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Report on Comparison of Natural Draft Burner Systems
Ship Shoal 207-A
Production Platform
Offshore Gulf of Mexico

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Comparison of Burner Systems on the Steam Generator at SS 207A

Introduction

The Steam Generator at SS 207A is equipped with two different burner systems. One system is a conventional unit equipped with a burner and pilot. The other is a system incorporating air control valves that monitors and responds automatically to the fuel demand to maintain the secondary air in the combustion chamber at a low percentage (2-5%). For purposes of this report the conventional burner will be designated CB, while the automatic air control burner system will be designated ASAC.

Combustion Basics

The steam generator relies on twin natural draft firetubes to supply heat to the process. Natural draft firetubes typically use low-pressure, partial pre-mix burners in which part of the air required for combustion, the primary air, is drawn into the burner and mixed with the fuel prior to reaching the flame at the burner tip. Secondary air is drawn around the burner through the firetube by stack draft and mixed with the fuel at the flame. Any secondary air not required for combustion is excess air.

The exact amount of primary and secondary air required to provide the oxygen needed to burn a fuel is called the theoretical or stoichiometric air. Ideal combustion at this level would yield an exhaust gas with no oxygen or combustibles. In practice, some additional air (excess air) must be added to compensate for inefficiencies in mixing and to insure complete combustion.

Excess air decreases combustion efficiency in two ways;

- The sensible heat used to warm the excess air to exhaust gas temperature is lost out the stack.
- Increased excess air lowers the flame temperature. Excess air of only 16.2% (3.4% excess oxygen) lowers the flame temperature 262 degrees, thus reducing the temperature difference between the flame and the process so that less heat is transferred per unit area of firetube. Figure 1 illustrates the effect of excess air on overall efficiency.

