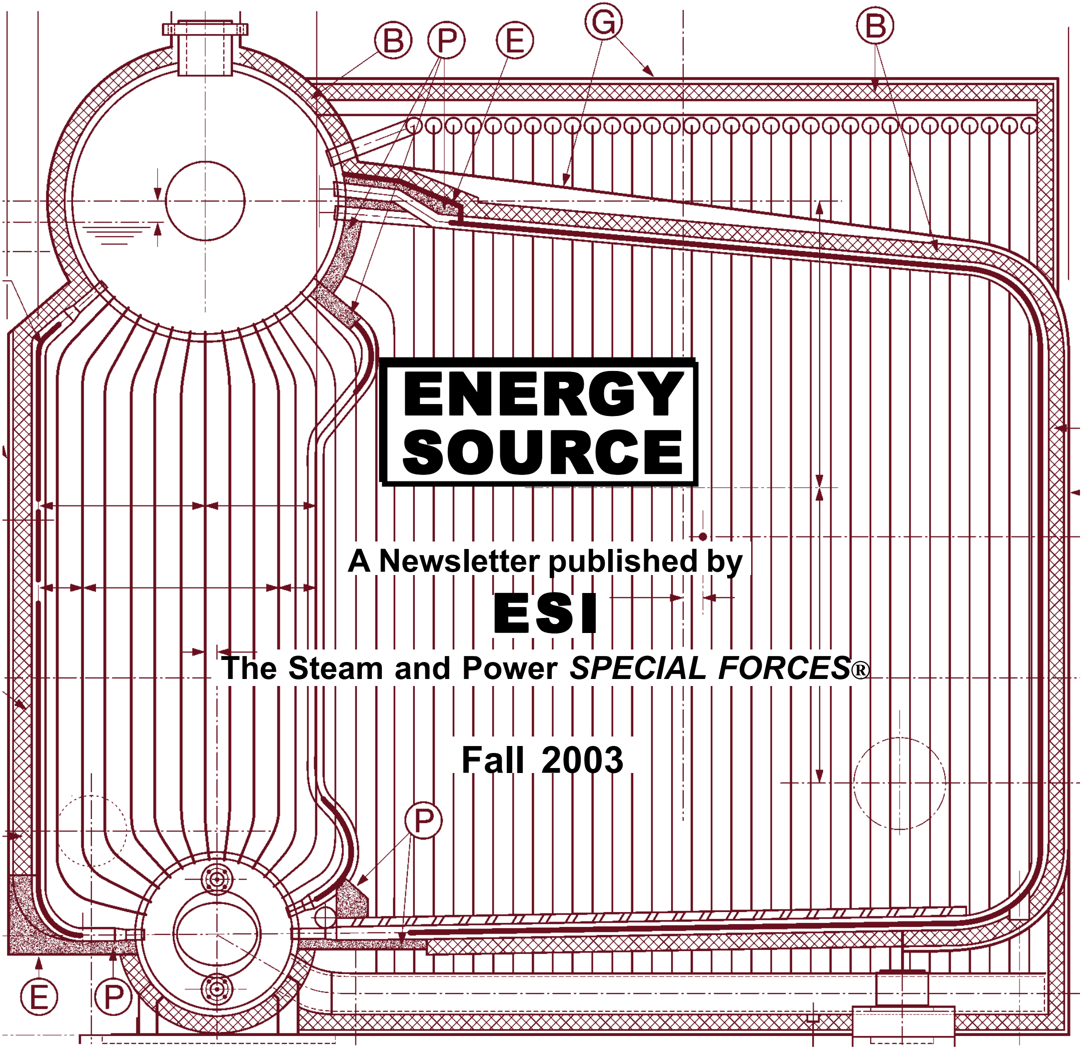

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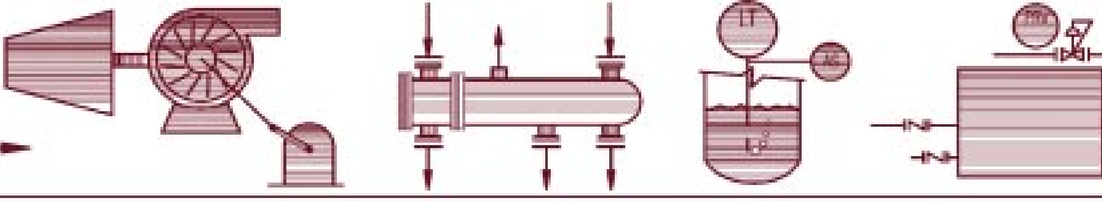

