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BOILER EFFICIENCY

FACTS YOU SHOULD KNOW
ABOUT FIRETUBE BOILERS AND
BOILER EFFICIENCY

Foreward

Today's process and heating applications continue to be powered by steam and hot water. The mainstay technology for generating heating or process energy is the packaged firetube boiler. The packaged firetube boiler has proven to be highly efficient and cost effective in generating energy for process and heating applications.

Conducting a thorough evaluation of boiler equipment requires review of boiler type, feature and benefit comparison, maintenance requirements and fuel usage requirements. Of these evaluation criteria, a key factor is fuel usage or boiler efficiency.

Boiler efficiency, in the simplest terms, represents the difference between the energy input and energy output. A typical boiler will consume many times the initial capital expense in fuel usage annually. Consequently, a difference of just a few percentage points in boiler efficiency between units can translate into substantial savings. The efficiency data used for comparison between boilers must be based on proven performance to produce an accurate comparison of fuel usage. However, over the years, efficiency has been represented in confusing terms or in ways where the efficiency value did not accurately represent proven fuel usage values. Sometimes the representation of "boiler efficiency" does not truly represent the comparison of energy input and energy output of the equipment.

This Efficiency Facts Booklet is designed to clearly define boiler efficiency. It will also give you the background in efficiency needed to ask the key questions when evaluating efficiency data, and provide you with the tools necessary to accurately compare fuel usage of boiler products, specifically firetube type boilers.

Remember, the initial cost of a boiler is the lowest portion of your boiler investment. Fuel costs and maintenance costs represent the largest portion of your boiler equipment investment. Not all boilers are created equal. Some basic design differences can reveal variations in expected efficiency performance levels. Evaluating these design differences can provide insight into what efficiency value and resulting operating costs you can expect.

However, every boiler operates under the same fundamental thermodynamic principles. Therefore, a maximum theoretical efficiency can be calculated for a given boiler design. The maximum value represents the highest available efficiency of the unit. If you are evaluating a boiler where the stated efficiencies are higher than the theoretical efficiency value, watch out! The efficiency value you are utilizing may not truly represent the fuel usage of the unit.

In the end efficiency comes down to value. The value of the boiler. The value of the burner. The value of the support provided throughout the life of the equipment.

Cleaver-Brooks, we have built our reputation by manufacturing the highest efficiency and highest value products in the industry. We pride ourselves in providing you with the most comprehensive and reliable service support through our "best in the industry" representative network. When it comes to efficiency, we believe in sticking to the facts. Because the facts say there is a difference between boilers and boiler companies. The value of buying a higher efficiency CB boiler will pay dividends every day, every year, throughout the life of the equipment.

Introduction

Why choose the most efficient boiler?

When you buy a boiler, you really are putting a down payment on the purchase of steam or hot water. The payments to generate the power are ongoing over the life of the equipment and are driven by fuel to steam efficiency and maintenance costs. Even with economical fuel costs, the selection of a high efficiency boiler will result in substantial cost savings. A boiler installation costing \$75,000 can easily consume over \$400,000 in fuel every year it operates. Selection of a boiler with "designed-in" low maintenance costs and high efficiency can really provide savings and maximize your boiler investment.

Efficiency is only useful if it is repeatable and sustainable over the life of the equipment. Choosing the most efficient boiler is more than just choosing the vendor who is willing to meet a given efficiency value. The burner technology must be proven to be capable of holding the air/fuel ratio year in and year out. Make sure the burner design includes reliable and repeatable features. How do you tell? Ask any boiler technician who has worked on a variety of boiler/burner designs. Burners with high pressure drop design, quality fan and damper design, and simple linkage assemblies are easy to tune and accurately hold the air to fuel ratios. Burners with blade or louver damper designs and complex linkage assemblies tend to be harder to set-up over the firing range of the boiler and tend not to accurately hold the air to fuel ratio as the boiler operates.

Why choose the most efficient boiler? Because the dividends paid back each year far outweigh any initial cost savings of a less efficient design. What is the most efficient boiler? One that not only starts up efficiently but continues to operate efficiently year in and year out.

Replace or Repair.

The decision to purchase a new boiler is typically driven by the needed replacement of an old boiler, an expansion of an existing boiler room, or construction of a new boiler room facility.

When considering the replacement of an old boiler, review the following points to make sure you are performing a comprehensive evaluation of your situation.

1. Maintenance Costs

Review your maintenance costs carefully. The old unit is costing you money in various ways, including emergency maintenance, downtime, major maintenance requirements (past and pending), difficult-to-find and expensive parts requirements, operator time in keeping the unit on-line, and overall vessel, burner, and refractory problems. Many of these costs can be hidden within your overall maintenance budget. You are paying the price for having outdated boiler room equipment. But the costs need to be investigated and totaled.

2. Boiler performance

New packaged firetube boilers have much higher performance standards than older design units. Turndown, excess air, automatic operation, accurate-repeatable air/fuel ratio burner designs, computer linked combustion controls, low emission technology, and high guaranteed efficiency all are now available on premium designed packaged firetube boilers. The result is low operating costs and automatic power generation for your facility. All cost saving reasons to consider a new packaged firetube boiler.

3. Fuel Usage

If your old unit is designed to fire low grade fuel oil, or if you need to evaluate propane or any other different fuel capability, review the conversion costs along with existing maintenance, performance, and efficiency issues to see if the time is right to consider a new boiler purchase. Many times an investment is made in an old unit when the costs associated with the next major maintenance requirement will justify a new unit. The result is wasted money on the

old unit upgrade.

4. Efficiency

Your Cleaver-Brooks representative can help check out the efficiency of your old boiler with a simple stack analysis. The data will give you a general idea of the difference between the fuel cost of the existing boiler and a new unit. Based on the results of the stack evaluation, a more comprehensive evaluation of your boiler room requirements should be performed. Boiler size, load characteristics, turndown requirements, back-up requirements, fuel type, control requirements, and emission requirements, all should be evaluated. The result will be an accurate review of the potential savings in fuel, maintenance, and boiler room efficiency that can mean substantial cost improvement for your facility.

Efficiency Feature Comparisons

All firetube boilers are the same? Not true! The fact is there are key feature differences between firetube boilers.

The efficiency of a firetube boiler is not a mysterious calculation. High efficiency is the result of tangible design considerations incorporated into the boiler. Reviewing some basic design differences from one boiler to another can provide you with valuable insight on expected efficiency performance. The following design issues should be considered during your boiler evaluation.

1. Number of boiler passes.

The number of boiler passes simply represents the number of times the hot combustion gas travels across the boiler (heat exchanger). A boiler with two passes provides two opportunities for the hot gasses to exchange heat to the water in the boiler. A 4-pass unit provides four opportunities for heat transfer. Many comparisons have been made regarding efficiency and number of boiler passes but, the facts are clear and indisputable. The stack temperature of a 4-pass boiler will be lower than the stack temperature of a similar size 2- or 3-pass boiler operating under similar conditions. The 4-pass will

have higher efficiencies and lower fuel costs. This is not an opinion. It is basic heat exchanger physics. The 4-pass design yields higher heat-transfer coefficients.

Many times the lower pass unit will include turbulators or will be tested at less than capacity firing rates to prove lower stack temperatures. Don't be fooled. Turbulators may help pass an efficiency test but will cost you in maintenance down the road. In fact, you would not need maintenance intensive, boiler tube, add-on devices if the boiler was designed for proper flue gas velocities in the first place. Each boiler pass should be designed with a cross sectional area providing proper flue gas velocity and heat transfer. When it comes to efficiency, the proof is indeed in the passes and in correct heat transfer design.

2. Burner / boiler compatibility

The term packaged boiler is sometimes used even if a burner manufactured by one vendor is bolted on to a boiler manufactured by a different vendor. Is bolting a "Buy-out" burner on a vessel really a packaged boiler? And more importantly, why does it matter? A true packaged boiler/burner design includes a burner and boiler developed as a single unit, accounting for furnace geometry, radiant and convection heat transfer characteristics, and verified burner performance in the specific boiler package. Development as a truly packaged unit assures the performance of the unit is proven and verified during development.

You can put an engine from one automobile into a different automobile. The car will probably run. It will get you from point "A" to point "B." But how about performance? Will the car give fuel efficiency and reliable performance for the life of the car? Would you take a long trip where you had to depend on such a car? And if you need service, who will take accountability to repair and guarantee the car?

A boiler provides the same scenario. The buy-out burner will fire the unit. But, will you have capacity, efficiency, turndown, excess air performance and emission

performance too? And, who will make sure the unit gives you performance after the initial start-up? Is there even a single accountable manufacturer to make the unit perform in the first place? Buy-out burner packaging can result in lower performance levels and higher start-up and maintenance requirements. It also can cost you money every time you have a problem and the local service people cannot get factory support. You may think you saved money with a buy-out burner package. But did you really?

3. Repeatable air/ fuel control

The efficiency of the boiler depends on the ability of the burner to provide the proper air to fuel mixture throughout the firing rate, day in and day out, without the need for complex set-up or adjustments. Many burner designs can deliver the required air-to-fuel mix with enough time provided to adjust the burner or for a single test period. The problem is many of these complex linkage designs don't hold air to fuel settings over time. And, often, they are adjusted at high excess air levels to account for the inconsistency in the burner performance. The fact is you pay for the unit based on the actual ability to operate efficiently. When it comes to choosing the burner, insist on a simple linkage assembly and accessible burner design for true efficiency and real savings.

An additional burner feature to look for is the fan design. Squirrel cage type fans do not provide as reliable air control as a reverse curve fan will provide. Aluminum cast fan design also provides tight tolerances and maximum fan life. Furthermore, register or blade type damper assemblies tend to have limited control of air at low firing conditions and tend to be much less repeatable than radial damper designs. Control of combustion air is critical to burner performance. If the burner cannot provide repeatable air control, again the typical solution is to set the burner up at high excess air levels, resulting in substantial dollars wasted

every time you fire the unit. The facts are clear: Reverse fan and radial damper design result in high efficiency and repeatable fuel savings, thus performance paying dividends throughout the life of the boiler.