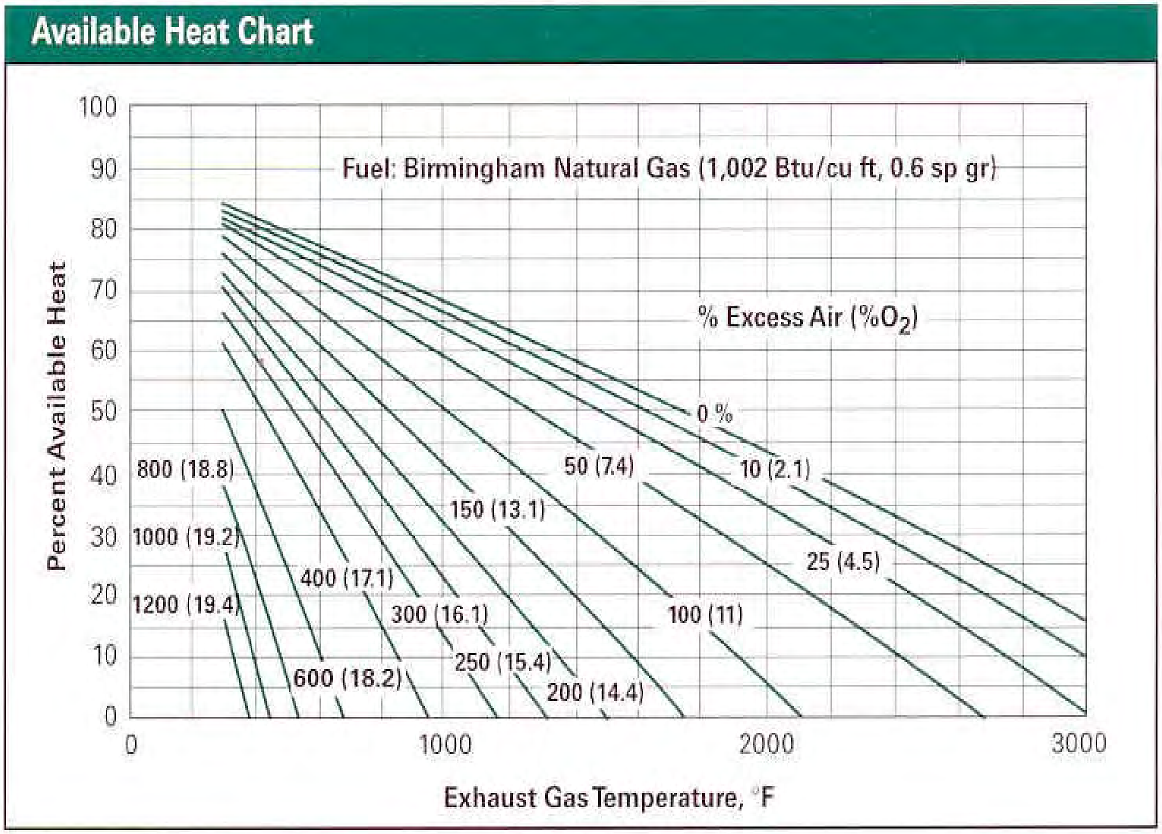


Figure 1: Source: Process Heat Tip Sheet #2, U.S. Department of Energy, DOE/GO-102002-1552.

Typically, firetubes with uncontrolled secondary air, such as the conventional burner system, CB, operate with stack exhaust gas temperatures of 600 to 1100 degrees and excess air of 100 to 600 percent depending on the process loads and the diameter of the firetube. This operating envelope covers efficiencies ranging from 60% to less than 10%, with large diameter firetubes tending to the low end of the efficiency range.

Field performance tests have been conducted on various sizes and types of equipment to determine typical combustion efficiencies. Large diameter firetubes generally exhibit lower efficiencies than small diameter firetubes. This is because a large firetube has the ability to draw excess air (due to stack draft) in proportion to its crossectional area (a function of its diameter squared), whereas the ability to deliver energy from the firetube to the process is in proportion to the surface area (a function of the diameter). Therefore large firetubes are able to draw huge quantities of excess air and, if left uncontrolled, are prone to low efficiencies. Field tests of large firetubes have yielded combustion efficiencies ranging from 8 to 60 percent depending on operating mode and service. Generally, an efficiency of 25 to 35% is normal for large diameter firetubes, while small firetubes may exhibit an efficiency of 50% or more.

The temperature of the exhaust gases in the stack is indicative of the energy wasted by inefficient combustion. Any heat contained in the exhaust gases is not used in heating the process, and cooling the exhaust gases is a primary goal in attaining increased efficiency. The best way to cool the stack temperature and to increase efficiency is by controlling the secondary air in a narrow band of about 10 to 25% (2.1 to 4.5% excess oxygen). Reducing the excess air will cool the exhaust gases to about 500 to 600 degrees and increase the overall efficiency to 75 to 80% (higher heating value basis) as illustrated in Figure 1.

In addition to operating with uncontrolled secondary air, many firetubes operate in off-on (snap acting) mode. During the off cycle, the stack continues to draft ambient air into the firetube, thereby acting as a negative heat exchanger to the process. Large quantities of heat are lost from the process during the off cycle. Equipment designed with multiple firetubes, such as the steam generator at SS 207A, suffer this negative effect if one or more of the firetubes is idle. Therefore, control of the flow of air into the combustion chamber while the firetube is idle is also an important objective in attaining the highest efficiency for a natural draft firetube.

Description of the ASAC Burner System

The ASAC is designed to regulate the secondary air in proportion to the burner fuel pressure. The ASAC is designed with an interior baffle in the flame arrestor housing to separate the combustion chamber from the air intake section of the flame arrestor housing. Air control valves are mounted on the baffle. The ASAC uses pressure from the burner fuel manifold to operate the air control valves to regulate the amount of excess air flowing into the combustion chamber. The air valves are adjustable to compensate for fuel composition and altitude. The system is designed to maintain the excess oxygen in a narrow band across the entire firing range of the burner. Primary air is controlled by use of a partial pre-mix venturi type burner. The ASAC eliminates the negative heat exchange effect associated with idle firetubes by preventing air flow through the firetube by closing the air control valves if the firetube is idle.

Operations at SS 207A

The steam generator at SS 207A supplies heat to the oil treater and fuel gas preheater. Oil production at SS 207A is generally in the range of 3000 to 3500 barrels of oil per day, and the fuel gas requirements for the entire platform are generally in the range of 500 to 550 Mscfd. This report will review the production of October 4 and October 5, 2004 to determine the effect of using the ASAC.

