short-circuit so they do not pass over the entire heating surface. Leaking baffles result in high outlet gas temperature, and decreased efficiency. Leaking baffles ca usually be distinguished from fouled heat transfer surfac by their effect on draft loss: leaking baffles decrease gas loss, while fouled surfaces increase draft loss. Always investigate and report a change in flue gas temperature or draft loss.

e. Fuel/Air Ratio Optimization. Reference paragraph 3-20a, Combustion Controls-Fuel/Air Ratio Adjustment. Know the proper excess air levels for each firing rate. When proper levels are known, corrective action can be taken if the fuel/air ratio is out of adjustment. Some corrective actions, such as returning the oil header pressure or temperature to the correct operating point, adjusting the stoker feed, returning the furnace draft to the operating point, or biasing the fuel/air ratio may be taken by the operator. If additional corrective action is required, note this in the boiler log and inform the responsible personnel. The optimum fuel/air ratio for a winter load is probably not optimum for a summer load. Determine the optimum ratio over the full load range of the boiler, and post a chart where it can be readily accessed by the operators. Table 3-1 gives recommended oxygen, carbon dioxide, and excess air levels at full load, 50 percent load, and 25 percent load for typical equipment. All boilers will not be able to operate at these levels, but this level of performance is possible with modern, correctly adjusted equipment. Plant modifications to reach these levels may b economically justified based on fuel savings resulting from improved combustion efficiency.

Table 3-1. Flue Gas Analysis at 25%, 50%, and 100% Load
For Natural Gas, No. 2 Oil, No. 6 Oil, and Stoker Coal

	FUEL											
	Natural Gas			No. 2 Oil			No. 6 Oil			Stoker Coal		
Load, Percent	25	50	100	25	50	100	25	50	100	25	50	100
O_2, Percent	4.0	3.0	2.0	5.0	4.0	2.5	5.5	4.5	3.0	7.0	6.0	5.0
CO_2, Percent	9.6	10.1	10.7	11.9	12.6	13.8	12.2	13.0	14.1	12.4	13.3	14.2
Excess Air, Percent	21.1	15.1	9.5	29.2	22.0	12.6	33.6	25.8	15.8	48.5	38.8	30.3

3-35. OPTIMIZING BOILER EFFICIENCY

Boiler efficiency accounts for the energy loss included in combustion efficiency plus the energy losses associated with heat radiated from the boiler casing, heat removed with blowdown, and heat lost due to incomplete combustion. Boiler efficiency is affected by the stability of the combustion controls. Boiler efficiency is always less than combustion efficiency.

a. Reduce Radiation Losses. Inspect, maintain, and improve boiler, flue, and pipe insulation. Improved insulation is often available and economically justified. Radiation losses can be minimized by the proper selection of operating and standby boilers, and the temperture at which standby boilers are maintained. For some plants operating with non-critical load, a standby boiler need not be maintained in hot condition. Close the inlet and outlet dampers of any standby boilers. This will help to minimize the natural draft air flow which will cool the boiler.

b. Reduce Blowdown Losses. Blowdown is necessary to control steam boiler water quality and minimize scale formation. Reduced scale formation helps to maintain combustion efficiency near clean boiler levels and reduces side maintenance. Blowdown is a form of preventive maintenance that should be carefully controlled (reference paragraph 4-8). Continuous blowdown is recommended for steam boilers because blowdown heat exchangers can be used to recover much of the heat in the blowdown water by preheating make-up water. Automatic control of continuous blowdown is also recommended to improve the accuracy of the blowdown procedure and help minimize losses.

c. Reduce Unburned Carbon Losses. Unburned carbon losses from oil- and gas- fired boilers are usually negligible because the fuels burn easily and excess air levels and smoke are easily controlled. Unburned carbon losses for stoker fired boilers, however, can be significant. Stokers should be carefully maintained and operated to minimize unburned carbon losses. Ash reinjection systems are an important part of a spreader stoker system which must be maintained in good operative condition. Overfire air is also very important on any stoker system to obtain proper mixing of air and combustion gases. Reference operation procedures in paragraph 3-17.

d. Stabilize Combustion Controls. The combustion control system must accurately establish the correct fuel/air ration to optimize combustion efficiency. Combustion controls are designed to regulate fuel and air flows to satisfy load demand, establish correct fuel/air ratio, and minimize the time spent at inefficient firing conditions. Combustion controls are stabilized by making the proper adjustments to the proportional band, integral, and rate settings to best respond to the load conditions. It is common that the best settings for winter load conditions are not best for summer conditions. The assistance of the control manufacturer may be required to determine the best settings. Settings should be changed only by trained and authorized personnel.

3-36. OPTIMIZING CENTRAL BOILER PLANT EFFICIENCY

Overall plant efficiency is always less than boiler efficiency. Reference paragraph 1-13 for an initial discussion of Central Boiler Plant efficiency. After individual boiler efficiency is optimized, then consideration must be given to proper boiler selection, deaerator control, use of steam driven auxiliaries, building energy conservation, and modifications or additions to plant equipment.

a. Boiler Selection. The best use of available boilers is necessary to optimize plant efficiency. A curve of efficiency versus load should be developed for each boiler based upon the data obtained when the fuel/air ratios were developed. Figure 3-6 illustrates such a curve. With this information it is possible to select which boiler or group of boilers is best suited to operate at a given load. For a steam demand of 30,000 PPH, operation of boilers #1 and #2 would be most economical. If efficiency of particular boiler is good over a very small range, it ma be best to baseload that boiler in that range and allow the other boiler(s) to handle load swings. Two boilers operating at partial load may be more efficient than one boiler operating near its design capacity. A Standing Operating Procedure should be developed establishing which boilers should operate for a given load.