4. Heating surface

The heating surface in square feet per boiler horsepower represents, in general terms, how hard the vessel is working. The standard heating surface for a firetube boiler is five square feet per boiler horsepower. How do we know this? Cleaver-Brooks set the standard and provides five square feet as a base design criteria for our firetube products. Proper heating surface means longer boiler life and higher efficiency. Five square feet is the standard.

5. Vessel design

Pressure vessel design is regulated by strict ASME code requirements. However, there are many variations in vessel design that will still meet the ASME codes. Water circulation, low stress design and accessibility are key criteria for proper pressure vessel design. Specific features to look for include a single tubesheet design. Single tubesheet design provides minimum weldments for low tube sheet stresses and excellent water circulation. In addition to the single tubesheet design, the boiler should include proper tube spacing, cross sectional area sizing in each pass for proper heat transfer, low furnace location, and proper inlet and outlet location. Proper circulation must be incorporated into the design for highest boiler efficiency and longevity. Fully accessible front and rear tube sheets for ease of inspection and low re-tubing costs are also key design criteria to look for. You will inspect your boiler often, usually every year. Single tube sheet design assures the longest lasting tube sheet and longest tube life.

Accessible front and rear heads assure the lowest inspection and re-tubing costs if they occur. Both result in the highest efficiency and lowest possible maintenance costs for your boiler equipment.

Defining boiler efficiency

Combustion Efficiency

Combustion efficiency is an indication of the burner's ability to burn fuel. The amount of unburned fuel and excess air in the exhaust are used to assess a burner's combustion efficiency. Burners resulting in low levels of unburned fuel while operating at low excess air levels are considered efficient. Well designed burners firing gaseous and liquid fuels operate at excess air levels of 15% and result in negligible unburned fuel. By operating at only 15% excess air, less heat from the combustion process is being used to heat excess air, which increases the available heat for the load. Combustion efficiency is not the same for all fuels and, generally, gaseous and liquid fuels burn more efficiently than solid fuels.

Thermal Efficiency

Thermal efficiency is a measure of the effectiveness of the heat exchanger of the boiler. It measures the ability of the exchanger to transfer heat from the combustion process to the water or steam in the boiler. Because thermal efficiency is solely a measurement of the effectiveness of the heat exchanger of the boiler, it does not account for radiation and convection losses due to the boiler's shell, water column, or other components. Since thermal efficiency does not account for radiation and convection losses, it is not a true indication of the boiler's fuel usage and should not be used in economic evaluations.

Boiler Efficiency

The term "boiler efficiency" is often substituted for thermal efficiency or fuel-to-steam efficiency. When the term "boiler efficiency" is used, it is important to know which type of efficiency is being represented. Why? Because thermal efficiency, which does not account for radiation and convection losses, is not an indication of the true boiler efficiency. Fuel-to-steam efficiency, which does account for radiation and convection losses, is a true indication of overall boiler efficiency. The term "boiler efficiency" should be defined by the boiler manufacturer before it is used in any economic evaluation.

Fuel-To-Steam Efficiency

Fuel-to-steam efficiency is a measure of the overall efficiency of the boiler. It accounts for the effectiveness of the heat exchanger as well as the radiation and convection losses.

It is an indication of the true boiler efficiency and should be the efficiency used in economic evaluations.

As prescribed by the ASME Power Test Code, PTC 4.1, the fuel-to-steam efficiency of a boiler can be determined by two methods; the Input-Output Method and the Heat Loss Method.

Input-Output Method

The Input-Output efficiency measurement method is based on the ratio of the output-to-input of the boiler. It is calculated by dividing the boiler output (in BTUs) by the boiler input (in BTUs) and multiplying by 100. The actual input and output of the boiler are determined through instrumentation and the data is used in calculations that result in the fuel-to-steam efficiency.

Heat Loss Method

The Heat Balance efficiency measurement method is based on accounting for all the heat losses of the boiler. The actual measurement method consists of subtracting from 100 percent the total percent stack, radiation, and convection losses. The resulting value is the boiler's fuel-to-steam efficiency. The heat balance method accounts for stack losses and radiation and convection losses.

Stack Losses: Stack temperature is a measure of the heat carried away by dry flue gases and the moisture loss. It is a good indicator of boiler efficiency. The stack temperature is the temperature of the combustion gases (dry and water vapor) leaving the boiler and reflects the energy that did not transfer from the fuel to the steam or hot water. The lower the stack temperature, the more effective the heat exchanger design, and the higher the fuel-to-steam efficiency.

Radiation and Convection Losses: All boilers have radiation and convection losses. The losses represent heat radiating from the boiler (radiation losses) and heat lost due to air flowing across the boiler (convection losses). Radiation and convection losses, expressed in Btu/hr, are essentially constant throughout the firing range of a particular boiler, but vary between different boiler types, sizes, and operating pressures.

Components of efficiency (impact and sensitivity)

Boiler efficiency, when calculated by the ASME heat balance method, includes stack losses and radiation and convection losses. But what factors have the most effect or “sensitivity” on boiler efficiency? As discussed earlier, the basic boiler design is the major factor. However, there is room for interpretation when calculating efficiency. Indeed if desired, you can make a boiler appear more efficient than it really is by using a little creativity in the efficiency calculation. The following are the key factors to understanding efficiency calculations.

1. Flue gas temperature (Stack temperature)
2. Fuel specification
3. Excess air
4. Ambient air temperature
5. Radiation and convection losses.

1. Flue Gas Temperature

Flue gas temperature or “stack temperature” is the temperature of the combustion gases as they exit the boiler. The flue gas temperature must be a proven value for the efficiency calculation to be reflective of the true fuel usage of the boiler. A potential way to manipulate an efficiency value is to utilize a lower-than-actual flue gas temperature in the calculation. When reviewing an efficiency guarantee or calculation, check the flue gas temperature. Is it realistic? Is it near or less than the saturation temperature of the fluid in the boiler? And can the vendor of the equipment refer you to an existing jobsite where these levels of flue gas temperatures exist? Jobsite conditions will vary and have an effect on flue gas temperature. However, if the efficiency value is accurate, the flue gas temperatures should be confirmable in existing applications. Don't be fooled by estimated stack

temperatures. Make sure the stack temperature is proven.

Figure 1 shows flue gas temperature vs theoretical fuel-to-steam efficiency. This table represents the maximum theoretical efficiency you can achieve at a given flue gas temperature. The table can be used as follows. If a boiler is represented to be 85% efficient firing natural gas, follow the 85% on the left to the natural gas line and down to the flue gas temperature. The result is approximately 270 deg.F. This shows the boiler would have to operate at a 270 deg. F. stack temperature to meet the 85% efficiency, or the efficiency calculation was based on an unrealistically low hydrogen content fuel. If a boiler is represented to be 85% efficient on natural gas at a 350° F stack temperature, check the fuel specification. A Boiler cannot operate at 85% efficiency at 350° F stack temperature when firing natural gas per Figure 1.

2. Fuel specification

The fuel specification can also have a dramatic effect on efficiency. In the case of gaseous fuels, the higher the hydrogen content, the more water vapor is formed during combustion. This water vapor uses energy as it changes phase in the combustion process. Higher water vapor losses when firing the fuel result in lower efficiency. This is one reason why fuel oil fires at higher efficiency levels than natural gas. To get an accurate efficiency calculation, a fuel specification that represents the jobsite fuel to be fired must be used. When reviewing an efficiency guarantee or calculation, check the fuel specification. Is it representative of the fuel you will use in the boiler? The representation of efficiency using fuel with low hydrogen content will not provide an accurate evaluation of your actual fuel usage.

Figure 2 shows the degree to which efficiency can be affected by fuel specification. The graph indicates the effect of the hydrogen-to-carbon ratio on efficiency for five different gaseous fuels. At identical operating conditions, efficiencies can vary as much as 2.5-3.0%, based solely on the hydrogen-to-carbon ratio of the fuel. When evaluating boiler efficiency, knowing the actual fuel specification is a must.