Table 1

Measured Parameter	**October 4 (ASAC)**	**October 5 (CB)**
Oil production, barrels per day	3248	3272
Water production, barrels per day (1)	10	262
Oil gravity, degrees API	33.6	33.4
Temperature of fluid entering the treater, degrees F	103	110
Treater temperature, degrees F	128	125
Platform fuel gas flow rate, Mscfd	568	562
Fuel gas gravity, air = 1.0 (2)	0.604	0.604
Fuel gas heat content, BTU per scf, net dry (2)	1070.5	1070.5
Gas temperature upstream of fuel gas preheater and pressure control valve, degrees F	97	98
Temperature of gas after preheater and pressure reduction, degrees F	92	95
Pressure drop across fuel gas control valve, psi	956	940

(1) Water production determined by shake out method of fluids entering the treater.
(2) Determined from gas analysis.

Determination of Process Duties

The information from Table 1 may be used to determine the process duty requirements for each day.

Heat required for oil:

Qo = m * Cp * dT where

> m = mass of oil, pounds per day
> Cp = heat capacity of oil, BTU per (pound * degree F)
> dT = temperature rise across the treater, degrees F
>
> The mass of oil is determined from the flow rate and the API gravity. The heat capacity is assumed constant at 0.482 BTU per (pound * degree F).

Heat required for water can be similarly determined using a density of 68.6 pounds per cubic foot (salt water) and a heat capacity of 1.0. It should be noted that the water production indicated for October 4 is surprisingly low. As the water content was determined by a shake out of the fluids entering the treater, the accuracy of this value (and the accuracy of the October 5 reading) may be questioned. However, inaccuracies in the values used (10 BBL per day for October 4 and 262 BBL per day for October 5) do not invalidate the overall conclusions. The values used result in conservative estimates of the ASAC efficiency as the values tend to depress the efficiency calculations for the ASAC.

The heat required for the platform fuel gas is more complicated as a pressure reduction is taken from 1070 psig to 120 psig. An equation of state, or an enthalpy chart can be used to determine the heat required for the fuel gas.

On the basis of the preceding discussion, the duties required by the treater and the fuel gas preheater for October 4 and 5 are tabulated below.

Calculated Duties	**October 4 (ASAC)**	**October 5 (CB)**
Duty required to heat oil, MBTU per day	11,752	7112
Duty required to heat water, MBTU per day	94	1513
Duty required to heat platform fuel gas, MBTU per day	710	689
Total calculated duty for all production, MBTU per day	12,556	9314

The steam generator has a design capacity of 8 MM BTU per hour (4 MM BTU per hour per firetube). Only one firetube was operated at a time. Therefore, the steam generator was operating in the range of about 10 to 13% of design capacity.