b. Deaerator Control. Reference paragraphs 4-6g and 4-16c. Deaerators consume a significant amount of steam to heat and deaerate feedwater. Some of the steam is vented to atmosphere and lost. The amount vented ranges from one-tenth percent to one percent of the plant load and is dependent upon both the original design of the deaerator and vent condenser and their proper operation. With poor operation or design, 5 percent or more of the plant load can be vented through the deaerator. If operation alone does not resolve excessive venting, equipment modification or replacement should be considered.

c. Steam Driven Auxiliaries. Steam driven fans and pumps may be useful in providing a plant that can be operated in case of electric failure. Care must be taken, however, in utilizing such drives, because they can have a significant effect on plant efficiency. The efficiency of a non-condensing steam turbine is only about 20 percent. Suitable uses for the exhaust steam must, therefore, be developed if steam turbines are to be used effectively Operate steam drives only when a use for the low pressure exhaust steam is available.

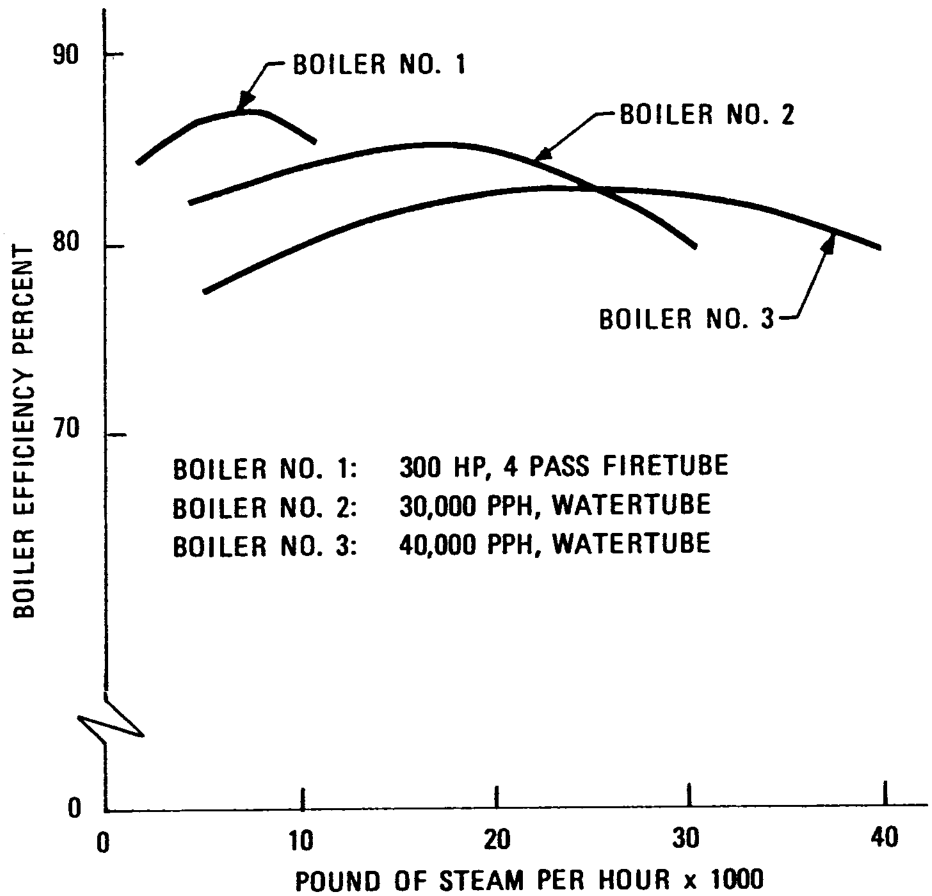

FIGURE 3-6. BOILER EFFICIENCY VERSUS LOAD

d. Plant Building Conservation. Overall plant efficiency can be improved by minimizing the use of plant generated energy for building heating. Use waste heat from condensate return, blowdown water, or boiler radiation whenever possible. Insulate the building. Maintain building steam traps and repair all water or steam leaks immediately. Provide vent condensers on condensate wells, deaerators or deaerating heaters, and use the minimum steam pressure practical in heat exchangers. Reference paragraph 1-2b(1) Energy Losses.

e. Equipment Modifications or Additions. Existing equipment which does not operate efficiently should be modified or replaced if economically justified. Economizers or air heaters should be considered for boilers that normally operate with flue gas temperatures above 500° F, if these boilers operate for significant periods of the year. Five percent improvement in boiler efficiency is common and can often economically justify the addition of such equipment. Improvements to external water treatment may be justified if significant reductions in blowdown quantities can be realized. The addition of a blowdown heat recovery system should be considered. The use of vent condensers, condensate heat recovery systems, improved steam traps, and upgraded boiler combustion controls should also be considered. The economics of such modifications should be carefully reviewed, but it will often be found that the potential energy savings will quickly pay back the capital investment required.

f. Distribution System Effects on Plant Efficiency. If less water is returned to the central plant than was supplied in the form of steam or hot water, plant efficiency is reduced. Make-up water must be heated from its supply temperature, usually about 60° F, while condensate return water needs only to be heated from its already elevated temperature of 150 to 180° F. It is important to monitor supply and return flows as well as makeup flow and determine if excessive losses occur. Note that temperature compensation is required for accurate flow comparison. If losses are determined to be excessive or other problems develop, appropriate personnel should be alerted so repairs to the distribution system can be made. Distribution system losses should not exceed five to ten percent of supplied flow in a steam system and one percent in a hot water system.