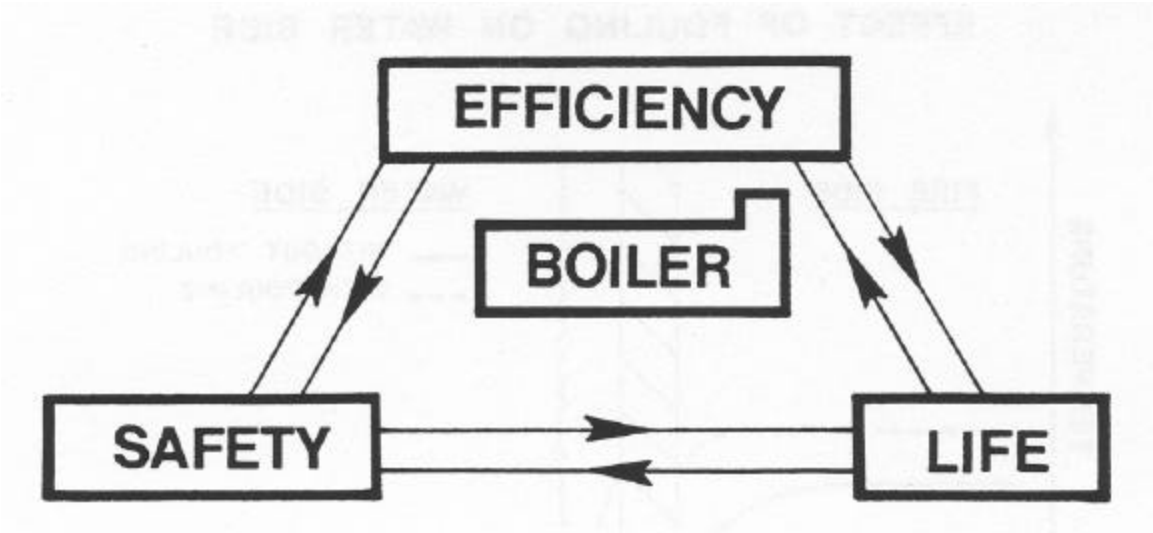
BOILER EFFICIENCY IMPROVEMENT
Operator Manual



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CHAPTER 1

Introduction

This manual is intended for boiler operators. Technical detail has been suppressed and a "how to" approach has been adopted.

Readers interested in more technical detail are referred to a comprehensive manual by the authors entitled, Boiler Efficiency Improvement. This manual is available from the Boiler Efficiency Institute.

CHAPTER 2

Methods to Improve Boiler Efficiency

2.0 Introduction

This chapter describes eleven ways to improve boiler efficiency and the measurements necessary to assess the potential savings for each method are indicated. Furthermore, the adjustments required to effect each saving are discussed.

2.1 Dollar Savings

Table 2.1 shows the money saved by improving the efficiency of a boiler by 5 percent. Most of the more than 2,000 boilers tested by the authors have higher potential savings. The table lists annual savings for operation at various continuous loads expressed in boiler horsepower and pounds per hour of steam production. Savings for different fuel prices in dollars per million BTU are given. The equivalent price in cents per gallon for oil and dollars per thousand cubic feet of gas are also included in the table.

2.2 #1 Potential – Reduce Excess Air

Typical Annual Savings – 5 Percentage Points

$11,500 on 100 HP

Save: $133,333 on 40,000 lb/hr

Table 2.1: Dollars Saved Annually by Improving Boiler Efficiency by 5 Percent

Steam Production	Fuel Price				
	$2.00* or $0.30/gal	$3.00* or $0.45/gal	$4.00* or $0.60/gal	$5.00* or $0.75/gal	$10.00* or $1.50/gal
100 HP or 3,450 lb/hr	$ 4,600	$ 6,900	$ 9,200	$ 11,500	$ 23,000
200 HP or 6,900 lb/hr	$ 9,200	$ 13,800	$ 18,400	$ 23,000	$ 46,000
400 HP or 13,800 lb/hr	$ 18,400	$ 27,600	$ 36,800	$ 46,000	$ 92,000
800 HP or 27,600 lb/hr	$ 36,800	$ 55,200	$ 73,600	$ 92,000	$ 184,000
40,000 lb/hr	$ 53,333	$ 80,000	$ 106,667	$ 133,333	$ 266,666
60,000 lb/hr	$ 80,000	$ 120,000	$ 160,000	$ 200,000	$ 400,000
80,000 lb/hr	$ 106,667	$160,000	$ 213,334	$ 266,667	$ 533,333
100,000 lb/hr	$133,333	$200,000	$ 266,666	$ 333,333	$ 666,666
200,000 lb/hr	$266,667	$400,000	$ 733,333	$ 666,667	$1,333,333
300,000 lb/hr	$400,000	$600,000	$ 800,000	$1,000,000	$2,000,000
400,000 lb/hr	$533,333	$800,000	$1,066,666	$1,333,333	$2,666,666
500,000 lb/hr	$666,667	$1,000,000	$1,333,334	$1,666,667	$3,333,333
1,000,000lb/hr	$1,333,333	$2,000,000	$2,666,667	$3,333,333	$6,666,666

*Price in $/million BTU or $/thousand cubic foot of gas

Explanation

Excess air means there is more air for combustion than is required. Figure 2.1 shows why this results in efficiency loss. The extra air is heated up and thrown away.

Figure 2.2 is a graph of efficiency versus excess air (or deficient air). Curves for two different flue gas temperatures are given. Note that the
efficiency drops by 4 percent between no excess air and 100 percent excess air. Also note that the efficiency drops very rapidly with deficient air.

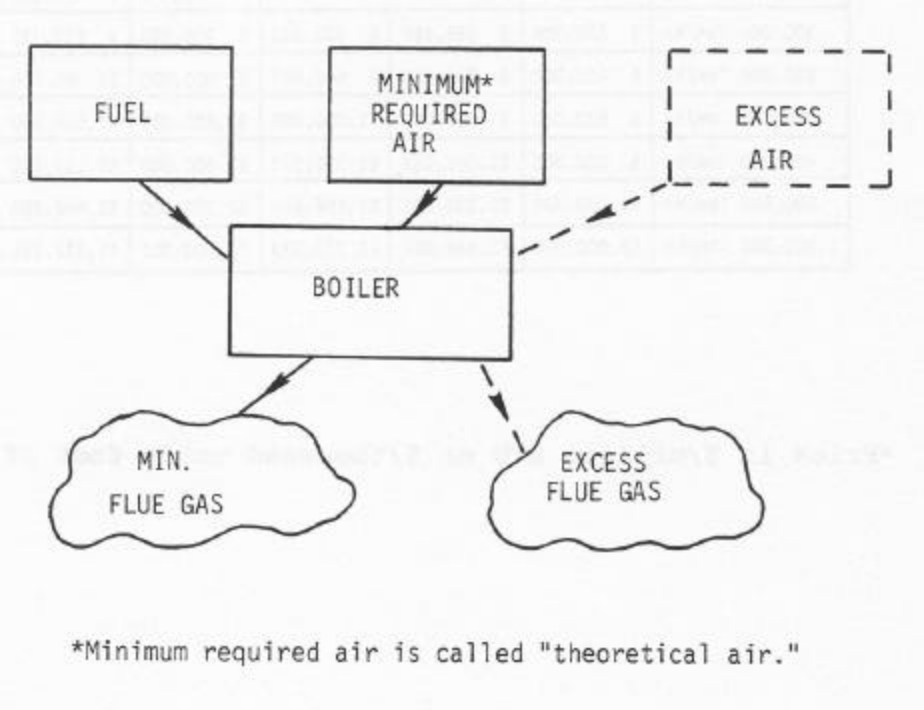

Figure 2.1: Explanation of Excess Air

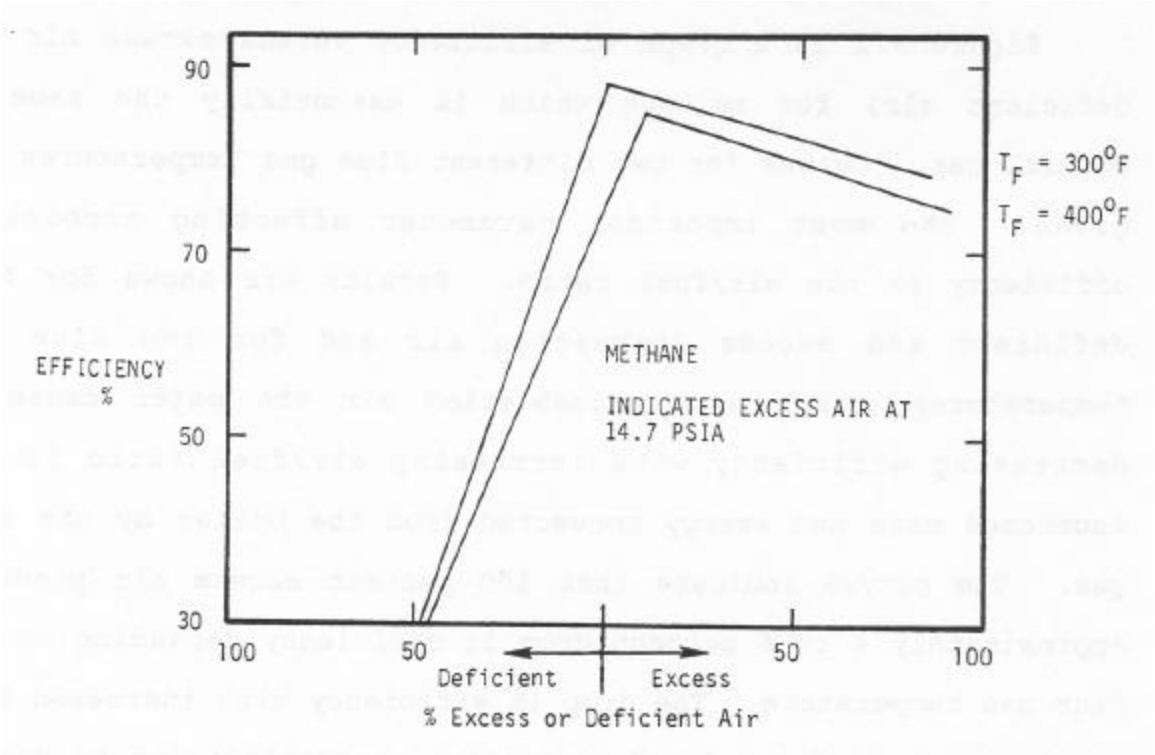

Figure 2.2: Efficiency Loss Due to Various Amounts of Combustion Air

Using deficient air is bad for three reasons:

(1) It decreases efficiency.
(2) It soots on the fireside.
(3) The flue gases are potentially explosive.

Therefore, many operators use high levels of excess air to avoid the possibility of deficient air operation. There are many reasons for using excess air:

a. The burner-control system is not perfect.
b. The air density changes due to temperature, pressure, and relative humidity changes in the boiler room.
c. Control systems have "slop" in them.
d. The burner needs maintenance.
e. The fuel composition varies.
f. The viscosity of oil is improperly controlled.
g. Atomizing steam or air properties are improperly controlled.

Some important points to know about excess air are listed in Table 2.2.

Table 2.2: Required Levels of Excess Air

1. On well designed systems the following levels of excess air are possible:

Fuel	**Excess Air**
Natural Gas	10%
No. 2 Oil	12%
No. 6 Oil	15%

2. Low excess air systems can perform with less excess air than listed above.
3. Some systems (for example, natural draft air supply) require even more air than listed above.
4. The closer excess air is controlled the more often it must be adjusted to avoid sooting.

Symptom

It is very easy to detect excess air. The oxygen in the air that is not used for combustion is discharged in the flue gas. Therefore, a simple measurement of oxygen level in the exhaust gas tells us how much excess air is being used. This measurement can be made with several different instruments described in Chapter 3. Once the percent oxygen present is known, the excess air can be determined from the tables in Appendix A.

Action Required

The excess air can be reduced by increasing the fuel flow rate or decreasing the air flow at a fixed firing rate. The air/fuel ratio can be reduced until incomplete combustion occurs. Incomplete combustion is indicated by smoke or carbon monoxide. Smoke can be used as an indicator of minimum air on liquid or solid fuels and carbon monoxide must be used for natural gas. Tuning of a boiler should be accomplished in the following manner.

1. Set the boiler on a fixed firing rate.
2. Adjust air or fuel until about 200 ppm of carbon monoxide or visible smoke (for oil or coal) appears in the exhaust. This is a minimum air/fuel ratio for the boiler unless changes are made.
3. If the excess oxygen is below the limits shown in Table 2.2 with the air/fuel ratio at a minimum value, the boiler is probably set up properly. If this is the case, increase the amount of excess air slightly to provide a satisfactory "cushion" of excess air. The amount of excess air cushion needed depends on how often the excess air levels are to be checked and adjusted, the type and condition of the control system, fuel property variations, etc.
4. If the excess oxygen is above the limits shown in Table 2.2, then changes to the boiler and its operating condition need to be made. Explore changes one at a time. For example, with the air/fuel ratio at its minimum value and the boiler on manual fire, change the oil preheat temperature and observe the effect on CO (or smoke) in the exhaust. Continue changes until the O_2 is reduced to a minimum value with 200 ppm CO in the exhaust. This procedure can be used to explore other effects such as atomizing flue properties, fouled burners, etc.

2.3 #2 Potential – Install Economizer

Typical Annual Savings – 3 Percentage Points

\$6,900 on 100 HP

Save: \$80,000 on 40,000 lb/hr

Explanation

The temperature in flue gas represents heat. This heat can be captured in some cases with a heat exchanger (economizer), which preheats feedwater. Figure 2.3 shows a schematic of an economizer installed in the stack of a boiler.

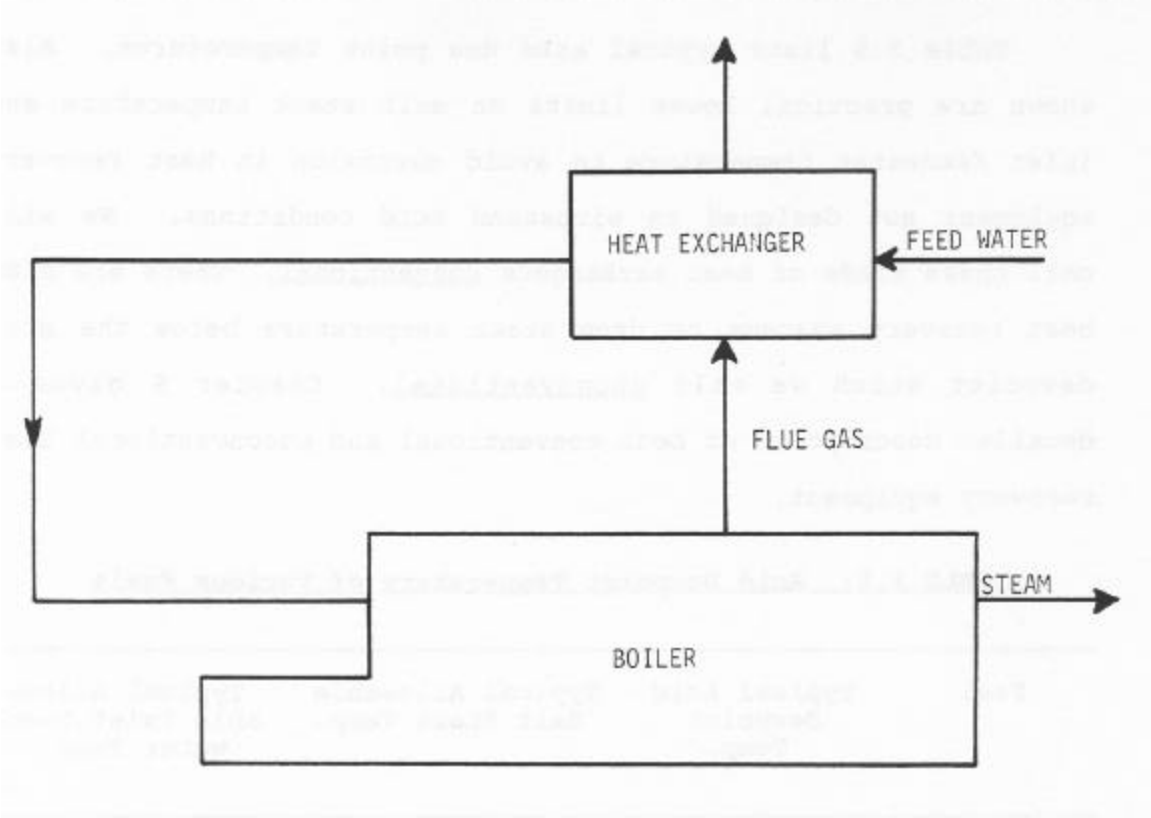

Figure 2.3: Typical Economizer Installation

An economizer is appropriate only if insufficient heat transfer surface exists in the boiler to remove the heat released in the flame. Also, it must be remembered that with conventional economizers there is a minimum temperature to avoid corrosion. The minimum temperature to avoid corrosion is dependent on the fuel used and the economizer design.

Figure 2.4 shows the percentage point efficiency improvement versus increase in feedwater temperature. A rule of thumb is that raising the water temperature by 10°F increases efficiency by 1 percentage point.

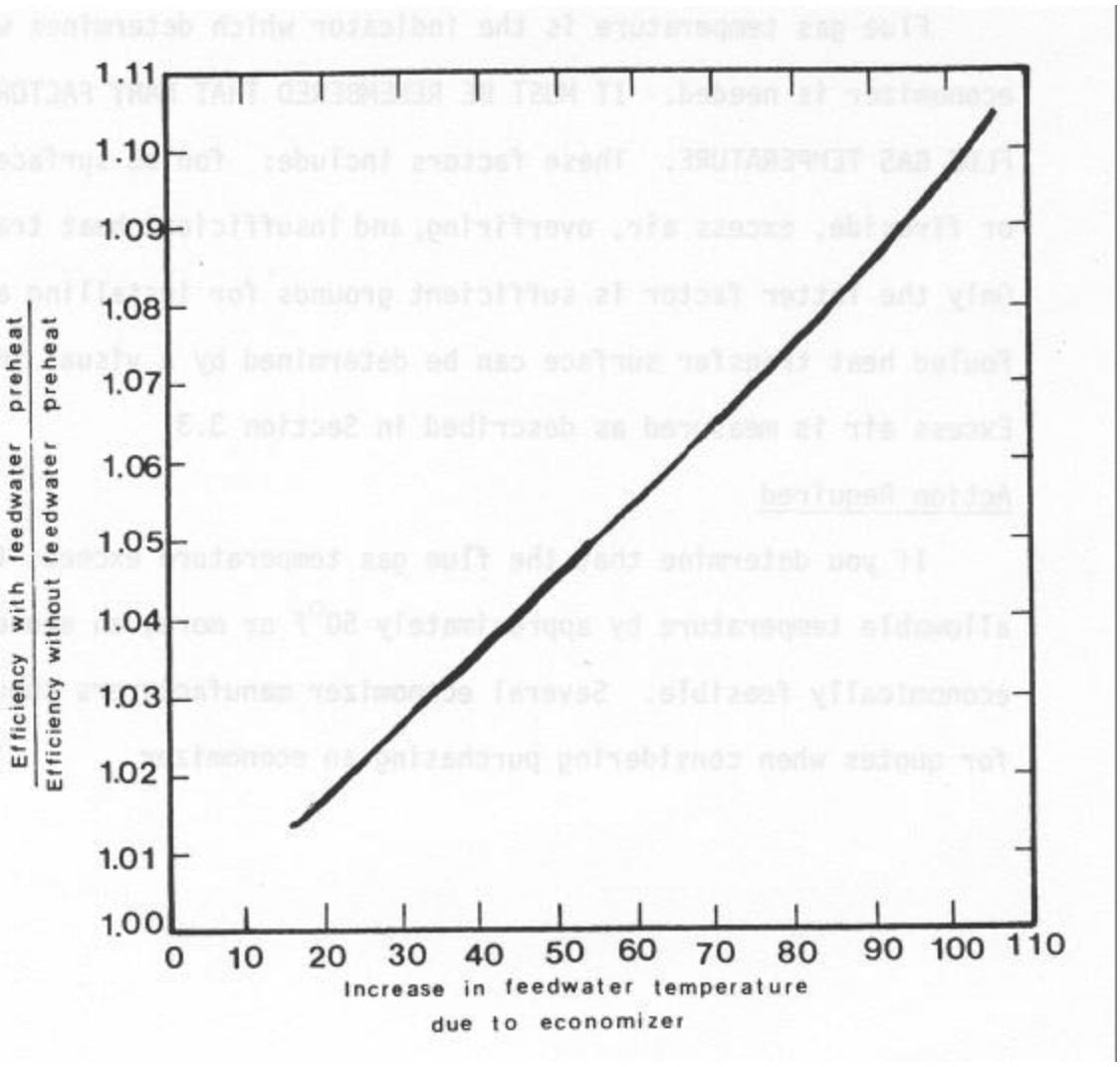

Figure 2.4: Improvement Due to Preheating Feedwater

Symptom

Flue gas temperature is the indicator determining whether an economizer is needed. **It must be remembered that many factors cause high flue gas temperature.** These factors include:

- fouled surfaces on the water or fireside,
- excess air,
- overfiring, and
- insufficient heat transfer surface.

Only the latter factor is sufficient grounds for installing an economizer. Fouled heat transfer surface can be determined by a visual inspection. Excess air is measured as described in Section 3.3.

Action Required

If you determine that the flue gas temperature exceeds the minimum allowable temperature by approximately 50°F or more, an economizer may be economically feasible. Several economizer manufacturers should be consulted for quotes when considering purchasing an economizer.

2.4 #3 Potential – Reduce Scale and Deposits

Typical Annual Savings – 2 Percentage Points

$4,600 on 100 HP

Save: $53,333 on 40,000 lb/hr

Explanation

Scale or deposits serve as an insulator in the same way one uses insulation in the wall of a home. This point is illustrated in Figure 2.5, which shows that more heat from the flame goes up the stack rather than to the water due to these deposits.

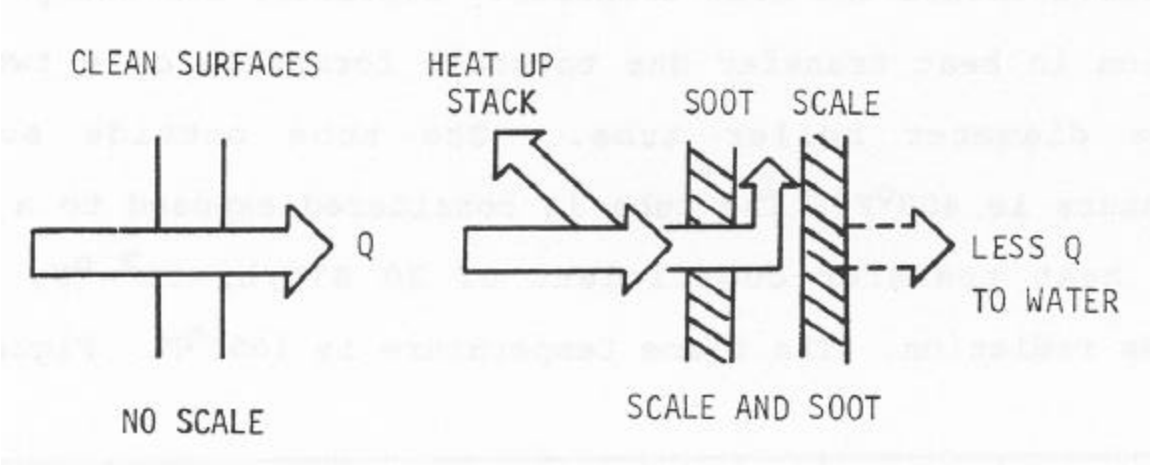

Figure 2.5: Diversion of Heat by Scale and Soot

Figure 2.6 shows the reduction in efficiency due to scale thickness. For example, 1/32 inch of scale can reduce efficiency by 3 percentage points.

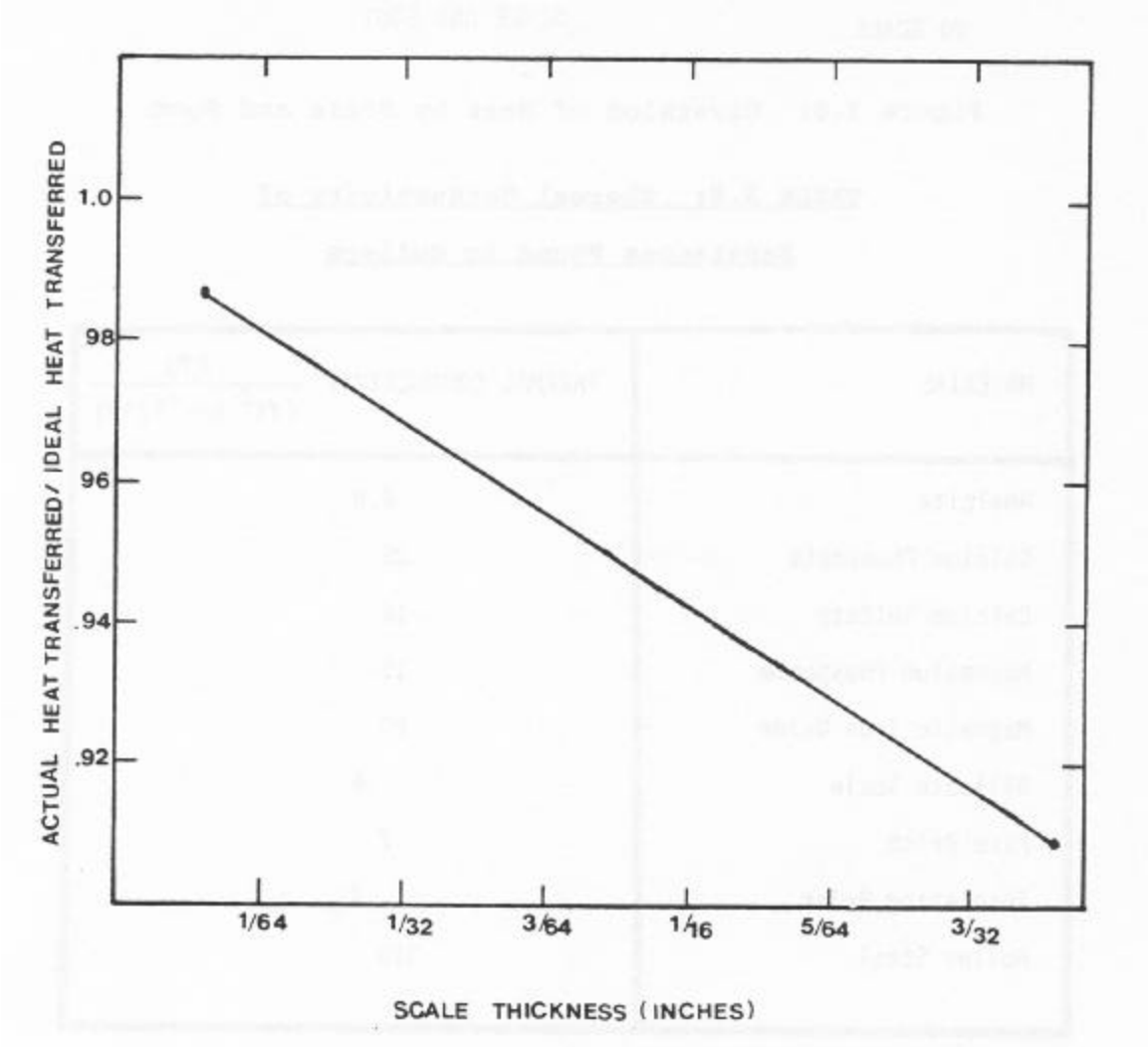

Figure 2.6: Reduction of Heat Transfer Due to Scale

Symptom

The best indirect indicator for scale or deposit buildup is the flue gas temperature. If (at the same load and same excess air) the flue gas temperature rises with time, the effect probably is due to scale or deposits. Of course, these problems can be detected by a visual observation.

Action Required

Soot is primarily caused by incomplete combustion. Incomplete combustion can be due to deficient air, a fouled burner, defective burner, slop in linkage, etc. Adjust excess air as described in Section 2.2. Make adjustments and repairs as necessary to eliminate smoke and carbon monoxide.

Scale formation is due to poor water quality. First, the water should be soft entering the boiler. TDS must be reduced below the limits shown in Table 2.3. Sufficient phosphate or chelant must be fed in the boiler to control hardness.

The major water quality parameters that must be controlled are shown in Table 2.3 along with the approximate limits and residual concentrations for boilers under 200 psia.

Table 2.3: Boiler Water Residuals

Feed Water	Softness	Less than 1 ppm
Feed Water	Oxygen	Less than 20 ppb
Boiler Water	Hardness	Less than 1 ppm
Boiler Water	pH	9.5 to 11
Boiler Water	TDS	Less than 3500 ppm
Boiler Water	Sulfite	30 to 60 ppm
Boiler Water	Alkalinity	Less than 800 ppm
Boiler Water	Phosphate	20 to 40 ppm
Condensate	pH	7.5
Condensate	TDS	Less than 20 ppm

2.5 #4 Potential – Reduce Blowdown

Typical Annual Savings – 1 Percentage Point

$2,300 on 100 HP

Save: $26,666 on 40,000 lb/hr

Explanation

Blowdown results in the energy in the hot water being lost to the sewer unless energy recovery equipment is used (see Section 2.6). The efficiency loss due to various amounts of blowdown in shown in Figure 2.7.