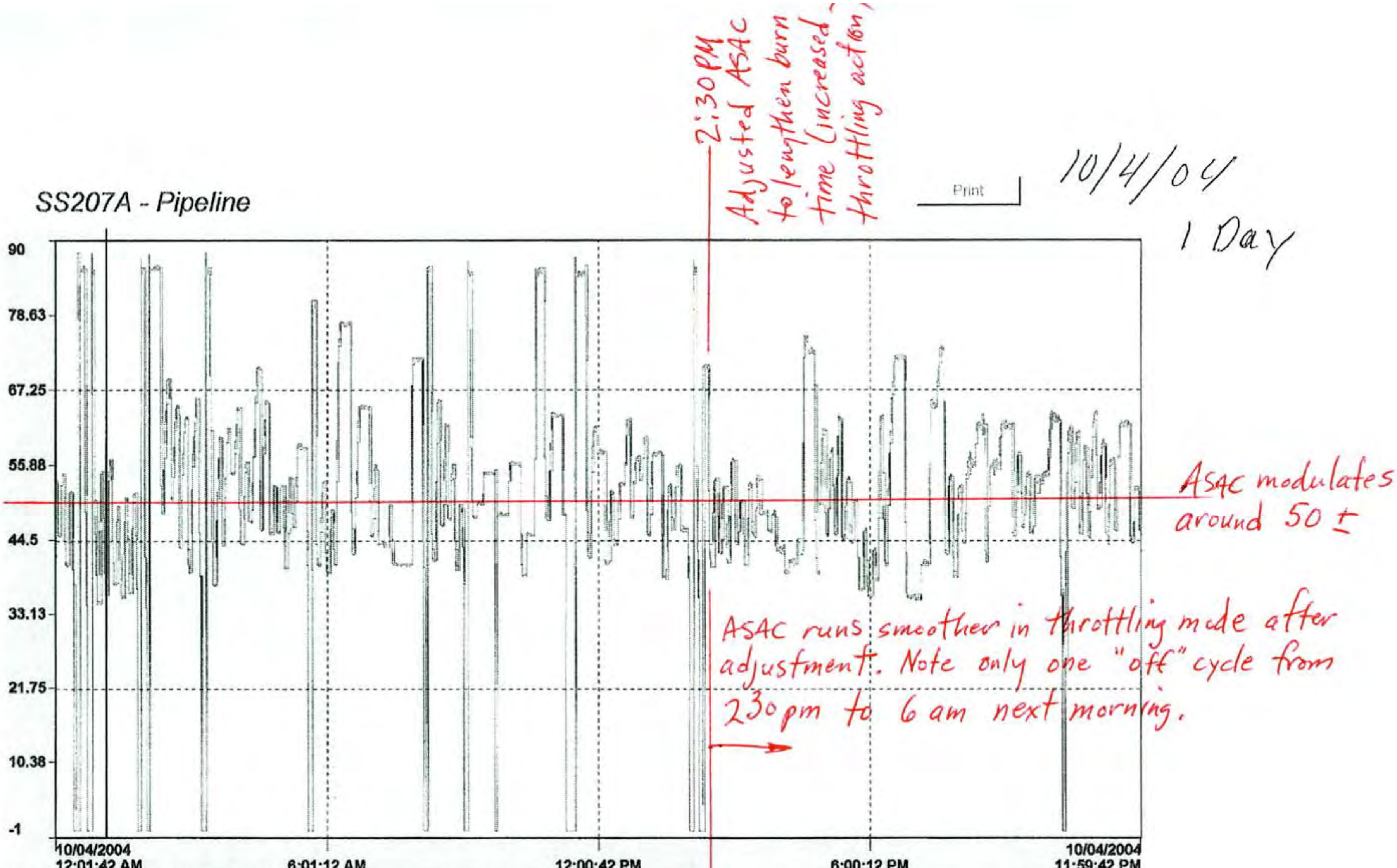
Burner Performance

The fuel used to fire the burners was tracked and accumulated daily by use of a 1” orifice meter with 0.375” orifice and Rosemount differential pressure transmitter reporting to the platform SCADA system. The orifice calculation to determine flow rate is well known and will not be discussed here. The fuel consumed on October 4 was reported as 52 Mscf. The fuel reported for October 5 was 69 Mscf. A copy of the burner performance charts are shown as Figures 2 and 3.

Analysis of the burner fuel totals and the performance profiles offers some interesting insights to the overall efficiency of the burners and the entire steam heating process on the platform. The first thing that is immediately noticed is that 17 Mscf less fuel was consumed on October 4 though the calculated process loads were 35% higher. This indicates that the heating process (when adjusted for process load) used on October 4 (the ASAC) was 1.8 times more efficient.

$$\frac{12{,}556}{9314} \times \frac{69}{52} = 1.8$$, or stated another way, ASAC used 44% less fuel (load adjusted)