THE BUYER'S GUIDE TO PACKAGE BOILER DESIGN

By: William L. Reeves, P.E., President, ESI

Editor's Note: "The Buyer's Guide To Package Boiler Design" continues with a discussion regarding the factors that really determine boiler operating efficiency. This series of articles is focused on the critical items one should consider when purchasing a new package boiler. Please see our Spring and Summer 2003 Issues of the ENERGY SOURCE for the first two articles in this series.

The actual determination and verification of boiler efficiency is a relatively simple principle. In order to understand or challenge the claims often made by sales representatives, one needs to understand the basic parameters that make up boiler efficiency. Boiler efficiency is simply a measure of the ratio of input versus output or how much of the energy you put into a boiler comes out in the useful steam produced. The input is a measure of how much fuel goes into the burner per hour in terms of millions of btus. The output is a measure of the total pounds of steam produced per hour multiplied by the enthalpy (btu) rise in that pound of steam that actually started out as water.

In a package boiler firing natural gas or oil, assuming that the ambient conditions are the same for each boiler considered, there are simply only five factors that affect boiler efficiency. They are as follows:

- Combustion efficiency
- Burner excess air
- Stack flue gas temperature
- Blowdown rate
- Radiation losses

If a sales representative is claiming that his unit is more efficient than the competition, he should be able to demonstrate how his equipment gains a decided advantage in one of these areas.

Combustion Efficiency

When a fuel is burned, all the hydrocarbons in the fuel should be burned to completion forming carbon dioxide and water vapor. The combustion reaction equation for natural gas is as follows:

$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$

Combustion efficiency is a measure of what percentage of the hydrocarbons in the fuel is actually converted completely to carbon dioxide and water. Any incomplete combustion results in carbon monoxide (CO) or other forms of carbon emissions such as soot. If the CO or soot is allowed to exit the boiler without being completely burned to form carbon dioxide and water vapor, energy is lost. Complete combustion of the CO and carbon releases additional heat that can be absorbed in the steam produced.

ENERGY SOURCE

The *ENERGY SOURCE* is published quarterly for customers, employees, and friends of ESI Inc. of Tennessee.

ESI is the Steam and Power *SPECIAL FORCES®* providing clients with innovative, cost-effective, and environmentally-friendly solutions.

If you have any suggestions or comments about the newsletter feel free to call us at 770-427-6200 or e-mail us at energysource@esitenn.com.

Deanna White
Managing Editor

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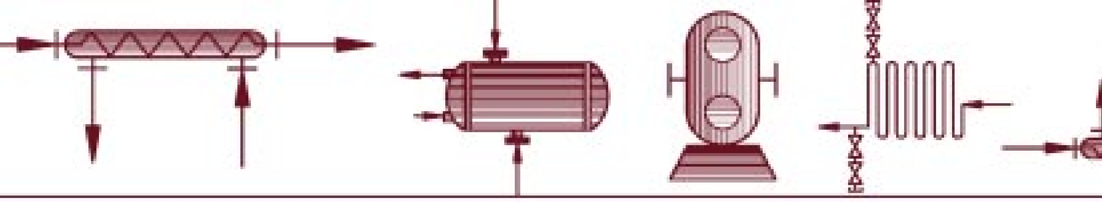

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Modern environmental regulations have caused a basic conflict in the operation of natural gas and oil-fired burners. Within reason, higher available excess oxygen in the combustion region results in a hotter flame temperature. These two factors together result in better combustion efficiency reducing CO formation; however, they also promote the formation of nitrogen oxides (NO_x). NO_x is an undesirable emission that, combined with hydrocarbon emissions in the air, form photochemical smog and consequently, is highly regulated and controlled. CO is also an undesirable emission that is regulated and controlled. Therefore, the basic dilemma is that burner technology performance can be a compromise between CO and NO_x emissions formation; i.e., a compromise of combustion efficiency versus NO_x emissions.