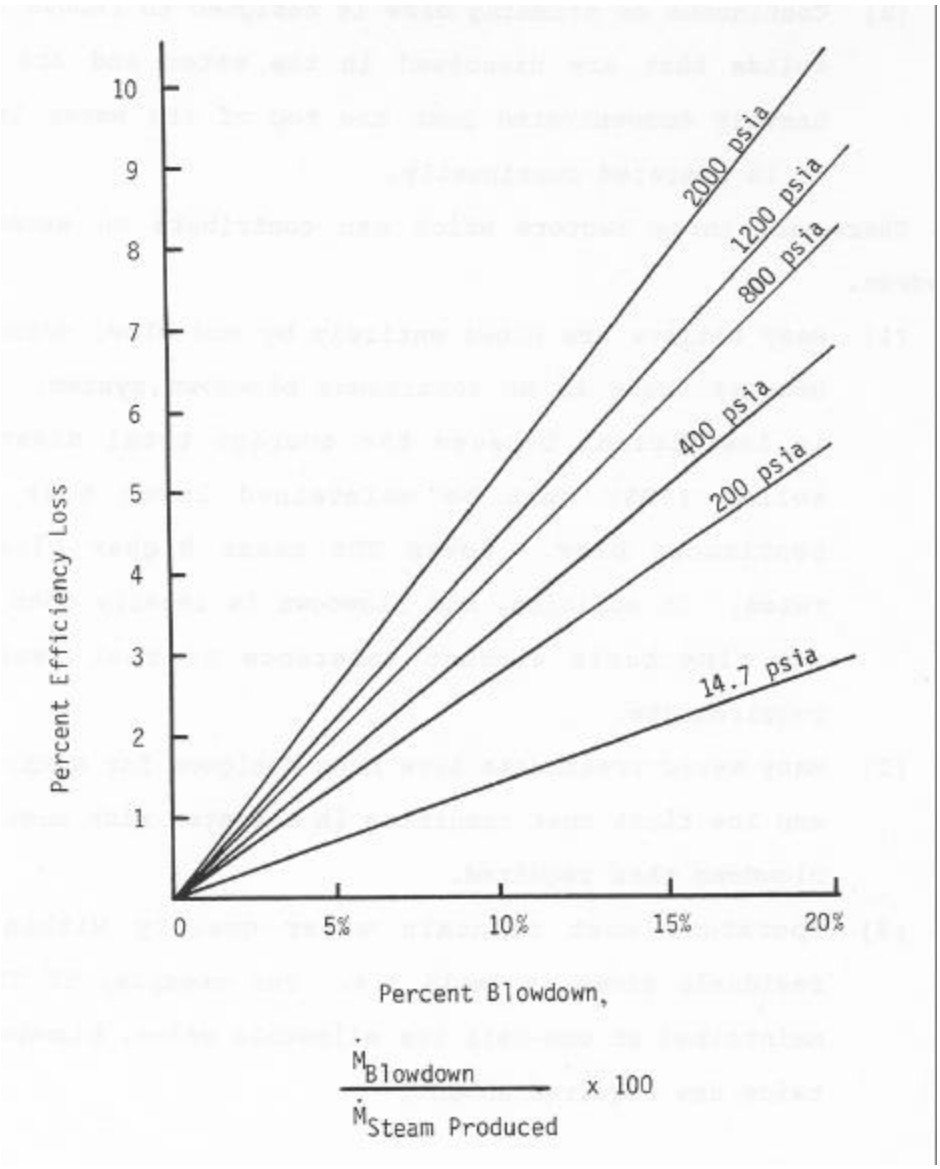

Figure 2.7: Efficiency Loss Due to Blowdown

There are two types of blowdown.

(1) Mud blow is designed to remove the heavy sludge that accumulates at the bottom of the water level. Mud blow is done for a few seconds on several hour intervals.
(2) Continuous or skimming blow is designed to remove light solids that are dissolved in the water and float near the top of the water level. It is operated continually.

There are three factors that can contribute to excessive blowdown.

(1) Many boilers are blown entirely by mud blow because the continuous blowdown system has never been connected. Removing the light solids near the top of the water requires removal of most of the water; i.e., the collection efficiency is very poor.
(2) Many water treatments have been designed for simplicity and low first cost resulting in a system with much more blowdown than required.
(3) Operators must maintain water quality within the residuals shown in Table 2.3. For example, if TDS is maintained at one-half its allowable value, blowdown is twice the required amount.

Symptom

First, check to be sure mud blowdown is only being used for the purpose intended – to remove sludge. Second, observe the closeness of the various water quality parameters to the tolerances shown in Table 2.3. If alkalinity is near its maximum value while TDS is much less than its limit, the treatment process can be changed and blowdown reduced – consult an expert. Third, check the water quality in the boiler using standard chemical tests. These tests should include residuals for phosphate or chelant and sulfite. Also, the level of TDS, alkalinity, suspended solids and silica should be measured. Depending on type of treatment, other properties may also require measurement.

Action Required

Adjusting the continuous blowdown rate will change TDS, alkalinity, suspended solids and silica. The residual of any chemical feed is also affected by blowdown but should be changed by adjusting the chemical feed rate.

2.6 #5 Potential – Recover Waste Heat From Blowdown

Typical Annual Savings – 1 Percentage Point

$2,300 on 100 HP

Save: $26,666 on 40,000 lb/hr

Explanation

As shown in the previous section, blowdown contains energy. Most of the energy in blowdown can be captured by the systems shown in Figure 2.8. First, a tank into which the steam is expanded can be installed. This tank causes some of the blowdown water to flash to steam. The steam is then used to preheat feedwater. About 60 percent of the blowdown energy can be saved in this way. Most of the remaining energy can be saved by running the liquid effluent from the flash tank through a counterflow heat exchanger that is used to preheat feedwater.

Symptom

Any boiler with significant makeup (say 5 percent) is a candidate for blowdown waste heat recovery. High-pressure boilers yield larger savings (see Figure 2.7).

Action Required

Install system as shown in Figure 2.8. Make decisions based on proper economic analysis.

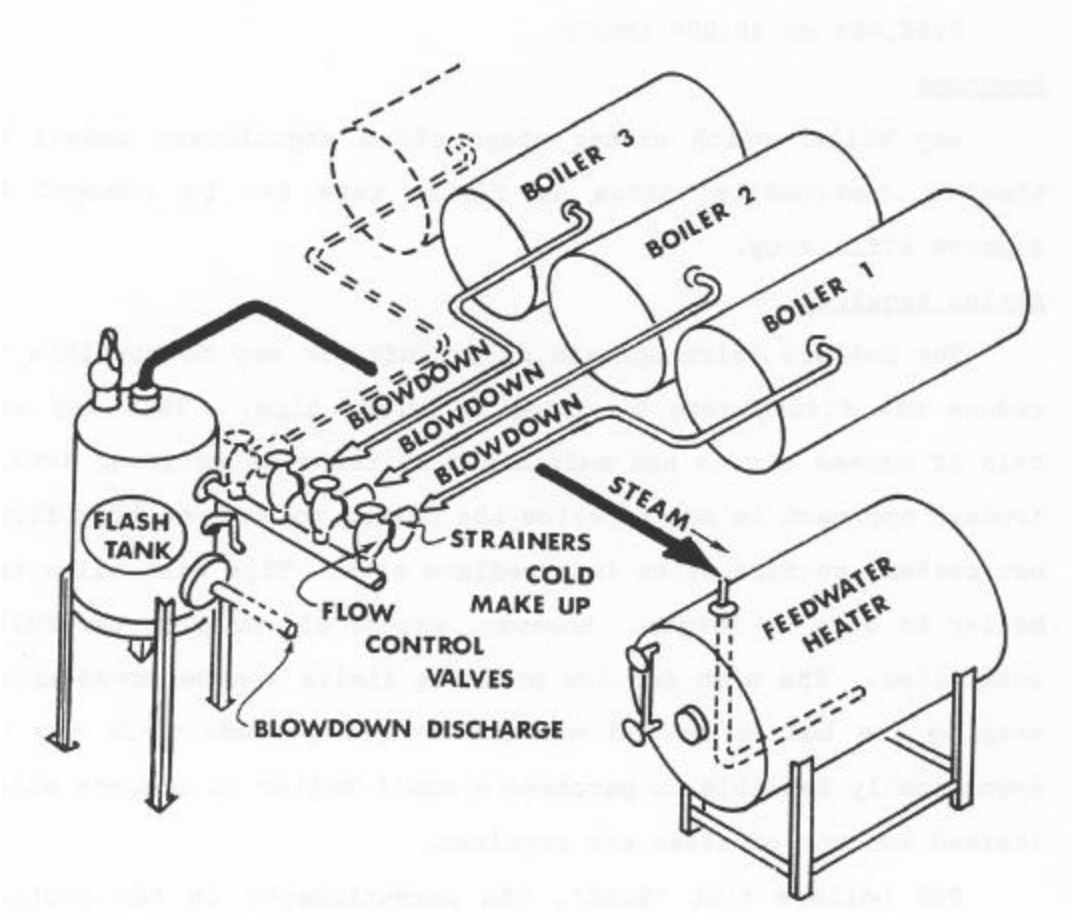

Figure 2.8: Blowdown Waste Heat Recovery System

2.7 #6 Potential – Stop Dynamic Operation on Applicable Boilers

Typical Annual Savings

$23,000 on 100 HP

Save: $266,666 on 40,000 lb/hr

Explanation

Two types of operation are described below.

First, a boiler may come on for a few minutes and than be off for several minutes. Figure 2.9 shows that there are large losses due to purging, free convection through the boiler and skin heat transfer losses. Note that all of these effects remove useful heat from the boiler.

Second, a boiler may "hunt." By this it is meant that the firing rate is continually adjusting to satisfy a stringent requirement to maintain boiler pressure. Figure 2.10 shows that the excess air levels are much higher while the boiler is "hunting" than when it is in steady operation. Of course, high excess air means low efficiency.

Symptoms

Any boiler that either stays off a significant amount of time or continually varies in firing rate can be changed to improve efficiency.

Action Required

For boilers operating on and off, it may be possible to reduce the firing rate by changing burner tips. This may not help if excess air is not maintained at the same or a lower level. Another approach is not to allow the boiler to move to high fire but rather to fire at an intermediate rate. This will allow the boiler to stay on longer. Usually the most economic action is to purchase a small boiler to operate while limited amounts of steam are required.

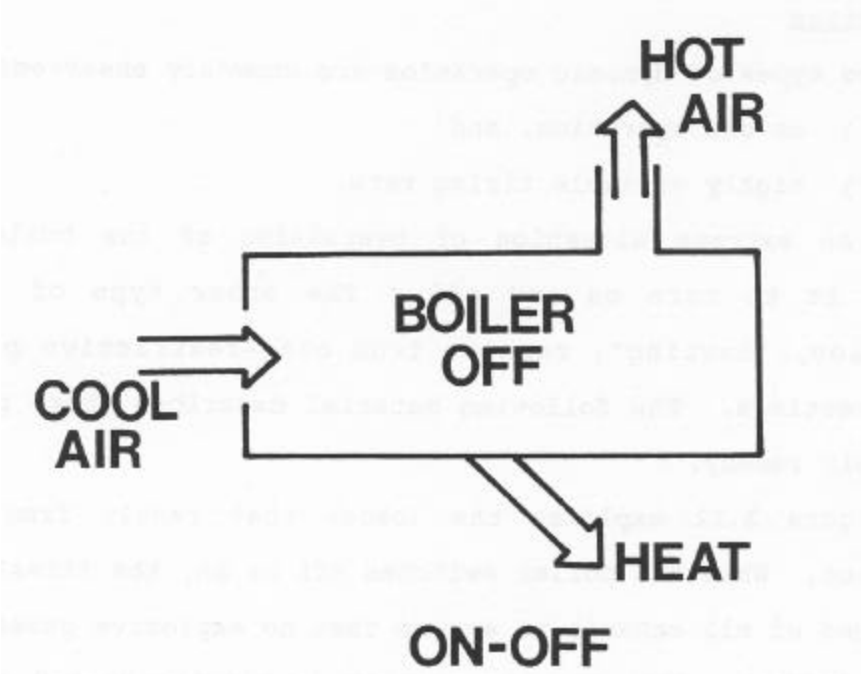

Figure 2.9: Losses Due to On-Off Operation

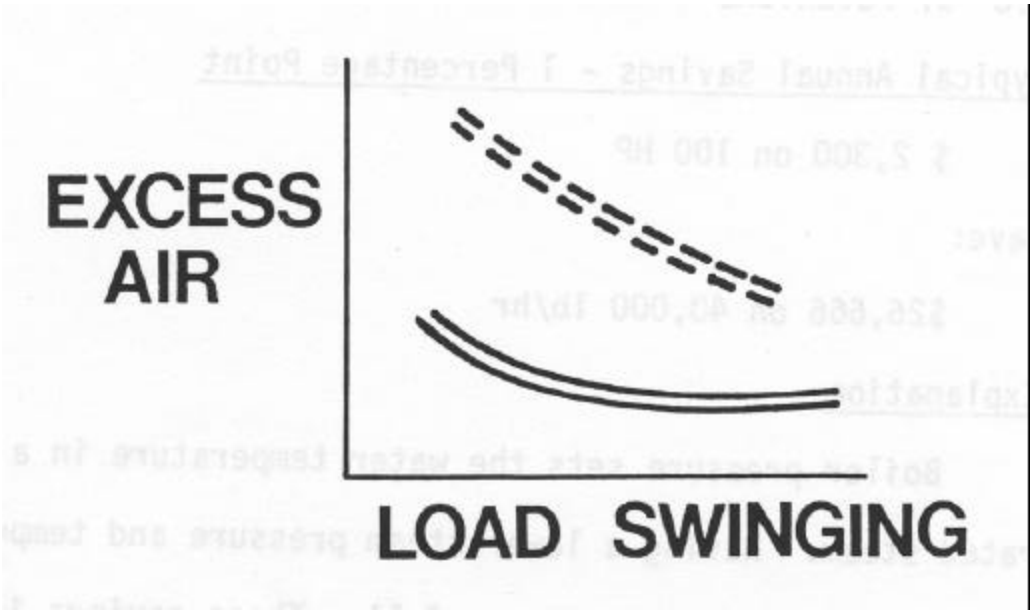

Figure 2.10: Swinging Firing Rate

For boilers that "hunt", the potentiometer in the control system, which sets the sensitivity of firing to boiler pressure, can be adjusted such that the boiler changes firing with relatively large variations from the set point boiler pressure. This will result in larger steam pressure fluctuations; however, the typical operation does not require exact control of boiler pressure.

2.8 #7 Potential – Reduce Boiler Pressure

Typical Annual Savings – 1 Percentage Point

$2,300 on 100 HP

Save: $26,666 on 40,000 lb/hr

Explanation

Boiler pressure sets the water temperature in a boiler producing saturated steam. Having a lower steam pressure and temperature yields a number of savings as shown in Figure 2.11. These savings include lower stack temperature due to improved heat transfer, less heat loss from the cooler boiler skin, less heat loss from the cooler steam pipes and less steam leaks caused by the lower pressure. Many systems have reducing stations that drop the boiler pressure. Usually it is quite easy to change these systems to operate at a lower pressure. The process requirements generally determine the minimum boiler pressure.

There can be problems with the boiler in reducing pressure. The boiler circulation may be upset or the lines may have insufficient capacity to transport the low-pressure steam. For water-tube boilers, it is very important to time mud blowdown when the boiler is operating at part load in order to avoid upsetting circulation.

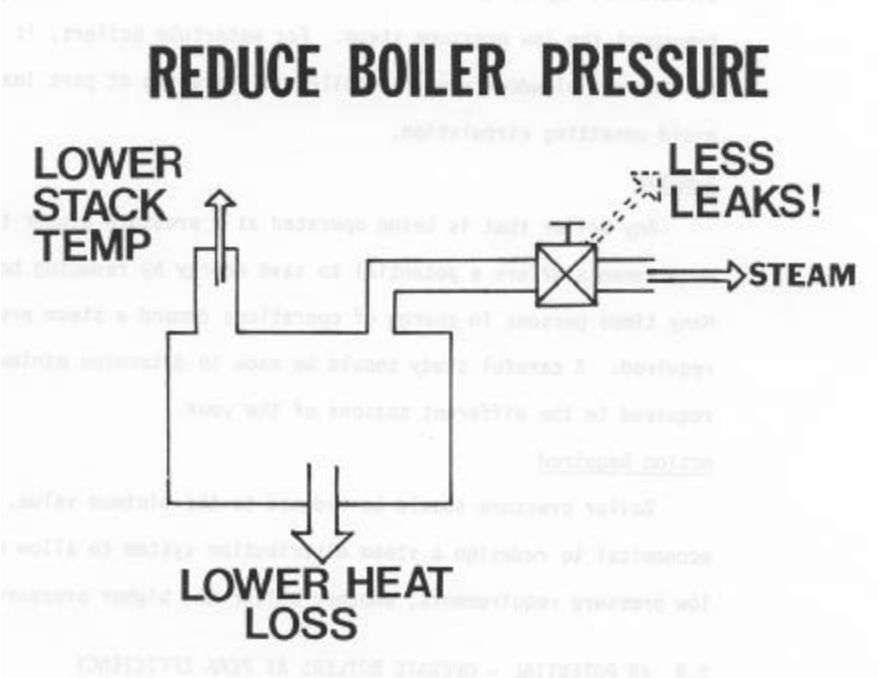

Figure 2.11: Effect of Reducing Boiler Pressure

Symptom

Any boiler that is being operated at a pressure higher than the process requirements offers a potential to save energy by reducing boiler pressure. Many times persons in charge of operations demand a steam pressure not really required. A careful study should be made to determine minimum pressures required in the different seasons of the year.

Action Required

Boiler pressure should be reduced to the minimum value. It might be economical to redesign a steam distribution system to allow one boiler to supply low-pressure requirements; another boiler the higher pressure requirements.

2.9 #8 Potential – Operate Boilers at Peak Efficiency

Typical Annual Savings – 2 Percentage Points

$4,600 on 100 HP

Save: $53,333 on 40,000 lb/hr

Explanation

Plants having two or more boilers can save energy by load management such that each boiler is operated to obtain combined peak efficiency. Figure 2.12 shows an example of two boilers being operated two different ways to produce a required steam demand. Obviously one operating condition is far more efficient than the other.

Symptom

If operators determine firing schedules by the boilers they "like" or other such criteria, improved efficiency can be obtained by proper load selection.

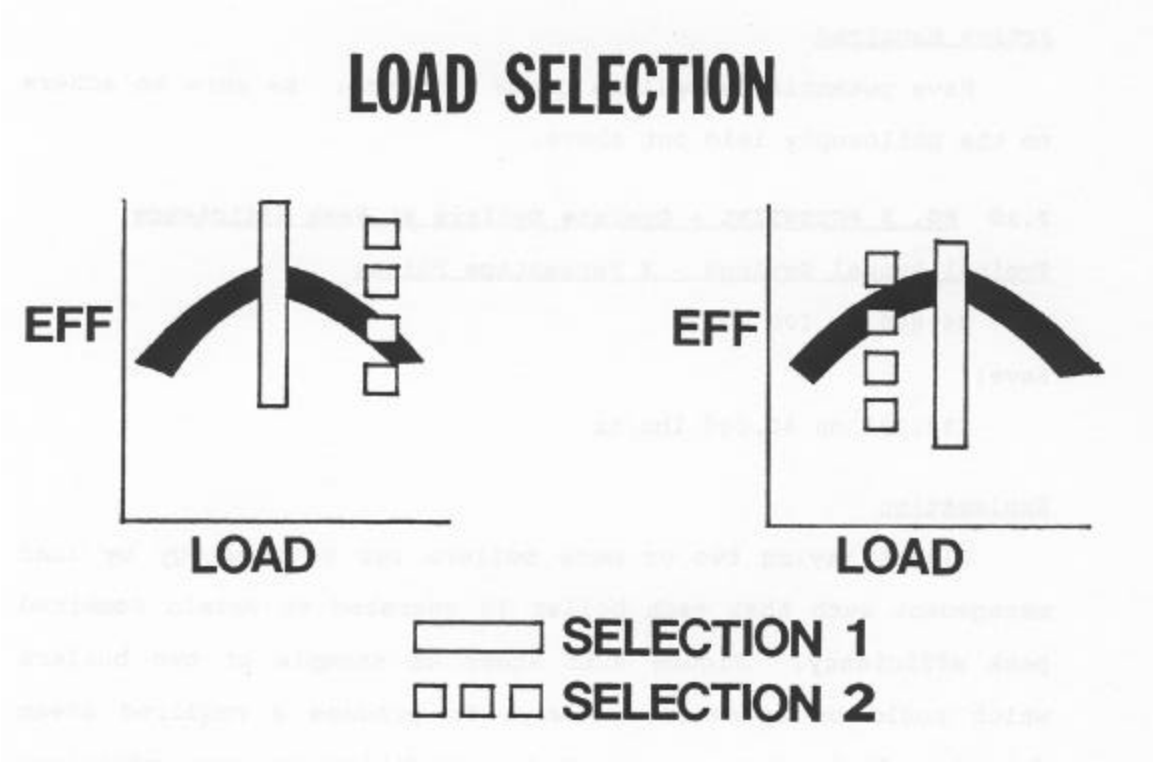

Figure 2.12: Multiple Boiler Load Optimization

Action Required

The efficiency versus load curve for each boiler should be obtained as described in Chapter 3. By adjusting firing of each boiler to operate at its peak efficiency, the maximum system efficiency can be achieved as shown in Figure 2.12.

2.10 #9 Potential – Preheat Combustion Air

Typical Annual Savings – 1 Percentage Point

$2,300 on 100 HP

Save: $26,666 on 40,000 lb/hr

Explanation

The boiler and stack lose heat to the boiler room. The heated air rises to the top of the boiler room. By arranging the inlet air ducts to the boiler so that it draws air higher in the boiler room and/or by forcing the hot air down, the combustion air can be preheated. A 40°F rise in combustion air temperature yields an approximate 1 percentage point improvement in boiler efficiency. A system for this purpose is illustrated in Figure 2.13.

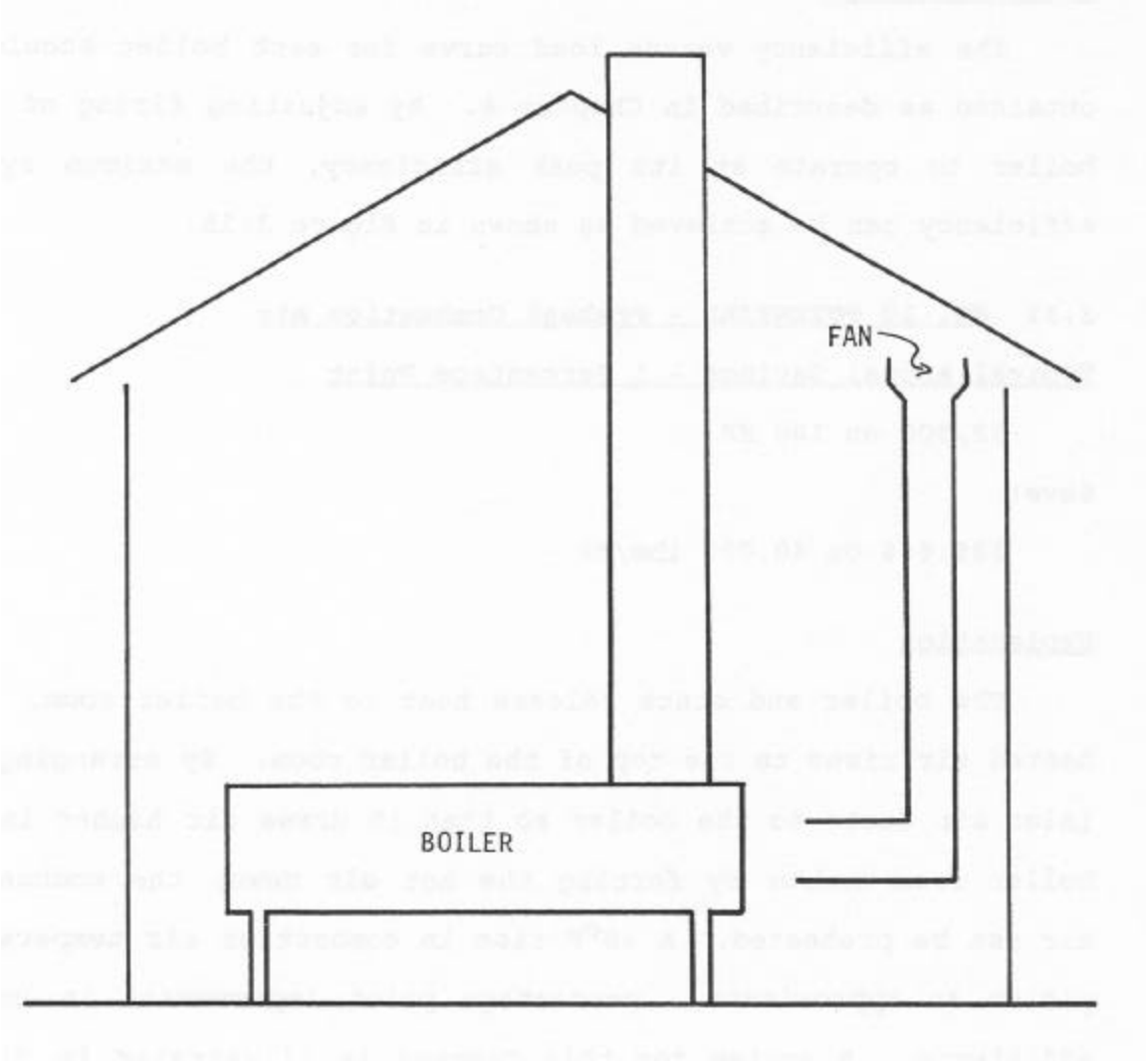

Figure 2.13: Waste Heat Recovery from Boiler Room

Symptom

Any boiler room with a layer of hot, stratified air results in an efficiency loss. Thus measuring the vertical temperature profile in the boiler room during each season will give an indication of the potential for preheating combustion air.

Action Required

Modify the air circulation system as shown in Figure 2.13.

2.11 #10 Potential – Switch from Steam to Air Atomization

Typical Annual Savings – 1 Percentage Point

$2,300 on 100 HP

Save: $26,666 on 40,000 lb/hr

Explanation

Air or steam is usually used to atomize heavy oils. Each fluid contains energy. The energy to produce the air is a tiny fraction of the energy in the fuel, while the energy in the steam is usually 1 percent or more of the energy in the fuel. Thus, air atomization saves about 1 percentage point in boiler efficiency.

Symptom

Any steam-atomized burner is a candidate for retrofit.

Action Required

Check economics to see if satisfactory return on investment is available. Implement as dictated by economics.

2.12 #11 Potential – If Natural Gas Costs the Same or More than Fuel Oil, Switch to Fuel Oil

Typical Annual Savings – 2 Percentage Points

$4,600 on 100 HP

Save: $53,332 on 40,000 lbm/hr

Explanation

The ratio of hydrogen atoms to carbon atoms in a fuel greatly affects the efficiency of a boiler. Hydrogen atoms form water vapor while carbon atoms form CO_2 in the complete combustion process. The latent heat of vaporization is lost when water vapor leaves the boiler stack because the vapor cannot be condensed due to an inherent corrosion problem. Thus, fuel having a high percentage hydrogen relative to carbon produces more water-vapor and greater energy loss than a fuel with a lower ratio of hydrogen to carbon.

Table 2.4 shows combustion efficiency versus carbon-hydrogen ratio assuming complete combustion with a theoretical amount of combustion air. The flue gas temperature is assumed to be 500°F. The variation in efficiency follows the discussion in the previous paragraph. Note

that Table 2.4 represents the ideal situation in that complete combustion is achieved with 0 percent excess air. In the practical case, the lower hydrogen-carbon ratio fuels require more excess air for complete combustion, which decreases the combustion efficiency. The trend shown in Table 2.4, however, is manifested in practice, and fuel oils can be burned with an efficiency approximately 2 percentage points higher.

Symptom

If natural gas costs the same or more than fuel oil per BTU delivered, this potential should be considered. One must recognize that there are increased maintenance and operating costs in switching to oil. Deposits on the fireside and incomplete combustion must not be allowed in order that this savings can be achieved.

Table 2.4: Combustion Efficiency for Different Fuels

Fuel	Combustion Efficiency	Hydrogen/Carbon Ratio
Gas	80.8	4
#2 Oil	87.4	2
#4 Oil	88.0	1.8
#6 Oil	88.2	1.6

Action

Determine if cheaper oil can be obtained and satisfactorily burned. If possible, switch to the higher efficiency oil.

2.13 Conclusions

In this chapter we have attempted to show what can be done to improve boiler efficiency. Necessary measurements and actions are given. A typical operator can find several of these actions that lead to improved efficiency.

Please note that there are no short cuts. Efficiency improvement from any given action is usually small. They all add up, however, to large savings.

These comments also mean that no magic gadget can yield large savings. It takes continued work and attention focused on all areas of boiler operation to obtain significant cost savings in purchased fuel.

CHAPTER 3

Instrumentation

3.0 Introduction

This chapter gives some details regarding instrumentation necessary to check boiler performance. The procedure for utilizing instrumentation in determining boiler efficiency is also given.

3.1 Instrumentation

Table 3.3 is a summary of instrumentation available to perform various measurements. Alternative instruments are listed. Sources of instrumentation are also given. These sources do not represent an endorsement of any particular product by the authors. However, the authors have used the equipment manufactured by the sources indicated. In most cases equivalent instrumentation is available from other sources.

The need to calibrate and maintain all instruments cannot be overemphasized. The operator should maintain standard gas samples for calibrating the flue gas measuring equipment. Temperature instruments can be calibrated by measuring the ice and boiling point. Standard water samples are available to check water-sampling instruments.

3.2 How to Conduct an Efficiency Test

Place the boiler on manual at the desired firing rate. Install instrumentation to measure the following quantities:

a. flue gas temperature
b. % O_2 in flue gas
c. ppm CO in flue gas
d. combustion air temperature

Figure 3.1 shows schematically how the flue gas sample and temperature can be obtained. Position the sampling tube (which can be a copper or steel tube ¼ to ½ inch in diameter) in the hottest portion of the flue gas – usually near the center of the exhaust duct. A thermocouple can be secured to the probe. The following steps are recommended:

1. Operate the boiler at the specified load for 30 minutes prior to beginning test.
2. Using an electronic flue gas analyzer determine CO and O_2 in exhaust gas.
3. Measure flue gas and combustion air temperature simultaneously with the readings in Step 2.
4. Record data in Table 3.1 below.

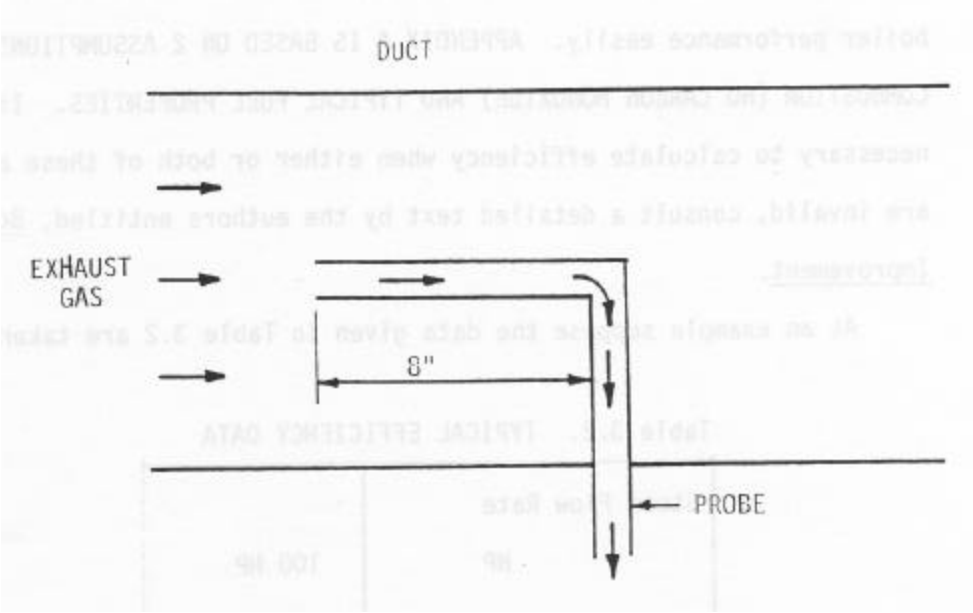

Figure 3.1: Stack Probe Configuration

Table 3.1: Efficiency Data

Steam Flow Rate lb/hr or HP	
CO (ppm)	
% O_2	
NO_X (ppm)	
Flue Gas Temperature, °F	
Combustion Air Temperature, °F	
Type Fuel	

3.3 How to Determine Efficiency

The data obtained as described in Section 3.2 will allow the efficiency to be determined.