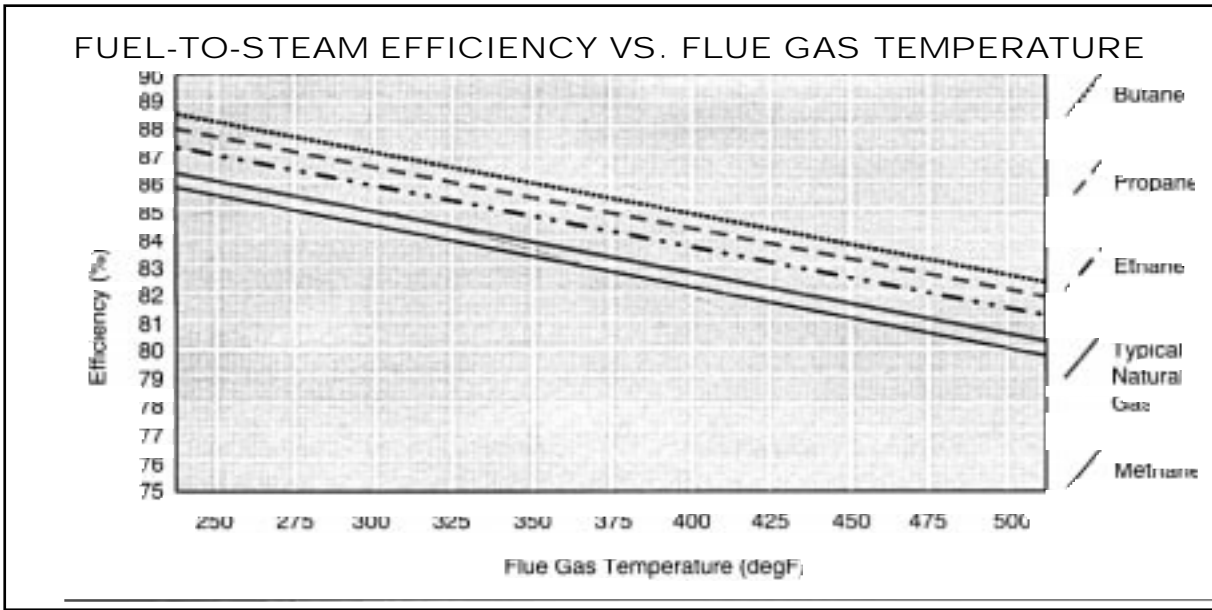


figure 1

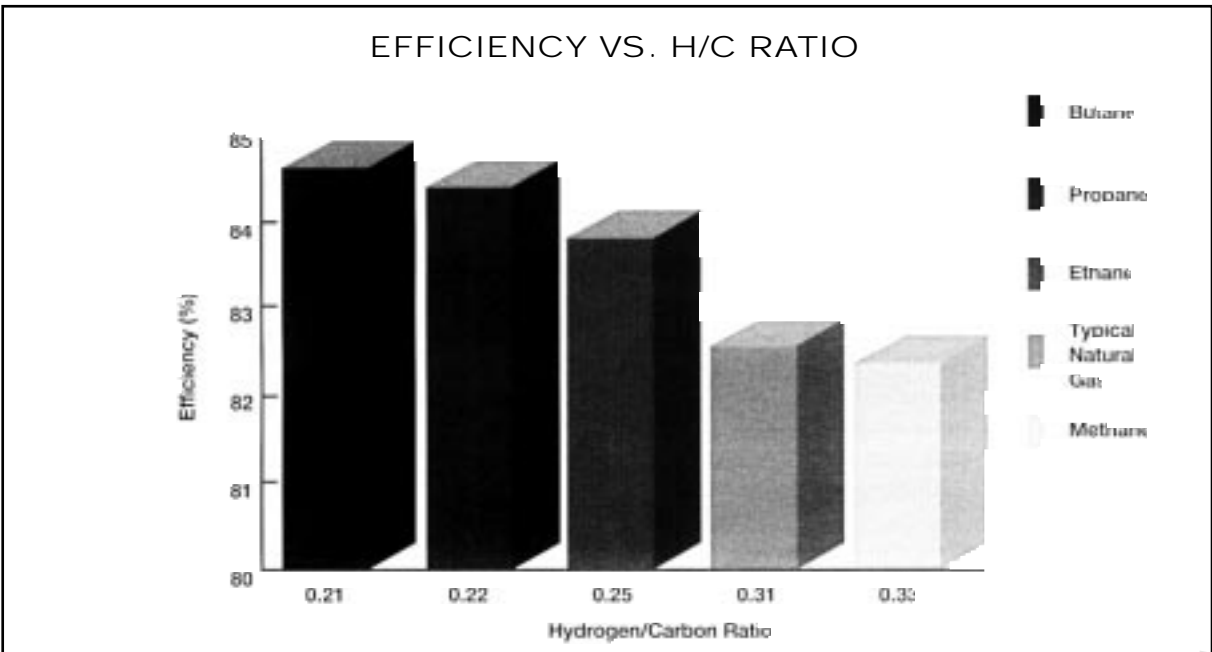


figure 2

3. Excess Air

Excess air is the extra air supplied to the burner beyond the required air for complete combustion. Excess air is supplied to the burner because a boiler firing without sufficient air or “fuel rich” is operating in a potentially dangerous condition. Therefore, excess air is supplied to the burner to provide a safety factor above the actual air required for combustion. However, excess air uses energy from combustion, thus taking away potential energy for transfer to water in the boiler. In this way, excess air reduces boiler efficiency. A quality burner design will allow firing at

minimum excess air levels of 15% (3% as O₂)*.

* O₂ represents percent oxygen in the flue gas. Excess air is measured by sampling the O₂ in the flue gas. If 15% excess air exists, the oxygen analyzer would measure the O₂ in the excess air and show a 3% measurement.

Seasonal changes in temperature and barometric pressure can cause the excess air in a boiler to fluctuate 5% - 10%. Furthermore, firing at low excess air levels can result in high CO and boiler sooting, specifically if the burner has

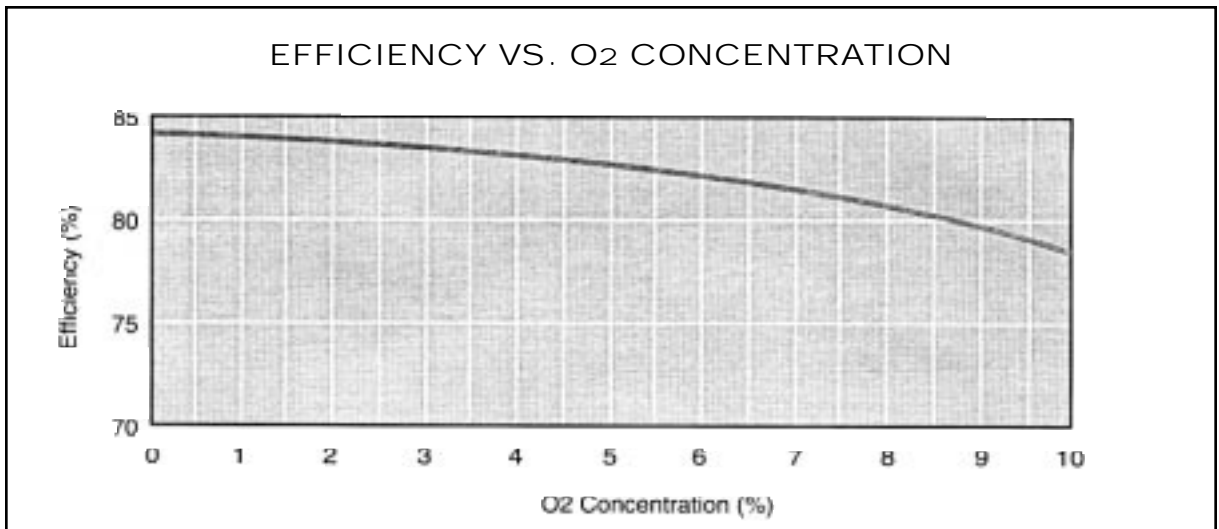


figure 3

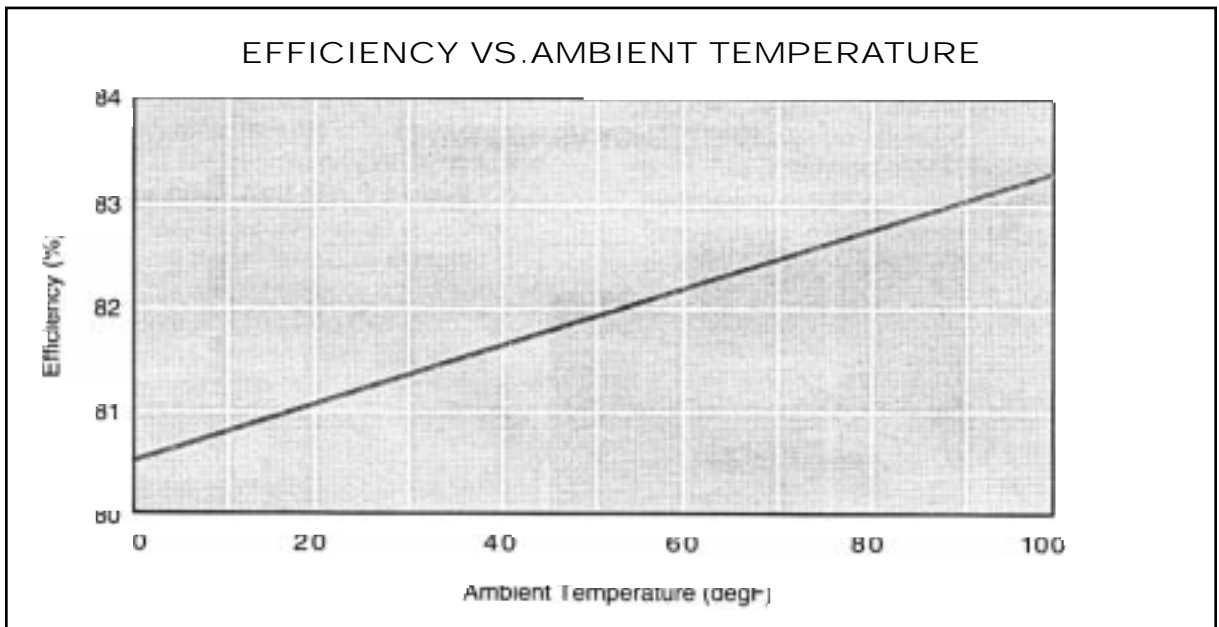


figure 4

complex linkage and lacks proper fan design. The fact is even burners theoretically capable of running at less than 15% excess air levels rarely are left at these settings in actual practice. A realistic excess air level for a boiler in operation is 15% if an appropriate safety factor is to be maintained.

When reviewing an efficiency guarantee or calculation, check the excess air levels. If 15% excess air is being used to calculate the efficiency, the burner should be of a very high quality design with repeatable damper and linkage features. Without these features, your boiler will not be operating at the low excess air values being

used for the calculation, at least not for long. If less than 15% excess air is being used for the calculation you are probably basing your fuel usage on a higher efficiency than will be achieved in your day to day operation. You should ask the vendor to recalculate the efficiency at realistic excess air values.