Combustion efficiency is generally dependent upon the burner and usually has little to do with the boiler unless the furnace geometry prevents completion of the combustion process. Generally, a boiler manufacturer proposal will not consider efficiency losses due to incomplete combustion to be significant because of the assumption that the burner will be tuned properly to achieve good combustion. Minor losses are accounted for in the manufacturer's margin when guaranteeing overall boiler efficiency. Carbon loss and combustion efficiency penalties are generally much more significant factors in solid fuel-fired boilers.

Burner Excess Air

Burner excess air is one of the most influential factors on boiler efficiency. When burning a fuel to completion, the actual quantity of air that is required to supply the theoretical amount of oxygen for complete combustion is referred to as Theoretical Air. Any amount of air above this Theoretical Air requirement is referred to as excess air. Excess air is necessary because in the burning process, there is a limited time available for the molecules of fuel and oxygen to find each other in a high enough temperature zone to achieve complete combustion.

When air is introduced into a boiler, 79% of the air is nitrogen that is heated up from ambient temperature. The energy left in this nitrogen and any extra oxygen when it exits the stack is referred to as dry gas loss. Any excess air above that required to achieve complete combustion results in decreased boiler efficiency from this additional dry gas loss.

The typical excess air requirement for most modern burners from about half load up to full capacity is approximately 15%. A figure of 15% excess air (115% Theoretical Air) corresponds to an oxygen content in the flue gas of approximately 3%.

Stack Flue Gas Temperature

The boiler stack flue gas temperature is reduced by extracting useful heat from the flue gas before it leaves the boiler system. This is typically done through the use of an air heater or economizer by preheating the combustion air or feedwater, respectively. Economizers rather than air heaters are the heat trap of choice in today's package boiler designs because they are more cost effective and cold air is preferred for low NO_x burner operations. A rough order of magnitude is for every 40ºF decrease in the economizer exit flue gas temperature, the boiler efficiency is increased by 1%. Therefore, you can see how critical the exit flue gas temperature is toward affecting boiler efficiency.

Theoretically, it makes sense to reduce the flue gas temperature as low as physically possible to improve efficiency. Practically, a boiler system should be designed to extract most of the useful heat from the flue gas stream to the point where (1) the additional heat to be recovered is too expensive because of the capital cost requirements of the heat exchange device, or (2) potential corrosion problems are created with low flue gas temperature condensation.

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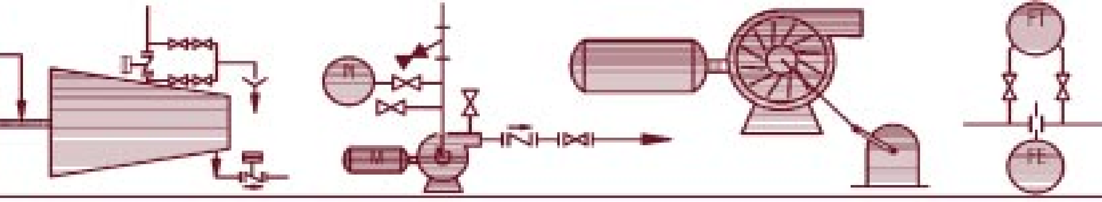

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A good target economizer exit flue gas temperature firing natural gas is between 300-325ºF, depending upon the boiler operating pressure. The design exit flue gas temperature when firing oil is typically around 350ºF to avoid cold end corrosion problems in the economizer associated with the sulfur content of the fuel oil.

Blowdown Rate

The make-up water chemistry and type of water treatment system, combined with the operating pressure of the boiler will dictate the blowdown rate for every boiler installation. The heat losses attributable to the continuous blowdown can be substantially reduced through the use of a blowdown heat recovery system that preheats make-up water to the deaerator by recovering heat in the continuous blowdown stream. Consequently, the heat losses and subsequent boiler system efficiency losses attributable to the boiler blowdown are identical for any boiler manufacturer or design.