Appendix A is a set of tables allowing one to determine the boiler performance easily. **Appendix A is based on two assumptions: complete combustion (no carbon monoxide) and typical fuel properties.** If it is necessary to calculate efficiency when either or both of these assumptions are invalid, consult a detailed text by the authors entitled, Boiler Efficiency Improvement.

As an example, suppose the data given in Table 3.2 are taken.

Table 3.2: Typical Efficiency Data

Steam Flow Rate	100 HP
% CO_2	8.5%
% O_2	7.0%
% CO	0
Flue Gas Temperature, °F	380°F
Combustion Air Temperature, °F	70°F
Type Fuel	Natural Gas

The flue gas temperature less combustion air temperature is:

$$380°F-70°F=310°F$$

On Page A.3, for an O_2 reading of 7.0%, the excess air is 44.9%. Under the 310°F column, the efficiency is read to be 80.9%.

The value of the CO_2 reading is to check the O_2 reading. If the CO_2 and O_2 are not close to the values in the table (say $\pm$ .1%), then either error in sampling has been made, incomplete combustion occurred and/or the fuel is not typical.

Table 3.3: Available Instrumentation

Type Measurement	**Instrument Description**	**Typical Price**	Comments	Sources
Temperature	Thermometer	$5-$30	Glass type thermometers can measure room temperature; metal dial thermometers are ideal for stack temperature. Accuracy $\pm$ 5°F is adequate.	Dwyer Michigan City, IN
	Thermocouple & Digital Readout	$200 to $500	Easy to read, remote indicating, accurate.	OmegaEngineering Stamford, CT Leeds&Northrup Northwales, PA
Flue Gas Composition	Orsat for Measuring CO_2 and O_2	$400	The Orsat is extremely accurate. It is not readily portable. The Orsat requires care in operation.	Burrell Pittsburgh, PA Hayes Mich. City, IN Fischer Pittsburgh, PA
	Electronic O_2 & combustibles indicator	$2,000	Almost instant response, portable, accurate, very handy for boiler tuning, needs calibration often.	Teledyne San Gabriel, CA Thermox Pittsburgh, PA Mine Safety Appl. Pittsburgh, PA Westinghouse Pittsburgh, PA

Table 3.3: Available Instrumentation (Continued)

Type Measurement	Description Of Instrument	Typical Price	Comments	Sources
Flue Gas Composition (Continued)	Smoke Spot Test for Measuring Unburned Fuel	$15	Good qualitative indication of smoke concentration	Dwyer Michigan City, IN Bacharach Pittsburgh, PA
	CO_2 and O_2 Indicators These instruments are simplified methods for chemically absorbing the desired species. Commonly called "dumb bells" due to shape.	$75 each	Easy to use, but not precise. Errors of $\pm$1 percent point in reading can occur. Good to get in "ball park" in short time.	Bacharach Pittsburgh, PA Dwyer (CO_2 only) Michigan City, IN
	CO Indicator. Consists of accurate metering pump to draw sample through a tube containing a chemical which undergoes a color change. Length of chemical in tube undergoing color change indicates concentration of CO.	$150	Relatively accurate, compact, portable, cheap, sufficient for boiler tuning.	Bacharach Pittsburgh, PA Mine Safety Appliances Pittsburgh, PA

Table 3.3: Available Instrumentation (Continued)

Type Measurement	Description Of Instrument	Typical Price	Comments	Sources
Water Quality	Apparatus for measuring concentration of hardness, sulfite, alkalinity, TDS, & amines by titration	$3-$30 per test	Drop set kits available for rapid, rough determination of end points. Measuring burettes available for more accurate end point determination. Reagents available in tablets—count tablets for end points.	Hach Chemical Ames, IA LaMotte Chemical Chestertown, MD
	Apparatus for measuring phosphate and PH by color comparison	$15 per test	Accurate and fast.	Hach Chemical Ames, IA LaMotte Chemical Chestertown, MD
	Conductivity meter for measuring TDS	$100 to $400	Accurate and fast.	Beckman Instruments Cedar Grove, NJ
Steam Leaks	Ultrasonic Detector	$500 to $900	Accurate.	UE Systems Inc. New York, NY

CHAPTER 4

Water Treatment

4.0 Introduction

This chapter is written to explain the basic problems, water quality measurements, and treatments of water in the boiler system.

4.1 Problems

Scale

Magnesium and calcium compounds such as dissolved limestone become insoluble in water when heated. Consequently, these compounds precipitate (fall out of solution) and cling to boiler tubes and surfaces. The scale formed in this way is an insulator; consequently, when heat is applied to one side of a tube with scale on the other side, less heat goes through the tube causing lower boiler efficiency. Also, the tube metal heats up causing a potential tube burnout. The scale also allows corrosive action to be more severe.

Corrosion

Corrosion is the removal of metal due to chemical and electrical phenomena. Two types of corrosion are prevalent in boilers:

1. Corrosion due to dissolved oxygen which results in numerous pits in the metal (and possibly pin holes), and
2. Acid corrosion.

Corrosion occurs when water conditions cause the breakdown of the magnetic layer on the tube surfaces. This layer of magnetic iron oxide is a thin layer of blackish-gray powdery material, which is an excellent heat conductor and protector against rust formation. Corrosion can occur in any part of the boiler system.

Carryover

Carryover refers to liquid water being entrained in steam and going into the steam line. This liquid water contains a large amount of dissolved solids and will cause severe plugging of valves and restricted areas. In addition, carryover usually results in a loss of energy because the water is trapped out and returns through condensate lines, which usually lose considerable heat through poor insulation and leaks. Carryover can result from excessive dissolved solids in boiler water which lowers the surface tension of the water and, hence, its ability to restrain liquid droplets from being entrained in the generated steam.

Sludge

Sludge results from the treatment process. However, the amount of sludge generated must be controlled through external boiler treatment (softening) described below and certain conditioners must be added to prevent sticking. Sticking of sludge is particularly prone to occur in restricted areas and bends such as the bend in a D-shape water tube boiler.

4.2 Water Quality Measurements

There are five basic properties defining water quality. Other parameters may also require measurement under some conditions. These five basic properties are defined below.

Alkalinity

Alkalinity is a measure of the concentration of carbonate, bicarbonate and hydroxyl ions in water usually expressed as equivalent parts per million (ppm) of calcium carbonate. High alkalinity of boiler water will result in excessive condensate pH. Low alkalinity results in the formation of "sticky" sludge that is difficult to control.

pH

pH is inversely proportional to the concentration of hydrogen ions. Thus, a low pH (less than 7) means a high level of hydrogen ions indicating an "acid" condition. Consequently low pH can result in corrosion.

Hardness

Hardness is a measure of the concentration of calcium and magnesium salts in water. (High concentrations of these compounds make it "hard" to dissolve soap—hence the name "hardness.") Hardness indicates a tendency of the water to form scale on heating the water.

Total Dissolved Solids (TDS)

TDS is a measure of the concentration of all dissolved solids in the water, which are in true suspension. TDS causes low water surface tension; hence, the tendency to cause carryover.

Silica

Silica is a measure of the concentration of silica dioxide. This compound can precipitate in low-pressure boilers (say under 200 psi) resulting in a very tenacious scale. In boilers operating at pressures used for power generation, silica can vaporize and subsequently "plate" onto turbine blades causing extensive damage.

4.2 Chemical Treatments

A typical boiler with its associated processes is shown in Figure 4.1. In this section the different treatments will be discussed beginning with the makeup water.

Clarification

This step is the removal of organic materials and suspended matter in settling tanks (clarifiers). This step has usually been performed by the city system. If water is not clarified, damage can occur to parts of the boiler system such as ion exchange softeners.

Softener

The purpose of the softening process is to remove scale-forming compounds called "hardness". There are two basic softening processes. First hardness can be precipitated and collected as sludge by feeding lime and soda. The other technique is the use of ion exchange beds to replace

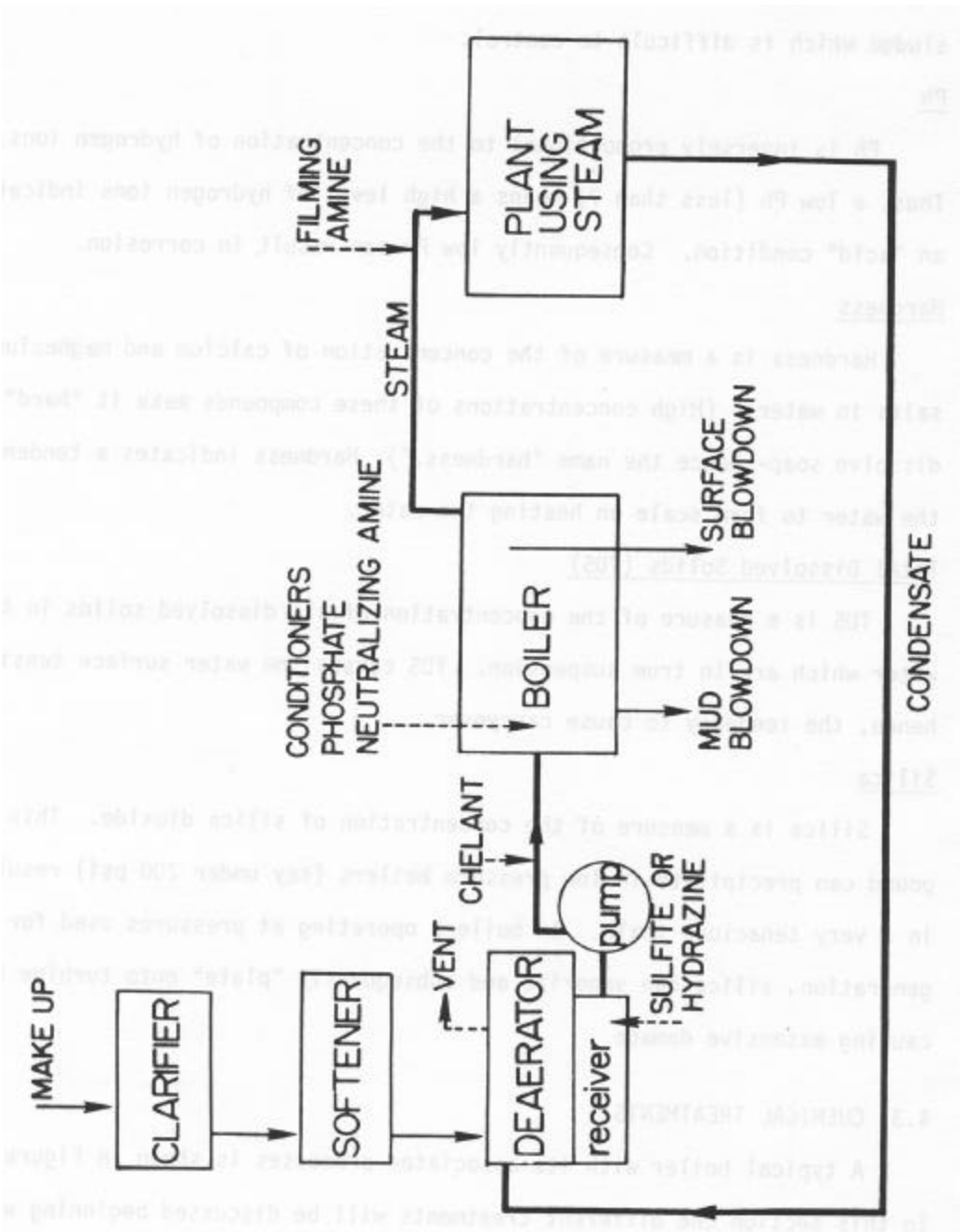

Figure 4.1: Steam Generating System

hardness ions with sodium and/or hydrogen ions. Use of sodium (brine) controls only hardness while hydrogen regeneration controls hardness and alkalinity. Operation of parallel ion exchangers (called split stream softening), one sodium and the other hydrogen, usually gives the best performance because good alkalinity control can yield reduced boiler blowdown.
In boilers used in power generation, ion exchange softeners are also used to remove certain negative ions. A treatment of this subject is beyond the scope of this book.

Ion exchange softening is usually preferable to lime-soda because of a greater reduction in hardness and easier control. In either case it is necessary that hardness leaving the softener is less than 1 ppm.

Deaeration

This process is the removal of oxygen and carbon dioxide gas, both of which lead to corrosion, by heating the water and causing these gases to be less soluble. Several pieces of equipment are available for this process; however, the most effective is a high efficiency deaerator in which the water containing oxygen and carbon dioxide is brought into intimate contact with the steam used to heat the water.

Chemical Scavenging

The feeding of sulfite (Na_2SO_3) or hydrazine (N_2H_4) will result in oxygen combining with these chemicals and eliminating free dissolved oxygen. Sulfite is usually the preferable chemical for industrial process boilers while hydrazine is preferable in higher pressure boilers. The proper residuals are shown in Table 4.1.

Hydrazine is toxic and cannot be used in food operations. Either chemical should be fed in the receiver section of the deaerator.

Table 4.1: Residual for Oxygen Scavengers

Boiler Pressure	**Residual of SO_3 (ppm)**	**Residual of N_2H_4 (ppm)**
0-150	30-60	.10
150-300	30-40	.10
300-600	20-30	.08
600-900	10-15	.06
900-1200	5-10	.03
1200-1500	3-7	.01
Above 1500	Use N_2H_4	.01

Boiler Internal Scale Control

Even though soft (<1 ppm) make-up water is used, scale control in the boiler is important. Two control methods are available. First, sodium phosphate can be fed into the boiler causing hardness compounds to precipitate as a sludge to be removed in mud blowdown. A residual of 20 ppm of phosphate is recommended to give proper control. A synthetic organic conditioner should be fed with the phosphate to prevent the sludge formed from sticking.

The second alternative is the use of a chelant, preferably EDTA, to chelate (lock in) the hardness in solution. This method can produce a cleaner boiler than the use of phosphate; however,

excess amounts of chelant produce corrosion. Generally, phosphate should be used in industrial/commercial type boilers and a chelant in higher pressure boilers. However, some organizations have effectively used chelants for process operations.

Phosphate should be fed into the boiler while a chelant is properly fed in the feed-water line.

Amines

Two different types of amines can be used to control condensate pH. First a neutralizing amine can be fed into the boiler. This amine vaporizes with the steam and neutralizes (i.e., raises the pH) the condensate to prevent corrosion. A combination of neutralizing amines should be fed to maintain a uniform condensate pH of about 7.4. Neutralizing amines are cost effective for systems having a high rate of condensate return.

The second amine treatment is to feed a filming amine into the steam line. This treatment results in a mono-molecular film coating the condensate line surface and protecting against corrosion. This treatment is best for high losses of condensate.

Oftentimes a combination of filming and neutralizing amine is the most cost effective.

Blowdown

Two types of blowdown are used on boilers. First, "mud" blowdown is provided to remove sludge at the bottom of the water. A few puffs lasting a few seconds per shift is usually adequate for the purpose of removing accumulated sludge.

The second type of blowdown is called continuous or skimming blowdown. Water near the top of the water in the boiler is continuously withdrawn to remove the buildup of light solids (TDS) that float near the top level of the water. The function of this blowdown is to maintain the water quality (primarily TDS and alkalinity) at the levels described in Table 4.2. The philosophy of continuous blowdown should be to try to maintain the residuals at near their maximum level without exceeding the specified limits. This will result in minimum blowdown and energy loss.

Mud blowdown should never be used in place of continuous blowdown. Continuous blowdown should be operated continuously.

4.2 Summary

Proper water quality requires that the operator understand the various processes. Rigid adherence to the prescribed program including regular water quality measurements is essential.

Table 4.2: Permissible Concentrations of Solids in Boilers

Maximum Pressure (psi)	Total Solids (ppm)	Total Alkalinity (ppm)	Boiler Water Suspended Solids (ppm)	Silica (ppm)
200	4000	800	350	250
300	3500	700	300	125
450	3000	600	250	125
600	2500	500	150	80
750	2000	400	100	70
900	1500	300	60	45
1000	1250	250	40	30
1500	1000	200	20	15

Chapter 5

Requirements

A summary of the general, daily, monthly, semi-annual and annual requirements is given in Tables 5.1 through 5.5.

Table 5.1: General Requirements

Item	Description	Comment
1	Information about boiler and subsystems	This information can be found in manuals furnished by manufacturers: a. Boiler b. Auxiliary equipment
2	Boiler Operating Procedure	Prepare & post detailed instructions for: a. Start-up b. Normal operation c. Shut-down
3	Parts List	Parts list of major items expected to be replaced: a. Name of part b. Number identifying part
4	Maintenance Records	Maintenance records: a. Date of maintenance b. Description of maintenance c. Person performing maintenance d. Part(s) replaced, repaired, and/or cleaned
5	Lubrication	Follow manufacturer's recommended procedures in lubricating all components.

Table 5.2: Daily Requirements

Item	Description	Comment
1	Check temperature of exhaust gases at two different firings.	Compare temperatures with tests performed after annual cleaning. (See Table 5.5 for reference data).
2	Check Steam Pressure	Is variation in steam pressure as expected under different loads? Wet steam may be produced if the pressure drops too fast (caused by excessive loading on the boiler).
3	Check for Unstable Water Level	Common causes of unstable water level are: a. Contaminates in boiler such as oil, excessive solids, excessive feedwater treatment, etc. b. Overload on boiler c. Malfunctions in equipment such as feed-water pump, water level control, etc.
4	Check Burner	a. Are controls functioning properly? b. Is burner clean? It may need cleaning several times daily if #6 fuel is used.
5	Check Motors & Auxiliary Equip.	Check to see that motors and auxiliary equipment are functioning properly.
6	Check Air Temperature in Boiler Room	The air temperature in the boiler room should not exceed or drop below recommended limits. Each 5°F change in air temperature changes the excess air by approximately 1 percent.
7	Check Blowdown	a. Bottom Blowdown—The frequency and amount of blowdown will depend upon the amount and condition of the feedwater. Check to see that blowdown valve does not leak. b. Surface Blowdown—Check operation of system and make sure that excessive blowdown does not occur.
8	Records	Keep daily records on: a. Type and amount of fuel used b. Exhaust gas temperature, excess oxygen & firing position c. Boiler room temperature at time (b) is measured
9	Blow Water Columns	Blow each water column and observe that the water level in the column recovers quickly.
10	Water Treatment	Test and adjust water treatment to maintain recommended levels

Table 5.3: Monthly Requirements

<table>
<tr><th>Item</th><th>Description</th><th>Comment</th></tr>
<tr><td>1</td><td>Check Exhaust Gas Composition and Temperature</td><td>a. Measure exhaust gas composition and temperature at selected firing positions
b. Recommended percentages of oxygen and maximum carbon monoxide in exhaust gases are:

<table><tr><th>Fuel</th><th>O_2 (%)</th><th>CO (ppm)</th></tr><tr><td>Natural Gas</td><td>2-1/2</td><td>100</td></tr><tr><td>No. 2 Fuel Oil</td><td>3-1/2</td><td>100</td></tr><tr><td>No. 6 Fuel Oil</td><td>4</td><td>100</td></tr><tr><td>Coal</td><td>5</td><td>100</td></tr></table>
These percentages may vary due to variations in composition of fuel and firing rate. For fuel oils and coal, the opacity should be less than 10 percent.</td></tr>
<tr><td>2</td><td>Check Water Level Control and Alarms</td><td>Perform a slow drain test on each low water cutout. Check the function of each shunt switch. Check low and high water alarms on the boiler, deaerator, and condensate tank.</td></tr>
<tr><td>3</td><td>Check Pilot and Burner Assemblies</td><td>a. Clean pilot and burner assemblies following recommended procedures.
b. Check assemblies:
- Spark gap
- Condition of electrode
- Condition of burner</td></tr>
<tr><td>4</td><td>Check Boiler Operating Characteristics</td><td>a. Stop fuel flow to burner and observe flame failure (characteristics & timing).
b. Start boiler and observe characteristics of flame.</td></tr>
<tr><td>5</td><td>Check Deaerator Operation</td><td>a. Check deaerator pressure and temperature and compare to historical values.</td></tr>
<tr><td>6</td><td>Check Blowdown and Water Treatment Procedures</td><td>a. Determine if blowdown procedure is adequate to prevent buildup of solids in boiler.
b. Determine if water treatment procedure is adequate to prevent undesirable effects.</td></tr>
<tr><td>7</td><td>Combustion Air Supply</td><td>a. Check combustion air inlet to boiler room to be sure adequate openings exist.
b. Check combustion air inlet to boiler & clean if fouled.</td></tr>
<tr><td>8</td><td>Check Fuel System</td><td>a. Check pressure gauge, pumps, filters, & transfer lines. Clean filters as required.</td></tr>
<tr><td>9</td><td>Check Belts and Packing Glands</td><td>a. Check belts for damage & proper tension.
b. Check packing glands for proper compression & leakage.</td></tr>
<tr><td>10</td><td>Check for Air Leaks</td><td>a. Around access openings.
b. Around flame scanner assembly.</td></tr>
</table>

Table 5.4: Semi-Annual Requirements

Item	Description	Comment
1	Exhaust Gases	a. Measure exhaust gas composition (O_2 & CO) and temperature over entire firing range. b. Compare composition and temperature readings with those of previous months and reference data. Tune as needed. Check the boiler for any unusual vibration after tuning.
2	Safety Valve	Lift the safety valves with steam pressure and record the lift pressure. Check for leaks after each test. Remove and recondition or replace as necessary.
3	Calibration	Calibrate all controls, gages, and recorders
4	Leaks	Check for combustion gas leaks into boiler room.
5	Furnace Pressure	Check furnace pressure at high fire to ensure there are no stack obstructions.
6	Safety Tests	Perform tests on each boiler safety device and interlock in accordance with established test procedures. Document the results of these tests.

Table 5.5: Annual Requirements

Item	Description	Comment
1	Clean Waterside Surfaces	Follow manufacturer's recommended procedure in cleaning and preparing waterside surfaces.
2	Clean Fireside	Follow manufacturer's recommended procedure in cleaning and preparing fireside surfaces.
3	Repair Refractories on Fireside	Use recommended materials and procedure to repair refractory.
	Safety Valve	Perform an accumulation test of the boiler safety valves.
5	Feedwater System	a. Clean condensate receivers and deaeration system. b. Clean and recondition feedwater pumps.
6	Fuel System	Clean and recondition system pumps, filters, burner, pilot, oil preheaters, oil storage tanks, etc.
7	Electrical Systems	a. Clean all electrical terminals. b. Check electronic controls and replace any defected parts. c. Check mercury switches and replace if deterioration has occurred.
8	Hydraulic and Pneumatic Valves	Check operation and repair any leaks.
9	Start-Up and Operation	Follow start-up and operation procedures.
10	Exhaust Gases	a. Make adjustments to give desired exhaust gas composition. b. Record composition, firing position and temperature (reference data).

Chapter 6

Introduction to Efficient Use of Steam

6.0 Introduction

The first task in reducing the amount of steam required is to prevent waste. Waste can occur while transporting the steam through lines due to inadequate insulation. The second task is to reduce the amount of heat needed to heat the buildings. A third task would be to insulate condensate lines and to stop steam leaks (visible or hidden).

6.1 Insulation

It is important to insulate all steam lines from the boiler to the location where the steam is being used. This insulation should be kept dry and any damage should be repaired.

A 100-foot section of 3-inch steam line that is not insulated will cost the owner about $3,000 every six months. The same length of 1-inch steam line will cost $1,000 every six months.

It is also important to insulate as much of the walls of the buildings being heated as possible. This is very important since the steam is used to maintain a selected temperature in the space being heated.

Effort should be made to maintain different buildings at different temperatures. In large buildings it is sometimes possible to provide different temperatures in different sections of the same building (zoning).

6.2 Steam Leaks

It is very important to stop all steam leaks (visible or hidden). Visible steam leaks are easy to detect while hidden steam leaks (traps, valves, etc.) are more difficult to locate.

Leaking steam traps can be detected by temperature or sonic measurements. Sonic measuring techniques are more accurate to detect these leaks. A program should be developed to check for leaking steam traps. These traps should be repaired or replaced as soon as possible. The cost associated with leaks is shown in Table 6.1.

Table 6.1: Cost of Leaking Steam Traps at 100 psig
(Steam Cost Figures at $7 per 1,000 lbs of steam)

Size of Leaking Orifice	Lbs of Steam Wasted Per Month	Cost Per Month	Cost Per Year
½”	835,000	$5,844	$70,128
1/16”	637,000	$4,458	$53,496
3/8”	470,000	$3,290	$39,480
5/16”	325,000	$2,274	$27,288
¼”	210,000	$1,470	$17,640
3/16”	117,000	$818	$9,816
1/8”	52,500	$368	$4,416

APPENDIX A

Combustion Efficiency Tables

This appendix contains tables for determining the amount of excess air and combustion efficiency for several typical fuels. The typical fuel compositions are defined in the comprehensive manual by the authors entitled, Boiler Efficiency Improvement.

The tables are based on the properties of standard fuels and complete combustion. If either assumption is not appropriate, the tables are invalid. Elaborate calculation procedures described in the text cited above are required.

An example of using the tables is given in Section 3.3. Tables for various fuels as listed in Table A.1 are included.

Table A.1: Efficiency Tables

NATURAL GAS

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	11.8	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6
2.2	0.5	11.5	86.3	86.1	85.9	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5
4.5	1.0	11.2	86.2	86.0	85.8	85.6	85.3	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4
6.9	1.5	11.0	86.1	85.9	85.7	85.5	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.2
9.5	2.0	10.7	86.1	85.8	85.6	85.4	85.2	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.3	83.1
12.1	2.5	10.4	86.0	85.7	85.5	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.7	83.4	83.2	83.0
15.0	3.0	10.1	85.9	85.7	85.4	85.2	85.0	84.7	84.5	84.2	84.0	83.8	83.5	83.3	83.0	82.8
18.0	3.5	9.8	85.8	85.6	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.6	83.4	83.1	82.9	82.6
21.1	4.0	9.6	85.7	85.5	85.2	85.0	84.7	84.5	84.2	84.0	83.7	83.5	83.2	83.0	82.7	82.5
24.5	4.5	9.3	85.6	85.4	85.1	84.8	84.6	84.3	84.1	83.8	83.6	83.3	83.1	82.8	82.6	82.3
28.1	5.0	9.0	85.5	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.2	82.9	82.6	82.4	82.1
31.9	5.5	8.7	85.4	85.1	84.9	84.6	84.3	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.2	81.9
35.9	6.0	8.4	85.3	85.0	84.7	84.4	84.2	83.9	83.6	83.3	83.1	82.8	82.5	82.2	82.0	81.7
40.3	6.5	8.2	85.1	84.9	84.6	84.3	84.0	83.7	83.4	83.2	82.9	82.6	82.3	82.0	81.7	81.5
44.9	7.0	7.9	85.0	84.7	84.4	84.1	83.8	83.5	83.3	83.0	82.7	82.4	82.1	81.8	81.5	81.2
49.9	7.5	7.6	84.8	84.5	84.2	84.0	83.7	83.4	83.1	82.8	82.5	82.2	81.9	81.6	81.3	80.9
55.3	8.0	7.3	84.7	84.4	84.1	83.8	83.5	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.7
61.1	8.5	7.0	84.5	84.2	83.9	83.6	83.2	82.9	82.6	82.3	82.0	81.6	81.3	81.0	80.7	80.4
67.3	9.0	6.7	84.3	84.0	83.7	83.3	83.0	82.7	82.3	82.0	81.7	81.4	81.0	80.7	80.4	80.0
74.2	9.5	6.5	84.1	83.8	83.4	83.1	82.8	82.4	82.1	81.7	81.4	81.0	80.7	80.3	80.0	79.7
81.6	10.0	6.2	83.9	83.5	83.2	82.8	82.5	82.1	81.8	81.4	81.1	80.7	80.3	80.0	79.6	79.3
89.8	10.5	5.9	83.6	83.3	82.9	82.5	82.2	81.8	81.4	81.1	80.7	80.3	79.9	79.6	79.2	78.8
98.7	11.0	5.6	83.4	83.0	82.6	82.2	81.8	81.5	81.1	80.7	80.3	79.9	79.5	79.1	78.7	78.3
108.7	11.5	5.3	83.1	82.7	82.3	81.9	81.5	81.1	80.7	80.3	79.9	79.4	79.0	78.6	78.2	77.8
119.7	12.0	5.1	82.7	82.3	81.9	81.5	81.1	80.6	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.2
132.0	12.5	4.8	82.4	81.9	81.5	81.0	80.6	80.2	79.7	79.3	78.8	78.4	77.9	77.5	77.0	76.6
145.8	13.0	4.5	82.0	81.5	81.0	80.6	80.1	79.6	79.1	78.7	78.2	77.7	77.3	76.8	76.3	75.8
161.5	13.5	4.2	81.5	81.0	80.5	80.0	79.5	79.0	78.5	78.0	77.5	77.0	76.5	76.0	75.5	75.0
179.5	14.0	3.9	81.0	80.4	79.9	79.4	78.8	78.3	77.8	77.2	76.7	76.2	75.7	75.1	74.6	74.0
200.2	14.5	3.7	80.3	79.8	79.2	78.6	78.1	77.5	76.9	76.4	75.8	75.2	74.7	74.1	73.5	72.9
224.3	15.0	3.4	79.6	79.0	78.4	77.8	77.2	76.6	76.0	75.3	74.7	74.1	73.5	72.9	72.3	71.7