Figure 3 shows excess air concentration vs efficiency. The chart can be used to review the impact of variations in excess air values on efficiency.

4. Ambient Temperature

Ambient temperature can have a dramatic effect on boiler efficiency. A 40 degree variation in ambient temperature can effect efficiency by 1% or more. Most boiler rooms are relatively warm.

MODEL CB 4-PASS BOILER—RADIATION AND CONVECTION LOSSES

Firing Rate (% of Load)	100-350 BHp		400-800 BHp	
	Op. Pressure = 10 PSIG	Op. Pressure = 125 PSIG	Op. Pressure = 10 PSIG	Op. Pressure = 125 PSIG
25%	1.6%	1.9%	1.0%	1.2%
50%	.7%	1.0%	.5%	.6%
75%	.5%	.7%	.3%	.4%
100%	.4%	.5%	.2%	.3%

table 1

Based on • still air conditions
• 80° F ambient air.

Therefore, most efficiency calculations are based on 80 deg. F ambient temperatures. When reviewing an efficiency guarantee or calculation, check the ambient air conditions utilized. If a higher than 80° F value was utilized, it is not consistent with standard engineering practice. And, if the boiler is going to be outside, the actual efficiency will be lower due to lower ambient air temperatures regardless of the boiler design. To determine your actual fuel usage, ask for the efficiency to be calculated at the lower ambient conditions. Or, use Figure 4 to estimate the effect the lower ambient air levels will have on the boiler efficiency.

5. Radiation and Convection losses

Radiation and convection losses represent the heat losses radiating from the boiler vessel. Boilers are insulated to minimize these losses. However, every boiler has radiation and convection losses. Some times efficiency is represented without any radiation and convection losses. This is not a true reflection of fuel usage of the boiler. The boiler design also can have an effect on radiation and convection losses. For example, a waterback design boiler tends to have much higher rear skin temperatures than a dryback design. This is easy to prove. Just go to the back of a quality dryback boiler and touch the rear door. Cool rear temperatures are the result of low radiation and convection losses in the rear of the boiler. Boilers operating with high rear temperatures are wasting energy every time the unit is fired.

Radiation and convection losses also are a function of air velocity across the boiler. A

typical boiler room does not have high wind velocities. Boilers operating outside, however, will have higher radiation and convection losses.

Table 1 shows expected radiation and convection losses for 4-pass firetube boilers designed and insulated for high efficiency.

Summary

Selection of a boiler with “designed-in” low maintenance costs and high efficiency can really pay off by providing ongoing savings and maximizing your boiler investment. Remember, first cost is a relatively small portion of your boiler investment.

High boiler efficiency is the result of specific design criteria, including:

- Number of boiler passes
- Burner / boiler compatibility
- Repeatable air/fuel control
- Heating surface
- Pressure vessel design

Boiler efficiency calculations that are accurate and representative of actual boiler fuel usage require the use of proven and verified data, including:

- Proven stack temperature
- Accurate fuel specification
- Actual operating excess air levels
- Proper ambient air temperature
- Proper radiation &

Boiler Efficiency Examples

The following pages are designed to provide the tools you need to calculate and compare boiler fuel costs.

The tables and figures can be used in two ways.

- A. You can determine the efficiency of a firetube boiler based on known stack temperature.
- B. You can compare fuel costs of firetube boilers operating at different efficiencies.

Efficiency based on stack temperature

Procedure

1. Determine the stack temperature of the boiler. Make sure the stack temperature is accurate and proven!
2. Determine the CO₂ level of the boiler. (If excess air as O₂ is available, O₂ can be converted to CO₂ using figure 5.)
3. Determine the ambient air temperature in the boiler room.
4. Subtract the ambient air temperature from the stack temperature to determine the net temperature and CO₂.
5. Use the “Hays charts” (tables 2, 3, 4) to determine the stack loss based on the net temperature.
6. Add the “Radiation and Convection” losses from table 1. (Note: the radiation and convection losses in the chart are based on model CB 4-pass firetube boilers. The radiation and convection losses from competitive equipment may be higher).
7. Subtract the stack losses and radiation and convection losses from 100 to get the Fuel-to-Steam efficiency.

EXAMPLE

Assume 15 lb. design, 100 HP CB Boiler, fired on gas at 100% of Rating.

Stack temperature is 320° F. and room temperature is 80° F.
(320 - 80 = 240)

You measure CO₂ of 10% with no CO.

From Hays chart, at 240° and 10% CO₂, you get stack loss of 15.2% going up the stack.
(See table 2)

Add .4% for “Radiation and Convection Losses”. (For a CB Boiler, see table 1)
15.2% plus .4% = 15.6%

100 - 15.6 = 84.4% Fuel-to-Steam Efficiency.

Fuel cost comparison of boilers with different efficiencies

Procedure

1. Determine the Fuel-to-Steam efficiencies of the units. CB efficiencies are shown in tables 5, 6, and 7. (If you do not know the efficiency of existing equipment or competitive equipment, it can be calculated per prior procedure based on stack temperature).
2. Select the fuel burning rates based on the efficiency from tables 8 and 9.
3. Determine the annual fuel usage based on the annual operating hours.
4. Determine the cost of the fuel used.
5. Compare the units to determine the annual savings.

EXAMPLE

You are evaluating three quotations, each covering a 400 BHp, 150 lb. design steam boiler to burn No. 2 oil or natural gas and operate at 125 PSIG. After evaluating freight, extras, etc., you estimate cost of \$70,000.00 for CB, \$64,000.00 for Alternate #1, and \$60,000.00 for Alternate #2.

The literature for both Alternatives guarantee 79% efficiency.

The CB FTSE guarantee would be 85.5% at 100% of Rating. (See tables 8 and 9)

400 BHp Output = 13,390,000 BTU/Hr.

No. 2 Oil = 140,000 BTU/Gal.

= \$0.40/Gal.

Input, BTU/Hr.	=	<u>@79%</u>	<u>@85.5%</u>
		16,950,000	15,660,819

Input, Gals. Oil/Hr. = 121.0 111.8

Assuming 4000 Hours of Operation/Year at full Output--

121.0 x 4000 x \$0.40 = \$193,600.00/yr. @ 79%

111.8 x 4000 x \$0.40 = 172,220.00/yr.

14,720.00/yr. Savings with CB

	Amortization if	Amortization if	Amortization if
	4000 Hrs./yr	3000 Hrs./yr.	2000 Hrs./yr.

<u>Extra Cost for CB</u>	<u>Operation</u>	<u>Operation</u>	<u>Operation</u>
vs. Alternate #1 = \$6000.00	.4 Years	.5 Years	.8 Years
vs. Alternate #2 = \$10,000.00	.6 Years	.9 Years	1.3 Years

CONCLUSION: First Cost can be deceiving!

Buy the Most Efficient Boiler!

Efficiency vs. Fuel Costs

If you select a boiler because of a lower first cost – and this unit is LESS EFFICIENT than the higher price boiler
– YOU WILL PAY the difference many times over – during the life of that boiler!

NOTE: The percent increase in fuel costs is greater than the nominal percent decrease in fuel-to-steam efficiency!

- e.g. A 3% drop in efficiency increases fuel costs 3.8% (85% vs 82%)
- e.g. A 5% drop in efficiency increases fuel costs 6.3% (85% vs 80%)
- e.g. A 7.5% drop in efficiency increases fuel costs 9.7% (85% vs 77.5%)
- e.g. A 10% drop in efficiency increases fuel costs 13.5% (85% vs 75%)

How is this proven?

A 200 Hp Unit has an output of 6,700,000 BTU/Hr.

Assume No. 6 oil @ 150,000 BTU/Gal.

	Boiler "X"	Boiler "CB"
Fuel-to-Steam Efficiency	= 80%	85%
Output ÷ Effic. = Input	= 8,375,000 BTU/Hr.	7,882,000 BTU/Hr.
Input – gal/Hr.	= 55.8	52.5
55.8/52.5	= 6.3% Increase in fuel usage	
	= 6.3% Increase in fuel costs	
	due to 5% decrease in fuel-to-steam efficiency.	



ENERGY CONSERVATION " PAYS - OFF "

OPERATING FUEL COST COMPARISON: _____ Job Name: _____

Location: _____

Date: _____

BOILER INFORMATION:

(1) Size: _____ BHp; Op. Pressure _____ PSIG; Fuel: No. _____ Oil
: _____ Gas

(2) Operating Hours/Year: _____ Hours at _____ % of Rating

(3) Fuel Cost: Oil _____ ¢/Gal; Gas _____ ¢/Therm

FUEL-TO-STEAM EFFICIENCY:

	No. 2 Oil	No. 6 Oil	Gas
(4) Cleaver-Brooks, Guaranteed	_____ %	_____ %	_____ %
(5) Other Mfgr. (Estimated) (Guaranteed	_____ %	_____ %	_____ %
(6) Savings (Nominal)	_____ %	_____ %	_____ %

COMPARISON:

	No. 2 Oil	No. 6 Oil	Gas
(7) Other Boiler	_____ GPH	_____ GPH	_____ Therms/Hr.
(8) Cleaver-Brooks	_____ GPH	_____ GPH	_____ Therms/Hr.
(9) Savings	_____ GPH	_____ GPH	_____ Therms/Hr.

