IMPORTANCE OF BOILER REFRACTORY

The importance of boiler refractory cannot be overstressed. We are going through a period where fuel efficiency is, and rightly should be, of utmost importance. As I have stated before - "fuel efficiency starts with combustion efficiency." There are many items on the market today designed to save fuel, we must start at the beginning of the process to eliminate waste, then add auxiliary fuel-saving equipment.

I have observed people installing temperature setback controls, etc., on installations where a dirty boiler existed and the unit was firing 10% under maximum efficiency. This, to me, is putting the cart before the horse. If we are to survive in today's market, we must place combustion efficiency first.

Recently, I had a problem with a pressure atomized, 70 gph burner, firing into a scotch marine boiler rated at 55 gph. The flame was impinging on the fire tube and unburned oil was accumulating inside the boiler. I immediately noticed the liner tile inside the combustion zone was missing. I telephoned the burner representative in this area and he told me that their burner did not need the liner tile and that it was more efficient to fire against the fire tube because heating surface is gained by removing the tile.

First of all, the tile is installed to hold heat around the flame, speeding up the combustion process. Remember the three T's of combustion: Temperature, Time, and Turbulence. The oil must burn rapidly, under a temperature hot enough to evaporate it, in order for the burner air to mix properly with the oil.

If the oil burns too slowly, we will have to add excess air in order to have air where we need it, when we need it. The burner is designed to mix the air and oil at a certain point. The oil that is splashing against the fire tube unburned is doing so because it is not evaporating where it should. When it hits the hot boiler, it will eventually evaporate and cause a greater percentage of the oil to burn CO instead of CO_2.

The diffuser is designed to give us a certain turbulence needed to mix the air and oil. If we slow down the time, we cannot slow down the turbulence simply by subtracting

air. That diffuser is designed to give the proper turbulence with around 2,000 cubic feet of air per gallon of oil. At 55 gph, our shutter will be adjusted to give approximately 110,000 cubic feet of air per hour. If our oil is not burning totally in the combustion zone and we have to add air, it will all be excess air. Although we are increasing the turbulence slightly when we add air, it is not in direct proportion and we will undoubtedly lower our CO_2.

Realizing we do not have laboratories in the field, and that all burners do not fire best in all situations, we must realize our limitations and try as best as we can to install a first class job. It is true that most manufacturers claim that their burners will fire into almost anything, but we all know that most burners have their limitations. Although most burners will fire under any conditions, it may not be the best way to go. If there is any doubt, install another burner or walk away from the job.

Secondly, I was told that by removing the tile, heating surface would be gained. Where? The fire tube is 30" in diameter giving a 94" circumference. The tile extended two feet into the boiler. 94" equals 2.6 ft.; 2.6 ft x 2 equals 5.2 sq. ft. of heating surface to be gained. On this size boiler, that is not a very big increase.

Our only heat loss with refractory is that which penetrates through the refractory and radiates into the boiler room. The liner tile is surrounded by the fire tube, which is surrounded by our boiler water. So, heat passing through the tile will only escape to water!

The heat used to heat up our tile will flow through the boiler when the burner is off and while the tile is cooling down. So, we are not saving any Btu's at all by removing the liner tile. We are wasting valuable Btu's because we are trying to fire our burner into a cold combustion zone, thus losing combustion efficiency.

This same theory would prove true of any scotch boiler or any wet base boiler where the fire box is surrounded by boiler water. In some cases, where a wet base boiler does not have a fire box, we have increased efficiency by adding a dutch oven to hold more heat around the flame.

A far greater problem occurs when filling in a fire box and firing through the door. This is becoming more and more popular, almost to the point of being accepted policy (accepted by some). Many manufacturers provide auxiliary equipment to assist with the installation if someone wants to fire through the boiler door.

First of all, on many boilers, if you fill in the fire box and install a hinged mounting plate in place of the door, there is no way of observing the flame. I once made a customer install a sight glass in the rear door of an old scotch boiler before I would adjust his burner. How can you tell if the fire is impinging on the boiler walls? As we all know, impingement may cause carbon build up which can be very dangerous.

The following are just a few of the facts concerning heat loss through a fire box. In future articles, I will discuss this type of heat loss in greater detail because I feel strongly that this is a very important subject.

According to ASTM Standards (Part 13, 1969), if we have a cold face temperature difference of 100°F and a boiler room air velocity of 20 feet per second, we will only lose 700 Btu's per square foot of surface per hour through the fire box wall. Naturally, this will depend on the fire box structure, which we will investigate deeper at a later date.