SS207A - Pipeline



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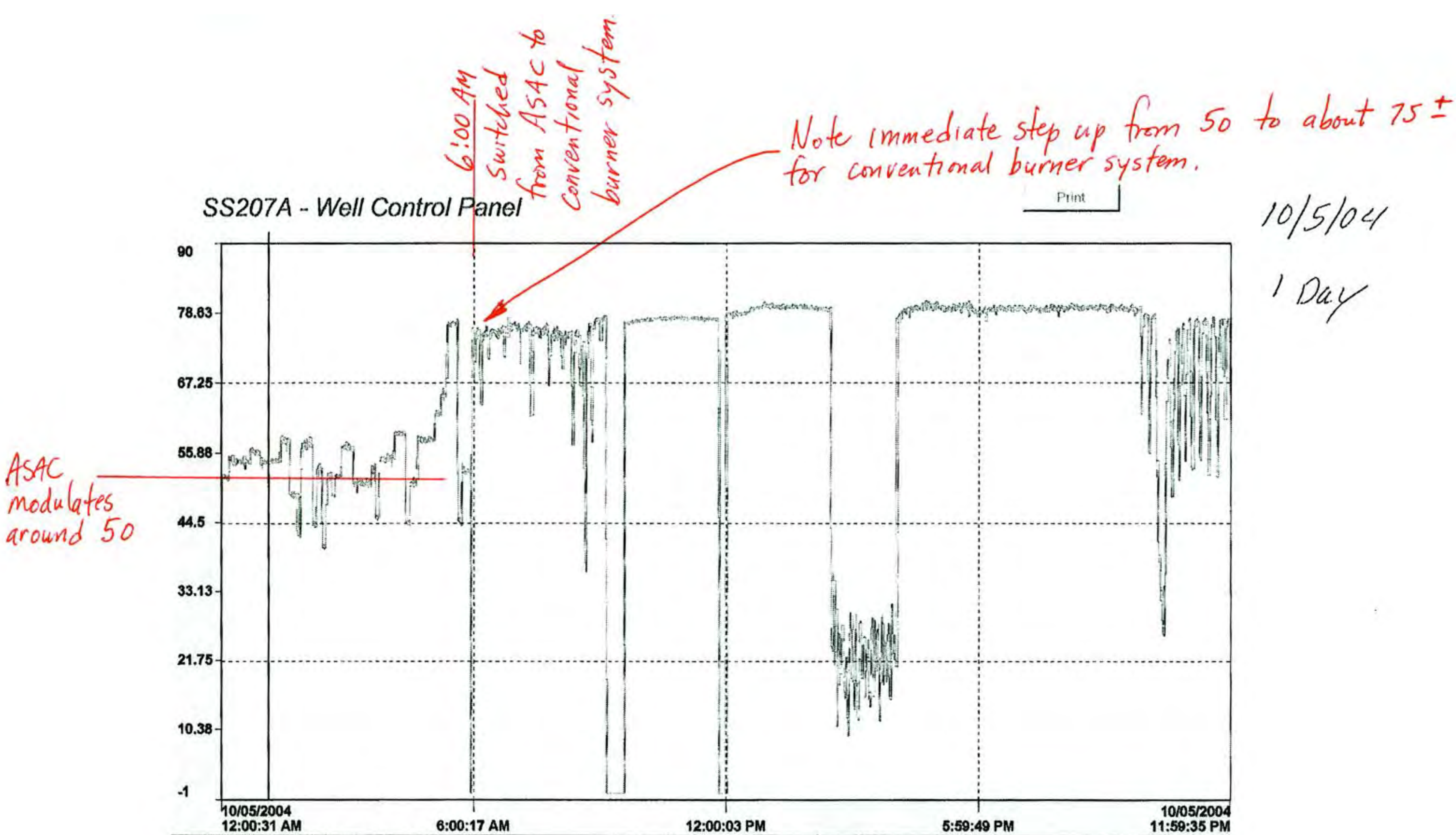
Max 88.060
Avg 207A Steam Gen FR
Min 0.000

SS207A - Well Control Panel



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Max 80.460
Avg 207A Steam Gen FR
Min 0.000

10/5/04

1 Day

The burner performance profile charts (Figures 2 and 3) show the effect of using the ASAC vs CB. The ASAC was in use on October 4 (Figure 2). Note the ragged profile prior to 2:30 pm. This profile indicates that the ASAC was regularly firing for brief, intense periods then going into the off mode. This is not the most efficient firing pattern. The ragged operating profile was due to the steam generator operating at only 13% capacity. The ASAC was monitored during this period and it was found that the ASAC would shut off when the fuel pressure reached about 2 psig (near the bottom end of its normally expected operating range), then would go dormant until the process temperature controller called for heat. When the temperature controller called for heat, the restart procedure would begin (including purging delay) and the ASAC would come on at near full fire capacity. These intense heating and off cycles resulted in overshooting the set point and delay in returning the ASAC to firing mode (purging delay) when the controller called for heat. The ASAC was adjusted to lower the shutoff pressure thus allowing the system to modulate around a lower demand point. This mitigated the likelihood of off-on operation of the system. Once adjusted, the ASAC maintained a relatively steady firing pattern from 2:30 pm on. Regardless of the firing pattern (pre and post 2:30 pm) the overall ASAC system operated in the 50 inches water column differential range.