NATURAL GAS

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	11.8	83.4	83.2	83.0	82.8	82.5	82.3	82.1	81.9	81.7	81.5	81.2	81.0	80.8	80.6
2.2	0.5	11.5	83.3	83.1	82.8	82.6	82.4	82.2	82.0	81.7	81.5	81.3	81.1	80.9	80.6	80.4
4.5	1.0	11.2	83.1	82.9	82.7	82.5	82.3	82.0	81.8	81.6	81.4	81.1	80.9	80.7	80.5	80.2
6.9	1.5	11.0	83.0	82.8	82.6	82.3	82.1	81.9	81.6	81.4	81.2	81.0	80.7	80.5	80.3	80.0
9.5	2.0	10.7	82.9	82.6	82.4	82.2	81.9	81.7	81.5	81.2	81.0	80.8	80.5	80.3	80.1	79.8
12.1	2.5	10.4	82.7	82.5	82.3	82.0	81.8	81.5	81.3	81.1	80.8	80.6	80.3	80.1	79.9	79.6
15.0	3.0	10.1	82.6	82.3	82.1	81.8	81.6	81.4	81.1	80.9	80.6	80.4	80.1	79.9	79.7	79.4
18.0	3.5	9.8	82.4	82.2	81.9	81.7	81.4	81.2	80.9	80.7	80.4	80.2	79.9	79.7	79.4	79.2
21.1	4.0	9.6	82.2	82.0	81.7	81.5	81.2	81.0	80.7	80.5	80.2	79.9	79.7	79.4	79.2	78.9
24.5	4.5	9.3	82.0	81.8	81.5	81.3	81.0	80.8	80.5	80.2	80.0	79.7	79.4	79.2	78.9	78.7
28.1	5.0	9.0	81.8	81.6	81.3	81.1	80.8	80.5	80.3	80.0	79.7	79.5	79.2	78.9	78.6	78.4
31.9	5.5	8.7	81.6	81.4	81.1	80.8	80.6	80.3	80.0	79.7	79.5	79.2	78.9	78.6	78.4	78.1
35.9	6.0	8.4	81.4	81.1	80.9	80.6	80.3	80.0	79.7	79.5	79.2	78.9	78.6	78.3	78.0	77.8
40.3	6.5	8.2	81.2	80.9	80.6	80.3	80.0	79.7	79.5	79.2	78.9	78.6	78.3	78.0	77.7	77.4
44.9	7.0	7.9	80.9	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9	77.6	77.3	77.0
49.9	7.5	7.6	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9	77.6	77.3	77.0	76.7
55.3	8.0	7.3	80.4	80.0	79.7	79.4	79.1	78.8	78.5	78.1	77.8	77.5	77.2	76.9	76.6	76.2
61.1	8.5	7.0	80.0	79.7	79.4	79.1	78.7	78.4	78.1	77.8	77.4	77.1	76.8	76.4	76.1	75.8
67.3	9.0	6.7	79.7	79.3	79.0	78.7	78.3	78.0	77.7	77.3	77.0	76.6	76.3	76.0	75.6	75.3
74.2	9.5	6.5	79.3	79.0	78.6	78.3	77.9	77.6	77.2	76.9	76.5	76.2	75.8	75.5	75.1	74.7
81.6	10.0	6.2	78.9	78.5	78.2	77.8	77.5	77.1	76.7	76.4	76.0	75.6	75.3	74.9	74.5	74.2
89.8	10.5	5.9	78.4	78.1	77.7	77.3	76.9	76.6	76.2	75.8	75.4	75.0	74.7	74.3	73.9	73.5
98.7	11.0	5.6	78.0	77.6	77.2	76.8	76.4	76.0	75.6	75.2	74.8	74.4	74.0	73.6	73.2	72.8
108.7	11.5	5.3	77.4	77.0	76.6	76.2	75.8	75.4	74.9	74.5	74.1	73.7	73.3	72.9	72.4	72.0
119.7	12.0	5.1	76.8	76.4	75.9	75.5	75.1	74.6	74.2	73.8	73.3	72.9	72.5	72.0	71.6	71.2
132.0	12.5	4.8	76.1	75.7	75.2	74.8	74.3	73.9	73.4	72.9	72.5	72.0	71.6	71.1	70.6	70.2
145.8	13.0	4.5	75.4	74.9	74.4	73.9	73.4	73.0	72.5	72.0	71.5	71.0	70.6	70.1	69.6	69.1
161.5	13.5	4.2	74.5	74.0	73.5	73.0	72.5	72.0	71.5	70.9	70.4	69.9	69.4	68.9	68.4	67.9
179.5	14.0	3.9	73.5	73.0	72.4	71.9	71.4	70.8	70.3	69.7	69.2	68.6	68.1	67.5	67.0	66.4
200.2	14.5	3.7	72.4	71.8	71.2	70.6	70.1	69.5	68.9	68.3	67.7	67.2	66.6	66.0	65.4	64.8
224.3	15.0	3.4	71.0	70.4	69.8	69.2	68.6	67.9	67.3	66.7	66.1	65.4	64.8	64.2	63.5	62.9

NATURAL GAS

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	11.8	80.4	80.1	79.9	79.7	79.5	79.3	79.0	78.8	78.6	78.4	78.1	77.9	77.7	77.5
2.2	0.5	11.5	80.2	80.0	79.7	79.5	79.3	79.1	78.8	78.6	78.4	78.2	77.9	77.7	77.5	77.2
4.5	1.0	11.2	80.0	79.8	79.5	79.3	79.1	78.9	78.6	78.4	78.2	77.9	77.7	77.5	77.2	77.0
6.9	1.5	11.0	79.8	79.6	79.3	79.1	78.9	78.6	78.4	78.2	77.9	77.7	77.5	77.2	77.0	76.8
9.5	2.0	10.7	79.6	79.4	79.1	78.9	78.7	78.4	78.2	77.9	77.7	77.5	77.2	77.0	76.7	76.5
12.1	2.5	10.4	79.4	79.1	78.9	78.7	78.4	78.2	77.9	77.7	77.4	77.2	76.9	76.7	76.5	76.2
15.0	3.0	10.1	79.2	78.9	78.7	78.4	78.2	77.9	77.7	77.4	77.2	76.9	76.7	76.4	76.2	75.9
18.0	3.5	9.8	78.9	78.7	78.4	78.2	77.9	77.6	77.4	77.1	76.9	76.6	76.4	76.1	75.9	75.6
21.1	4.0	9.6	78.7	78.4	78.1	77.9	77.6	77.4	77.1	76.8	76.6	76.3	76.1	75.8	75.5	75.3
24.5	4.5	9.3	78.4	78.1	77.9	77.6	77.3	77.1	76.8	76.5	76.3	76.0	75.7	75.4	75.2	74.9
28.1	5.0	9.0	78.1	77.8	77.6	77.3	77.0	76.7	76.5	76.2	75.9	75.6	75.4	75.1	74.8	74.5
31.9	5.5	8.7	77.8	77.5	77.2	77.0	76.7	76.4	76.1	75.8	75.6	75.3	75.0	74.7	74.4	74.1
35.9	6.0	8.4	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.5	75.2	74.9	74.6	74.3	74.0	73.7
40.3	6.5	8.2	77.1	76.8	76.5	76.2	75.9	75.6	75.3	75.1	74.8	74.5	74.2	73.9	73.6	73.3
44.9	7.0	7.9	76.7	76.4	76.1	75.8	75.5	75.2	74.9	74.6	74.3	74.0	73.7	73.4	73.1	72.8
49.9	7.5	7.6	76.3	76.0	75.7	75.4	75.1	74.8	74.5	74.1	73.8	73.5	73.2	72.9	72.6	72.2
55.3	8.0	7.3	75.9	75.6	75.3	74.9	74.6	74.3	74.0	73.6	73.3	73.0	72.7	72.3	72.0	71.7
61.1	8.5	7.0	75.4	75.1	74.8	74.4	74.1	73.8	73.4	73.1	72.8	72.4	72.1	71.8	71.4	71.1
67.3	9.0	6.7	74.9	74.6	74.2	73.9	73.6	73.2	72.9	72.5	72.2	71.8	71.5	71.1	70.8	70.4
74.2	9.5	6.5	74.4	74.0	73.7	73.3	73.0	72.6	72.2	71.9	71.5	71.2	70.8	70.4	70.1	69.7
81.6	10.0	6.2	73.8	73.4	73.0	72.7	72.3	71.9	71.6	71.2	70.8	70.4	70.1	69.7	69.3	68.9
89.8	10.5	5.9	73.1	72.7	72.4	72.0	71.6	71.2	70.8	70.4	70.0	69.6	69.2	68.9	68.5	68.1
98.7	11.0	5.6	72.4	72.0	71.6	71.2	70.8	70.4	70.0	69.6	69.2	68.8	68.4	67.9	67.5	67.1
108.7	11.5	5.3	71.6	71.2	70.8	70.3	69.9	69.5	69.1	68.6	68.2	67.8	67.4	66.9	66.5	66.1
119.7	12.0	5.1	70.7	70.3	69.8	69.4	68.9	68.5	68.1	67.6	67.2	66.7	66.3	65.8	65.4	64.9
132.0	12.5	4.8	69.7	69.3	68.8	68.3	67.9	67.4	66.9	66.5	66.0	65.5	65.1	64.6	64.1	63.6
145.8	13.0	4.5	68.6	68.1	67.6	67.1	66.6	66.2	65.7	65.2	64.7	64.2	63.7	63.2	62.7	62.2
161.5	13.5	4.2	67.3	66.8	66.3	65.8	65.3	64.7	64.2	63.7	63.2	62.6	62.1	61.6	61.1	60.5
179.5	14.0	3.9	65.9	65.3	64.8	64.2	63.7	63.1	62.6	62.0	61.5	60.9	60.3	59.8	59.2	58.7
200.2	14.5	3.7	64.2	63.6	63.1	62.5	61.9	61.3	60.7	60.1	59.5	58.9	58.3	57.7	57.1	56.5
224.3	15.0	3.4	62.3	61.7	61.0	60.4	59.7	59.1	58.5	57.8	57.2	56.5	55.9	55.3	54.6	54.0

NATURAL GAS

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	11.8	77.2	77.0	76.8	76.6	76.3	76.1	75.9	75.7	75.4	75.2	75.0	74.7	74.5	74.3
2.2	0.5	11.5	77.0	76.8	76.6	76.3	76.1	75.9	75.6	75.4	75.2	74.9	74.7	74.5	74.2	74.0
4.5	1.0	11.2	76.8	76.5	76.3	76.1	75.8	75.6	75.4	75.1	74.9	74.6	74.4	74.2	73.9	73.7
6.9	1.5	11.0	76.5	76.3	76.0	75.8	75.6	75.3	75.1	74.8	74.6	74.3	74.1	73.9	73.6	73.4
9.5	2.0	10.7	76.2	76.0	75.8	75.5	75.3	75.0	74.8	74.5	74.3	74.0	73.8	73.5	73.3	73.0
12.1	2.5	10.4	76.0	75.7	75.5	75.2	75.0	74.7	74.5	74.2	74.0	73.7	73.4	73.2	72.9	72.7
15.0	3.0	10.1	75.7	75.4	75.1	74.9	74.6	74.4	74.1	73.9	73.6	73.4	73.1	72.8	72.6	72.3
18.0	3.5	9.8	75.3	75.1	74.8	74.6	74.3	74.0	73.8	73.5	73.2	73.0	72.7	72.5	72.2	71.9
21.1	4.0	9.6	75.0	74.7	74.5	74.2	73.9	73.7	73.4	73.1	72.9	72.6	72.3	72.0	71.8	71.5
24.5	4.5	9.3	74.6	74.4	74.1	73.8	73.5	73.3	73.0	72.7	72.4	72.2	71.9	71.6	71.3	71.1
28.1	5.0	9.0	74.3	74.0	73.7	73.4	73.1	72.9	72.6	72.3	72.0	71.7	71.4	71.2	70.9	70.6
31.9	5.5	8.7	73.8	73.6	73.3	73.0	72.7	72.4	72.1	71.8	71.5	71.3	71.0	70.7	70.4	70.1
35.9	6.0	8.4	73.4	73.1	72.8	72.5	72.2	71.9	71.6	71.4	71.1	70.8	70.5	70.2	69.9	69.6
40.3	6.5	8.2	73.0	72.7	72.4	72.0	71.7	71.4	71.1	70.8	70.5	70.2	69.9	69.6	69.3	69.0
44.9	7.0	7.9	72.5	72.1	71.8	71.5	71.2	70.9	70.6	70.3	70.0	69.6	69.3	69.0	68.7	68.4
49.9	7.5	7.6	71.9	71.6	71.3	71.0	70.6	70.8	70.0	69.7	69.4	69.0	68.7	68.4	68.1	67.7
55.3	8.0	7.3	71.4	71.0	70.7	70.4	70.0	69.7	69.4	69.0	68.7	66.4	68.0	67.7	67.4	67.0
61.1	8.5	7.0	70.7	70.4	70.1	69.7	69.4	69.0	68.7	68.3	68.0	67.6	67.3	67.0	66.6	66.3
67.3	9.0	6.7	70.1	69.7	69.4	69.0	68.6	68.3	67.9	67.6	67.2	66.9	66.5	66.2	65.8	65.4
74.2	9.5	6.5	69.3	69.0	68.6	68.2	67.9	67.5	67.1	66.8	66.4	66.0	65.7	65.3	64.9	64.5
81.6	10.0	6.2	68.5	68.2	67.8	67.4	67.0	66.6	66.3	65.9	65.5	65.1	64.7	64.3	63.9	63.6
89.8	10.5	5.9	67.7	67.3	66.9	66.5	66.1	65.7	65.3	64.9	64.5	64.1	63.7	63.3	62.9	62.5
98.7	11.0	5.6	66.7	66.3	65.9	65.5	65.1	64.6	64.2	63.8	63.4	63.0	62.6	62.1	61.7	61.3
108.7	11.5	5.3	65.7	65.2	64.8	64.4	63.9	63.5	63.1	62.6	62.2	61.8	61.3	60.9	60.4	60.0
119.7	12.0	5.1	64.5	64.0	63.6	63.1	62.7	62.2	61.8	61.3	60.8	60.4	59.9	59.5	59.0	58.6
132.0	12.5	4.8	63.2	62.7	62.2	61.7	61.3	60.8	60.3	59.8	59.3	58.9	58.4	57.9	57.4	56.9
145.8	13.0	4.5	61.7	61.2	60.7	60.2	59.7	59.2	58.7	58.2	57.7	57.1	56.6	56.1	55.6	55.1
161.5	13.5	4.2	60.0	59.5	58.9	58.4	57.9	57.3	56.8	56.3	55.7	55.2	54.7	54.1	53.6	53.0
179.5	14.0	3.9	58.1	57.5	57.0	56.4	55.8	55.3	54.7	54.1	53.6	53.0	52.4	51.8	51.3	50.7
200.2	14.5	3.7	55.9	55.3	54.7	54.1	53.5	52.9	52.3	51.6	51.0	50.4	49.8	49.2	48.6	48.0
224.3	15.0	3.4	53.3	52.7	52.0	51.4	50.7	50.1	49.4	48.7	48.1	47.4	46.8	46.1	45.5	44.8

NUMBER 2 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	15.6	90.6	90.4	90.2	90.0	89.8	89.6	89.4	89.2	89.0	88.8	88.6	88.4	88.2	88.0
2.3	0.5	15.2	90.5	90.3	90.1	89.9	89.7	89.5	89.3	89.1	88.9	88.7	88.5	88.3	88.0	87.8
4.7	1.0	14.9	90.4	90.2	90.0	89.8	89.6	89.4	89.2	89.0	88.8	88.6	88.3	88.1	87.9	87.7
7.2	1.5	14.5	90.4	90.1	89.9	89.7	89.5	89.3	89.1	88.9	88.7	88.4	88.2	88.0	87.8	87.6
9.9	2.0	14.1	90.3	90.1	89.8	89.6	89.4	89.2	89.0	88.8	88.5	88.3	88.1	87.9	87.7	87.4
12.6	2.5	13.7	90.2	90.0	89.8	89.5	89.3	89.1	88.9	88.6	88.4	88.2	88.0	87.7	87.5	87.3
15.6	3.0	13.4	90.1	89.9	89.7	89.4	89.2	89.0	88.7	88.5	88.3	88.1	87.8	87.6	87.4	87.1
18.7	3.5	13.0	90.0	89.8	89.5	89.3	89.1	88.9	88.6	88.4	88.2	87.9	87.7	87.5	87.2	87.0
22.0	4.0	12.6	89.9	89.7	89.4	89.2	89.0	88.7	88.5	88.3	88.0	87.8	87.5	87.3	87.0	86.8
25.5	4.5	12.3	89.8	89.6	89.3	89.1	88.8	88.6	88.3	88.1	87.9	87.6	87.4	87.1	86.9	86.6
29.2	5.0	11.9	89.7	89.5	89.2	89.0	88.7	88.5	88.2	87.9	87.7	87.4	87.2	86.9	86.7	86.4
33.2	5.5	11.5	89.6	89.3	89.1	88.8	88.6	88.3	88.0	87.8	87.5	87.3	87.0	86.7	86.5	86.2
37.4	6.0	11.1	89.5	89.2	88.9	88.7	88.4	88.1	87.9	87.6	87.3	87.1	86.8	86.5	86.3	86.0
41.9	6.5	10.8	89.3	89.1	88.8	88.5	88.2	88.0	87.7	87.4	87.1	86.9	86.6	86.3	86.0	85.8
46.8	7.0	10.4	89.2	88.9	88.6	88.3	88.1	87.8	87.5	87.2	86.9	86.6	86.4	86.1	85.8	85.5
52.0	7.5	10.0	89.0	88.7	88.4	88.2	87.9	87.6	87.3	87.0	86.7	86.4	86.1	85.8	85.5	85.2
57.6	8.0	9.7	88.9	88.6	88.3	88.0	87.7	87.4	87.1	86.8	86.5	86.2	85.9	85.6	85.2	84.9
63.6	8.5	9.3	88.7	88.4	88.1	87.8	87.4	87.1	86.8	86.5	86.2	85.9	85.6	85.3	84.9	84.6
70.2	9.0	8.9	88.5	88.2	87.8	87.5	87.2	86.9	86.6	86.2	85.9	85.6	85.3	84.9	84.6	84.3
77.3	9.5	8.5	88.3	87.9	87.6	87.3	86.9	86.6	86.3	85.9	85.6	85.3	84.9	84.6	84.2	83.9
85.0	10.0	8.2	88.0	87.7	87.4	87.0	86.7	86.3	86.0	85.6	85.3	84.9	84.6	84.2	83.9	83.5
93.5	10.5	7.8	87.8	87.4	87.1	86.7	86.3	86.0	85.6	85.3	84.9	84.5	84.2	83.8	83.4	83.1
102.9	11.0	7.4	87.5	87.1	86.8	86.4	86.0	85.6	85.2	84.9	84.5	84.1	83.7	83.3	82.9	82.6
113.2	11.5	7.1	87.2	86.8	86.4	86.0	85.6	85.2	84.8	84.4	84.0	83.6	83.2	82.8	82.4	82.0
124.7	12.0	6.7	86.9	86.5	86.0	85.6	85.2	84.8	84.4	84.0	83.5	83.1	82.7	82.3	81.8	81.4
137.5	12.5	6.3	86.5	86.1	85.6	85.2	84.7	84.3	83.9	83.4	83.0	82.5	82.1	81.6	81.2	80.7
152.0	13.0	6.0	86.1	85.6	85.1	84.7	84.2	83.7	83.3	82.8	82.3	81.9	81.4	80.9	80.5	80.0
168.3	13.5	5.6	85.6	85.1	84.6	84.1	83.6	83.1	82.6	82.1	81.6	81.1	80.6	80.1	79.6	79.1
187.0	14.0	5.2	85.0	84.5	84.0	83.5	82.9	82.4	81.9	81.3	80.8	80.3	79.8	79.2	78.7	78.2
208.6	14.5	4.8	84.4	83.8	83.3	82.7	82.1	81.6	81.0	80.4	79.9	79.3	78.7	78.2	77.6	77.0
233.7	15.0	4.5	83.6	83.0	82.4	81.8	81.2	80.6	80.0	79.4	78.8	78.2	77.5	76.9	76.3	75.7

NUMBER 2 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	15.6	87.8	87.6	87.4	87.1	86.9	86.7	86.5	86.3	86.1	85.9	85.7	85.5	85.3	85.1
2.3	0.5	15.2	87.6	87.4	87.2	87.0	86.8	86.6	86.4	86.2	86.0	85.8	85.5	85.3	85.1	84.9
4.7	1.0	14.9	87.5	87.3	87.1	86.9	86.7	86.4	86.2	86.0	85.8	85.6	85.4	85.2	84.9	84.7
7.2	1.5	14.5	87.4	87.2	86.9	86.7	86.5	86.3	86.1	85.8	85.6	85.4	85.2	85.0	84.7	84.5
9.9	2.0	14.1	87.2	87.0	86.8	86.6	86.3	86.1	85.9	85.7	85.4	85.2	85.0	84.8	84.5	84.3
12.6	2.5	13.7	87.1	86.8	86.6	86.4	86.2	85.9	85.7	85.5	85.3	85.0	84.8	84.6	84.3	84.1
15.6	3.0	13.4	86.9	86.7	86.5	86.2	86.0	85.8	85.5	85.3	85.1	84.8	84.6	84.3	84.1	83.9
18.7	3.5	13.0	86.7	86.5	86.3	86.0	85.8	85.6	85.3	85.1	84.8	84.6	84.4	84.1	83.9	83.6
22.0	4.0	12.6	86.6	86.3	86.1	85.8	85.6	85.3	85.1	84.9	84.6	84.4	84.1	83.9	83.6	83.4
25.5	4.5	12.3	86.4	86.1	85.9	85.6	85.4	85.1	84.9	84.6	84.4	84.1	83.9	83.6	83.4	83.1
29.2	5.0	11.9	86.2	85.9	85.7	85.4	85.1	84.9	84.6	84.4	84.1	83.9	83.6	83.3	83.1	82.8
33.2	5.5	11.5	86.0	85.7	85.4	85.2	84.9	84.6	84.4	84.1	83.8	83.6	83.3	83.0	82.8	82.5
37.4	6.0	11.1	85.7	85.5	85.2	84.9	84.6	84.4	84.1	83.8	83.6	83.3	83.0	82.7	82.5	82.2
41.9	6.5	10.8	85.5	85.2	84.9	84.6	84.4	84.1	83.8	83.5	83.2	83.0	82.7	82.4	82.1	81.8
46.8	7.0	10.4	85.2	84.9	84.6	84.4	84.1	83.8	83.5	83.2	82.9	82.6	82.3	82.0	81.7	81.5
52.0	7.5	10.0	84.9	84.6	84.3	84.1	83.8	83.5	83.2	82.9	82.6	82.3	82.0	81.7	81.4	81.0
57.6	8.0	9.7	84.6	84.3	84.0	83.7	83.4	83.1	82.8	82.5	82.2	81.9	81.6	81.2	80.9	80.6
63.6	8.5	9.3	84.3	84.0	83.7	83.4	83.0	82.7	82.4	82.1	81.8	81.4	81.1	80.8	80.5	80.1
70.2	9.0	8.9	84.0	83.6	83.3	83.0	82.6	82.3	82.0	81.6	81.3	81.0	80.6	80.3	80.0	79.6
77.3	9.5	8.5	83.6	83.2	82.9	82.5	82.2	81.9	81.5	81.2	80.8	80.5	80.1	79.8	79.4	79.1
85.0	10.0	8.2	83.1	82.8	82.4	82.1	81.7	81.4	81.0	80.6	80.3	79.9	79.6	79.2	78.8	78.5
93.5	10.5	7.8	82.7	82.3	81.9	81.6	81.2	80.8	80.5	80.1	79.7	79.3	79.0	78.6	78.2	77.8
102.9	11.0	7.4	82.2	81.8	81.4	81.0	80.6	80.2	79.8	79.5	79.1	78.7	78.3	77.9	77.5	77.1
113.2	11.5	7.1	81.6	81.2	80.8	80.4	80.0	79.6	79.2	78.8	78.4	77.9	77.5	77.1	76.7	76.3
124.7	12.0	6.7	81.0	80.6	80.1	79.7	79.3	78.9	78.4	78.0	77.6	77.1	76.7	76.3	75.8	75.4
137.5	12.5	6.3	80.3	79.9	79.4	79.0	78.5	78.0	77.6	77.1	76.7	76.2	75.8	75.3	74.9	74.4
152.0	13.0	6.0	79.5	79.0	78.6	78.1	77.6	77.1	76.7	76.2	75.7	75.2	74.7	74.3	73.8	73.3
168.3	13.5	5.6	78.6	78.1	77.6	77.1	76.6	76.1	75.6	75.1	74.6	74.1	73.6	73.0	72.5	72.0
187.0	14.0	5.2	77.6	77.1	76.5	76.0	75.5	74.9	74.4	73.8	73.3	72.8	72.2	71.7	71.1	70.6
208.6	14.5	4.8	76.4	75.9	75.3	74.7	74.1	73.6	73.0	72.4	71.8	71.2	70.7	70.1	69.5	68.9
233.7	15.0	4.5	75.1	74.5	73.8	73.2	72.6	72.0	71.3	70.7	70.1	69.5	68.8	68.2	67.6	66.9

NUMBER 2 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	15.6	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.4	83.2	83.0	82.8	82.5	82.3	82.1
2.3	0.5	15.2	84.7	84.5	84.3	84.0	83.8	83.6	83.4	83.2	83.0	82.8	82.5	82.3	82.1	81.9
4.7	1.0	14.9	84.5	84.3	84.1	83.8	83.6	83.4	83.2	83.0	82.7	82.5	82.3	82.1	81.9	81.6
7.2	1.5	14.5	84.3	84.1	83.9	83.6	83.4	83.2	83.0	82.7	82.5	82.3	82.1	81.8	81.6	81.4
9.9	2.0	14.1	84.1	83.9	83.6	83.4	83.2	82.9	82.7	82.5	82.3	82.0	81.8	81.6	81.3	81.1
12.6	2.5	13.7	83.9	83.6	83.4	83.2	82.9	82.7	82.5	82.2	82.0	81.8	81.5	81.3	81.0	80.8
15.6	3.0	13.4	83.6	83.4	83.2	82.9	82.7	82.4	82.2	82.0	81.7	81.5	81.2	81.0	80.7	80.5
18.7	3.5	13.0	83.4	83.1	82.9	82.7	82.4	82.2	81.9	81.7	81.4	81.2	80.9	80.7	80.4	80.2
22.0	4.0	12.6	83.1	82.9	82.6	82.4	82.1	81.9	81.6	81.4	81.1	80.9	80.6	80.4	80.1	79.6
25.5	4.5	12.3	82.8	82.6	82.3	82.1	81.8	81.6	81.3	81.0	80.8	80.5	80.3	80.0	79.7	79.5
29.2	5.0	11.9	82.6	82.3	82.0	81.8	81.5	81.2	81.0	80.7	80.4	80.2	79.9	79.6	79.4	79.1
33.2	5.5	11.5	82.2	82.0	81.7	81.4	81.2	80.9	80.6	80.3	80.1	79.8	79.5	79.2	79.0	78.7
37.4	6.0	11.1	81.9	81.6	81.3	81.1	80.8	80.5	80.2	79.9	79.7	79.4	79.1	78.8	78.5	78.3
41.9	6.5	10.8	81.5	81.3	81.0	80.7	80.4	80.1	79.8	79.5	79.2	79.0	78.7	78.4	78.1	77.8
46.8	7.0	10.4	81.2	80.9	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9	77.6	77.3
52.0	7.5	10.0	80.7	80.4	80.1	79.8	79.5	79.2	78.9	78.6	78.3	78.0	77.7	77.4	77.1	76.7
57.6	8.0	9.7	80.3	80.0	79.7	79.4	79.0	78.7	78.4	78.1	77.8	77.5	77.1	76.8	76.5	76.2
63.6	8.5	9.3	79.8	79.5	79.2	78.8	78.5	78.2	77.9	77.5	77.2	76.9	76.5	76.2	75.9	75.5
70.2	9.0	8.9	79.3	79.0	78.6	78.3	77.9	77.6	77.3	76.9	76.6	76.2	75.9	75.6	75.2	74.9
77.3	9.5	8.5	78.7	78.4	78.0	77.7	77.3	77.0	76.6	76.3	75.9	75.6	75.2	74.9	74.5	74.1
85.0	10.0	8.2	78.1	77.8	77.4	77.0	76.7	76.3	75.9	75.6	75.2	74.8	74.4	74.1	73.7	73.3
93.5	10.5	7.8	77.4	77.1	76.7	76.3	75.9	75.5	75.2	74.8	74.4	74.0	73.6	73.2	72.8	72.5
102.9	11.0	7.4	76.7	76.3	75.9	75.5	75.1	74.7	74.3	73.9	73.5	73.1	72.7	72.3	71.9	71.5
113.2	11.5	7.1	75.9	75.5	75.0	74.6	74.2	73.8	73.4	73.0	72.5	72.1	71.7	71.3	70.8	70.4
124.7	12.0	6.7	75.0	74.5	74.1	73.7	73.2	72.8	72.3	71.9	71.5	71.0	70.6	70.1	69.7	69.2
137.5	12.5	6.3	74.0	73.5	73.0	72.6	72.1	71.6	71.2	70.7	70.3	69.8	69.3	68.8	68.4	67.9
152.0	13.0	6.0	72.8	72.3	71.8	71.3	70.9	70.4	69.9	69.4	68.9	68.4	67.9	67.4	66.9	66.4
168.3	13.5	5.6	71.5	71.0	70.5	70.0	69.4	68.9	68.4	67.9	67.4	66.8	66.3	65.8	65.3	64.7
187.0	14.0	5.2	70.0	69.5	68.9	68.4	67.8	67.3	66.7	66.2	65.6	65.0	64.5	63.9	63.4	62.8
208.6	14.5	4.8	68.3	67.7	67.1	66.5	65.9	65.4	64.8	64.2	63.6	63.0	62.4	61.8	61.2	60.6
233.7	15.0	4.5	66.3	65.7	65.0	64.4	63.8	63.1	62.5	61.8	61.2	60.6	59.9	59.3	58.6	58.0

NUMBER 2 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	15.6	81.9	81.7	81.5	81.3	81.0	80.8	80.6	80.4	80.2	80.0	79.7	79.5	79.3	79.1
2.3	0.5	15.2	81.7	81.4	81.2	81.0	80.8	80.6	80.3	80.1	79.9	79.7	79.5	79.2	79.0	78.8
4.7	1.0	14.9	81.4	81.2	81.0	80.7	80.5	80.3	80.1	79.8	79.6	79.4	79.2	78.9	78.7	78.5
7.2	1.5	14.5	81.1	80.9	80.7	80.5	80.2	80.0	79.8	79.5	79.3	79.1	78.8	78.6	78.4	78.1
9.9	2.0	14.1	80.9	80.6	80.4	80.2	79.9	79.7	79.5	79.2	79.0	78.8	78.5	78.3	78.0	77.8
12.6	2.5	13.7	80.6	80.3	80.1	79.9	79.6	79.4	79.1	78.9	78.7	78.4	78.2	77.9	77.7	77.4
15.6	3.0	13.4	80.3	80.0	79.8	79.5	79.3	79.0	78.8	78.5	78.3	78.0	77.8	77.6	77.3	77.1
18.7	3.5	13.0	79.9	79.7	79.4	79.2	78.9	78.7	78.4	78.2	77.9	77.7	77.4	77.2	76.9	76.7
22.0	4.0	12.6	79.6	79.3	79.1	78.8	78.6	78.3	78.0	77.8	77.5	77.3	77.0	76.7	76.5	76.2
25.5	4.5	12.3	79.2	79.0	78.7	78.4	78.2	77.9	77.6	77.4	77.1	76.8	76.6	76.3	76.0	75.8
29.2	5.0	11.9	78.8	78.6	78.3	78.0	77.7	77.5	77.2	76.9	76.7	76.4	76.1	75.8	75.6	75.3
33.2	5.5	11.5	78.4	78.1	77.9	77.6	77.3	77.0	76.7	76.5	76.2	75.9	75.6	75.3	75.1	74.8
37.4	6.0	11.1	78.0	77.7	77.4	77.1	76.8	76.5	76.3	76.0	75.7	75.4	75.1	74.8	74.5	74.2
41.9	6.5	10.8	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.4	75.1	74.8	74.5	74.2	73.9	73.6
46.8	7.0	10.4	77.0	76.7	76.4	76.1	75.8	75.5	75.2	74.9	74.6	74.2	73.9	73.6	73.3	73.0
52.0	7.5	10.0	76.4	76.1	75.8	75.5	75.2	74.9	74.6	74.2	73.9	73.6	73.3	73.0	72.7	72.3
57.6	8.0	9.7	75.8	75.5	75.2	74.9	74.6	74.2	73.9	73.6	73.3	72.9	72.6	72.3	71.9	71.6
63.6	8.5	9.3	75.2	74.9	74.5	74.2	73.9	73.5	73.2	72.9	72.5	72.2	71.9	71.5	71.2	70.8
70.2	9.0	8.9	74.5	74.2	73.8	73.5	73.1	72.8	72.4	72.1	71.7	71.4	71.0	70.7	70.3	70.0
77.3	9.5	8.5	73.8	73.4	73.1	72.7	72.3	72.0	71.6	71.3	70.9	70.5	70.2	69.8	69.4	69.1
85.0	10.0	8.2	73.0	72.6	72.2	71.8	71.5	71.1	70.7	70.3	70.0	69.6	69.2	68.8	68.4	68.1
93.5	10.5	7.8	72.1	71.7	71.3	70.9	70.5	70.1	69.7	69.3	68.9	68.5	68.1	67.8	67.4	67.0
102.9	11.0	7.4	71.1	70.7	70.3	69.9	69.5	69.0	68.6	68.2	67.8	67.4	67.0	66.6	66.2	65.7
113.2	11.5	7.1	70.0	69.6	69.1	68.7	68.3	67.9	67.4	67.0	66.6	66.1	65.7	65.3	64.8	64.4
124.7	12.0	6.7	68.8	68.3	67.9	67.4	67.0	66.5	66.1	65.6	65.2	64.7	64.3	63.8	63.4	62.9
137.5	12.5	6.3	67.4	67.0	66.5	66.0	65.6	65.1	64.6	64.1	63.7	63.2	62.7	62.2	61.7	61.3
152.0	13.0	6.0	65.9	65.4	64.9	64.4	63.9	63.4	62.9	62.4	61.9	61.4	60.9	60.4	59.9	59.4
168.3	13.5	5.6	64.2	63.7	63.1	62.6	62.1	61.6	61.0	60.5	60.0	59.4	58.9	58.3	57.8	57.3
187.0	14.0	5.2	62.2	61.7	61.1	60.5	60.0	59.4	58.8	58.3	57.7	57.1	56.6	56.0	55.4	54.9
208.6	14.5	4.8	60.0	59.4	58.8	58.2	57.6	56.9	56.3	55.7	55.1	54.5	53.9	53.3	52.7	52.1
233.7	15.0	4.5	57.3	56.7	56.0	55.4	54.7	54.1	53.4	52.8	52.1	51.4	50.8	50.1	49.5	48.8