ANNUAL FUEL SAVINGS WITH CLEAVER-BROOKS:

A) Oil Fuel:

_____ GPH x _____ Hrs./Yr. = _____ Gal./Yr. = Saved!

_____ Gal./Yr. x \$ _____ /Gal. = \$ _____ /Yr. = Saved!

B) Gas Fuel:

_____ Therms/Hr. x _____ Hrs./Yr. = _____ Therms/Yr. = Saved!

_____ Therms/Yr. x \$ _____ /Therm = \$ _____ /Yr. = Saved!

CO₂ TO O₂ CONVERSION CHART

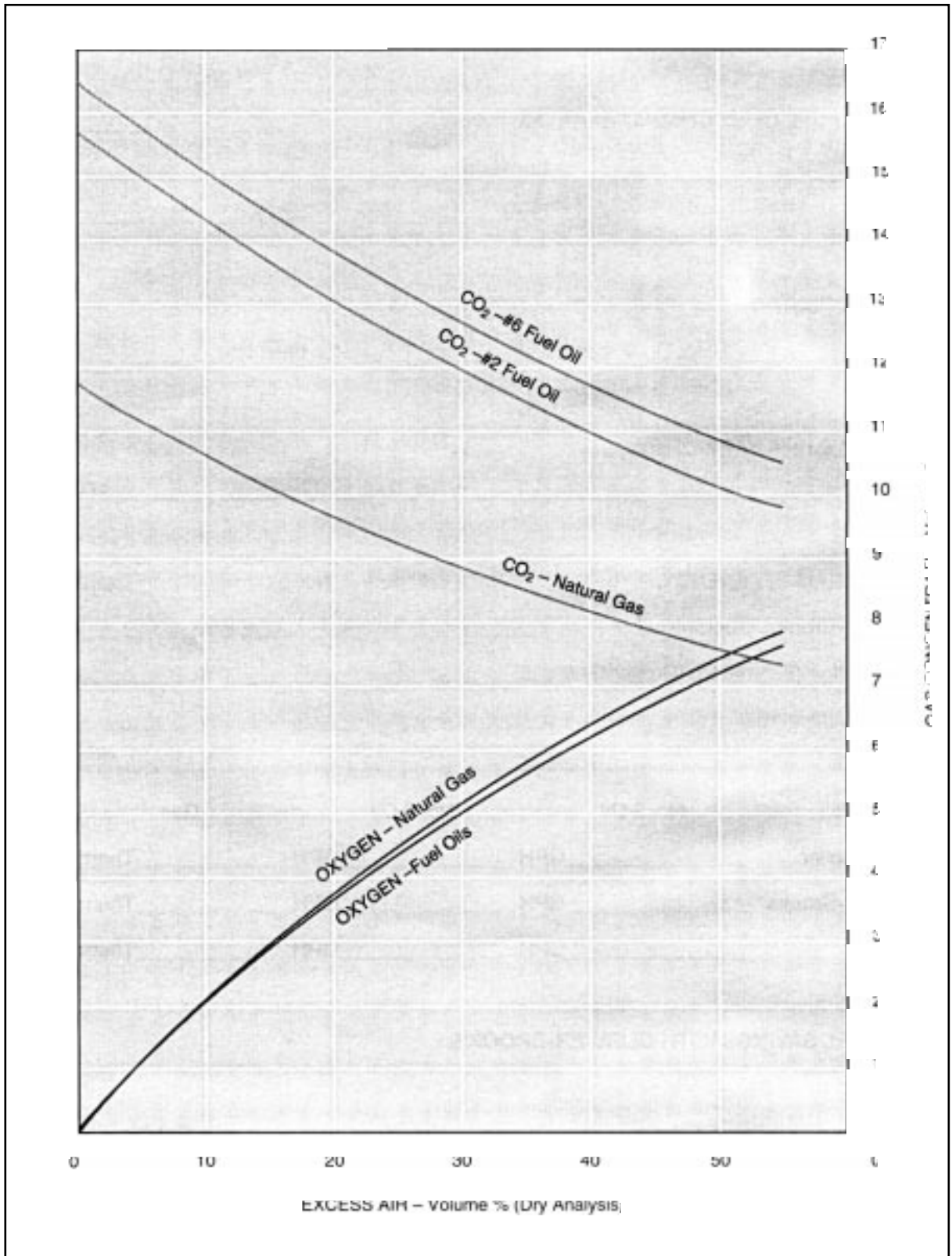


figure 5

STACK LOSS - % - NATURAL GAS

% CO ₂	DIFFERENCE BETWEEN FLUE GAS AND ROOM TEMPERATURES IN DEGREES FAHRENHEIT																																	
	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	750	800	850	900	950	1000		
3.0	23.1	24.4	25.9	27.2	28.6	30.0	31.3	32.8	34.1	35.8	36.9	38.2	39.8	41.0	42.2	43.8	45.0	46.3	47.8	49.0	50.0													
3.5	21.2	22.5	23.8	24.9	26.1	27.2	28.4	29.6	30.9	32.0	33.2	34.4	35.8	36.8	37.9	39.2	40.3	41.6	42.8	43.8	45.0	46.2	47.7	48.3	49.8									
4.0	19.9	20.9	22.0	23.1	24.1	25.1	26.2	27.2	28.3	29.4	30.4	31.8	32.5	33.8	34.8	35.8	36.8	37.8	38.8	39.9	40.9	42.1	43.0	44.1	45.2	46.2	48.8							
4.5	18.9	19.9	20.9	21.8	22.7	23.6	24.5	25.5	26.4	27.3	28.3	29.2	30.2	31.2	32.2	33.0	34.0	34.9	35.9	36.8	37.8	38.6	39.8	40.4	41.5	42.6	44.8	47.2	49.8					
5.0	18.0	18.9	19.8	20.6	21.4	22.2	23.1	24.0	24.9	25.8	26.8	27.5	28.3	29.1	30.1	30.9	31.8	32.5	33.6	34.3	35.7	36.2	36.9	37.8	38.8	39.7	41.8	43.8	46.0	48.2				
5.5	17.4	18.1	18.9	19.8	20.5	21.2	22.1	22.9	23.8	24.5	25.2	26.2	26.9	27.8	28.5	29.2	30.0	30.8	31.8	32.3	33.2	34.1	34.9	35.8	36.3	37.3	39.2	41.0	43.0	45.3	47.2	49.0		
6.0	16.8	17.4	18.2	18.9	19.6	20.4	21.1	21.8	22.7	23.3	24.1	24.9	25.5	26.2	27.0	27.8	28.4	29.2	30.0	30.8	31.5	32.2	32.9	33.8	34.3	35.2	36.8	38.8	40.4	42.5	44.3	46.2		
6.5	16.3	16.9	17.6	18.4	19.0	19.8	20.4	21.1	21.8	22.4	23.2	23.8	24.5	25.2	25.9	26.5	27.2	27.9	28.7	29.2	30.0	30.9	31.4	32.1	32.8	33.5	34.6	36.8	38.4	40.3	42.0	43.8		
7.0	15.8	16.5	17.1	17.8	18.4	19.1	19.8	20.4	21.0	21.8	22.3	22.9	23.6	24.2	24.9	25.5	26.2	26.8	27.4	28.0	28.8	29.4	30.0	30.8	31.2	32.0	33.8	35.3	36.8	38.3	40.0	41.8		
7.5	15.5	16.1	16.7	17.2	17.9	18.5	19.1	19.8	20.3	20.9	21.5	22.2	22.8	23.3	24.0	24.6	25.2	25.8	26.4	26.9	27.7	28.2	28.8	29.4	30.1	30.8	32.2	33.8	35.2	36.8	38.3	39.9		
8.0	15.2	15.7	16.3	16.9	17.4	18.0	18.6	19.2	19.8	20.3	20.9	21.5	22.1	22.8	23.2	23.8	24.4	25.0	25.5	26.0	26.7	27.2	27.8	28.4	29.0	29.5	31.0	32.4	33.8	35.4	36.8	38.2		
8.5	14.9	15.4	15.9	16.5	17.1	17.6	18.2	18.7	19.3	19.8	20.4	20.9	21.4	22.0	22.5	23.1	23.7	24.2	24.8	25.3	25.8	26.4	26.9	27.4	28.1	28.6	29.9	31.3	32.8	34.2	35.4	36.8		
9.0	14.6	15.2	15.7	16.2	16.6	17.2	17.8	18.3	18.8	19.3	19.9	20.4	20.9	21.4	21.9	22.5	23.0	23.5	24.1	24.5	25.2	25.8	26.2	26.7	27.2	27.8	29.0	30.3	31.8	33.0	34.3	35.7		
9.5	14.4	14.9	15.4	15.9	16.4	16.9	17.4	17.9	18.4	18.9	19.5	19.9	20.5	20.9	21.4	21.9	22.4	22.9	23.4	23.8	24.4	24.9	25.4	25.9	26.4	26.9	28.2	29.4	30.8	32.0	33.3	34.5		
10	14.2	14.6	15.2	15.6	16.1	16.6	17.1	17.5	18.1	18.5	19.0	19.5	20.0	20.4	20.8	21.4	21.8	22.4	22.8	23.3	23.8	24.2	24.8	25.2	25.8	26.2	27.4	28.6	29.8	31.2	32.2	33.4		
11		14.4	14.7	15.2	15.6	16.1	16.5	16.9	17.4	17.8	18.4	18.8	19.3	19.6	20.2	20.5	20.9	21.4	21.9	22.3	22.8	23.2	23.7	24.2	24.6	25.0	26.2	27.2	28.3	29.5	30.8	31.8		
12			14.4	14.8	15.2	15.6	16.1	16.5	16.9	17.3	17.8	18.2	18.6	19.0	19.4	19.8	20.2	20.6	21.1	21.4	21.9	22.3	22.8	23.2	23.6	24.0	25.1	26.1	27.2	28.3	29.2	30.3		