Assuming a typical water analysis with sodium zeolite water softeners used for water treatment in a low pressure boiler operation, the continuous blowdown rate is generally around 5% of the total steam flow. With no continuous blowdown heat recovery and a 100,000 pph boiler operating at 150 psig saturated, the blowdown heat loss is about 0.71 mmbtu/hr or about 0.6% of the total heat input.

Radiation Losses

When a boiler is operating, there are parts of the boiler external surfaces that are hot to the touch. Any surface that is above the ambient temperature radiates heat to the surrounding air and other fixtures. This heat loss from radiation results in a decrease in boiler operating efficiency. Typically, the heat loss from radiation of a package boiler operating at full-rated capacity is about 0.50 to 0.80% of the total heat input. There may be slight differences in radiation losses between manufacturers due to the insulation thickness.

Summary

The table below demonstrates the effect of the different parameters discussed herein on boiler efficiency. The data was generated for a 100,000 pph boiler operating at standard ambient conditions with feedwater at 228ºF. The first column is the baseline data. The other columns demonstrate the effect on boiler efficiency by each of the variables discussed. Since this data assumes natural gas firing, all results assume 100% combustion efficiency; i.e., no efficiency loss due to incomplete combustion.

Parameter	Base Case	Change Excess Air	Change Exit Gas Temperature	Change Blowdown
Excess Air (%)	15	**25**	15	15
Exit Gas Temperature (°F)	325	325	**375**	325
Blowdown (%)	0	0	0	**5**
Dry Gas Loss (%)	4.56	4.98	5.51	4.56
H_2O In Fuel Loss (%)	10.73	10.73	10.95	10.73
H_2O In Air Loss (%)	0.13	0.14	0.15	0.13
Radiation Loss (%)	0.76	0.76	0.76	0.76
Blowdown Loss (%)	0	0	0	0.58
Manufacturer Margin (%)	1.00	1.00	1.00	1.00
Boiler Efficiency (%)	82.82	82.39	81.63	82.24

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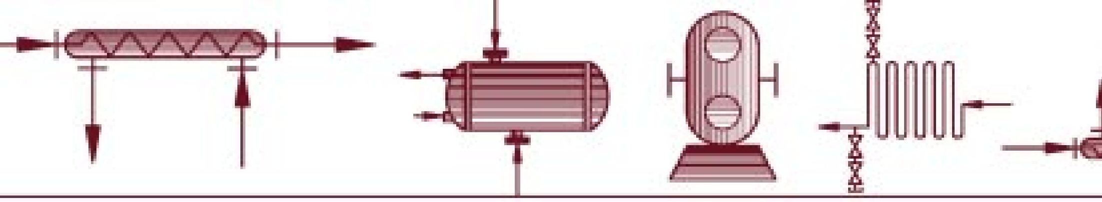


New Demineralization Plant Experiences Unexpected Problems During Start-Up

By: Mitch Mason, Mechanical Engineer, ESI

Editor's Note: ESI was the Engineer for a New 1300 GPM Demineralization System for Cognis Corporation in Cincinnati, Ohio. Please see the Summer 2000 Issue of the ENERGY SOURCE for additional information about this system. This article discusses an unexpected problem Cognis experienced during start-up of the system.

Due to the timing associated with integrating this new water treatment system with other plant activities, the system was hydrotested with firewater and start-up did not commence for about seven months thereafter. After hydrotesting, the system was not drained due to uncertainty with the start-up schedule. Within an hour after placing the new demineralization plant on-line to the boilers, multiple weld leaks in the demineralization water piping prompted a shutdown of the new system. A metallurgical investigation ensued immediately. The cause of the leaks was identified as microbiologically influenced corrosion (MIC) of the stainless steel welds. In laymans terms, bacteria attached to the stainless steel welds, and byproducts of their metabolism caused localized corrosion. The bacteria came from the firewater that was used for hydrotesting the piping. The firewater remaining in the pipes for seven months allowed the bacteria to flourish.