NUMBER 4 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	16.2	91.2	91.0	90.8	90.6	90.4	90.2	90.0	89.8	89.6	89.4	89.2	89.0	88.8	88.6
2.3	0.5	15.8	91.1	90.9	90.7	90.5	90.3	90.1	89.9	89.7	89.5	89.3	89.1	88.9	88.7	88.5
4.7	1.0	15.4	91.0	90.8	90.6	90.4	90.2	90.0	89.8	89.6	89.4	89.2	89.0	88.8	88.6	88.3
7.3	1.5	15.0	91.0	90.8	90.6	90.3	90.1	89.9	89.7	89.5	89.3	89.1	88.9	88.6	88.4	88.2
9.9	2.0	14.6	90.9	90.7	90.5	90.2	90.0	89.8	89.6	89.4	89.2	88.9	88.7	88.5	88.3	88.1
12.7	2.5	14.3	90.8	90.6	90.4	90.2	89.9	89.7	89.5	89.3	89.0	88.8	88.6	88.4	88.2	87.9
15.7	3.0	13.9	90.7	90.5	90.3	90.0	89.8	89.6	89.4	89.1	88.9	88.7	88.5	88.2	88.0	87.8
18.9	3.5	13.5	90.6	90.4	90.2	89.9	89.7	89.5	89.2	89.0	88.8	88.5	88.3	88.1	87.8	87.6
22.2	4.0	13.1	90.5	90.3	90.1	89.8	89.6	89.3	89.1	88.9	88.6	88.4	88.2	87.9	87.7	87.4
25.7	4.5	12.7	90.4	90.2	89.9	89.7	89.5	89.2	89.0	88.7	88.5	88.2	88.0	87.7	87.5	87.2
29.5	5.0	12.3	90.3	90.1	89.8	89.6	89.3	89.1	88.8	88.6	88.3	88.1	87.8	87.6	87.3	87.0
33.4	5.5	11.9	90.2	89.9	89.7	89.4	89.2	88.9	88.7	88.4	88.1	87.9	87.6	87.4	87.1	86.8
37.7	6.0	11.6	90.1	89.8	89.5	89.3	89.0	88.8	88.5	88.2	88.0	87.7	87.4	87.2	86.9	86.6
42.3	6.5	11.2	89.9	89.7	89.4	89.1	88.8	88.6	88.3	88.0	87.8	87.5	87.2	86.9	86.7	86.4
47.1	7.0	10.8	89.8	89.5	89.2	89.0	88.7	88.4	88.1	87.8	87.5	87.3	87.0	86.7	86.4	86.1
52.4	7.5	10.4	89.6	89.3	89.1	88.8	88.5	88.2	87.9	87.6	87.3	87.0	86.7	86.4	86.1	85.8
58.0	8.0	10.0	89.5	89.2	88.9	88.6	88.3	88.0	87.7	87.4	87.1	86.8	86.5	86.2	85.9	85.6
64.1	8.5	9.6	89.3	89.0	88.7	88.4	88.1	87.7	87.4	87.1	86.8	86.5	86.2	85.9	85.5	85.2
70.7	9.0	9.3	89.1	88.8	88.5	88.1	87.8	87.5	87.2	86.8	86.5	86.2	85.9	85.5	85.2	84.9
77.8	9.5	8.9	88.9	88.5	88.2	87.9	87.5	87.2	86.9	86.5	86.2	85.9	85.5	85.2	84.8	84.5
85.7	10.0	8.5	88.7	88.3	88.0	87.6	87.3	86.9	86.6	86.2	85.9	85.5	85.2	84.8	84.5	84.1
94.2	10.5	8.1	88.4	88.0	87.7	87.3	86.9	86.6	86.2	85.9	85.5	85.1	84.8	84.4	84.0	83.6
103.7	11.0	7.7	88.1	87.7	87.4	87.0	86.6	86.2	85.8	85.5	85.1	84.7	84.3	83.9	83.5	83.2
114.1	11.5	7.3	87.8	87.4	87.0	86.6	86.2	85.8	85.4	85.0	84.6	84.2	83.8	83.4	83.0	82.6
125.6	12.0	6.9	87.5	87.1	86.6	86.2	85.8	85.4	85.0	84.5	84.1	83.7	83.3	82.8	82.4	82.0
138.6	12.5	6.6	87.1	86.6	86.2	85.8	85.3	84.9	84.4	84.0	83.6	83.1	82.7	82.2	81.8	81.3
153.1	13.0	6.2	86.7	86.2	85.7	85.3	84.8	84.3	83.9	83.4	82.9	82.4	82.0	81.5	81.0	80.6
169.6	13.5	5.8	86.2	85.7	85.2	84.7	84.2	83.7	83.2	82.7	82.2	81.7	81.2	80.7	80.2	79.7
188.4	14.0	5.4	85.6	85.1	84.6	84.0	83.5	83.0	82.4	81.9	81.4	80.8	80.3	79.8	79.2	78.7
210.1	14.5	5.0	85.0	84.4	83.8	83.3	82.7	82.1	81.6	81.0	80.4	79.9	79.3	78.7	78.1	77.6
235.4	15.0	4.6	84.2	83.6	83.0	82.4	81.8	81.2	80.6	79.9	79.3	78.7	78.1	77.5	76.9	76.2

NUMBER 4 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	16.2	88.4	88.2	88.0	87.8	87.6	87.4	87.2	87.0	86.8	86.6	86.3	86.1	85.9	85.7
2.3	0.5	15.8	88.3	88.1	87.9	87.6	87.4	87.2	87.0	86.8	86.6	86.4	86.2	86.0	85.8	85.5
4.7	1.0	15.4	88.1	87.9	87.7	87.5	87.3	87.1	86.9	86.6	86.4	86.2	86.0	85.8	85.6	85.4
7.3	1.5	15.0	88.0	87.8	87.6	87.4	87.1	86.9	86.7	86.5	86.3	86.0	85.8	85.6	85.4	85.2
9.9	2.0	14.6	87.9	87.6	87.4	87.2	87.0	86.7	86.5	86.3	86.1	85.9	85.6	85.4	85.2	85.0
12.7	2.5	14.3	87.7	87.5	87.2	87.0	86.8	86.6	86.3	86.1	85.9	85.7	85.4	85.2	85.0	84.7
15.7	3.0	13.9	87.5	87.3	87.1	86.8	86.6	86.4	86.1	85.9	85.7	85.4	85.2	85.0	84.7	84.5
18.9	3.5	13.5	87.4	87.1	86.9	86.7	86.4	86.2	85.9	85.7	85.5	85.2	85.0	84.7	84.5	84.3
22.2	4.0	13.1	87.2	86.9	86.7	86.5	86.2	86.0	85.7	85.5	85.2	85.0	84.7	84.5	84.3	84.0
25.7	4.5	12.7	87.0	86.7	86.5	86.3	86.0	85.8	85.5	85.2	85.0	84.7	84.5	84.2	84.0	83.7
29.5	5.0	12.3	86.8	86.5	86.3	86.0	85.8	85.5	85.3	85.0	84.7	84.5	84.2	84.0	83.7	83.4
33.4	5.5	11.9	86.6	86.3	86.1	85.8	85.5	85.3	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.1
37.7	6.0	11.6	86.3	86.1	85.8	85.5	85.3	85.0	84.7	84.4	84.2	83.9	83.6	83.3	83.1	82.8
42.3	6.5	11.2	86.1	85.8	85.5	85.3	85.0	84.7	84.4	84.1	83.9	83.6	83.3	83.0	82.7	82.4
47.1	7.0	10.8	85.8	85.5	85.3	85.0	84.7	84.4	84.1	83.8	83.5	83.2	82.9	82.7	82.4	82.1
52.4	7.5	10.4	85.6	85.3	85.0	84.7	84.4	84.1	83.8	83.5	83.2	82.9	82.6	82.3	82.0	81.7
58.0	8.0	10.0	85.2	84.9	84.6	84.3	84.0	83.7	83.4	83.1	82.8	82.5	82.2	81.8	81.5	81.2
64.1	8.5	9.6	84.9	84.6	84.3	84.0	83.6	83.3	83.0	82.7	82.4	82.0	81.7	81.4	81.1	80.7
70.7	9.0	9.3	84.6	84.2	83.9	83.6	83.2	82.9	82.6	82.2	81.9	81.6	81.2	80.9	80.6	80.2
77.8	9.5	8.9	84.2	83.8	83.5	83.1	82.8	82.5	82.1	81.8	81.4	81.1	80.7	80.4	80.0	79.7
85.7	10.0	8.5	83.7	83.4	83.0	82.7	82.3	82.0	81.6	81.2	80.9	80.5	80.2	79.8	79.4	79.1
94.2	10.5	8.1	83.3	82.9	82.5	82.2	81.8	81.4	81.0	80.7	80.3	79.9	79.5	79.2	78.8	78.4
103.7	11.0	7.7	82.8	82.4	82.0	81.6	81.2	80.8	80.4	80.0	79.6	79.3	78.9	78.5	78.1	77.7
114.1	11.5	7.3	82.2	81.8	81.4	81.0	80.6	80.2	79.8	79.3	78.9	78.5	78.1	77.7	77.3	76.9
125.6	12.0	6.9	81.6	81.1	80.7	80.3	79.9	79.4	79.0	78.6	78.1	77.7	77.3	76.8	76.4	76.0
138.6	12.5	6.6	80.9	80.4	80.0	79.5	79.1	78.6	78.2	77.7	77.3	76.8	76.3	75.9	75.4	75.0
153.1	13.0	6.2	80.1	79.6	79.1	78.7	78.2	77.7	77.2	76.7	76.3	75.8	75.3	74.8	74.3	73.8
169.6	13.5	5.8	79.2	78.7	78.2	77.7	77.2	76.7	76.1	75.6	75.1	74.6	74.1	73.6	73.1	72.6
188.4	14.0	5.4	78.2	77.6	77.1	76.6	76.0	75.5	74.9	74.4	73.8	73.3	72.7	72.2	71.6	71.1
210.1	14.5	5.0	77.0	76.4	75.8	75.3	74.7	74.1	73.5	72.9	72.3	71.8	71.2	70.6	70.0	69.4
235.4	15.0	4.6	75.6	75.0	74.4	73.7	73.1	72.5	71.9	71.2	70.6	70.0	69.3	68.7	68.1	67.4

NUMBER 4 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	16.2	85.5	85.3	85.1	84.9	84.7	84.5	84.3	84.0	83.8	83.6	83.4	83.2	83.0	82.8
2.3	0.5	15.8	85.3	85.1	84.9	84.7	84.5	84.3	84.0	83.8	83.6	83.4	83.2	83.0	82.8	82.5
4.7	1.0	15.4	85.1	84.9	84.7	84.5	84.3	84.1	83.8	83.6	83.4	83.2	82.9	82.7	82.5	82.3
7.3	1.5	15.0	84.9	84.7	84.5	84.3	84.0	83.8	83.6	83.4	83.2	82.9	82.7	82.5	82.2	82.0
9.9	2.0	14.6	84.7	84.5	84.3	84.0	83.8	83.6	83.4	83.1	82.9	82.7	82.4	82.2	82.0	81.7
12.7	2.5	14.3	84.5	84.3	84.0	83.8	83.6	83.3	83.1	82.9	82.6	82.4	82.2	81.9	81.7	81.5
15.7	3.0	13.9	84.3	84.0	83.8	83.6	83.3	83.1	82.8	82.6	82.4	82.1	81.9	81.6	81.4	81.1
18.9	3.5	13.5	84.0	83.8	83.5	83.3	83.0	82.8	82.6	82.3	82.1	81.8	81.6	81.3	81.1	80.8
22.2	4.0	13.1	83.8	83.5	83.3	83.0	82.8	82.5	82.3	82.0	81.7	81.5	81.2	81.0	80.7	80.5
25.7	4.5	12.7	83.5	83.2	83.0	82.7	82.4	82.2	81.9	81.7	81.4	81.2	80.9	80.6	80.4	80.1
29.5	5.0	12.3	83.2	82.9	82.7	82.4	82.1	81.9	81.6	81.3	81.1	80.8	80.5	80.3	80.0	79.7
33.4	5.5	11.9	82.9	82.6	82.3	82.0	81.8	81.5	81.2	81.0	80.7	80.4	80.1	79.9	79.6	79.3
37.7	6.0	11.6	82.5	82.2	82.0	81.7	81.4	81.1	80.8	80.6	80.3	80.0	79.7	79.4	79.2	78.9
42.3	6.5	11.2	82.2	81.9	81.6	81.3	81.0	80.7	80.4	80.1	79.9	79.6	79.3	79.0	78.7	78.4
47.1	7.0	10.8	81.8	81.5	81.2	80.9	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9
52.4	7.5	10.4	81.4	81.1	80.7	80.4	80.1	79.8	79.5	79.2	78.9	78.6	78.3	78.0	77.7	77.4
58.0	8.0	10.0	80.9	80.6	80.3	80.0	79.6	79.3	79.0	78.7	78.4	78.1	77.7	77.4	77.1	76.8
64.1	8.5	9.6	80.4	80.1	79.8	79.4	79.1	78.8	78.5	78.1	77.8	77.5	77.1	76.8	76.5	76.1
70.7	9.0	9.3	79.9	79.6	79.2	78.9	78.5	78.2	77.9	77.5	77.2	76.8	76.5	76.2	75.8	75.5
77.8	9.5	8.9	79.3	79.0	78.6	78.3	77.9	77.6	77.2	76.9	76.5	76.2	75.8	75.4	75.1	74.7
85.7	10.0	8.5	78.7	78.3	78.0	77.6	77.2	76.9	76.5	76.1	75.8	75.4	75.0	74.7	74.3	73.9
94.2	10.5	8.1	78.0	77.6	77.3	76.9	76.5	76.1	75.7	75.4	75.0	74.6	74.2	73.8	73.4	73.0
103.7	11.0	7.7	77.3	76.9	76.5	76.1	75.7	75.3	74.9	74.5	74.1	73.7	73.3	72.9	72.5	72.1
114.1	11.5	7.3	76.5	76.0	75.6	75.2	74.8	74.4	73.9	73.5	73.1	72.7	72.3	71.8	71.4	71.0
125.6	12.0	6.9	75.5	75.1	74.7	74.2	73.8	73.3	72.9	72.5	72.0	71.6	71.1	70.7	70.2	69.8
138.6	12.5	6.6	74.5	74.0	73.6	73.1	72.7	72.2	71.7	71.3	70.8	70.3	69.9	69.4	68.9	68.5
153.1	13.0	6.2	73.4	72.9	72.4	71.9	71.4	70.9	70.4	69.9	69.4	68.9	68.4	67.9	67.4	67.0
169.6	13.5	5.8	72.0	71.5	71.0	70.5	70.0	69.4	68.9	68.4	67.9	67.4	66.8	66.3	65.8	65.2
188.4	14.0	5.4	70.5	70.0	69.4	68.9	68.3	67.8	67.2	66.7	66.1	65.5	65.0	64.4	63.9	63.3
210.1	14.5	5.0	68.8	68.2	67.6	67.0	66.5	65.9	65.3	64.7	64.1	63.5	62.9	62.3	61.7	61.1
235.4	15.0	4.6	66.8	66.2	65.5	64.9	64.3	63.6	63.0	62.3	61.7	61.0	60.4	59.7	59.1	58.4

NUMBER 4 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	16.2	82.6	82.3	82.1	81.9	81.7	81.5	81.3	81.0	80.8	80.6	80.4	80.2	80.0	79.7
2.3	0.5	15.8	82.3	82.1	81.9	81.7	81.4	81.2	81.0	80.8	80.6	80.3	80.1	79.9	79.7	79.4
4.7	1.0	15.4	82.1	81.8	81.6	81.4	81.2	80.9	80.7	80.5	80.3	80.0	79.8	79.6	79.4	79.1
7.3	1.5	15.0	81.8	81.6	81.3	81.1	80.9	80.6	80.4	80.2	80.0	79.7	79.5	79.3	79.0	78.8
9.9	2.0	14.6	81.5	81.3	81.0	80.8	80.6	80.3	80.1	79.9	79.6	79.4	79.2	78.9	78.7	78.5
12.7	2.5	14.3	81.2	81.0	80.7	80.5	80.3	80.0	79.8	79.5	79.3	79.1	78.8	78.6	78.3	78.1
15.7	3.0	13.9	80.9	80.7	80.4	80.2	79.9	79.7	79.4	79.2	78.9	78.7	78.4	78.2	78.0	77.7
18.9	3.5	13.5	80.6	80.3	80.1	79.8	79.6	79.3	79.1	78.8	78.6	78.3	78.1	77.8	77.5	77.3
22.2	4.0	13.1	80.2	80.0	79.7	79.5	79.2	78.9	78.7	78.4	78.2	77.9	77.6	77.4	77.1	76.9
25.7	4.5	12.7	79.9	79.6	79.3	79.1	78.8	78.5	78.3	78.0	77.7	77.5	77.2	76.9	76.7	76.4
29.5	5.0	12.3	79.5	79.2	78.9	78.6	78.4	78.1	77.8	77.6	77.3	77.0	76.7	76.5	76.2	75.9
33.4	5.5	11.9	79.0	78.8	78.5	78.2	77.9	77.6	77.4	77.1	76.8	76.5	76.2	76.0	75.7	75.4
37.7	6.0	11.6	78.6	78.3	78.0	77.7	77.4	77.2	76.9	76.6	76.3	76.0	75.7	75.4	75.1	74.9
42.3	6.5	11.2	78.1	77.8	77.5	77.2	76.9	76.6	76.3	76.0	75.8	75.5	75.2	74.9	74.6	74.3
47.1	7.0	10.8	77.6	77.3	77.0	76.7	76.4	76.1	75.8	75.5	75.2	74.9	74.6	74.2	73.9	73.6
52.4	7.5	10.4	77.0	76.7	76.4	76.1	75.8	75.5	75.2	74.9	74.5	74.2	73.9	73.6	73.3	73.0
58.0	8.0	10.0	76.5	76.1	75.8	75.5	75.2	74.8	74.5	74.2	73.9	73.5	73.2	72.9	72.6	72.2
64.1	8.5	9.6	75.8	75.5	75.1	74.8	74.5	74.1	73.8	73.5	73.1	72.8	72.5	72.1	71.8	71.4
70.7	9.0	9.3	75.1	74.8	74.4	74.1	73.7	73.4	73.0	72.7	72.3	72.0	71.6	71.3	70.9	70.6
77.8	9.5	8.9	74.4	74.0	73.6	73.3	72.9	72.6	72.2	71.8	71.5	71.1	70.7	70.4	70.0	69.6
85.7	10.0	8.5	73.5	73.2	72.8	72.4	72.0	71.7	71.3	70.9	70.5	70.2	69.8	69.4	69.0	68.6
94.2	10.5	8.1	72.6	72.3	71.9	71.5	71.1	70.7	70.3	69.9	69.5	69.1	68.7	68.3	67.9	67.5
103.7	11.0	7.7	71.7	71.2	70.8	70.4	70.0	69.6	69.2	68.8	68.4	68.0	67.5	67.1	66.7	66.3
114.1	11.5	7.3	70.6	70.1	69.7	69.3	68.8	68.4	68.0	67.6	67.1	66.7	66.3	65.8	65.4	65.0
125.6	12.0	6.9	69.3	68.9	68.4	68.0	67.5	67.1	66.6	66.2	65.7	65.3	64.8	64.4	63.9	63.5
138.6	12.5	6.6	68.0	67.5	67.0	66.6	66.1	65.6	65.1	64.7	64.2	63.7	63.2	62.7	62.3	61.8
153.1	13.0	6.2	66.5	66.0	65.5	65.0	64.4	63.9	63.4	62.9	62.4	61.9	61.4	60.9	60.4	59.9
169.6	13.5	5.8	64.7	64.2	63.7	63.1	62.6	62.1	61.5	61.0	60.5	59.9	59.4	58.8	58.3	57.8
188.4	14.0	5.4	62.7	62.2	61.6	61.0	60.5	59.9	59.3	58.8	58.2	57.6	57.0	56.5	55.9	55.3
210.1	14.5	5.0	60.5	59.8	59.2	58.6	58.0	57.4	56.8	56.2	55.6	55.0	54.4	53.7	53.1	52.5
235.4	15.0	4.6	57.8	57.1	56.5	55.8	55.2	54.5	53.9	53.2	52.5	51.9	51.2	50.6	49.9	49.2

NUMBER 6 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	16.5	91.4	91.2	91.0	90.8	90.6	90.4	90.2	90.0	89.8	89.6	89.4	89.2	89.0	88.8
2.3	0.5	16.1	91.3	91.1	90.9	90.7	90.5	90.3	90.1	89.9	89.7	89.5	89.3	89.1	88.9	88.6
4.7	1.0	15.7	91.3	91.0	90.8	90.6	90.4	90.2	90.0	89.8	89.6	89.4	89.2	88.9	88.7	88.5
7.3	1.5	15.3	91.2	91.0	90.8	90.5	90.3	90.1	89.9	89.7	89.5	89.3	89.0	88.8	88.6	88.4
10.0	2.0	14.9	91.1	90.9	90.7	90.4	90.2	90.0	89.8	89.6	89.3	89.1	88.9	88.7	88.5	88.2
12.8	2.5	14.5	91.0	90.8	90.6	90.3	90.1	89.9	89.7	89.4	89.2	89.0	88.8	88.5	88.3	88.1
15.8	3.0	14.1	90.9	90.7	90.5	90.2	90.0	89.8	89.6	89.3	89.1	88.9	88.6	88.4	88.2	87.9
18.9	3.5	13.7	90.8	90.6	90.4	90.1	89.9	89.7	89.4	89.2	88.9	88.7	88.5	88.2	88.0	87.8
22.3	4.0	13.3	90.7	90.5	90.2	90.0	89.8	89.5	89.3	89.0	88.8	88.6	88.3	88.1	87.8	87.6
25.8	4.5	13.0	90.6	90.4	90.1	89.9	89.6	89.4	89.1	88.9	88.6	88.4	88.1	87.9	87.6	87.4
29.6	5.0	12.6	90.5	90.3	90.0	89.8	89.5	89.2	89.0	88.7	88.5	88.2	88.0	87.7	87.5	87.2
33.6	5.5	12.2	90.4	90.1	89.9	89.6	89.3	89.1	88.8	88.6	88.3	88.0	87.8	87.5	87.2	87.0
37.9	6.0	11.8	90.3	90.0	89.7	89.5	89.2	88.9	88.7	88.4	88.1	87.8	87.6	87.3	87.0	86.8
42.4	6.5	11.4	90.1	89.8	89.6	89.3	89.0	88.7	88.5	88.2	87.9	87.6	87.4	87.1	86.8	86.5
47.3	7.0	11.0	90.0	89.7	89.4	89.1	88.8	88.6	88.3	88.0	87.7	87.4	87.1	86.8	86.5	86.3
52.6	7.5	10.6	89.8	89.5	89.2	88.9	88.6	88.3	88.1	87.8	87.5	87.2	86.9	86.6	86.3	86.0
58.2	8.0	10.2	89.6	89.3	89.0	88.7	88.4	88.1	87.8	87.5	87.2	86.9	86.6	86.3	86.0	85.7
64.3	8.5	9.8	89.5	89.1	88.8	88.5	88.2	87.9	87.6	87.3	86.9	86.6	86.3	86.0	85.7	85.3
71.0	9.0	9.4	89.3	88.9	88.6	88.3	88.0	87.6	87.3	87.0	86.6	86.3	86.0	85.7	85.3	85.0
78.2	9.5	9.0	89.0	88.7	88.4	88.0	87.7	87.4	87.0	86.7	86.3	86.0	85.6	85.3	85.0	84.6
86.0	10.0	8.6	88.8	88.5	88.1	87.8	87.4	87.0	86.7	86.3	86.0	85.6	85.3	84.9	84.5	84.2
94.6	10.5	8.2	88.6	88.2	87.8	87.4	87.1	86.7	86.3	86.0	85.6	85.2	84.9	84.5	84.1	83.7
104.1	11.0	7.9	88.3	87.9	87.5	87.1	86.7	86.3	86.0	85.6	85.2	84.8	84.4	84.0	83.6	83.2
114.5	11.5	7.5	88.0	87.6	87.1	86.7	86.3	85.9	85.5	85.1	84.7	84.3	83.9	83.5	83.1	82.7
126.1	12.0	7.1	87.6	87.2	86.8	86.3	85.9	85.5	85.1	84.6	84.2	83.8	83.3	82.9	82.5	82.1
139.1	12.5	6.7	87.2	86.8	86.3	85.9	85.4	85.0	84.5	84.1	83.6	83.2	82.7	82.3	81.8	81.4
153.7	13.0	6.3	86.8	86.3	85.8	85.4	84.9	84.4	83.9	83.5	83.0	82.5	82.0	81.5	81.1	80.6
170.2	13.5	5.9	86.3	85.8	85.3	84.8	84.3	83.8	83.3	82.8	82.2	81.7	81.2	80.7	80.2	79.7
189.1	14.0	5.5	85.7	85.2	84.6	84.1	83.6	83.0	82.5	82.0	81.4	80.9	80.3	79.8	79.2	78.7
210.9	14.5	5.1	85.1	84.5	83.9	83.3	82.8	82.2	81.6	81.0	80.4	79.9	79.3	78.7	78.1	77.5
236.4	15.0	4.7	84.3	83.7	83.1	82.4	81.8	81.2	80.6	79.9	79.3	78.7	78.1	77.4	76.8	76.2

NUMBER 6 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	16.5	88.6	88.4	88.2	87.9	87.7	87.5	87.3	87.1	86.9	86.7	86.5	86.3	86.1	85.9
2.3	0.5	16.1	88.4	88.2	88.0	87.8	87.6	87.4	87.2	87.0	86.8	86.5	86.3	86.1	85.9	85.7
4.7	1.0	15.7	88.3	88.1	87.9	87.7	87.4	87.2	87.0	86.8	86.6	86.4	86.1	85.9	85.7	85.5
7.3	1.5	15.3	88.2	87.9	87.7	87.5	87.3	87.1	86.8	86.6	86.4	86.2	86.0	85.7	85.5	85.3
10.0	2.0	14.9	88.0	87.8	87.6	87.3	87.1	86.9	86.7	86.4	86.2	86.0	85.8	85.5	85.3	85.1
12.8	2.5	14.5	87.9	87.6	87.4	87.2	86.9	86.7	86.5	86.3	86.0	85.8	85.6	85.3	85.1	84.9
15.8	3.0	14.1	87.7	87.5	87.2	87.0	86.8	86.5	86.3	86.1	85.8	85.6	85.3	85.1	84.9	84.6
18.9	3.5	13.7	87.5	87.3	87.0	86.8	86.6	86.3	86.1	85.8	85.6	85.4	85.1	84.9	84.6	84.4
22.3	4.0	13.3	87.3	87.1	86.8	86.6	86.4	86.1	85.9	85.6	85.4	85.1	84.9	84.6	84.4	84.1
25.8	4.5	13.0	87.1	86.9	86.6	86.4	86.1	85.9	85.6	85.4	85.1	84.9	84.6	84.3	84.1	83.8
29.6	5.0	12.6	86.9	86.7	86.4	86.2	85.9	85.6	85.4	85.1	84.9	84.6	84.3	84.1	83.8	83.5
33.6	5.5	12.2	86.7	86.5	86.2	85.9	85.6	85.4	85.1	84.8	84.6	84.3	84.0	83.8	83.5	83.2
37.9	6.0	11.8	86.5	86.2	85.9	85.7	85.4	85.1	84.8	84.6	84.3	84.0	83.7	83.4	83.2	82.9
42.4	6.5	11.4	86.2	85.9	85.7	85.4	85.1	84.8	84.5	84.2	84.0	83.7	83.4	83.1	82.8	82.5
47.3	7.0	11.0	86.0	85.7	85.4	85.1	84.8	84.5	84.2	83.9	83.6	83.3	83.0	82.7	82.4	82.1
52.6	7.5	10.6	85.7	85.4	85.1	84.8	84.5	84.2	83.9	83.6	83.3	82.9	82.6	82.3	82.0	81.7
58.2	8.0	10.2	85.4	85.0	84.7	84.4	84.1	83.8	83.5	83.2	82.9	82.5	82.2	81.9	81.6	81.3
64.3	8.5	9.8	85.0	84.7	84.4	84.1	83.7	83.4	83.1	82.8	82.4	82.1	81.8	81.5	81.1	80.8
71.0	9.0	9.4	84.7	84.3	84.0	83.7	83.3	83.0	82.6	82.3	82.0	81.6	81.3	81.0	80.6	80.3
78.2	9.5	9.0	84.3	83.9	83.6	83.2	82.9	82.5	82.2	81.8	81.5	81.1	80.8	80.4	80.1	79.7
86.0	10.0	8.6	83.8	83.5	83.1	82.7	82.4	82.0	81.7	81.3	80.9	80.6	80.2	79.8	79.5	79.1
94.6	10.5	8.2	83.4	83.0	82.6	82.2	81.8	81.5	81.1	80.7	80.3	79.9	79.6	79.2	78.8	78.4
104.1	11.0	7.9	82.8	82.4	82.0	81.7	81.3	80.9	80.5	80.1	79.7	79.3	78.9	78.5	78.1	77.7
114.5	11.5	7.5	82.3	81.8	81.4	81.0	80.6	80.2	79.8	79.4	78.9	78.5	78.1	77.7	77.3	76.8
126.1	12.0	7.1	81.6	81.2	80.8	80.3	79.9	79.4	79.0	78.6	78.1	77.7	77.3	76.8	76.4	75.9
139.1	12.5	6.7	80.9	80.4	80.0	79.5	79.1	78.6	78.2	77.7	77.2	76.8	76.3	75.8	75.4	74.9
153.7	13.0	6.3	80.1	79.6	79.1	78.6	78.2	77.7	77.2	76.7	76.2	75.7	75.2	74.7	74.2	73.8
170.2	13.5	5.9	79.2	78.7	78.2	77.6	77.1	76.6	76.1	75.6	75.1	74.5	74.0	73.5	73.0	72.5
189.1	14.0	5.5	78.1	77.6	77.1	76.5	76.0	75.4	74.9	74.3	73.7	73.2	72.6	72.1	71.5	71.0
210.9	14.5	5.1	76.9	76.4	75.8	75.2	74.6	74.0	73.4	72.8	72.2	71.6	71.0	70.4	69.8	69.2
236.4	15.0	4.7	75.5	74.9	74.3	73.6	73.0	72.4	71.7	71.1	70.5	69.8	69.2	68.5	67.9	67.2