table 2

STACK LOSS - % - NO. 2 OIL

% CO ₂	DIFFERENCE BETWEEN FLUE GAS AND ROOM TEMPERATURES IN DEGREES FAHRENHEIT																																	
	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	750	800	850	900	950	1000		
3.0	24.1	25.8	27.7	29.3	31.3	33.9	34.8	36.4	38.2	40.0	42.9	44.8	45.5	47.0	49.0	50.8	52.4	54.3	56.0	57.9	59.6	61.5	63.5	65.0	66.8	68.8								
3.5	21.7	23.1	24.8	26.2	27.8	29.2	31.7	32.5	33.9	35.3	36.9	38.5	40.0	41.7	43.1	44.8	46.1	47.8	49.4	50.9	52.2	53.9	55.7	57.0	58.3	60.0	63.8	67.8						
4.0	19.9	21.2	22.5	24.9	25.2	26.5	27.9	29.2	31.7	32.0	33.3	35.8	36.0	37.3	38.7	40.0	41.4	42.9	44.1	45.5	46.9	48.1	49.8	50.9	52.1	53.8	57.0	60.2	63.9	67.1				
4.5	18.4	19.7	20.8	22.0	23.2	24.4	25.6	26.9	28.0	29.3	30.4	31.8	32.9	34.2	35.6	36.7	37.8	39.0	40.1	41.2	42.5	43.8	45.0	46.3	47.4	48.8	51.8	54.6	57.8	60.9	63.9	66.9		
5.0	17.2	18.5	19.5	20.7	21.7	22.7	23.8	24.9	26.0	27.1	28.2	29.4	30.3	31.5	32.7	33.8	34.9	35.9	36.8	38.0	39.2	40.1	41.7	42.4	43.7	44.7	47.4	50.1	52.9	55.8	58.3	61.2		
5.5	16.3	17.4	18.4	19.4	20.4	21.3	22.3	23.3	24.3	25.4	26.3	27.3	28.4	29.4	30.6	31.4	32.4	33.6	34.5	35.3	36.4	37.4	38.4	39.6	40.3	41.7	44.0	46.5	49.0	51.8	54.1	56.5		
6.0	15.6	16.5	17.4	18.3	19.3	20.4	21.2	22.0	23.0	23.9	24.9	25.8	26.8	27.7	28.6	29.5	30.4	31.4	32.3	33.1	34.2	35.0	36.0	36.9	37.9	38.9	41.0	43.5	45.8	48.0	50.3	52.8		
6.5	14.9	15.7	16.7	17.5	18.4	19.3	20.1	20.9	21.8	22.7	23.6	24.5	25.3	26.1	27.0	27.8	28.8	29.6	30.6	31.3	32.3	33.0	34.1	34.8	35.7	36.5	38.7	40.8	42.9	45.1	47.5	49.7		
7.0	14.4	15.3	16.0	16.8	17.8	18.4	19.3	20.1	20.9	21.7	22.4	23.2	24.1	24.9	25.7	26.5	27.3	28.1	28.9	29.8	30.5	31.4	32.3	33.0	33.8	34.6	36.5	38.6	40.5	42.7	44.7	46.6		
7.5	13.9	14.6	15.4	16.2	16.9	17.7	18.5	19.2	20.1	20.7	21.3	22.2	23.0	23.8	24.5	25.2	26.0	26.8	27.5	28.2	29.0	29.8	30.6	31.3	32.2	32.9	34.8	36.5	38.5	40.3	42.3	44.2		
8.0	13.5	14.3	14.9	15.7	16.3	17.1	17.7	18.5	19.3	20.0	20.7	21.4	22.1	22.8	23.5	24.2	25.0	25.7	26.3	27.0	27.8	28.5	29.2	30.0	30.8	31.5	33.2	35.0	36.8	38.5	40.2	42.1		
8.5	13.2	13.8	14.5	15.2	15.8	16.5	17.3	17.8	18.6	19.3	20.0	20.6	21.3	21.9	22.6	23.3	23.9	24.6	25.3	25.9	26.7	27.3	28.0	28.8	29.4	30.1	31.8	33.5	35.2	36.9	38.7	40.2		
9.0	12.8	13.4	14.1	14.7	15.4	16.0	16.7	17.3	17.9	18.6	19.3	20.0	20.6	21.2	21.8	22.4	23.1	23.8	24.4	25.0	25.7	26.3	27.0	27.7	28.3	28.9	30.5	32.1	33.8	35.3	37.0	38.5		
9.5	12.5	13.2	13.7	14.3	14.9	15.7	16.3	16.8	17.4	18.1	18.6	19.3	19.9	20.5	21.1	21.7	22.4	22.9	23.5	24.1	24.8	25.4	26.0	26.7	27.2	27.9	29.4	31.0	32.5	34.0	35.5	37.2		
10	12.3	12.8	13.4	14.0	14.6	15.2	15.7	16.3	16.9	17.5	18.1	18.7	19.3	20.0	20.5	21.0	21.6	22.2	22.8	23.4	24.0	24.6	25.1	25.8	26.3	27.0	28.3	29.9	31.4	32.9	34.4	35.7		
11	11.8	12.4	12.8	13.4	13.9	14.5	15.0	15.5	16.2	16.7	17.2	17.8	18.3	18.7	19.4	20.0	20.5	20.9	21.5	22.0	22.6	23.1	23.7	24.2	24.8	25.3	26.7	28.0	29.4	31.8	32.1	33.5		
12	11.4	11.8	12.5	12.9	13.4	13.9	14.4	14.9	15.4	15.9	16.4	16.9	17.4	17.9	18.4	18.9	19.5	20.0	20.5	20.9	21.4	22.9	22.4	22.9	23.5	24.0	25.2	26.5	27.8	29.0	30.2	31.7		
13	11.2	11.6	12.1	12.5	12.9	13.4	13.9	14.3	14.7	15.3	15.8	16.3	16.7	17.2	17.7	18.1	18.6	19.1	19.6	20.1	20.5	21.1	21.3	21.8	22.3	22.8	24.0	25.2	26.3	27.5	28.8	30.0		
14		11.3	11.8	12.2	12.6	13.0	13.4	13.8	14.3	14.8	15.3	15.6	16.2	16.5	16.9	17.4	17.8	18.3	18.7	19.2	19.7	20.2	20.6	21.0	21.4	21.8	22.9	24.1	25.2	26.2	27.4	28.6		
15			11.4	11.7	12.4	12.6	13.1	13.5	13.8	14.3	14.8	15.3	15.6	15.9	16.4	16.7	17.3	17.7	18.1	18.4	18.9	19.4	19.8	20.3	20.6	21.0	22.0	23.1	24.2	25.2	26.2	27.3		

table 3

F A C T S

STACK LOSS - % - NO. 6 OIL

% CO ₂	DIFFERENCE BETWEEN FLUE GAS AND ROOM TEMPERATURES IN DEGREES FAHRENHEIT																																
	200	220	240	260	280	300	320	340	360	380	400	420	440	460	480	500	520	540	560	580	600	620	640	660	680	700	750	800	850	900	950	1000	
3.0	24.5	26.5	28.5	30.2	32.2	34.5	36.5	38.2	40.4	42.2	44.4	46.4	48.2	50.0	52.3	54.3	56.3	58.2	60.3	62.0	64.1	66.2	68.1	70.1									
3.5	21.8	23.4	25.2	26.8	28.6	30.4	32.1	33.8	35.5	37.4	39.0	40.6	42.2	44.0	45.6	47.5	49.2	51.0	49.4	50.9	52.2	53.9	55.7	57.0	58.3	60.0	63.8	67.8					
4.0	19.8	21.2	22.8	24.2	25.7	27.3	28.8	30.2	31.6	32.5	34.8	36.3	37.8	39.4	40.8	42.2	43.8	45.1	46.9	48.2	49.8	51.2	52.9	54.2	56.0	57.8	61.1	65.0	68.9				
4.5	18.2	19.4	20.8	22.2	23.5	24.8	26.2	27.4	28.8	30.4	31.5	33.0	34.2	35.4	37.0	38.1	39.4	41.0	42.2	43.5	45.0	46.3	47.9	49.0	50.1	51.9	55.0	58.2	61.8	65.1	68.5		
5.0	16.8	18.0	19.3	20.4	21.7	22.8	23.2	25.3	26.6	27.8	29.0	30.3	31.4	32.6	33.8	35.3	36.2	37.5	38.8	39.8	41.0	42.3	43.8	44.9	46.1	47.5	50.1	53.6	56.3	59.8	62.3	65.8	
5.5	15.8	16.8	18.0	19.2	20.3	21.3	22.5	23.5	24.6	25.8	26.9	28.0	29.2	30.2	31.4	32.5	33.5	34.7	35.8	37.0	37.9	39.2	40.1	41.3	42.3	43.8	46.1	49.1	52.0	54.7	57.8	60.1	
6.0	14.8	15.8	16.9	18.0	19.0	20.0	21.1	22.0	23.1	24.2	25.2	26.3	27.3	28.2	29.3	30.3	31.3	32.3	33.5	34.3	35.3	36.5	37.5	38.3	39.7	40.5	43.0	45.8	48.2	50.9	53.5	56.0	
6.5	14.3	15.2	16.1	17.1	18.0	18.9	19.9	20.8	21.8	22.8	23.7	24.6	25.5	26.5	27.5	28.5	29.4	30.4	31.4	32.3	33.4	34.3	35.1	36.1	37.1	38.0	40.2	42.8	45.1	47.6	49.9	52.1	
7.0	13.5	14.4	15.3	16.2	17.1	17.9	18.8	19.7	20.6	21.5	22.4	23.3	24.2	25.0	25.8	26.8	27.7	28.6	29.0	30.2	31.2	32.2	33.0	33.9	34.9	35.8	37.9	40.1	42.1	44.4	46.8	49.0	
7.5	13.0	13.8	14.6	15.5	16.3	17.3	18.0	18.8	19.7	20.5	21.4	22.2	22.9	23.7	24.6	25.4	26.3	27.2	27.9	28.8	29.6	30.5	31.2	32.1	33.0	34.9	35.9	37.9	40.0	42.0	44.1	46.1	
8.0	12.5	13.3	14.1	14.8	15.7	16.4	17.3	18.0	18.8	19.6	20.4	21.2	21.9	22.7	23.5	24.2	25.0	25.8	26.6	27.4	28.2	29.0	29.9	30.6	31.5	32.1	34.1	36.0	38.0	40.0	41.9	43.9	
8.5	12.2	12.8	13.6	14.4	15.1	15.7	16.6	17.3	18.0	18.7	19.6	20.3	21.0	21.6	22.5	23.3	23.9	24.7	25.5	26.2	26.8	27.6	28.2	29.1	29.9	30.8	32.6	34.2	36.2	38.0	39.9	41.8	
9.0	11.7	12.4	13.2	13.8	14.6	15.3	15.9	16.6	17.4	18.1	18.8	19.5	20.2	20.8	21.6	22.3	22.9	23.7	24.4	25.0	25.7	26.5	27.1	27.9	28.7	29.4	31.1	32.9	34.6	36.3	38.0	39.9	
9.5	11.4	12.1	12.7	13.4	14.1	14.7	15.4	16.0	16.7	17.5	18.1	18.7	19.4	20.0	20.7	21.4	22.1	22.8	23.5	24.0	24.7	25.4	26.1	26.8	27.5	28.1	29.8	31.2	33.2	34.9	36.4	38.1	
10	11.2	11.7	12.3	13.0	13.7	14.4	14.8	15.5	16.2	16.8	17.5	18.2	18.7	19.4	20.0	20.6	21.3	21.9	22.6	23.2	23.8	24.5	25.1	25.8	26.4	27.0	28.7	30.1	31.8	33.5	35.0	36.7	
11	10.6	11.3	11.8	12.4	12.9	13.5	14.2	14.7	15.3	15.8	16.5	17.0	17.6	18.2	18.8	19.4	20.0	20.6	21.2	21.7	22.3	22.9	23.5	24.1	24.8	25.2	26.8	28.1	29.8	31.2	32.5	34.1	
12	10.2	10.7	11.3	11.7	12.3	12.8	13.4	13.8	14.5	15.1	15.6	16.2	16.7	17.2	17.8	18.3	18.8	19.4	19.9	20.4	21.0	21.6	22.1	22.7	23.1	23.8	25.0	26.4	27.9	29.1	30.5	31.9	
13		10.3	10.8	11.3	11.8	12.3	12.8	13.3	13.8	14.4	14.8	15.4	15.8	16.3	16.8	17.3	17.9	18.4	18.9	19.3	19.8	20.4	20.9	21.4	21.9	22.4	23.8	24.9	26.2	27.5	28.9	30.0	
14		9.8	10.4	10.8	11.4	11.8	12.3	12.8	13.3	13.7	14.3	14.7	15.2	15.6	16.2	16.6	17.1	17.5	18.0	18.5	18.8	19.4	19.9	20.4	20.9	21.2	22.5	23.7	24.9	26.1	27.2	28.5	
15			10.2	10.6	11.0	11.4	11.8	12.4	12.7	13.3	13.7	14.2	14.6	15.0	15.4	15.8	16.4	16.8	17.3	17.7	18.2	18.6	19.0	19.5	19.9	20.3	21.5	22.6	23.8	24.9	25.9	27.1	
16				10.3	10.7	11.1	11.5	11.8	12.3	12.8	13.3	13.7	14.0	14.4	14.8	15.3	15.7	16.2	16.6	16.9	17.4	17.9	18.2	18.8	19.1	19.5	20.6	21.6	22.7	23.8	24.8	25.9	