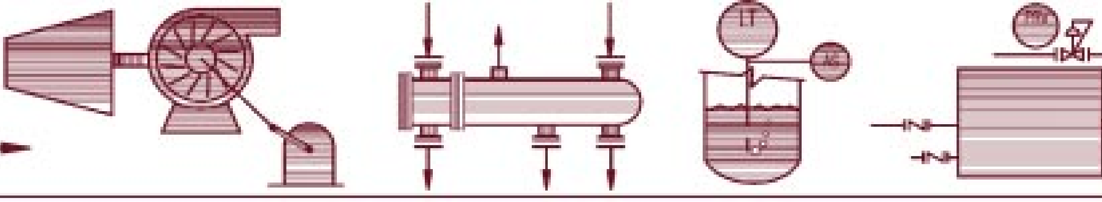
Approximately 100 welds were ground out and rewelded to remove all the contaminated regions of the piping. The smaller pipe systems (3" and 6") were replaced completely due to the large number of welded fittings and due to the fact that some attack was seen on the longitudinal factory seam weld of these pipes. Luckily, the 8" distribution headers, which account for most of the piping, did not require complete replacement because the seam welds were not affected. In these pipes, each weld was cut out and replaced with a 2-foot long dutchman. Chemical treatment of the system was not required because once demineralized water was circulated through the system it was enough to kill the remaining bacteria in the system.

This unexpected problem cost Cognis three weeks to their schedule and approximately $185,000 to effect repairs. Apparently, MIC is a common but not widely publicized phenomenon. If you are interested in additional information about MIC, visit the Nickel Development Institute web site @ www.nidi.org and search their technical pages for the article titled “Stainless steel for potable water treatment plants (PWTP) – Guidelines”. This article recommends the following operations and maintenance practices to avoid MIC:

- Drain promptly and blow-dry after hydrostatic testing or when the system is placed in extended standby. Alternately, circulate water if draining is not possible.
- Place in service within a few days after hydrostatic testing and provide for prompt draining should the system be placed in standby at some future date.
- Slope horizontal runs sufficiently so they will drain without leaving water between support points.

It is our hope that the information presented in this article will save another company from making the same mistake. Please feel free to contact Deanna White with ESI at 770-427-6200 or info@esitenn.com if you have any questions or comments.

Visit us on-line at www.esitenn.com



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One can see from this table that boiler efficiency is primarily affected by two operating variables, excess air and economizer exit gas temperature. After the boiler system is designed and installed, unless the economizer surface becomes dirty from firing oil and requires sootblowing, there is no practical way to reduce economizer exit gas temperature. Therefore, it really comes down to good combustion and excess air.

There is no magic formula to boiler efficiency. If properly designed, ultimately it comes down to the burner and combustion control system being designed and capable of operating the boiler and burner under all conditions, finding the optimum point that results in complete combustion and the lowest possible excess air.

Look for our Winter 2004 issue of the *ENERGY SOURCE* where we will discuss the current state of burner technology and typical emissions when firing natural gas or fuel oil.

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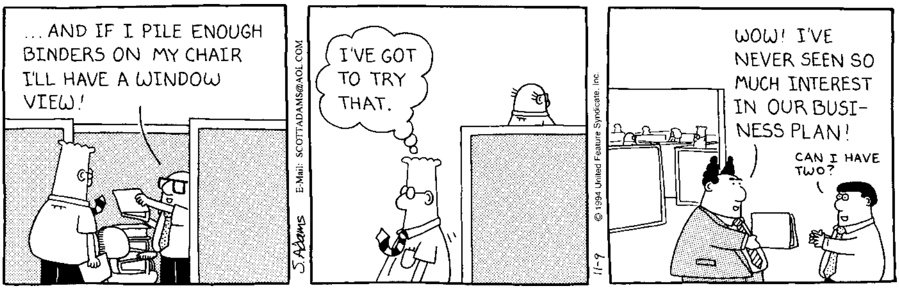

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