NUMBER 6 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less.0ombustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	16.5	85.7	85.4	85.2	85.0	84.8	84.6	84.4	84.2	83.9	83.7	83.5	83.3	83.1	82.9
2.3	0.5	16.1	85.5	85.3	85.0	84.8	84.6	84.4	84.2	83.9	83.7	83.5	83.3	83.1	82.9	82.6
4.7	1.0	15.7	85.3	85.1	84.8	84.6	84.4	84.2	83.9	83.7	83.5	83.3	83.1	82.8	82.6	82.4
7.3	1.5	15.3	85.1	84.8	84.6	84.4	84.2	83.9	83.7	83.5	83.3	83.0	82.8	82.6	82.3	82.1
10.0	2.0	14.9	84.8	84.6	84.4	84.2	83.9	83.7	83.5	83.2	83.0	82.8	82.5	82.3	82.1	81.8
12.8	2.5	14.5	84.6	84.4	84.2	83.9	83.7	83.4	83.2	83.0	82.7	82.5	82.3	82.0	81.8	81.5
15.8	3.0	14.1	84.4	84.1	83.9	83.7	83.4	83.2	82.9	82.7	82.4	82.2	82.0	81.7	81.5	81.2
18.9	3.5	13.7	84.1	83.9	83.6	83.4	83.1	82.9	82.6	82.4	82.1	81.9	81.6	81.4	81.1	80.9
22.3	4.0	13.3	83.9	83.6	83.4	83.1	82.8	82.6	82.3	82.1	81.8	81.6	81.3	81.1	80.8	80.5
25.8	4.5	13.0	83.6	83.3	83.1	82.8	82.5	82.3	82.0	81.7	81.5	81.2	81.0	80.7	80.4	80.2
29.6	5.0	12.6	83.3	83.0	82.7	82.5	82.2	81.9	81.7	81.4	81.1	80.9	80.6	80.3	80.0	79.8
33.6	5.5	12.2	82.9	82.7	82.4	82.1	81.8	81.6	81.3	81.0	80.7	80.5	80.2	79.9	79.6	79.4
37.9	6.0	11.8	82.6	82.3	82.0	81.8	81.5	81.2	80.9	80.6	80.3	80.0	79.8	79.5	79.2	78.9
42.4	6.5	11.4	82.2	81.9	81.7	81.4	81.1	80.8	80.5	80.2	79.9	79.6	79.3	79.0	78.7	78.4
47.3	7.0	11.0	81.8	81.5	81.2	80.9	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9
52.6	7.5	10.6	81.4	81.1	80.8	80.5	80.2	79.9	79.6	79.2	78.9	78.6	78.3	78.0	77.7	77.4
58.2	8.0	10.2	81.0	80.6	80.3	80.0	79.7	79.4	79.0	78.7	78.4	78.1	77.7	77.4	77.1	76.8
64.3	8.5	9.8	80.5	80.1	79.8	79.5	79.1	78.8	78.5	78.1	77.8	77.5	77.1	76.8	76.5	76.1
71.0	9.0	9.4	79.9	79.6	79.2	78.9	78.6	78.2	77.9	77.5	77.2	76.8	76.5	76.1	75.8	75.4
78.2	9.5	9.0	79.4	79.0	78.6	78.3	77.9	77.6	77.2	76.8	76.5	76.1	75.8	75.4	75.0	74.7
86.0	10.0	8.6	78.7	78.3	78.0	77.6	77.2	76.9	76.5	76.1	75.7	75.4	75.0	74.6	74.2	73.9
94.6	10.5	8.2	78.0	77.6	77.3	76.9	76.5	76.1	75.7	75.3	74.9	74.5	74.1	73.7	73.3	72.9
104.1	11.0	7.9	77.3	76.9	76.5	76.0	75.6	75.2	74.8	74.4	74.0	73.6	73.2	72.8	72.4	72.0
114.5	11.5	7.5	76.4	76.0	75.6	75.1	74.7	74.3	73.9	73.4	73.0	72.6	72.2	71.7	71.3	70.9
126.1	12.0	7.1	75.5	75.0	74.6	74.1	73.7	73.3	72.8	72.4	71.9	71.5	71.0	70.6	70.1	69.6
139.1	12.5	6.7	74.4	74.0	73.5	73.0	72.6	72.1	71.6	71.1	70.7	70.2	69.7	69.2	68.8	68.3
153.7	13.0	6.3	73.3	72.8	72.3	71.8	71.3	70.8	70.3	69.8	69.3	68.8	68.3	67.8	67.3	66.8
170.2	13.5	5.9	71.9	71.4	70.9	70.3	69.8	69.3	68.8	68.2	67.7	67.2	66.6	66.1	65.6	65.0
189.1	14.0	5.5	70.4	69.8	69.3	68.7	68.2	67.6	67.0	66.5	65.9	65.3	64.7	64.2	63.6	63.0
210.9	14.5	5.1	68.6	68.0	67.4	66.8	66.2	65.6	65.0	64.4	63.8	63.2	62.6	62.0	61.4	60.7
236.4	15.0	4.7	66.6	65.9	65.3	64.6	64.0	63.3	62.7	62.0	61.4	60.7	60.1	59.4	58.7	58.1

NUMBER 6 OIL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	16.5	82.7	82.4	82.2	82.0	81.8	81.6	81.3	81.1	80.9	80.7	80.5	80.2	80.0	79.8
2.3	0.5	16.1	82.4	82.2	82.0	81.7	81.5	81.3	81.1	80.8	80.6	80.4	80.2	79.9	79.7	79.5
4.7	1.0	15.7	82.1	81.9	81.7	81.5	81.2	81.0	80.8	80.6	80.3	80.1	79.9	79.6	79.4	79.2
7.3	1.5	15.3	81.9	81.6	81.4	81.2	81.0	80.7	80.5	80.3	80.0	79.8	79.5	79.3	79.1	78.8
10.0	2.0	14.9	81.6	81.4	81.1	80.9	80.6	80.4	80.2	79.9	79.7	79.5	79.2	79.0	78.7	78.5
12.8	2.5	14.5	81.3	81.0	80.8	80.6	80.3	80.1	79.8	79.6	79.3	79.1	78.9	78.6	78.4	78.1
15.8	3.0	14.1	81.0	80.7	80.5	80.2	80.0	79.7	79.5	79.2	79.0	78.7	78.5	78.2	78.0	77.7
18.9	3.5	13.7	80.6	80.4	80.1	79.9	79.6	79.4	79.1	78.9	78.6	78.3	78.1	77.8	77.6	77.3
22.3	4.0	13.3	80.3	80.0	79.8	79.5	79.2	79.0	78.7	78.5	78.2	77.9	77.7	77.4	77.1	76.9
25.8	4.5	13.0	79.9	79.6	79.4	79.1	78.8	78.6	78.3	78.0	77.8	77.5	77.2	76.9	76.7	76.4
29.6	5.0	12.6	79.5	79.2	79.0	78.7	78.4	78.1	77.9	77.6	77.3	77.0	76.7	76.5	76.2	75.9
33.6	5.5	12.2	79.1	78.8	78.5	78.2	77.9	77.7	77.4	77.1	76.8	76.5	76.2	76.0	75.7	75.4
37.9	6.0	11.8	78.6	78.3	78.0	77.7	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.4	75.1	74.8
42.4	6.5	11.4	78.1	77.8	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.4	75.1	74.8	74.5	74.2
47.3	7.0	11.0	77.6	77.3	77.0	76.7	76.4	76.1	75.8	75.4	75.1	74.8	74.5	74.2	73.9	73.6
52.6	7.5	10.6	77.0	76.7	76.4	76.1	75.8	75.5	75.1	74.8	74.5	74.2	73.9	73.5	73.2	72.9
58.2	8.0	10.2	76.4	76.1	75.8	75.5	75.1	74.8	74.5	74.1	73.8	73.5	73.1	72.8	72.5	72.1
64.3	8.5	9.8	75.8	75.4	75.1	74.8	74.4	74.1	73.7	73.4	73.1	72.7	72.4	72.0	71.7	71.3
71.0	9.0	9.4	75.1	74.7	74.4	74.0	73.7	73.3	73.0	72.6	72.3	71.9	71.5	71.2	70.8	70.5
78.2	9.5	9.0	74.3	73.9	73.6	73.2	72.8	72.5	72.1	71.7	71.4	71.0	70.6	70.3	69.9	69.5
86.0	10.0	8.6	73.5	73.1	72.7	72.3	72.0	71.6	71.2	70.8	70.4	70.0	69.6	69.3	68.9	68.5
94.6	10.5	8.2	72.6	72.2	71.8	71.4	71.0	70.6	70.2	69.8	69.4	69.0	68.6	68.2	67.8	67.4
104.1	11.0	7.9	71.5	71.1	70.7	70.3	69.9	69.5	69.1	68.6	68.2	67.8	67.4	67.0	66.5	66.1
114.5	11.5	7.5	70.4	70.0	69.6	69.1	68.7	68.3	67.8	67.4	66.9	66.5	66.1	65.6	65.2	64.7
126.1	12.0	7.1	69.2	68.7	68.3	67.8	67.4	66.9	66.4	66.0	65.5	65.1	64.6	64.1	63.7	63.2
139.1	12.5	6.7	67.8	67.3	66.8	66.4	65.9	65.4	64.9	64.4	63.9	63.5	63.0	62.5	62.0	61.5
153.7	13.0	6.3	66.2	65.7	65.2	64.7	64.2	63.7	63.2	62.7	62.2	61.6	61.1	60.6	60.1	59.6
170.2	13.5	5.9	64.5	63.9	63.4	62.9	62.3	61.8	61.2	60.7	60.1	59.6	59.1	58.5	58.0	57.4
189.1	14.0	5.5	62.5	61.9	61.3	60.7	60.2	59.6	59.0	58.4	57.8	57.3	56.7	56.1	55.5	54.9
210.9	14.5	5.1	60.1	59.5	58.9	58.3	57.7	57.0	56.4	55.8	55.2	54.6	53.9	53.3	52.7	52.1
236.4	15.0	4.7	57.4	56.8	56.1	55.4	54.8	54.1	53.4	52.8	52.1	51.4	50.7	50.1	49.4	48.7

PROPANE LIQUID FUEL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	13.8	88.7	88.5	88.3	88.1	87.9	87.7	87.5	87.3	87.1	86.8	86.6	86.4	86.2	86.0
2.2	0.5	13.4	88.6	88.4	88.2	88.0	87.8	87.6	87.4	87.2	87.0	86.7	86.5	86.3	86.1	85.9
4.6	1.0	13.1	88.5	88.3	88.1	87.9	87.7	87.5	87.3	87.1	86.9	86.6	86.4	86.2	86.0	85.8
7.0	1.5	12.8	88.5	88.2	88.0	87.8	87.6	87.4	87.2	87.0	86.7	86.5	86.3	86.1	85.9	85.7
9.6	2.0	12.5	88.4	88.2	87.9	87.7	87.5	87.3	87.1	86.9	86.6	86.4	86.2	86.0	85.8	85.5
12.4	2.5	12.1	88.3	88.1	87.9	87.6	87.4	87.2	87.0	86.7	86.5	86.3	86.1	85.8	85.6	85.4
15.3	3.0	11.8	88.2	88.0	87.8	87.5	87.3	87.1	86.8	86.6	86.4	86.2	85.9	85.7	85.5	85.2
18.3	3.5	11.5	88.1	87.9	87.7	87.4	87.2	87.0	86.7	86.5	86.3	86.0	85.8	85.6	85.3	85.1
21.5	4.0	11.1	88.0	87.8	87.6	87.3	87.1	86.8	86.6	86.4	86.1	85.9	85.6	85.4	85.2	84.9
25.0	4.5	10.8	87.9	87.7	87.4	87.2	87.0	86.7	86.5	86.2	86.0	85.7	85.5	85.2	85.0	84.7
28.6	5.0	10.5	87.8	87.6	87.3	87.1	86.8	86.6	86.3	86.1	85.8	85.6	85.3	85.0	84.8	84.5
32.5	5.5	10.2	87.7	87.5	87.2	86.9	86.7	86.4	86.2	85.9	85.6	85.4	85.1	84.9	84.6	84.3
36.6	6.0	9.8	87.6	87.3	87.1	86.8	86.5	86.3	86.0	85.7	85.5	85.2	84.9	84.7	84.4	84.1
41.0	6.5	9.5	87.5	87.2	86.9	86.6	86.4	86.1	85.8	85.5	85.3	85.0	84.7	84.4	84.2	83.9
45.8	7.0	9.2	87.3	87.0	86.8	86.5	86.2	85.9	85.6	85.3	85.1	84.8	84.5	84.2	83.9	83.6
50.9	7.5	8.8	87.2	86.9	86.6	86.3	86.0	85.7	85.4	85.1	84.8	84.6	84.3	84.0	83.7	83.4
56.3	8.0	8.5	87.0	86.7	86.4	86.1	85.8	85.5	85.2	84.9	84.6	84.3	84.0	83.7	83.4	83.1
62.2	8.5	8.2	86.8	86.5	86.2	85.9	85.6	85.3	85.0	84.7	84.4	84.0	83.7	83.4	83.1	82.8
68.6	9.0	7.9	86.6	86.3	86.0	85.7	85.4	85.0	84.7	84.4	84.1	83.7	83.4	83.1	82.8	82.4
75.6	9.5	7.5	86.4	86.1	85.8	85.4	85.1	84.8	84.4	84.1	83.8	83.4	83.1	82.8	82.4	82.1
83.2	10.0	7.2	86.2	85.9	85.5	85.2	84.8	84.5	84.1	83.8	83.4	83.1	82.7	82.4	82.0	81.7
91.5	10.5	6.9	86.0	85.6	85.3	84.9	84.5	84.2	83.8	83.4	83.1	82.7	82.4	82.0	81.6	81.3
100.7	11.0	6.6	85.7	85.3	84.9	84.6	84.2	83.8	83.4	83.1	82.7	82.3	81.9	81.5	81.2	80.8
110.8	11.5	6.2	85.4	85.0	84.6	84.2	83.8	83.4	83.0	82.6	82.2	81.8	81.4	81.1	80.7	80.3
122.0	12.0	5.9	85.1	84.7	84.2	83.8	83.4	83.0	82.6	82.2	81.8	81.3	80.9	80.5	80.1	79.7
134.6	12.5	5.6	84.7	84.3	83.8	83.4	83.0	82.5	82.1	81.7	81.2	80.8	80.3	79.9	79.5	79.0
148.7	13.0	5.2	84.3	83.8	83.4	82.9	82.4	82.0	81.5	81.1	80.6	80.1	79.7	79.2	78.7	78.3
164.7	13.5	4.9	83.8	83.3	82.8	82.4	81.9	81.4	80.9	80.4	79.9	79.4	78.9	78.4	77.9	77.4
183.0	14.0	4.6	83.3	82.8	82.2	81.7	81.2	80.7	80.2	79.6	79.1	78.6	78.1	77.5	77.0	76.5
204.1	14.5	4.3	82.7	82.1	81.5	81.0	80.4	79.9	79.3	78.8	78.2	77.6	77.1	76.5	75.9	75.4
228.7	15.0	3.9	81.9	81.3	80.7	80.1	79.5	78.9	78.3	77.7	77.1	76.5	75.9	75.3	74.7	74.1

PROPANE LIQUID FUEL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	13.8	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.8	83.5	83.3	83.1
2.2	0.5	13.4	85.7	85.5	85.3	85.1	84.9	84.7	84.4	84.2	84.0	83.8	83.6	83.4	83.2	83.0
4.6	1.0	13.1	85.6	85.4	85.2	84.9	84.7	84.5	84.3	84.1	83.9	83.6	83.4	83.2	83.0	82.8
7.0	1.5	12.8	85.4	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.2	83.0	82.8	82.6
9.6	2.0	12.5	85.3	85.1	84.9	84.6	84.4	84.2	84.0	83.7	83.5	83.3	83.1	82.8	82.6	82.4
12.4	2.5	12.1	85.2	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.3	83.1	82.9	82.6	82.4	82.2
15.3	3.0	11.8	85.0	84.8	84.5	84.3	84.1	83.8	83.6	83.4	83.1	82.9	82.7	82.4	82.2	81.9
18.3	3.5	11.5	84.8	84.6	84.4	84.1	83.9	83.6	83.4	83.2	82.9	82.7	82.4	82.2	82.0	81.7
21.5	4.0	11.1	84.7	84.4	84.2	83.9	83.7	83.4	83.2	82.9	82.7	82.5	82.2	82.0	81.7	81.5
25.0	4.5	10.8	84.5	84.2	84.0	83.7	83.5	83.2	83.0	82.7	82.5	82.2	82.0	81.7	81.5	81.2
28.6	5.0	10.5	84.3	84.0	83.8	83.5	83.3	83.0	82.7	82.5	82.2	82.0	81.7	81.4	81.2	80.9
32.5	5.5	10.2	84.1	83.8	83.5	83.3	83.0	82.8	82.5	82.2	82.0	81.7	81.4	81.2	80.9	80.6
36.6	6.0	9.8	83.9	83.6	83.3	83.0	82.8	82.5	82.2	81.9	81.7	81.4	81.1	80.8	80.6	80.3
41.0	6.5	9.5	83.6	83.3	83.1	82.8	82.5	82.2	81.9	81.7	81.4	81.1	80.8	80.5	80.2	80.0
45.8	7.0	9.2	83.4	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.1	80.8	80.5	80.2	79.9	79.6
50.9	7.5	8.8	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.7	80.4	80.1	79.8	79.5	79.2
56.3	8.0	8.5	82.8	82.5	82.2	81.9	81.6	81.3	80.9	80.6	80.3	80.0	79.7	79.4	79.1	78.8
62.2	8.5	8.2	82.5	82.2	81.8	81.5	81.2	80.9	80.6	80.2	79.9	79.6	79.3	79.0	78.6	78.3
68.6	9.0	7.9	82.1	81.8	81.5	81.1	80.8	80.5	80.2	79.8	79.5	79.2	78.8	78.5	78.2	77.8
75.6	9.5	7.5	81.7	81.4	81.1	80.7	80.4	80.0	79.7	79.4	79.0	78.7	78.3	78.0	77.6	77.3
83.2	10.0	7.2	81.3	81.0	80.6	80.3	79.9	79.6	79.2	78.9	78.5	78.1	77.8	77.4	77.1	76.7
91.5	10.5	6.9	80.9	80.5	80.2	79.8	79.4	79.0	78.7	78.3	77.9	77.6	77.2	76.8	76.4	76.1
100.7	11.0	6.6	80.4	80.0	79.6	79.2	78.9	78.5	78.1	77.7	77.3	76.9	76.5	76.1	75.7	75.4
110.8	11.5	6.2	79.8	79.4	79.0	78.6	78.2	77.8	77.4	77.0	76.6	76.2	75.8	75.4	75.0	74.6
122.0	12.0	5.9	79.2	78.8	78.4	78.0	77.6	77.1	76.7	76.3	75.9	75.4	75.0	74.6	74.1	73.7
134.6	12.5	5.6	78.6	78.1	77.7	77.2	76.8	76.3	75.9	75.4	75.0	74.5	74.1	73.6	73.2	72.7
148.7	13.0	5.2	77.8	77.3	76.9	76.4	75.9	75.5	75.0	74.5	74.0	73.6	73.1	72.6	72.1	71.6
164.7	13.5	4.9	76.9	76.4	75.9	75.4	74.9	74.4	73.9	73.4	72.9	72.4	71.9	71.4	70.9	70.4
183.0	14.0	4.6	76.0	75.4	74.9	74.4	73.8	73.3	72.8	72.2	71.7	71.2	70.6	70.1	69.5	69.0
204.1	14.5	4.3	74.8	74.2	73.7	73.1	72.5	72.0	71.4	70.8	70.3	69.7	69.1	68.5	67.9	67.4
228.7	15.0	3.9	73.5	72.9	72.3	71.7	71.0	70.4	69.8	69.2	68.6	68.0	67.3	66.7	66.1	65.5

PROPANE LIQUID FUEL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	13.8	82.9	82.7	82.5	82.3	82.1	81.9	81.6	81.4	81.2	81.0	80.8	80.6	80.3	80.1
2.2	0.5	13.4	82.7	82.5	82.3	82.1	81.9	81.7	81.4	81.2	81.0	80.8	80.6	80.3	80.1	79.9
4.6	1.0	13.1	82.6	82.3	82.1	81.9	81.7	81.4	81.2	81.0	80.8	80.6	80.3	80.1	79.9	79.7
7.0	1.5	12.8	82.4	82.1	81.9	81.7	81.5	81.2	81.0	80.8	80.5	80.3	80.1	79.9	79.6	79.4
9.6	2.0	12.5	82.2	81.9	81.7	81.5	81.2	81.0	80.8	80.5	80.3	80.1	79.8	79.6	79.4	79.1
12.4	2.5	12.1	81.9	81.7	81.5	81.2	81.0	80.8	80.5	80.3	80.1	79.8	79.6	79.3	79.1	78.9
15.3	3.0	11.8	81.7	81.5	81.2	81.0	80.7	80.5	80.3	80.0	79.8	79.5	79.3	79.1	78.8	78.6
18.3	3.5	11.5	81.5	81.2	81.0	80.7	80.5	80.2	80.0	79.7	79.5	79.2	79.0	78.7	78.5	78.2
21.5	4.0	11.1	81.2	81.0	80.7	80.5	80.2	80.0	79.7	79.4	79.2	78.9	78.7	78.4	78.2	77.9
25.0	4.5	10.8	80.9	80.7	80.4	80.2	79.9	79.7	79.4	79.1	78.9	78.6	78.4	78.1	77.8	77.6
28.6	5.0	10.5	80.7	80.4	80.1	79.9	79.6	79.3	79.1	78.8	78.5	78.3	78.0	77.7	77.5	77.2
32.5	5.5	10.2	80.3	80.1	79.8	79.5	79.3	79.0	78.7	78.4	78.2	77.9	77.6	77.3	77.1	76.8
36.6	6.0	9.8	80.0	79.7	79.5	79.2	78.9	78.6	78.3	78.1	77.8	77.5	77.2	76.9	76.7	76.4
41.0	6.5	9.5	79.7	79.4	79.1	78.8	78.5	78.2	77.9	77.7	77.4	77.1	76.8	76.5	76.2	75.9
45.8	7.0	9.2	79.3	79.0	78.7	78.4	78.1	77.8	77.5	77.2	76.9	76.6	76.3	76.0	75.7	75.4
50.9	7.5	8.8	78.9	78.6	78.3	78.0	77.7	77.4	77.1	76.8	76.5	76.1	75.8	75.5	75.2	74.9
56.3	8.0	8.5	78.5	78.1	77.8	77.5	77.2	76.9	76.6	76.3	75.9	75.6	75.3	75.0	74.7	74.3
62.2	8.5	8.2	78.0	77.7	77.3	77.0	76.7	76.4	76.0	75.7	75.4	75.1	74.7	74.4	74.1	73.7
68.6	9.0	7.9	77.5	77.2	76.8	76.5	76.1	75.8	75.5	75.1	74.8	74.4	74.1	73.8	73.4	73.1
75.6	9.5	7.5	76.9	76.6	76.2	75.9	75.5	75.2	74.8	74.5	74.1	73.8	73.4	73.1	72.7	72.4
83.2	10.0	7.2	76.3	76.0	75.6	75.3	74.9	74.5	74.2	73.8	73.4	73.1	72.7	72.3	72.0	71.6
91.5	10.5	6.9	75.7	75.3	74.9	74.5	74.2	73.8	73.4	73.0	72.6	72.3	71.9	71.5	71.1	70.7
100.7	11.0	6.6	75.0	74.6	74.2	73.8	73.4	73.0	72.6	72.2	71.8	71.4	71.0	70.6	70.2	69.8
110.8	11.5	6.2	74.2	73.7	73.3	72.9	72.5	72.1	71.7	71.3	70.8	70.4	70.0	69.6	69.2	68.7
122.0	12.0	5.9	73.3	72.8	72.4	72.0	71.5	71.1	70.7	70.2	69.8	69.4	68.9	68.5	68.0	67.6
134.6	12.5	5.6	72.3	71.8	71.4	70.9	70.5	70.0	69.5	69.1	68.6	68.2	67.7	67.2	66.8	66.3
148.7	13.0	5.2	71.2	70.7	70.2	69.7	69.2	68.8	68.3	67.8	67.3	66.8	66.3	65.8	65.3	64.9
164.7	13.5	4.9	69.9	69.4	68.9	68.4	67.9	67.3	66.8	66.3	65.8	65.3	64.8	64.2	63.7	63.2
183.0	14.0	4.6	68.5	67.9	67.4	66.8	66.3	65.7	65.2	64.6	64.1	63.5	63.0	62.4	61.9	61.3
204.1	14.5	4.3	66.8	66.2	65.6	65.0	64.5	63.9	63.3	62.7	62.1	61.5	60.9	60.3	59.8	59.2
228.7	15.0	3.9	64.8	64.2	63.6	63.0	62.3	61.7	61.1	60.4	59.8	59.2	58.5	57.9	57.3	56.6

PROPANE LIQUID FUEL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	13.8	79.9	79.7	79.5	79.3	79.0	78.8	78.6	78.4	78.2	77.9	77.7	77.5	77.3	77.1
2.2	0.5	13.4	79.7	79.5	79.2	79.0	78.8	78.6	78.3	78.1	77.9	77.7	77.4	77.2	77.0	76.8
4.6	1.0	13.1	79.4	79.2	79.0	78.8	78.5	78.3	78.1	77.8	77.6	77.4	77.2	76.9	76.7	76.5
7.0	1.5	12.8	79.2	78.9	78.7	78.5	78.3	78.0	77.8	77.6	77.3	77.1	76.9	76.6	76.4	76.2
9.6	2.0	12.5	78.9	78.7	78.4	78.2	78.0	77.7	77.5	77.3	77.0	76.8	76.5	76.3	76.1	75.8
12.4	2.5	12.1	78.6	78.4	78.1	77.9	77.7	77.4	77.2	76.9	76.7	76.4	76.2	76.0	75.7	75.5
15.3	3.0	11.8	78.3	78.1	77.8	77.6	77.3	77.1	76.8	76.6	76.3	76.1	75.8	75.6	75.3	75.1
18.3	3.5	11.5	78.0	77.7	77.5	77.2	77.0	76.7	76.5	76.2	76.0	75.7	75.5	75.2	75.0	74.7
21.5	4.0	11.1	77.7	77.4	77.1	76.9	76.6	76.4	76.1	75.9	75.6	75.3	75.1	74.8	74.5	74.3
25.0	4.5	10.8	77.3	77.0	76.8	76.5	76.2	76.0	75.7	75.4	75.2	74.9	74.6	74.4	74.1	73.8
28.6	5.0	10.5	76.9	76.7	76.4	76.1	75.8	75.6	75.3	75.0	74.7	74.5	74.2	73.9	73.6	73.4
32.5	5.5	10.2	76.5	76.2	76.0	75.7	75.4	75.1	74.8	74.6	74.3	74.0	73.7	73.4	73.2	72.9
36.6	6.0	9.8	76.1	75.8	75.5	75.2	74.9	74.7	74.4	74.1	73.8	73.5	73.2	72.9	72.6	72.3
41.0	6.5	9.5	75.6	75.3	75.0	74.7	74.4	74.1	73.9	73.6	73.3	73.0	72.7	72.4	72.1	71.8
45.8	7.0	9.2	75.1	74.8	74.5	74.2	73.9	73.6	73.3	73.0	72.7	72.4	72.1	71.8	71.5	71.2
50.9	7.5	8.8	74.6	74.3	74.0	73.7	73.3	73.0	72.7	72.4	72.1	71.8	71.5	71.1	70.8	70.5
56.3	8.0	8.5	74.0	73.7	73.4	73.1	72.7	72.4	72.1	71.8	71.4	71.1	70.8	70.5	70.1	69.8
62.2	8.5	8.2	73.4	73.1	72.7	72.4	72.1	71.7	71.4	71.1	70.7	70.4	70.1	69.7	69.4	69.0
68.6	9.0	7.9	72.7	72.4	72.0	71.7	71.4	71.0	70.7	70.3	70.0	69.6	69.3	68.9	68.6	68.2
75.6	9.5	7.5	72.0	71.6	71.3	70.9	70.6	70.2	69.9	69.5	69.1	68.8	68.4	68.0	67.7	67.3
83.2	10.0	7.2	71.2	70.8	70.5	70.1	69.7	69.3	69.0	68.6	68.2	67.8	67.5	67.1	66.7	66.3
91.5	10.5	6.9	70.3	70.0	69.6	69.2	68.8	68.4	68.0	67.6	67.2	66.8	66.4	66.1	65.7	65.3
100.7	11.0	6.6	69.4	69.0	68.6	68.2	67.8	67.4	67.0	66.5	66.1	65.7	65.3	64.9	64.5	64.1
110.8	11.5	6.2	68.3	67.9	67.5	67.1	66.6	66.2	65.8	65.4	64.9	64.5	64.1	63.6	63.2	62.8
122.0	12.0	5.9	67.2	66.7	66.3	65.8	65.4	64.9	64.5	64.0	63.6	63.1	62.7	62.2	61.8	61.3
134.6	12.5	5.6	65.8	65.4	64.9	64.4	64.0	63.5	63.0	62.6	62.1	61.6	61.1	60.7	60.2	59.7
148.7	13.0	5.2	64.4	63.9	63.4	62.9	62.4	61.9	61.4	60.9	60.4	59.9	59.4	58.9	58.4	57.9
164.7	13.5	4.9	62.7	62.2	61.6	61.1	60.6	60.1	59.5	59.0	58.5	58.0	57.4	56.9	56.4	55.8
183.0	14.0	4.6	60.8	60.2	59.7	59.1	58.5	58.0	57.4	56.9	56.3	55.7	55.2	54.6	54.0	53.5
204.1	14.5	4.3	58.6	58.0	57.4	56.8	56.2	55.6	55.0	54.4	53.8	53.2	52.6	52.0	51.4	50.8
228.7	15.0	3.9	56.0	55.4	54.7	54.1	53.4	52.8	52.1	51.5	50.8	50.2	49.5	48.9	48.2	47.6