table 4

NATURAL GAS FUEL BURNING RATES (THERMS/HR.) AT VARIOUS EFFICIENCIES

Boiler Size B Hp	Fuel - To - Steam Efficiency																
	60.0	62.5	65.0	67.5	70.0	72.5	75	76	77	78	79	80	81	82	83	84	85
100	55.8	53.6	51.5	49.6	47.9	46.2	44.7	44.1	43.5	43.0	42.4	41.9	41.4	40.9	40.4	39.9	39.4
125	69.8	67.0	64.4	62.0	59.8	57.7	55.8	55.1	54.4	53.7	53.0	52.3	51.7	51.1	50.4	49.8	49.3
150	83.7	80.4	77.3	74.4	71.8	69.3	67.0	66.1	65.2	64.4	63.6	62.8	62.0	61.3	60.5	59.8	59.1
200	111.6	107.2	102.0	99.2	95.7	92.4	89.3	88.1	87.0	85.9	84.8	83.7	82.7	81.8	80.7	79.7	78.8
250	139.5	133.9	128.8	124.0	119.6	115.5	111.6	110.1	108.7	107.3	106.0	104.6	103.4	102.1	100.9	99.7	98.5
300	167.4	160.7	154.5	148.8	143.5	138.6	133.9	132.2	130.5	128.8	127.2	125.5	124.0	122.5	121.0	119.6	118.2
350	195.3	187.5	180.3	173.6	167.4	161.6	156.2	154.2	152.2	150.2	148.3	146.5	144.7	142.9	141.2	139.5	137.9
400	223.2	214.3	206.0	198.4	191.3	184.7	178.6	176.2	173.9	171.7	169.5	167.5	165.3	163.3	161.4	159.4	157.6
500	279.0	267.8	257.5	248.0	239.1	230.9	223.2	220.3	217.4	214.6	211.9	209.3	206.7	204.2	201.7	199.3	197.0
600	334.8	321.4	309.0	297.6	287.0	277.1	267.8	264.3	260.9	257.5	254.3	251.0	248.0	245.0	242.0	239.1	236.3
700	390.6	374.9	360.5	347.2	334.8	323.2	312.5	308.3	304.3	300.4	296.6	293.0	289.3	285.8	282.3	279.0	275.7
800	446.4	428.5	412.0	396.8	382.6	369.4	357.1	352.4	347.8	343.4	339.0	335.0	330.6	326.6	322.7	318.8	315.1

Gas = 1,000 BTU/Gal. $\frac{\text{Output (BTU/Hr)}}{\text{FTSE}} = \text{Input (BTU/Hr)}$ FTSE = Fuel - to - Steam Efficiency $\frac{\text{Input (BTU/Hr)}}{100,000 \text{ BTU/Therm}} = \text{Therms/Hr}$

table 5

NO. 2 OIL FUEL BURNING RATES (GPH) AT VARIOUS EFFICIENCIES

Boiler Size B Hp	Fuel - To - Steam Efficiency																			
	60.0	62.5	65.0	67.5	70.0	72.5	75	76	77	78	79	80	81	82	83	84	85	86	87	88
100	40.0	38.5	37.0	35.5	34.0	33.0	32.0	31.5	31.0	30.5	30.5	30.0	29.5	29.0	29.0	28.5	28.0	28.0	27.5	27.0
125	50.0	48.0	46.0	44.5	42.5	41.0	40.0	39.5	39.0	38.0	37.5	37.0	36.5	36.0	35.5	35.0	35.0	34.5	34.0	34.0
150	60.0	57.5	55.0	53.0	51.0	49.5	48.0	47.0	46.5	46.0	45.5	45.0	44.5	43.5	43.0	42.5	42.0	41.5	41.0	41.0
200	79.5	76.5	73.5	71.0	68.5	66.0	64.0	63.0	62.0	61.5	60.5	60.0	59.0	58.5	57.5	57.0	56.5	55.5	55.0	54.5
250	99.5	95.5	92.0	88.5	85.5	82.5	79.5	78.5	77.5	76.5	75.5	74.5	74.0	73.0	72.0	71.0	70.5	69.5	68.5	68.0
300	119.5	115.0	110.5	106.5	102.5	99.0	95.5	94.5	93.0	92.0	91.0	89.5	88.5	87.5	86.5	85.5	84.5	83.5	82.5	81.5
350	139.5	134.0	129.0	124.0	119.5	115.5	111.5	110.0	108.5	107.5	106.0	104.5	103.5	102.0	101.0	99.5	98.5	97.5	96.0	95.0
400	159.5	153.0	147.0	141.5	136.5	132.0	127.5	126.0	124.0	122.5	121.0	119.5	118.0	116.5	115.0	114.0	112.5	111.0	110.0	108.5
500	199.5	191.5	184.0	177.0	171.0	165.0	159.5	157.5	155.5	153.5	151.5	149.5	147.5	146.0	144.0	142.5	140.5	139.0	137.5	136.0
600	239.0	229.5	220.5	212.5	205.0	198.0	191.5	189.0	186.5	184.0	181.5	179.5	177.0	175.0	173.0	171.0	169.0	167.0	165.0	163.0
700	279.0	268.0	257.5	248.0	239.0	231.0	223.0	220.0	217.5	214.5	212.0	209.0	206.5	204.0	201.5	199.0	197.0	194.5	192.5	190.0
800	319.0	306.0	294.5	283.5	273.5	264.0	255.0	251.5	248.5	245.0	242.0	239.0	236.0	233.5	230.5	227.5	225.0	222.5	220.0	217.5