The steam generator burner systems were switched at 6:00 am on October 5 from the ASAC to CB system. The result of the switch can be clearly seen on the performance chart, Figure 3. An immediate upward spike / plateau can be seen at 6:00 am. This indicates that the CB was consuming more fuel than the ASAC. The CB system maintained an almost constant 75 to 80 inches water column differential over the entire day with the exception of a couple of brief periods.

Determination of Process System Losses

Since the heating system (piping, fuel gas preheater, oil treater) are all operating at almost identical conditions from day to day, it can be assumed that the heat losses from these components will be approximately constant. A quick calculation of the total heat consumed on October 4 will give an indication of the total system losses. The total net heat consumed by the process is

$$52{,}000 * 1070.5 = 56 \text{ MM BTU per day}$$

There are two places that heat can be lost by the process, out the stack in the exhaust gases and out via the piping and vessels. The stack effluents from both the ASAC and CB systems were measured using a Bacharach PCA-65 combustion analyzer. Measurement of the ASAC system stack gases showed efficiencies ranging from 72 to 79% and excess oxygen ranging from 1 to 9% depending on the firing mode. At high firing rates the ASAC was most efficient. It is to be expected that as the ASAC begins to function near the edge of its operating window (1 to 2 psig fuel pressure to the burners), the efficiency will decline. This was evident as the excess oxygen in the system rose to about 9% at the lowest firing rates.

The CB system operated with excess oxygen ranging from 14 to 16.7% and efficiencies ranging from 42 to 49 percent. Using the average of the values measured by the Bacharach combustion analyzer, the ASAC system operates on the order of 1.7 times more effective than the CB.

$$\frac{76}{46} = 1.7, \text{ or the ASAC system used 41\% less fuel.}$$

This is in good agreement with the value of 1.8 (44%) cited above by measuring process duties and actual fuel consumed.

The “system” losses on October 4 are about 43 MM BTU per day – 3.4 times the amount required to heat the process. Based on the efficiency determined by using the Bacharach combustion analyzer (72% on October 4), the unrecoverable stack losses are about 5 MM BTU per day.

$$\frac{12{,}556}{0.72} - 12{,}556 = 4883 \text{ MBTU per day (use 5MM BTU per day)}$$

Additionally, there are stack losses that may be recoverable if the total system losses can be reduced. These stack losses are on the order of 11 MM BTU per day.

> 52,000 * 1070.5 * (1 - 0.72) – 4,883,000 = 10,700,000 (use 11 MM BTU per day) and total stack losses for the ASAC are about 16 MM BTU per day.

Therefore, the "system" losses from piping and vessels are on the order of 27 MM BTU per day. Assuming that the system losses are relatively constant from day to day, the total stack losses and the efficiency can be determined for October 5 when the CB system was used.

> 69,000 * 1070.5 – 27,000,000 – 9,314,000 = 37,550 MMBTU per day stack losses using the CB system (use 38 MM BTU per day)

Comparison of the total stack losses should give an indication of the relative efficiency for each system.

$$\frac{\text{CB losses}}{\text{ASAC losses}} = \frac{38}{16} = 2.4$$

On this basis, the ASAC system operates about 2.4 times more effectively than the CB. This number is about 50% higher than the value obtained by measuring the stack gases using the Bacharach combustion analyzer, but is still indicative of the substantial combustion inefficiency of the CB system. Admittedly, determination of the efficiency by this method is less accurate than using more direct methods such as the Bacharach combustion analyzer or determining the total fuel consumed and comparing it to the process loads, but it does give another indication that the ASAC is significantly more efficient than the CB.

Conclusions

1. The ASAC system was on the order of 1.7 to 1.8 times more efficient than a conventional burner system and saved at least 41 to 44% of the fuel consumed by the conventional burner system.

2. The calculations are conservative as the water content of the incoming fluids are considered possibly inaccurate, but the values skew the calculations toward conservative estimates of ASAC efficiency.

3. The system losses totally dominate the system measurements. Uninsulated portions of the system waste about 38 MM BTU per day. The primary source of heat loss is the uninsulated oil treater.


Burner Venturi
Fuel Inlet Piping
Air Control Valve