COAL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	18.6	92.5	92.3	92.1	91.8	91.6	91.3	91.1	90.9	90.6	90.4	90.1	89.9	89.7	89.4
2.4	0.5	18.1	92.4	92.2	92.0	91.7	91.5	91.2	91.0	90.7	90.5	90.2	90.0	89.8	89.5	89.3
4.8	1.0	17.7	92.3	92.1	91.9	91.6	91.4	91.1	90.9	90.6	90.4	90.1	89.9	89.6	89.4	89.1
7.5	1.5	17.2	92.3	92.0	91.7	91.5	91.2	91.0	90.7	90.5	90.2	90.0	89.7	89.4	89.2	88.9
10.2	2.0	16.8	92.2	91.9	91.6	91.4	91.1	90.9	90.6	90.3	90.1	89.8	89.5	89.3	89.0	88.8
13.1	2.5	16.4	92.0	91.8	91.5	91.3	91.0	90.7	90.5	90.2	89.9	89.6	89.4	89.1	88.8	88.6
16.2	3.0	15.9	91.9	91.7	91.4	91.1	90.8	90.6	90.3	90.0	89.8	89.5	89.2	88.9	88.6	88.4
19.4	3.5	15.5	91.8	91.5	91.3	91.0	90.7	90.4	90.1	89.9	89.6	89.3	89.0	88.7	88.4	88.2
22.8	4.0	15.0	91.7	91.4	91.1	90.8	90.6	90.3	90.0	89.7	89.4	89.1	88.8	88.5	88.2	87.9
26.4	4.5	14.6	91.6	91.3	91.0	90.7	90.4	90.1	89.8	89.5	89.2	88.9	88.6	88.3	88.0	87.7
30.3	5.0	14.2	91.4	91.1	90.8	90.5	90.2	89.9	89.6	89.3	89.0	88.7	88.4	88.1	87.8	87.5
34.4	5.5	13.7	91.3	91.0	90.7	90.3	90.0	89.7	89.4	89.1	88.8	88.5	88.1	87.8	87.5	87.2
38.8	6.0	13.3	91.1	90.8	90.5	90.2	89.8	89.5	89.2	88.9	88.5	88.2	87.9	87.6	87.2	86.9
43.5	6.5	12.8	90.9	90.6	90.3	90.0	89.6	89.3	89.0	88.6	88.3	88.0	87.6	87.3	87.0	86.6
48.5	7.0	12.4	90.8	90.4	90.1	89.7	89.4	89.1	88.7	88.4	88.0	87.7	87.3	87.0	86.6	86.3
53.9	7.5	11.9	90.6	90.2	89.9	89.5	89.2	88.8	88.4	88.1	87.7	87.4	87.0	86.7	86.3	85.9
59.7	8.0	11.5	90.4	90.0	89.6	89.3	88.9	88.5	88.2	87.8	87.4	87.1	86.7	86.3	85.9	85.6
65.9	8.5	11.1	90.1	89.8	89.4	89.0	88.6	88.2	87.9	87.5	87.1	86.7	86.3	85.9	85.6	85.2
72.7	9.0	10.6	89.9	89.5	89.1	88.7	88.3	87.9	87.5	87.1	86.7	86.3	85.9	85.5	85.1	84.7
80.1	9.5	10.2	89.6	89.2	88.8	88.4	88.0	87.6	87.2	86.7	86.3	85.9	85.5	85.1	84.7	84.3
88.1	10.0	9.7	89.3	88.9	88.5	88.0	87.6	87.2	86.8	86.3	85.9	85.5	85.0	84.6	84.2	83.7
96.9	10.5	9.3	89.0	88.6	88.1	87.7	87.2	86.8	86.3	85.9	85.4	85.0	84.5	84.1	83.6	83.2
106.6	11.0	8.8	88.7	88.2	87.7	87.3	86.8	86.3	85.9	85.4	84.9	84.4	84.0	83.5	83.0	82.6
117.3	11.5	8.4	88.3	87.8	87.3	86.8	86.3	85.8	85.3	84.8	84.3	83.8	83.4	82.9	82.4	81.9
129.2	12.0	8.0	87.8	87.3	86.8	86.3	85.8	85.3	84.7	84.2	83.7	83.2	82.7	82.1	81.6	81.1
142.5	12.5	7.5	87.4	86.8	86.3	85.7	85.2	84.6	84.1	83.5	83.0	82.4	81.9	81.3	80.8	80.2
157.5	13.0	7.1	86.8	86.2	85.7	85.1	84.5	83.9	83.4	82.8	82.2	81.6	81.0	80.4	79.9	79.3
174.4	13.5	6.6	86.2	85.6	85.0	84.4	83.7	83.1	82.5	81.9	81.3	80.7	80.1	79.4	78.8	78.2
193.8	14.0	6.2	85.5	84.8	84.2	83.5	82.9	82.2	81.6	80.9	80.3	79.6	78.9	78.3	77.6	76.9
216.1	14.5	5.8	84.7	84.0	83.3	82.6	81.9	81.2	80.5	79.8	79.1	78.3	77.6	76.9	76.2	75.5
242.2	15.0	5.3	83.7	83.0	82.2	81.5	80.7	79.9	79.2	78.4	77.7	76.9	76.1	75.4	74.6	73.8

COAL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	18.6	89.2	88.9	88.7	88.4	88.2	87.9	87.7	87.5	87.2	87.0	86.7	86.5	86.2	86.0
2.4	0.5	18.1	89.0	88.8	88.5	88.3	88.0	87.8	87.5	87.3	87.0	86.8	86.5	86.2	86.0	85.7
4.8	1.0	17.7	88.8	88.6	88.3	88.1	87.8	87.6	87.3	87.1	86.8	86.5	86.3	86.0	85.8	85.5
7.5	1.5	17.2	88.7	88.4	88.2	87.9	87.6	87.4	87.1	86.8	86.6	86.3	86.1	85.8	85.5	85.3
10.2	2.0	16.8	88.5	88.2	88.0	87.7	87.4	87.2	86.9	86.6	86.3	86.1	85.8	85.5	85.3	85.0
13.1	2.5	16.4	88.3	88.0	87.8	87.5	87.2	86.9	86.7	86.4	86.1	85.8	85.6	85.3	85.0	84.7
16.2	3.0	15.9	88.1	87.8	87.5	87.3	87.0	86.7	86.4	86.1	85.8	85.6	85.3	85.0	84.7	84.4
19.4	3.5	15.5	87.9	87.6	87.3	87.0	86.7	86.4	86.2	85.9	85.6	85.3	85.0	84.7	84.4	84.1
22.8	4.0	15.0	87.7	87.4	87.1	86.8	86.5	86.2	85.9	85.6	85.3	85.0	84.7	84.4	84.1	83.8
26.4	4.5	14.6	87.4	87.1	86.8	86.5	86.2	85.9	85.6	85.3	85.0	84.7	84.4	84.1	83.8	83.4
30.3	5.0	14.2	87.2	86.8	86.5	86.2	85.9	85.6	85.3	85.0	84.7	84.3	84.0	83.7	83.4	83.1
34.4	5.5	13.7	86.9	86.6	86.2	85.9	85.6	85.3	85.0	84.6	84.3	84.0	83.7	83.3	83.0	82.7
38.8	6.0	13.3	86.6	86.3	85.9	85.6	85.3	84.9	84.6	84.3	83.9	83.6	83.3	82.9	82.6	82.3
43.5	6.5	12.8	86.3	85.9	85.6	85.3	84.9	84.6	84.2	83.9	83.6	83.2	82.9	82.5	82.2	81.8
48.5	7.0	12.4	85.9	85.6	85.2	84.9	84.5	84.2	83.8	83.5	83.1	82.8	82.4	82.1	81.7	81.4
53.9	7.5	11.9	85.6	85.2	84.9	84.5	84.1	83.8	83.4	83.0	82.7	82.3	81.9	81.6	81.2	80.8
59.7	8.0	11.5	85.2	84.8	84.5	84.1	83.7	83.3	82.9	82.6	82.2	81.8	81.4	81.1	80.7	80.3
65.9	8.5	11.1	84.8	84.4	84.0	83.6	83.2	82.8	82.4	82.1	81.7	81.3	80.9	80.5	80.1	79.7
72.7	9.0	10.6	84.3	83.9	83.5	83.1	82.7	82.3	81.9	81.5	81.1	80.7	80.3	79.9	79.5	79.0
80.1	9.5	10.2	83.8	83.4	83.0	82.6	82.2	81.7	81.3	80.9	80.5	80.1	79.6	79.2	78.8	78.3
88.1	10.0	9.7	83.3	82.9	82.4	82.0	81.6	81.1	80.7	80.2	79.8	79.4	78.9	78.5	78.0	77.6
96.9	10.5	9.3	82.7	82.3	81.8	81.4	80.9	80.4	80.0	79.5	79.1	78.6	78.1	77.7	77.2	76.7
106.6	11.0	8.8	82.1	81.6	81.1	80.6	80.2	79.7	79.2	78.7	78.2	77.8	77.3	76.8	76.3	75.8
117.3	11.5	8.4	81.4	80.9	80.4	79.9	79.4	78.9	78.4	77.8	77.3	76.8	76.3	75.8	75.3	74.8
129.2	12.0	8.0	80.6	80.0	79.5	79.0	78.5	77.9	77.4	76.9	76.3	75.8	75.3	74.7	74.2	73.7
142.5	12.5	7.5	79.7	79.1	78.6	78.0	77.5	76.9	76.3	75.8	75.2	74.7	74.1	73.5	73.0	72.4
157.5	13.0	7.1	78.7	78.1	77.5	76.9	76.3	75.7	75.2	74.6	74.0	73.4	72.8	72.2	71.6	71.0
174.4	13.5	6.6	77.6	76.9	76.3	75.7	75.1	74.4	73.8	73.2	72.5	71.9	71.3	70.6	70.0	69.4
193.8	14.0	6.2	76.3	75.6	74.9	74.3	73.6	72.9	72.3	71.6	70.9	70.2	69.6	68.9	68.2	67.5
216.1	14.5	5.8	74.8	74.1	73.4	72.6	71.9	71.2	70.5	69.8	69.0	68.3	67.6	66.9	66.1	65.4
242.2	15.0	5.3	73.1	72.3	71.5	70.7	70.0	69.2	68.4	67.6	66.8	66.1	65.3	64.5	63.7	62.9

COAL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	18.6	85.7	85.5	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.2	82.9	82.7	82.4
2.4	0.5	18.1	85.5	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.2	82.9	82.6	82.4	82.1
4.8	1.0	17.7	85.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.1	82.9	82.6	82.3	82.1	81.8
7.5	1.5	17.2	85.0	84.7	84.5	84.2	83.9	83.6	83.4	83.1	82.8	82.6	82.3	82.0	81.7	81.5
10.2	2.0	16.8	84.7	84.4	84.2	83.9	83.6	83.3	83.1	82.8	82.5	82.2	82.0	81.7	81.4	81.1
13.1	2.5	16.4	84.4	84.2	83.9	83.6	83.3	83.0	82.7	82.5	82.2	81.9	81.6	81.3	81.0	80.8
16.2	3.0	15.9	84.1	83.9	83.6	83.3	83.0	82.7	82.4	82.1	81.8	81.5	81.2	81.0	80.7	80.4
19.4	3.5	15.5	83.8	83.5	83.2	82.9	82.6	82.3	82.1	81.8	81.5	81.2	80.9	80.6	80.3	80.0
22.8	4.0	15.0	83.5	83.2	82.9	82.6	82.3	82.0	81.7	81.4	81.1	80.8	80.4	80.1	79.8	79.5
26.4	4.5	14.6	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.6	80.3	80.0	79.7	79.4	79.1
30.3	5.0	14.2	82.8	82.4	82.1	81.8	81.5	81.2	80.8	80.5	80.2	79.9	79.5	79.2	78.9	78.6
34.4	5.5	13.7	82.4	82.0	81.7	81.4	81.0	80.7	80.4	80.1	79.7	79.4	79.1	78.7	78.4	78.1
38.8	6.0	13.3	81.9	81.6	81.3	80.9	80.6	80.2	79.9	79.6	79.2	78.9	78.5	78.2	77.8	77.5
43.5	6.5	12.8	81.5	81.1	80.8	80.4	80.1	79.7	79.4	79.0	78.7	78.3	78.0	77.6	77.3	76.9
48.5	7.0	12.4	81.0	80.6	80.3	79.9	79.6	79.2	78.8	78.5	78.1	77.7	77.4	77.0	76.6	76.3
53.9	7.5	11.9	80.5	80.1	79.7	79.4	79.0	78.6	78.2	77.9	77.5	77.1	76.7	76.3	76.0	75.6
59.7	8.0	11.5	79.9	79.5	79.1	78.7	78.4	78.0	77.6	77.2	76.8	76.4	76.0	75.6	75.2	74.9
65.9	8.5	11.1	79.3	78.9	78.5	78.1	77.7	77.3	76.9	76.5	76.1	75.7	75.3	74.9	74.5	74.1
72.7	9.0	10.6	78.6	78.2	77.8	77.4	77.0	76.6	76.1	75.7	75.3	74.9	74.5	74.0	73.6	73.2
80.1	9.5	10.2	77.9	77.5	77.1	76.6	76.2	75.8	75.3	74.9	74.5	74.0	73.6	73.1	72.7	72.3
88.1	10.0	9.7	77.1	76.7	76.2	75.8	75.3	74.9	74.4	74.0	73.5	73.1	72.6	72.2	71.7	71.3
96.9	10.5	9.3	76.3	75.8	75.3	74.9	74.4	73.9	73.5	73.0	72.5	72.0	71.6	71.1	70.6	70.1
106.6	11.0	8.8	75.3	74.8	74.4	73.9	73.4	72.9	72.4	71.9	71.4	70.9	70.4	69.9	69.4	68.9
117.3	11.5	8.4	74.3	73.8	73.3	72.7	72.2	71.7	71.2	70.7	70.2	69.6	69.1	68.6	68.1	67.6
129.2	12.0	8.0	73.1	72.6	72.1	71.5	71.0	70.4	69.9	69.3	68.8	68.2	67.7	67.1	66.6	66.0
142.5	12.5	7.5	71.8	71.3	70.7	70.1	69.6	69.0	68.4	67.8	67.3	66.7	66.1	65.5	64.9	64.4
157.5	13.0	7.1	70.4	69.8	69.2	68.6	68.0	67.4	66.8	66.1	65.5	64.9	64.3	63.7	63.1	62.5
174.4	13.5	6.6	68.7	68.1	67.4	66.8	66.2	65.5	64.9	64.2	63.6	62.9	62.3	61.6	61.0	60.3
193.8	14.0	6.2	66.8	66.2	65.5	64.8	64.1	63.4	62.7	62.0	61.3	60.7	60.0	59.3	58.6	57.9
216.1	14.5	5.8	64.7	63.9	63.2	62.5	61.7	61.0	60.3	59.5	58.8	58.0	57.3	56.5	55.8	55.0
242.2	15.0	5.3	62.1	61.3	60.5	59.8	59.0	58.2	57.4	56.6	55.8	55.0	54.2	53.4	52.5	51.7

COAL

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	18.6	82.2	81.9	81.6	81.4	81.1	80.9	80.6	80.3	80.1	79.8	79.6	79.3	79.0	78.8
2.4	0.5	18.1	81.8	81.6	81.3	81.1	80.8	80.5	80.3	80.0	79.7	79.5	79.2	78.9	78.7	78.4
4.8	1.0	17.7	81.5	81.3	81.0	80.7	80.5	80.2	79.9	79.6	79.4	79.1	78.8	78.5	78.3	78.0
7.5	1.5	17.2	81.2	80.9	80.6	80.4	80.1	79.8	79.5	79.3	79.0	78.7	78.4	78.1	77.9	77.6
10.2	2.0	16.8	80.8	80.6	80.3	80.0	79.7	79.4	79.1	78.9	78.6	78.3	78.0	77.7	77.4	77.1
13.1	2.5	16.4	80.5	80.2	79.9	79.6	79.3	79.0	78.7	78.4	78.1	77.9	77.6	77.3	77.0	76.7
16.2	3.0	15.9	80.1	79.8	79.5	79.2	78.9	78.6	78.3	78.0	77.7	77.4	77.1	76.8	76.5	76.2
19.4	3.5	15.5	79.7	79.4	79.0	78.7	78.4	78.1	77.8	77.5	77.2	76.9	76.6	76.3	76.0	75.7
22.8	4.0	15.0	79.2	78.9	78.6	78.3	78.0	77.7	77.3	77.0	76.7	76.4	76.1	75.8	75.5	75.1
26.4	4.5	14.6	78.7	78.4	78.1	77.8	77.5	77.1	76.8	76.5	76.2	75.9	75.5	75.2	74.9	74.6
30.3	5.0	14.2	78.2	77.9	77.6	77.3	76.9	76.6	76.3	75.9	75.6	75.3	75.0	74.6	74.3	74.0
34.4	5.5	13.7	77.7	77.4	77.0	76.7	76.4	76.0	75.7	75.4	75.0	74.7	74.3	74.0	73.6	73.3
38.8	6.0	13.3	77.2	76.8	76.5	76.1	75.8	75.4	75.1	74.7	74.4	74.0	73.7	73.3	73.0	72.6
43.5	6.5	12.8	76.6	76.2	75.8	75.5	75.1	74.8	74.4	74.0	73.7	73.3	73.0	72.6	72.2	71.9
48.5	7.0	12.4	75.9	75.5	75.2	74.8	74.4	74.1	73.7	73.3	72.9	72.6	72.2	71.8	71.4	71.1
53.9	7.5	11.9	75.2	74.8	74.4	74.1	73.7	73.3	72.9	72.5	72.1	71.8	71.4	71.0	70.6	70.2
59.7	8.0	11.5	74.5	74.1	73.7	73.3	72.9	72.5	72.1	71.7	71.3	70.9	70.5	70.1	69.7	69.3
65.9	8.5	11.1	73.7	73.2	72.8	72.4	72.0	71.6	71.2	70.8	70.4	70.0	69.5	69.1	68.7	68.3
72.7	9.0	10.6	72.8	72.4	71.9	71.5	71.1	70.7	70.2	69.8	69.4	68.9	68.5	68.1	67.7	67.2
80.1	9.5	10.2	71.8	71.4	70.9	70.5	70.1	69.6	69.2	68.7	68.3	67.8	67.4	66.9	66.5	66.0
88.1	10.0	9.7	70.8	70.3	69.9	69.4	69.0	68.5	68.0	67.6	67.1	66.6	66.2	65.7	65.2	64.8
96.9	10.5	9.3	69.7	69.2	68.7	68.2	67.7	67.3	66.8	66.3	65.8	65.3	64.8	64.3	63.9	63.4
106.6	11.0	8.8	68.4	67.9	67.4	66.9	66.4	65.9	65.4	64.9	64.4	63.9	63.4	62.9	62.3	61.8
117.3	11.5	8.4	67.0	66.5	66.0	65.4	64.9	64.4	63.9	63.3	62.8	62.3	61.7	61.2	60.7	60.1
129.2	12.0	8.0	65.5	64.9	64.4	63.8	63.3	62.7	62.2	61.6	61.0	60.5	59.9	59.4	58.8	58.2
142.5	12.5	7.5	63.8	63.2	62.6	62.0	61.4	60.9	60.3	59.7	59.1	58.5	57.9	57.3	56.7	56.1
157.5	13.0	7.1	61.9	61.2	60.6	60.0	59.4	58.8	58.1	57.5	56.9	56.3	55.6	55.0	54.4	53.8
174.4	13.5	6.6	59.7	59.0	58.4	57.7	57.0	56.4	55.7	55.1	54.4	53.7	53.1	52.4	51.7	51.1
193.8	14.0	6.2	57.2	56.5	55.8	55.1	54.4	53.7	53.0	52.3	51.5	50.8	50.1	49.4	48.7	48.0
216.1	14.5	5.8	54.3	53.5	52.8	52.0	51.3	50.5	49.8	49.0	48.3	47.5	46.7	46.0	45.2	44.4
242.2	15.0	5.3	50.9	50.1	49.3	48.5	47.7	46.9	46.1	45.2	44.4	43.6	42.8	42.0	41.1	40.3

WOOD 0% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	20.4	89.2	89.0	88.8	88.7	88.5	88.3	88.1	88.0	87.8	87.6	87.5	87.3	87.1	86.9
2.4	0.5	19.9	89.1	89.0	88.8	88.6	88.4	88.3	88.1	87.9	87.7	87.5	87.4	87.2	87.0	86.8
5.0	1.0	19.4	89.1	88.9	88.7	88.5	88.4	88.2	88.0	87.8	87.6	87.5	87.3	87.1	86.9	86.7
7.6	1.5	19.0	89.0	88.8	88.7	88.5	88.3	88.1	87.9	87.7	87.6	87.4	87.2	87.0	86.8	86.6
10.4	2.0	18.5	89.0	88.8	88.6	88.4	88.2	88.0	87.8	87.7	87.5	87.3	87.1	86.9	86.7	86.5
13.4	2.5	18.0	88.9	88.7	88.5	88.3	88.1	87.9	87.8	87.6	87.4	87.2	87.0	86.8	86.6	86.4
16.5	3.0	17.5	88.8	88.6	88.4	88.2	88.0	87.9	87.7	87.5	87.3	87.1	86.9	86.7	86.5	86.3
19.8	3.5	17.0	88.7	88.6	88.4	88.2	88.0	87.8	87.6	87.4	87.2	87.0	86.8	86.6	86.4	86.2
23.3	4.0	16.5	88.7	88.5	88.3	88.1	87.9	87.7	87.5	87.3	87.0	86.8	86.6	86.4	86.2	86.0
27.1	4.5	16.0	88.6	88.4	88.2	88.0	87.8	87.6	87.3	87.1	86.9	86.7	86.5	86.3	86.1	85.9
31.0	5.0	15.6	88.5	88.3	88.1	87.9	87.7	87.4	87.2	87.0	86.8	86.6	86.4	86.2	85.9	85.7
35.2	5.5	15.1	88.4	88.2	88.0	87.8	87.5	87.3	87.1	86.9	86.7	86.4	86.2	86.0	85.8	85.6
39.7	6.0	14.6	88.3	88.1	87.9	87.6	87.4	87.2	87.0	86.7	86.5	86.3	86.1	85.8	85.6	85.4
44.5	6.5	14.1	88.2	88.0	87.8	87.5	87.3	87.1	86.8	86.6	86.4	86.1	85.9	85.7	85.4	85.2
49.6	7.0	13.6	88.1	87.9	87.6	87.4	87.2	86.9	86.7	86.4	86.2	86.0	85.7	85.5	85.2	85.0
55.1	7.5	13.1	88.0	87.7	87.5	87.2	87.0	86.8	86.5	86.3	86.0	85.8	85.5	85.3	85.0	84.8
61.1	8.0	12.6	87.8	87.6	87.3	87.1	86.8	86.6	86.3	86.1	85.8	85.6	85.3	85.1	84.8	84.6
67.5	8.5	12.2	87.7	87.4	87.2	86.9	86.7	86.4	86.1	85.9	85.6	85.4	85.1	84.8	84.6	84.3
74.4	9.0	11.7	87.6	87.3	87.0	86.7	86.5	86.2	85.9	85.7	85.4	85.1	84.9	84.6	84.3	84.0
82.0	9.5	11.2	87.4	87.1	86.8	86.6	86.3	86.0	85.7	85.4	85.2	84.9	84.6	84.3	84.0	83.7
90.2	10.0	10.7	87.2	86.9	86.6	86.3	86.1	85.8	85.5	85.2	84.9	84.6	84.3	84.0	83.7	83.4
99.2	10.5	10.2	87.0	86.7	86.4	86.1	85.8	85.5	85.2	84.9	84.6	84.3	84.0	83.7	83.4	83.1
109.1	11.0	9.7	86.8	86.5	86.2	85.9	85.5	85.2	84.9	84.6	84.3	84.0	83.6	83.3	83.0	82.7
120.1	11.5	9.2	86.6	86.2	85.9	85.6	85.2	84.9	84.6	84.3	83.9	83.6	83.3	82.9	82.6	82.3
132.2	12.0	8.8	86.3	85.9	85.6	85.3	84.9	84.6	84.2	83.9	83.5	83.2	82.8	82.5	82.1	81.8
145.9	12.5	8.3	86.0	85.6	85.3	84.9	84.5	84.2	83.8	83.5	83.1	82.7	82.4	82.0	81.6	81.3
161.2	13.0	7.8	85.7	85.3	84.9	84.5	84.1	83.7	83.4	83.0	82.6	82.2	81.8	81.4	81.1	80.7
178.5	13.5	7.3	85.3	84.9	84.5	84.1	83.7	83.3	82.8	82.4	82.0	81.6	81.2	80.8	80.4	80.0
198.3	14.0	6.8	84.8	84.4	84.0	83.6	83.1	82.7	82.3	81.8	81.4	81.0	80.5	80.1	79.7	79.2
221.2	14.5	6.3	84.3	83.9	83.4	83.0	82.5	82.0	81.6	81.1	80.7	80.2	79.7	79.3	78.8	78.3
247.9	15.0	5.8	83.8	83.3	82.8	82.3	81.8	81.3	80.8	80.3	79.8	79.3	78.8	78.3	77.8	77.3

WOOD 0% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	20.4	86.8	86.6	86.4	86.2	86.0	85.9	85.7	85.5	85.3	85.1	85.0	84.8	84.6	84.4
2.4	0.5	19.9	86.7	86.5	86.3	86.1	85.9	85.7	85.6	85.4	85.2	85.0	84.8	84.7	84.5	84.3
5.0	1.0	19.4	86.6	86.4	86.2	86.0	85.8	85.6	85.4	85.3	85.1	84.9	84.7	84.5	84.3	84.1
7.6	1.5	19.0	86.4	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.6	84.4	84.2	84.0
10.4	2.0	18.5	86.3	86.1	85.9	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.8
13.4	2.5	18.0	86.2	86.0	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.1	83.9	83.7
16.5	3.0	17.5	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.3	84.1	83.9	83.7	83.5
19.8	3.5	17.0	86.0	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.3	84.1	83.9	83.7	83.5	83.3
23.3	4.0	16.5	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.3	83.1
27.1	4.5	16.0	85.7	85.5	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.7	83.5	83.3	83.1	82.9
31.0	5.0	15.6	85.5	85.3	85.1	84.9	84.6	84.4	84.2	84.0	83.8	83.5	83.3	83.1	82.9	82.6
35.2	5.5	15.1	85.3	85.1	84.9	84.7	84.4	84.2	84.0	83.8	83.5	83.3	83.1	82.9	82.6	82.4
39.7	6.0	14.6	85.2	84.9	84.7	84.5	84.2	84.0	83.8	83.5	83.3	83.1	82.8	82.6	82.4	82.1
44.5	6.5	14.1	85.0	84.7	84.5	84.3	84.0	83.8	83.5	83.3	83.1	82.8	82.6	82.3	82.1	81.9
49.6	7.0	13.6	84.8	84.5	84.3	84.0	83.8	83.5	83.3	83.1	82.8	82.6	82.3	82.1	81.8	81.6
55.1	7.5	13.1	84.5	84.3	84.0	83.8	83.5	83.3	83.0	82.8	82.5	82.3	82.0	81.8	81.5	81.3
61.1	8.0	12.6	84.3	84.0	83.8	83.5	83.3	83.0	82.7	82.5	82.2	82.0	81.7	81.4	81.2	80.9
67.5	8.5	12.2	84.0	83.8	83.5	83.2	83.0	82.7	82.4	82.2	81.9	81.6	81.4	81.1	80.8	80.5
74.4	9.0	11.7	83.8	83.5	83.2	82.9	82.7	82.4	82.1	81.8	81.5	81.3	81.0	80.7	80.4	80.1
82.0	9.5	11.2	83.5	83.2	82.9	82.6	82.3	82.0	81.7	81.5	81.2	80.9	80.6	80.3	80.0	79.7
90.2	10.0	10.7	83.1	82.8	82.5	82.2	81.9	81.6	81.3	81.0	80.7	80.4	80.1	79.8	79.5	79.2
99.2	10.5	10.2	82.8	82.5	82.1	81.8	81.5	81.2	80.9	80.6	80.3	80.0	79.7	79.4	79.0	78.7
109.1	11.0	9.7	82.4	82.0	81.7	81.4	81.1	80.8	80.4	80.1	79.8	79.5	79.1	78.8	78.5	78.2
120.1	11.5	9.2	81.9	81.6	81.3	80.9	80.6	80.2	79.9	79.6	79.2	78.9	78.5	78.2	77.9	77.5
132.2	12.0	8.8	81.4	81.1	80.7	80.4	80.0	79.7	79.3	79.0	78.6	78.3	77.9	77.5	77.2	76.8
145.9	12.5	8.3	80.9	80.5	80.2	79.8	79.4	79.0	78.7	78.3	77.9	77.5	77.2	76.8	76.4	76.0
161.2	13.0	7.8	80.3	79.9	79.5	79.1	78.7	78.3	77.9	77.5	77.1	76.7	76.4	76.0	75.6	75.2
178.5	13.5	7.3	79.6	79.2	78.8	78.3	77.9	77.5	77.1	76.7	76.3	75.8	75.4	75.0	74.6	74.2
198.3	14.0	6.8	78.8	78.3	77.9	77.5	77.0	76.6	76.1	75.7	75.3	74.8	74.4	73.9	73.5	73.0
221.2	14.5	6.3	77.9	77.4	76.9	76.5	76.0	75.5	75.0	74.6	74.1	73.6	73.1	72.7	72.2	71.7
247.9	15.0	5.8	76.8	76.3	75.8	75.3	74.8	74.3	73.8	73.3	72.7	72.2	71.7	71.2	70.7	70.2