No. 2 Oil = 140,000 BTU/Gal. $\frac{\text{Output (BTU/Hr)}}{\text{FTSE}} = \text{Input (BTU/Hr)}$ FTSE = Fuel - to - Steam Efficiency $\frac{\text{Input (BTU/Hr)}}{140,000 \text{ BTU/Gal.}} = \text{GPH}$

table 6

NO. 6 OIL FUEL BURNING RATES (GPH) AT VARIOUS

Boiler Size B Hp	Fuel - To - Steam Efficiency																			
	60.0	62.5	65.0	67.5	70.0	72.5	75	76	77	78	79	80	81	82	83	84	85	86	87	88
100	37.0	35.5	34.5	33.0	32.0	31.0	30.0	29.5	29.0	28.5	28.5	28.0	27.5	27.0	27.0	26.5	26.0	26.0	25.5	25.5
125	46.5	44.5	43.0	41.5	40.0	38.5	37.0	36.5	36.0	36.0	35.5	35.0	34.5	34.0	33.5	33.2	33.0	32.5	32.0	31.5
150	56.0	53.5	51.5	49.5	48.0	46.0	44.5	44.0	43.5	43.0	42.5	42.0	41.5	41.0	40.5	40.0	39.5	39.0	38.5	38.0
200	74.5	71.5	68.5	66.0	64.0	61.5	59.5	58.5	58.0	57.0	56.5	56.0	55.0	54.5	54.0	53.0	52.5	52.0	51.5	50.5
250	93.0	89.5	86.0	82.5	79.5	77.0	74.5	73.5	72.5	71.5	70.5	69.5	69.0	68.0	67.0	66.5	65.5	65.0	64.0	63.5
300	111.5	107.0	103.0	99.0	95.5	92.5	89.5	88.0	87.0	86.0	85.0	83.5	82.5	81.5	80.5	79.5	79.0	78.0	77.0	76.0
350	130.0	125.0	120.0	115.5	111.5	107.5	104.0	103.0	101.5	100.0	99.0	97.5	96.5	95.5	94.0	93.0	92.0	91.0	90.0	89.0
400	149.0	143.0	137.5	132.5	127.5	123.0	119.0	117.5	116.0	114.5	113.0	111.5	110.0	109.0	107.5	106.5	105.0	104.0	102.5	101.5
500	186.0	178.5	171.5	165.5	159.5	154.0	149.0	147.0	145.0	143.0	141.0	139.5	138.0	136.0	134.5	133.0	131.5	130.0	128.5	127.0
600	223.0	214.0	206.0	198.5	191.5	184.5	178.5	176.0	174.0	171.5	169.5	167.5	165.5	163.5	161.5	159.5	157.5	155.5	154.0	152.0
700	260.5	250.0	240.5	231.5	223.0	215.5	208.5	205.5	203.0	200.5	198.0	195.5	193.0	190.5	188.0	186.0	184.0	181.5	179.5	177.5
800	297.5	285.0	274.5	264.5	255.0	246.5	238.0	235.0	232.0	229.0	226.0	223.0	220.5	217.5	215.0	212.5	210.0	207.5	205.0	203.0

No. 6 Oil = 150,000 BTU/Gal. $\frac{\text{Output (BTU/Hr)}}{\text{FTSE}} = \text{Input (BTU/Hr)}$ FTSE = Fuel - to - Steam Efficiency $\frac{\text{Input (BTU/Hr)}}{150,000 \text{ BTU/Gal.}} = \text{GPH}$

table 7

**GUARANTEED FUEL-TO-STEAM EFFICIENCIES
NATURAL GAS**

BOILER SIZE	OPERATING PRESSURE = 10 psi				OPERATING PRESSURE = 125 psi			
	% OF LOAD				% OF LOAD			
	25%	50%	75%	100%	25%	50%	75%	100%
100	84.4	85.0	84.8	84.4	81.5	82.4	82.3	82.2
125	83.3	83.6	83.4	83.2	80.4	80.9	81.0	81.0
150	84.4	84.6	84.5	84.3	81.5	82.0	82.0	82.1
200	85.0	85.3	85.1	84.9	82.2	82.7	82.7	82.7
250	85.0	84.7	84.0	83.3	82.0	82.0	81.6	81.3
300	85.3	85.3	84.6	83.9	82.6	82.7	82.2	81.9
350	85.3	85.7	85.2	84.5	82.6	83.2	82.8	82.5
400	84.5	84.7	84.6	84.4	81.8	82.2	82.4	82.2
500	85.5	85.7	85.5	85.2	82.8	83.2	83.3	83.1
600	85.7	86.0	85.8	85.6	82.9	83.5	83.6	83.5
700	85.7	86.2	86.0	85.7	83.0	83.6	83.6	83.6
800	85.8	86.1	85.9	85.6	83.1	83.6	83.7	83.5

table 8

* See notes.

**GUARANTEED FUEL-TO-STEAM EFFICIENCIES
NO. 2 OIL**

BOILER SIZE	OPERATING PRESSURE = 10 psi				OPERATING PRESSURE = 125 psi			
	% OF LOAD				% OF LOAD			
	25%	50%	75%	100%	25%	50%	75%	100%
100	87.8	88.4	88.1	87.7	84.8	85.7	85.6	85.5
125	86.7	86.9	86.7	86.6	83.7	84.2	84.3	84.3
150	87.8	88.0	87.8	87.6	84.8	85.3	85.3	85.4
200	88.4	88.7	88.4	88.2	85.6	86.0	86.0	86.0
250	88.3	88.1	87.4	86.7	85.3	85.3	84.9	84.7
300	88.6	88.7	88.0	87.3	85.9	86.0	85.5	85.2
350	88.6	89.0	88.5	87.8	85.9	86.6	86.1	85.8
400	87.9	88.1	87.9	87.6	85.1	85.5	85.6	85.5
500	88.9	89.0	88.9	88.6	86.1	86.5	86.6	86.4
600	89.0	89.4	89.2	89.0	86.2	86.8	86.9	86.8
700	89.1	89.5	89.3	89.1	86.3	86.9	87.0	86.9
800	89.2	89.5	89.3	89.0	86.4	86.9	87.0	86.8

table 9

* See notes.

**GUARANTEED FUEL-TO-STEAM EFFICIENCIES
NO. 6 OIL**

BOILER SIZE	OPERATING PRESSURE = 10 psi				OPERATING PRESSURE = 125 psi			
	% OF LOAD				% OF LOAD			
	25%	50%	75%	100%	25%	50%	75%	100%
100	88.2	88.5	88.3	88.0	84.6	85.8	85.9	85.8
125	87.2	87.4	87.2	87.0	84.1	84.6	84.7	84.8
150	88.4	88.5	88.3	88.1	85.3	85.8	85.8	85.8
200	88.9	89.2	88.9	88.7	86.0	86.5	86.4	86.5
250	88.8	88.5	87.8	87.1	85.8	85.7	85.3	85.0
300	89.1	89.2	88.4	87.7	86.3	86.4	86.0	85.6
350	89.1	89.5	89.0	88.4	86.4	87.0	86.6	86.2
400	88.4	88.5	88.4	88.1	85.5	85.9	86.0	85.9
500	89.4	89.5	89.3	89.2	86.5	86.9	87.0	86.9
600	89.5	89.9	89.7	89.4	86.7	87.3	87.4	87.2
700	89.6	90.0	89.8	89.6	86.8	87.3	87.4	87.4
800	89.7	90.0	89.8	89.5	86.9	87.4	87.5	87.3

table 10

* See notes.

NOTES:

1. Efficiencies Based on the Following Fuel Analysis

Natural Gas:

Carbon, % (wt) = 68.98
Hydrogen, % (wt) = 22.31
Sulfur, % (wt) = 0.0
Heating Value, Btu/lb = 21,830

No. 2 Oil:

Carbon, % (wt) = 85.8
Hydrogen, % (wt) = 12.7
Sulfur, % (wt) = 0.2
Heating Value, Btu/lb = 19,420

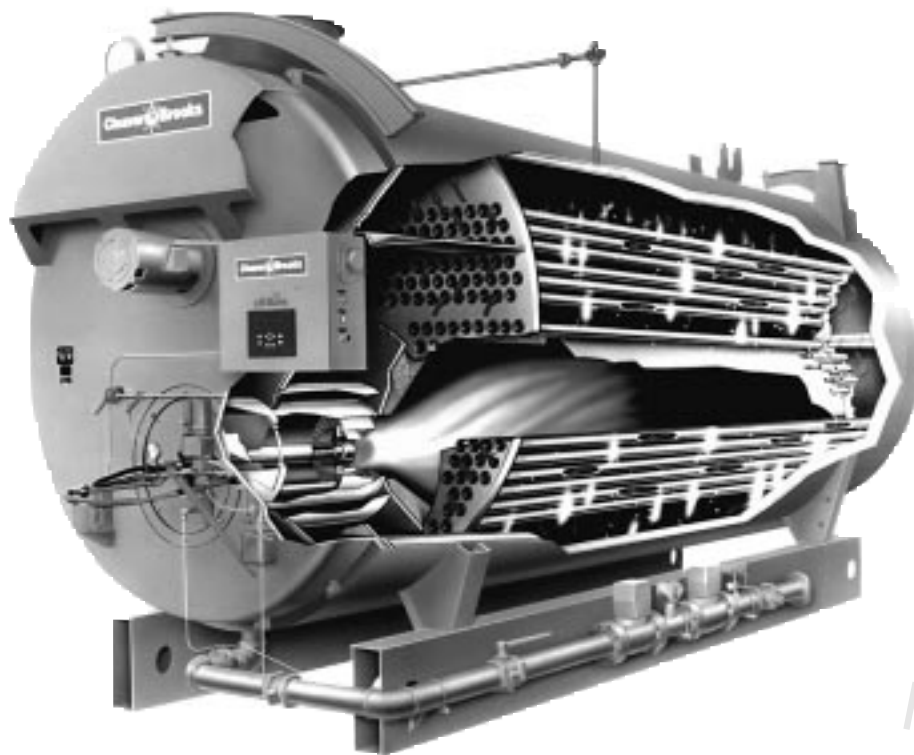
No. 6 Oil:

Carbon, % (wt) = 86.6
Hydrogen, % (wt) = 10.9
Sulfur, % (wt) = 2.09
Heating Value, Btu/lb = 18,330

2. Efficiencies based on ambient air temperature of 80° F, relative humidity of 30%, and 15% excess air in the exhaust.

3. Efficiencies include radiation and convection losses as indicated in table 1.

4. Any efficiency verification testing will be based on the stack loss method.



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