I used a 100°F temperature difference because it is assumed a 130°F to 160°F cold face temperature is normal. Cold face is the outside surface of the fire box. A 100°F difference in temperature, figuring 80°F boiler room air, would mean a 180°F cold face temperature, well above normal. A 20 feet per second boiler room air velocity is also above normal, although velocity does not greatly effect the heat loss through the fire box.

Perhaps 700 Btu's per square foot per hour sounds like a substantial amount. Let's see. If we have a burner firing 50 gph into an average sized fire box, it would be 3' wide x 3' deep x 12' long. This fire box would only contain 90 square feet of surface. 90 x 700 Btu's (per square foot per hour) equals 63,000 Btu's per hour heat loss. Again this may sound like a lot of Btu's.

Figuring our oil at 140,000 Btu's per gallon, we will burn 50 x 140,000 or 7,000,000 Btu's per hour, continuously running,

$$\begin{array}{r} 63{,}000 \\ \underline{\times\ \ \ \ 111} \\ 7{,}000{,}000 \end{array}$$

will give us .9% of our Btu input lost to the surrounding area.

Remember, any energy required to heat the fire box will initially be transferred into the boiler when the burner shuts down. This heat will travel until the fire box is lowered to water temperature.

Again, our CO_2 will drop. It will have to drop because the three T's of combustion will be forgotten. We will burn slower and usually we can observe tiny droplets of oil entering the combustion chamber. Our CO_2 may drop as low as 7%. If it does drop this low, we will have 120% excess air. Figuring we could adjust to 12% CO_2 in the fire box, we would only have 30% excess air. That extra 90% excess air would be heated from boiler room temperature and carried out the stack, wasting more Btu's.

Considering we will need approximately 1,500 cubic feet of air per gallon of oil then: 1,500 x 50 gph equals 75,000 cubic feet of air required. 75,000 cubic feet, plus 120% excess will give us 165,000 cubic feet of air per hour at 7% CO_2. Figuring 30% excess air in the same manner, we arrive at the figure of 97,500 cubic feet of air per hour at 12% CO_2. This excess air would have to be heated from the ambient temperature (80°F) to the stack temperature of 450°F. We would be wasting the Btu content of 67,500 cubic feet of air at the temperature difference of 370°F.

In order to determine the Btu content of the 67,500 cubic feet of air, we will solve in the following manner. Remember the sum of the gases entering the process of combustion are equal to the sum leaving the process. We will be solving according to weight, so we must convert our quantities:

There are 13.6 cubic feet of air per pound at 80°F (boiler room temperature).

We will assume our oil weight at 8 pounds per gallon.

$$\frac{\text{cu. ft. of air}}{13.6}$$

plus (8 x 50 gph) equals the total weight of dry flue gases.

$$\frac{165{,}000}{13.6}$$

plus (8 x 50) equals 12,532 pounds at 7% CO_2.

97,500
13.6

plus (8 x 50) equals 7,569 pounds at 12% CO_2.

Btu content of dry flue gases equals .24 x temperature difference x weight.
.24 x 370 x 12,532 equals 1,112,841.6 Btu's at 7% CO_2.
.24 x 370 x 7,569 equals 672,127.2 Btu's at 12% CO_2.

1,112,841.6 at 7% CO_2
-672,127.2 at 12% CO_2

440,714.4 Btu's difference

When we figured the heat loss through the fire box, we arrived at 63,000 Btu's per hour. According to the above calculations, by filling in the fire box (dropping our CO_2 to 7%), we are wasting 440,714.2 more Btu's up the stack. So in this case at least, we are definitely not saving by filling in the fire box. We are actually wasting an extra 377,714 Btu's.

While it is true that we waste heat through the fire box, as you can see, we only waste what heat travels through the walls. If we want our equipment to absorb more of our heat, thus lowering our stack temperature and cutting down waste, let's go about it in the proper way. Install a draft damper or turbulators and be certain our boiler is clean.

We need the high CO_2. So leave the boiler in such a manner as it will produce a high CO_2 and treat the stack temperature separately, as it should be.

Another serious problem with firing through the boiler door is that of damaging the boiler itself. Firing the burner too close to the crown sheet of the boiler, subjecting the bare metal to the heat of combustion will cause a great deal of expansion and contraction and will cause undue stress to the boiler.

Some boilers are designed to carry a 600°F stack temperature. So, fire it close to capacity; obtain a high CO_2; and deal with the high stack temperature through better draft control, turbulators, economizers, etc.