WOOD 0% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	20.4	84.2	84.1	83.9	83.7	83.5	83.3	83.1	83.0	82.8	82.6	82.4	82.2	82.0	81.8
2.4	0.5	19.9	84.1	83.9	83.7	83.5	83.4	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.7
5.0	1.0	19.4	83.9	83.8	83.6	83.4	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.9	81.7	81.5
7.6	1.5	19.0	83.8	83.6	83.4	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.7	81.5	81.3
10.4	2.0	18.5	83.6	83.4	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.6	81.4	81.2	81.0
13.4	2.5	18.0	83.5	83.3	83.1	82.9	82.6	82.4	82.2	82.0	81.8	81.6	81.4	81.2	81.0	80.8
16.5	3.0	17.5	83.3	83.1	82.9	82.7	82.4	82.2	82.0	81.8	81.6	81.4	81.2	81.0	80.8	80.6
19.8	3.5	17.0	83.1	82.9	82.7	82.4	82.2	82.0	81.8	81.6	81.4	81.2	81.0	80.8	80.5	80.3
23.3	4.0	16.5	82.9	82.7	82.4	82.2	82.0	81.8	81.6	81.4	81.1	80.9	80.7	80.5	80.3	80.1
27.1	4.5	16.0	82.6	82.4	82.2	82.0	81.8	81.6	81.3	81.1	80.9	80.7	80.4	80.2	80.0	79.8
31.0	5.0	15.6	82.4	82.2	82.0	81.7	81.5	81.3	81.1	80.8	80.6	80.4	80.2	79.9	79.7	79.5
35.2	5.5	15.1	82.2	81.9	81.7	81.5	81.2	81.0	80.8	80.6	80.3	80.1	79.9	79.6	79.4	79.1
39.7	6.0	14.6	81.9	81.7	81.4	81.2	81.0	80.7	80.5	80.2	80.0	79.8	79.5	79.3	79.0	78.8
44.5	6.5	14.1	81.6	81.4	81.1	80.9	80.7	80.4	80.2	79.9	79.7	79.4	79.2	78.9	78.7	78.4
49.6	7.0	13.6	81.3	81.1	80.8	80.6	80.3	80.1	79.8	79.6	79.3	79.1	78.8	78.6	78.3	78.0
55.1	7.5	13.1	81.0	80.7	80.5	80.2	80.0	79.7	79.5	79.2	78.9	78.7	78.4	78.2	77.9	77.6
61.1	8.0	12.6	80.7	80.4	80.1	79.9	79.6	79.3	79.1	78.8	78.5	78.3	78.0	77.7	77.4	77.2
67.5	8.5	12.2	80.3	80.0	79.7	79.5	79.2	78.9	78.6	78.4	78.1	77.8	77.5	77.2	77.0	76.7
74.4	9.0	11.7	79.9	79.6	79.3	79.0	78.7	78.4	78.2	77.9	77.6	77.3	77.0	76.7	76.4	76.2
82.0	9.5	11.2	79.4	79.1	78.8	78.5	78.2	78.0	77.7	77.4	77.1	76.8	76.5	76.2	75.9	75.6
90.2	10.0	10.7	78.9	78.6	78.3	78.0	77.7	77.4	77.1	76.8	76.5	76.2	75.9	75.6	75.3	74.9
99.2	10.5	10.2	78.4	78.1	77.8	77.5	77.1	76.8	76.5	76.2	75.9	75.5	75.2	74.9	74.6	74.3
109.1	11.0	9.7	77.8	77.5	77.2	76.8	76.5	76.2	75.8	75.5	75.2	74.8	74.5	74.2	73.8	73.5
120.1	11.5	9.2	77.2	76.8	76.5	76.1	75.8	75.5	75.1	74.8	74.4	74.1	73.7	73.4	73.0	72.7
132.2	12.0	8.8	76.5	76.1	75.7	75.4	75.0	74.7	74.3	73.9	73.6	73.2	72.8	72.5	72.1	71.7
145.9	12.5	8.3	75.7	75.3	74.9	74.5	74.1	73.8	73.4	73.0	72.6	72.2	71.8	71.5	71.1	70.7
161.2	13.0	7.8	74.8	74.4	74.0	73.6	73.2	72.8	72.4	72.0	71.5	71.1	70.7	70.3	69.9	69.5
178.5	13.5	7.3	73.7	73.3	72.9	72.5	72.0	71.6	71.2	70.8	70.3	69.9	69.5	69.1	68.6	68.2
198.3	14.0	6.8	72.6	72.1	71.7	71.2	70.8	70.3	69.9	69.4	69.0	68.5	68.0	67.6	67.1	66.7
221.2	14.5	6.3	71.2	70.8	70.3	69.8	69.3	68.8	68.3	67.9	67.4	66.9	66.4	65.9	65.4	64.9
247.9	15.0	5.8	69.7	69.1	68.6	68.1	67.6	67.1	66.6	66.0	65.5	65.0	64.5	63.9	63.4	62.9

WOOD 0% MOSITURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	20.4	81.7	81.5	81.3	81.1	80.9	80.7	80.5	80.3	80.1	80.0	79.8	79.6	79.4	79.2
2.4	0.5	19.9	81.5	81.3	81.1	80.9	80.7	80.5	80.3	80.1	79.9	79.7	79.5	79.3	79.2	79.0
5.0	1.0	19.4	81.3	81.1	80.9	80.7	80.5	80.3	80.1	79.9	79.7	79.5	79.3	79.1	78.9	78.7
7.6	1.5	19.0	81.1	80.9	80.7	80.5	80.3	80.1	79.9	79.7	79.5	79.3	79.1	78.9	78.7	78.5
10.4	2.0	18.5	80.8	80.6	80.4	80.2	80.0	79.8	79.6	79.4	79.2	79.0	78.8	78.6	78.4	78.2
13.4	2.5	18.0	80.6	80.4	80.2	80.0	79.8	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.9
16.5	3.0	17.5	80.4	80.2	79.9	79.7	79.5	79.3	79.1	78.9	78.7	78.5	78.2	78.0	77.8	77.6
19.8	3.5	17.0	80.1	79.9	79.7	79.5	79.2	79.0	78.8	78.6	78.4	78.2	77.9	77.7	77.5	77.3
23.3	4.0	16.5	79.8	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.8	77.6	77.4	77.2	77.0
27.1	4.5	16.0	79.5	79.3	79.1	78.9	78.6	78.4	78.2	78.0	77.7	77.5	77.3	77.1	76.8	76.6
31.0	5.0	15.6	79.2	79.0	78.8	78.5	78.3	78.1	77.9	77.6	77.4	77.2	76.9	76.7	76.5	76.2
35.2	5.5	15.1	78.9	78.7	78.4	78.2	78.0	77.7	77.5	77.3	77.0	76.8	76.5	76.3	76.1	75.8
39.7	6.0	14.6	78.6	78.3	78.1	77.8	77.6	77.4	77.1	76.9	76.6	76.4	76.1	75.9	75.6	75.4
44.5	6.5	14.1	78.2	77.9	77.7	77.4	77.2	76.9	76.7	76.4	76.2	75.9	75.7	75.4	75.2	74.9
49.6	7.0	13.6	77.8	77.5	77.3	77.0	76.8	76.5	76.3	76.0	75.7	75.5	75.2	75.0	74.7	74.4
55.1	7.5	13.1	77.4	77.1	76.8	76.6	76.3	76.0	75.8	75.5	75.2	75.0	74.7	74.4	74.2	73.9
61.1	8.0	12.6	76.9	76.6	76.4	76.1	75.8	75.5	75.3	75.0	74.7	74.4	74.2	73.9	73.6	73.3
67.5	8.5	12.2	76.4	76.1	75.8	75.6	75.3	75.0	74.7	74.4	74.1	73.9	73.6	73.3	73.0	72.7
74.4	9.0	11.7	75.9	75.6	75.3	75.0	74.7	74.4	74.1	73.8	73.5	73.2	72.9	72.6	72.3	72.1
82.0	9.5	11.2	75.3	75.0	74.7	74.4	74.1	73.8	73.5	73.2	72.9	72.6	72.2	71.9	71.6	71.3
90.2	10.0	10.7	74.6	74.3	74.0	73.7	73.4	73.1	72.8	72.4	72.1	71.8	71.5	71.2	70.9	70.5
99.2	10.5	10.2	73.9	73.6	73.3	73.0	72.6	72.3	72.0	71.7	71.3	71.0	70.7	70.3	70.0	69.7
109.1	11.0	9.7	73.2	72.8	72.5	72.1	71.8	71.5	71.1	70.8	70.4	70.1	69.8	69.4	69.1	68.7
120.1	11.5	9.2	72.3	72.0	71.6	71.2	70.9	70.5	70.2	69.8	69.5	69.1	68.8	68.4	68.0	67.7
132.2	12.0	8.8	71.4	71.0	70.6	70.2	69.9	69.5	69.1	68.8	68.4	68.0	67.6	67.3	66.9	66.5
145.9	12.5	8.3	70.3	69.9	69.5	69.1	68.7	68.4	68.0	67.6	67.2	66.8	66.4	66.0	65.6	65.2
161.2	13.0	7.8	69.1	68.7	68.3	67.9	67.5	67.1	66.6	66.2	65.8	65.4	65.0	64.6	64.1	63.7
178.5	13.5	7.3	67.8	67.3	66.9	66.5	66.0	65.6	65.1	64.7	64.3	63.8	63.4	63.0	62.5	62.1
198.3	14.0	6.8	66.2	65.8	65.3	64.8	64.4	63.9	63.4	63.0	62.5	62.0	61.6	61.1	60.6	60.2
221.2	14.5	6.3	64.4	63.9	63.4	63.0	62.5	62.0	61.5	61.0	60.5	60.0	59.5	59.0	58.5	58.0
247.9	15.0	5.8	62.4	61.8	61.3	60.8	60.2	59.7	59.2	58.6	58.1	57.6	57.0	56.5	56.0	55.4

WOOD 17% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			170	180	190	200	210	220	230	240	250	260	270	280	290	300
0.0	0.0	20.4	86.5	86.3	86.1	85.9	85.8	85.6	85.4	85.2	85.0	84.8	84.7	84.5	84.3	84.1
2.4	0.5	19.9	86.4	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.8	84.6	84.4	84.2	84.0
5.0	1.0	19.4	86.4	86.2	86.0	85.8	85.6	85.4	85.2	85.1	84.9	84.7	84.5	84.3	84.1	83.9
7.6	1.5	18.9	86.3	86.1	85.9	85.7	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.8
10.4	2.0	18.5	86.3	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.3	84.1	83.9	83.7
13.4	2.5	18.0	86.2	86.0	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.8	83.6
16.5	3.0	17.5	86.1	85.9	85.7	85.5	85.3	85.1	84.9	84.7	84.5	84.3	84.1	83.9	83.7	83.5
19.8	3.5	17.0	86.1	85.8	85.6	85.4	85.2	85.0	84.8	84.6	84.4	84.2	84.0	83.7	83.5	83.3
23.3	4.0	16.5	86.0	85.8	85.6	85.3	85.1	84.9	84.7	84.5	84.3	84.1	83.8	83.6	83.4	83.2
27.1	4.5	16.0	85.9	85.7	85.5	85.2	85.0	84.8	84.6	84.4	84.1	83.9	83.7	83.5	83.3	83.0
31.0	5.0	15.5	85.8	85.6	85.4	85.1	84.9	84.7	84.5	84.2	84.0	83.8	83.6	83.3	83.1	82.9
35.2	5.5	15.1	85.7	85.5	85.3	85.0	84.8	84.6	84.3	84.1	83.9	83.7	83.4	83.2	83.0	82.7
39.7	6.0	14.6	85.6	85.4	85.2	84.9	84.7	84.5	84.2	84.0	83.7	83.5	83.3	83.0	82.8	82.6
44.5	6.5	14.1	85.5	85.3	85.0	84.8	84.6	84.3	84.1	83.8	83.6	83.3	83.1	82.9	82.6	82.4
49.6	7.0	13.6	85.4	85.2	84.9	84.7	84.4	84.2	83.9	83.7	83.4	83.2	82.9	82.7	82.4	82.2
55.1	7.5	13.1	85.3	85.0	84.8	84.5	84.3	84.0	83.8	83.5	83.2	83.0	82.7	82.5	82.2	82.0
61.1	8.0	12.6	85.2	84.9	84.6	84.4	84.1	83.8	83.6	83.3	83.1	82.8	82.5	82.3	82.0	81.7
67.5	8.5	12.2	85.0	84.7	84.5	84.2	83.9	83.7	83.4	83.1	82.8	82.6	82.3	82.0	81.7	81.5
74.4	9.0	11.7	84.9	84.6	84.3	84.0	83.7	83.5	83.2	82.9	82.6	82.3	82.1	81.8	81.5	81.2
81.9	9.5	11.2	84.7	84.4	84.1	83.8	83.5	83.2	83.0	82.7	82.4	82.1	81.8	81.5	81.2	80.9
90.2	10.0	10.7	84.5	84.2	83.9	83.6	83.3	83.0	82.7	82.4	82.1	81.8	81.5	81.2	80.9	80.6
99.2	10.5	10.2	84.3	84.0	83.7	83.4	83.1	82.8	82.4	82.1	81.8	81.5	81.2	80.9	80.6	80.2
109.1	11.0	9.7	84.1	83.8	83.5	83.1	82.8	82.5	82.2	81.8	81.5	81.2	80.8	80.5	80.2	79.9
120.1	11.5	9.2	83.9	83.5	83.2	82.8	82.5	82.2	81.8	81.5	81.1	80.8	80.5	80.1	79.8	79.4
132.2	12.0	8.8	83.6	83.2	82.9	82.5	82.2	81.8	81.5	81.1	80.7	80.4	80.0	79.7	79.3	79.0
145.8	12.5	8.3	83.3	82.9	82.6	82.2	81.8	81.4	81.1	80.7	80.3	79.9	79.6	79.2	78.8	78.4
161.1	13.0	7.8	83.0	82.6	82.2	81.8	81.4	81.0	80.6	80.2	79.8	79.4	79.0	78.6	78.2	77.8
178.5	13.5	7.3	82.6	82.2	81.8	81.3	80.9	80.5	80.1	79.7	79.3	78.8	78.4	78.0	77.6	77.2
198.3	14.0	6.8	82.1	81.7	81.3	80.8	80.4	79.9	79.5	79.1	78.6	78.2	77.7	77.3	76.8	76.4
221.2	14.5	6.3	81.6	81.2	80.7	80.2	79.8	79.3	78.8	78.3	77.9	77.4	76.9	76.5	76.0	75.5
247.8	15.0	5.8	81.1	80.6	80.1	79.5	79.0	78.5	78.0	77.5	77.0	76.5	76.0	75.5	75.0	74.5

WOOD 17% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			310	320	330	340	350	360	370	380	390	400	410	420	430	440
0.0	0.0	20.4	83.9	83.7	83.5	83.3	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.6	81.4
2.4	0.5	19.9	83.8	83.6	83.4	83.2	83.0	82.9	82.7	82.5	82.3	82.1	81.9	81.7	81.5	81.3
5.0	1.0	19.4	83.7	83.5	83.3	83.1	82.9	82.7	82.5	82.3	82.1	81.9	81.7	81.5	81.4	81.2
7.6	1.5	18.9	83.6	83.4	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.6	81.4	81.2	81.0
10.4	2.0	18.5	83.5	83.3	83.1	82.9	82.7	82.5	82.3	82.1	81.9	81.7	81.5	81.2	81.0	80.8
13.4	2.5	18.0	83.4	83.2	83.0	82.8	82.5	82.3	82.1	81.9	81.7	81.5	81.3	81.1	80.9	80.7
16.5	3.0	17.5	83.2	83.0	82.8	82.6	82.4	82.2	82.0	81.8	81.6	81.3	81.1	80.9	80.7	80.5
19.8	3.5	17.0	83.1	82.9	82.7	82.5	82.3	82.0	81.8	81.6	81.4	81.2	81.0	80.7	80.5	80.3
23.3	4.0	16.5	83.0	82.8	82.5	82.3	82.1	81.9	81.7	81.4	81.2	81.0	80.8	80.5	80.3	80.1
27.1	4.5	16.0	82.8	82.6	82.4	82.1	81.9	81.7	81.5	81.2	81.0	80.8	80.6	80.3	80.1	79.9
31.0	5.0	15.5	82.7	82.4	82.2	82.0	81.7	81.5	81.3	81.1	80.8	80.6	80.4	80.1	79.9	79.7
35.2	5.5	15.1	82.5	82.3	82.0	81.8	81.6	81.3	81.1	80.8	80.6	80.4	80.1	79.9	79.7	79.4
39.7	6.0	14.6	82.3	82.1	81.8	81.6	81.3	81.1	80.9	80.6	80.4	80.1	79.9	79.6	79.4	79.2
44.5	6.5	14.1	82.1	81.9	81.6	81.4	81.1	80.9	80.6	80.4	80.1	79.9	79.6	79.4	79.1	78.9
49.6	7.0	13.6	81.9	81.7	81.4	81.2	80.9	80.6	80.4	80.1	79.9	79.6	79.4	79.1	78.8	78.6
55.1	7.5	13.1	81.7	81.4	81.2	80.9	80.6	80.4	80.1	79.9	79.6	79.3	79.1	78.8	78.5	78.3
61.1	8.0	12.6	81.5	81.2	80.9	80.6	80.4	80.1	79.8	79.6	79.3	79.0	78.7	78.5	78.2	77.9
67.5	8.5	12.2	81.2	80.9	80.6	80.4	80.1	79.8	79.5	79.2	79.0	78.7	78.4	78.1	77.8	77.6
74.4	9.0	11.7	80.9	80.6	80.3	80.1	79.8	79.5	79.2	78.9	78.6	78.3	78.0	77.7	77.5	77.2
81.9	9.5	11.2	80.6	80.3	80.0	79.7	79.4	79.1	78.8	78.5	78.2	77.9	77.6	77.3	77.0	76.7
90.2	10.0	10.7	80.3	80.0	79.7	79.4	79.1	78.7	78.4	78.1	77.8	77.5	77.2	76.9	76.6	76.3
99.2	10.5	10.2	79.9	79.6	79.3	79.0	78.6	78.3	78.0	77.7	77.4	77.0	76.7	76.4	76.1	75.7
109.1	11.0	9.7	79.5	79.2	78.9	78.5	78.2	77.9	77.5	77.2	76.9	76.5	76.2	75.8	75.5	75.2
120.1	11.5	9.2	79.1	78.7	78.4	78.0	77.7	77.3	77.0	76.6	76.3	75.9	75.6	75.2	74.9	74.5
132.2	12.0	8.8	78.6	78.2	77.9	77.5	77.1	76.8	76.4	76.0	75.7	75.3	74.9	74.6	74.2	73.8
145.9	12.5	8.3	78.0	77.7	77.3	76.9	76.5	76.1	75.8	75.4	75.0	74.6	74.2	73.8	73.4	73.1
161.1	13.0	7.8	77.4	77.0	76.6	76.2	75.8	75.4	75.0	74.6	74.2	73.8	73.4	73.0	72.6	72.2
178.5	13.5	7.3	76.7	76.3	75.9	75.5	75.0	74.6	74.2	73.8	73.3	72.9	72.5	72.0	71.6	71.2
198.3	14.0	6.8	75.9	75.5	75.0	74.6	74.1	73.7	73.2	72.8	72.3	71.9	71.4	71.0	70.5	70.0
221.2	14.5	6.3	75.0	74.5	74.1	73.6	73.1	72.6	72.1	71.6	71.2	70.7	70.2	69.7	69.2	68.7
247.8	15.0	5.8	73.9	73.4	72.9	72.4	71.9	71.4	70.8	70.3	69.8	69.3	68.8	68.2	67.7	67.2

WOOD 17% MOISTURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			450	460	470	480	490	500	510	520	530	540	550	560	570	580
0.0	0.0	20.4	81.2	81.0	80.9	80.7	80.5	80.3	80.1	79.9	79.7	79.5	79.3	79.1	78.9	78.7
2.4	0.5	19.9	81.1	80.9	80.7	80.5	80.3	80.1	79.9	79.7	79.5	79.3	79.1	78.9	78.7	78.5
5.0	1.0	19.4	81.0	80.8	80.6	80.3	80.1	79.9	79.7	79.5	79.3	79.1	78.9	78.7	78.5	78.3
7.6	1.5	18.9	80.8	80.6	80.4	80.2	80.0	79.8	79.6	79.4	79.2	78.9	78.7	78.5	78.3	78.1
10.4	2.0	18.5	80.6	80.4	80.2	80.0	79.8	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.9
13.4	2.5	18.0	80.5	80.2	80.0	79.8	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.9	77.7
16.5	3.0	17.5	80.3	80.1	79.8	79.6	79.4	79.2	79.0	78.8	78.5	78.3	78.1	77.9	77.7	77.4
19.8	3.5	17.0	80.1	79.9	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.9	77.6	77.4	77.2
23.3	4.0	16.5	79.9	79.6	79.4	79.2	79.0	78.7	78.5	78.3	78.1	77.8	77.6	77.4	77.1	76.9
27.1	4.5	16.0	79.7	79.4	79.2	79.0	78.7	78.5	78.3	78.0	77.8	77.6	77.3	77.1	76.9	76.6
31.0	5.0	15.5	79.4	79.2	78.9	78.7	78.5	78.2	78.0	77.8	77.5	77.3	77.0	76.8	76.6	76.3
35.2	5.5	15.1	79.2	78.9	78.7	78.4	78.2	78.0	77.7	77.5	77.2	77.0	76.7	76.5	76.2	76.0
39.7	6.0	14.6	78.9	78.7	78.4	78.2	77.9	77.7	77.4	77.2	76.9	76.7	76.4	76.2	75.9	75.7
44.5	6.5	14.1	78.6	78.4	78.1	77.9	77.6	77.4	77.1	76.8	76.6	76.3	76.1	75.8	75.6	75.3
49.6	7.0	13.6	78.3	78.1	77.8	77.5	77.3	77.0	76.8	76.5	76.2	76.0	75.7	75.4	75.2	74.9
55.1	7.5	13.1	78.0	77.7	77.5	77.2	76.9	76.7	76.4	76.1	75.8	75.6	75.3	75.0	74.8	74.5
61.1	8.0	12.6	77.7	77.4	77.1	76.8	76.5	76.3	76.0	75.7	75.4	75.1	74.9	74.6	74.3	74.0
67.5	8.5	12.2	77.3	77.0	76.7	76.4	76.1	75.8	75.6	75.3	75.0	74.7	74.4	74.1	73.8	73.5
74.4	9.0	11.7	76.9	76.6	76.3	76.0	75.7	75.4	75.1	74.8	74.5	74.2	73.9	73.6	73.3	73.0
81.9	9.5	11.2	76.4	76.1	75.8	75.5	75.2	74.9	74.6	74.3	74.0	73.7	73.4	73.0	72.7	72.4
90.2	10.0	10.7	75.9	75.6	75.3	75.0	74.7	74.4	74.0	73.7	73.4	73.1	72.8	72.4	72.1	71.8
99.2	10.5	10.2	75.4	75.1	74.8	74.4	74.1	73.8	73.4	73.1	72.8	72.4	72.1	71.8	71.4	71.1
109.1	11.0	9.7	74.8	74.5	74.1	73.8	73.5	73.1	72.8	72.4	72.1	71.7	71.4	71.0	70.7	70.3
120.1	11.5	9.2	74.2	73.8	73.5	73.1	72.8	72.4	72.0	71.7	71.3	71.0	70.6	70.2	69.9	69.5
132.2	12.0	8.8	73.5	73.1	72.7	72.3	72.0	71.6	71.2	70.8	70.5	70.1	69.7	69.3	69.0	68.6
145.8	12.5	8.3	72.7	72.3	71.9	71.5	71.1	70.7	70.3	69.9	69.5	69.1	68.7	68.3	67.9	67.5
161.1	13.0	7.8	71.8	71.4	70.9	70.5	70.1	69.7	69.3	68.9	68.5	68.0	67.6	67.2	66.8	66.4
178.5	13.5	7.3	70.7	70.3	69.9	69.4	69.0	68.6	68.1	67.7	67.2	66.8	66.4	65.9	65.5	65.0
198.3	14.0	6.8	69.6	69.1	68.7	68.2	67.7	67.3	66.8	66.3	65.9	65.4	64.9	64.5	64.0	63.5
221.2	14.5	6.3	68.2	67.7	67.2	66.8	66.3	65.8	65.3	64.8	64.3	63.8	63.3	62.8	62.3	61.8
247.8	15.0	5.8	66.7	66.1	65.6	65.1	64.5	64.0	63.5	62.9	62.4	61.9	61.3	60.8	60.3	59.7

WOOD 17% MOSITURE

Excess Air	% O_2	% CO_2	Combustion Efficiency Flue Gas Temperature Less Combustion Air Temperature, °F													
			590	600	610	620	630	640	650	660	670	680	690	700	710	720
0.0	0.0	20.4	78.5	78.3	78.1	77.9	77.7	77.5	77.3	77.1	76.9	76.7	76.5	76.3	76.1	75.9
2.4	0.5	19.9	78.3	78.1	77.9	77.7	77.5	77.3	77.1	76.9	76.7	76.5	76.3	76.1	75.9	75.6
5.0	1.0	19.4	78.1	77.9	77.7	77.5	77.3	77.1	76.9	76.7	76.5	76.2	76.0	75.8	75.6	75.4
7.6	1.5	18.9	77.9	77.7	77.5	77.3	77.1	76.9	76.6	76.4	76.2	76.0	75.8	75.6	75.4	75.1
10.4	2.0	18.5	77.7	77.5	77.3	77.0	76.8	76.6	76.4	76.2	76.0	75.7	75.5	75.3	75.1	74.9
13.4	2.5	18.0	77.5	77.2	77.0	76.8	76.6	76.4	76.1	75.9	75.7	75.5	75.3	75.0	74.8	74.6
16.5	3.0	17.5	77.2	77.0	76.8	76.5	76.3	76.1	75.9	75.6	75.4	75.2	75.0	74.7	74.5	74.3
19.8	3.5	17.0	77.0	76.7	76.5	76.3	76.0	75.8	75.6	75.4	75.1	74.9	74.7	74.4	74.2	74.0
23.3	4.0	16.5	76.7	76.4	76.2	76.0	75.8	75.5	75.3	75.1	74.8	74.6	74.3	74.1	73.9	73.6
27.1	4.5	16.0	76.4	76.2	75.9	75.7	75.4	75.2	75.0	74.7	74.5	74.2	74.0	73.8	73.5	73.3
31.0	5.0	15.5	76.1	75.8	75.6	75.4	75.1	74.9	74.6	74.4	74.1	73.9	73.6	73.4	73.2	72.9
35.2	5.5	15.1	75.8	75.5	75.3	75.0	74.8	74.5	74.3	74.0	73.8	73.5	73.3	73.0	72.8	72.5
39.7	6.0	14.6	75.4	75.2	74.9	74.6	74.4	74.1	73.9	73.6	73.4	73.1	72.8	72.6	72.3	72.1
44.5	6.5	14.1	75.0	74.8	74.5	74.3	74.0	73.7	73.5	73.2	72.9	72.7	72.4	72.1	71.9	71.6
49.6	7.0	13.6	74.6	74.4	74.1	73.8	73.6	73.3	73.0	72.8	72.5	72.2	71.9	71.7	71.4	71.1
55.1	7.5	13.1	74.2	73.9	73.7	73.4	73.1	72.8	72.5	72.3	72.0	71.7	71.4	71.2	70.9	70.6
61.1	8.0	12.6	73.7	73.5	73.2	72.9	72.6	72.3	72.0	71.7	71.5	71.2	70.9	70.6	70.3	70.0
67.5	8.5	12.2	73.2	73.0	72.7	72.4	72.1	71.8	71.5	71.2	70.9	70.6	70.3	70.0	69.7	69.4
74.4	9.0	11.7	72.7	72.4	72.1	71.8	71.5	71.2	70.9	70.6	70.3	70.0	69.7	69.4	69.0	68.7
81.9	9.5	11.2	72.1	71.8	71.5	71.2	70.9	70.5	70.2	69.9	69.6	69.3	69.0	68.7	68.3	68.0
90.2	10.0	10.7	71.5	71.1	70.8	70.5	70.2	69.9	69.5	69.2	68.9	68.5	68.2	67.9	67.6	67.2
99.2	10.5	10.2	70.8	70.4	70.1	69.8	69.4	69.1	68.7	68.4	68.1	67.7	67.4	67.0	66.7	66.4
109.1	11.0	9.7	70.0	69.6	69.3	68.9	68.6	68.2	67.9	67.5	67.2	66.8	66.5	66.1	65.8	65.4
120.1	11.5	9.2	69.1	68.8	68.4	68.0	67.7	67.3	66.9	66.6	66.2	65.8	65.5	65.1	64.7	64.4
132.2	12.0	8.8	68.2	67.8	67.4	67.0	66.7	66.3	65.9	65.5	65.1	64.7	64.4	64.0	63.6	63.2
145.8	12.5	8.3	67.1	66.7	66.3	65.9	65.5	65.1	64.7	64.3	63.9	63.5	63.1	62.7	62.3	61.9
161.2	13.0	7.8	65.9	65.5	65.1	64.7	64.3	63.8	63.4	63.0	62.6	62.1	61.7	61.3	60.8	60.4
178.5	13.5	7.3	64.6	64.1	63.7	63.3	62.8	62.4	61.9	61.5	61.0	60.6	60.1	59.7	59.2	58.7
198.3	14.0	6.8	63.0	62.6	62.1	61.6	61.2	60.7	60.2	59.7	59.2	58.8	58.3	57.8	57.3	56.8
221.2	14.5	6.3	61.3	60.8	60.3	59.8	59.2	58.7	58.2	57.7	57.2	56.7	56.2	55.7	55.2	54.7
247.8	15.0	5.8	59.2	58.6	58.1	57.6	57.0	56.5	55.9	55.4	54.8	54.3	53.7	53.2	52.6	52.1

APPENDIX B

Table B.1: Steam Tables (Saturation)

Absolute Pressure* (psia)	Temperature (°F)	Specific Volume (ft^3/lb)		Enthalpy (BTU/lb)	
		Liquid	Vapor	Liquid	Vapor
15	213.03	0.016723	26.29	181.19	1150.9
20	227.96	0.016830	20.09	196.26	1156.4
30	250.34	0.017004	13.748	218.93	1164.3
40	267.26	0.017146	10.501	236.16	1170.0
50	281.03	0.017269	8.518	250.24	1174.4
60	292.73	0.017378	7.177	262.25	1178.0
70	302.96	0.017478	6.209	272.79	1181.0
80	312.07	0.017570	5.474	282.21	1183.6
90	320.31	0.017655	4.898	290.76	1185.9
100	327.86	0.017736	4.434	298.61	1187.8
110	334.82	0.017813	4.051	305.88	1189.6
120	341.30	0.017886	3.730	312.67	1191.1
130	347.37	0.017957	3.457	319.04	1192.5
140	353.08	0.018024	3.221	325.05	1193.8
150	358.48	0.018089	3.016	330.75	1194.9
160	363.60	0.018152	2.836	336.16	1196.0
170	368.47	0.018214	2.676	341.33	1196.9
180	373.13	0.018273	2.533	346.29	1197.8
190	377.59	0.018331	2.405	351.04	1198.6
200	381.86	0.018387	2.289	355.6	1199.3
250	401.04	0.01853	1.8448	376.2	1202.1
300	417.43	0.018896	1.5442	394.1	1203.9
350	431.82	0.019124	1.3267	409.9	1204.9
400	444.70	0.019340	1.1620	424.2	1205.5

*Gauge Pressure + Atmospheric Pressure = Absolute Pressure

NOTES

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