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The Magnificent Boiler Furnace

The average utility boiler furnace was designed about 30 or more years ago. In 1974 these furnaces were firing about 80% bituminous coal, according to DOE records of coal production. Now, western PRB has been much more prevalent, and PRB now represents about 46% of total coal consumption for power generation. Fuel switching is one factor that brings to mind the term “The Magnificent Boiler Furnace”. Many furnaces designed for bituminous coal have been successfully switched to western PRB, and been operated at high load factor with a very flat production cost of electricity, and ever decreasing emissions.

Looking back and remembering, who would have expected in 1975 that pulverized coal furnaces would be pushed for more than 2 years before major burner maintenance overhauls? Enamored with getting the fundamentals right, as a first step in optimizing combustion, I thought this would be a timely subject. The large utility boiler furnaces that produce over half of our country’s electricity average over 30 years old. Many of these furnaces have been demanded to switch from bituminous coal to western fuel, to operate at high load factors without slagging; operate for longer periods between major burner overhauls and operate with retrofitted low NO_x burner systems. The record, when fuel fouling and slagging characteristics are considered alone, is quite impressive.

The pulverized coal furnaces of 30+ years ago designs have had tremendous, but effective improvements. Many of these improvements are comparatively low capital cost with huge benefits. The innovation and ingenuity of engineers has not been asleep at the switch! Our industry has done great things in the last 30 years. Some examples of advances that have contributed to advanced furnace performance are:

- Water lances for furnace cleaning
- Low NO_x burners
- Applications of combustion airflow measurement and control
- High momentum overfire air systems as part of a “Total Combustion Optimization System”, as designed by STORM
- Load cell gravimetric coal feeders for fuel measurement and metering
- Fuel line balancing techniques
- Pulverizer fineness improvements through classifier improvements

- Weld deposited alloys and techniques to combat fireside waterwall wastage
- High temperature sealing techniques to reduce air in-leakage such as High Temperature Technologies, Inc., ISO-MEMBRANE®".
- Pulverizer and fuel burning component wear resistant materials—i.e. chrome carbide weld deposited alloys, ceramics, AR-400 and more (These contribute to consistent fuel fineness and distribution into the furnace).
- Low water consuming bottom ash hoppers

At Storm, we attempt to follow five principles in our work with customers, which are:

1. Apply the fundamentals
2. Treat the boiler or fuel burning system comprehensively
3. Recommend cost-effective solutions
4. Recommend steps to preserve and maintain optimum performance
5. Consider all aspects of capacity, reliability, environmental, and efficiency.

Considering The Fundamentals Of The Furnace

For years we have referred to the coal pulverizer as the "Heart" of a pulverized coal fired boiler. Volumes of previous Newsletters and literature have been published on our views (proven to be successful) on the 13 Essentials of Optimum Combustion, and how to measure, "tweak" and improve on these inputs. Well, it could be argued that if the pulverizer of a large utility boiler is the "Heart", well then the furnace is equally important. The fact of the matter is, Storm principle No. 2 (from above) and reinforcing all components are important for highly efficient, high load factor, reliable and environmentally acceptable operation.

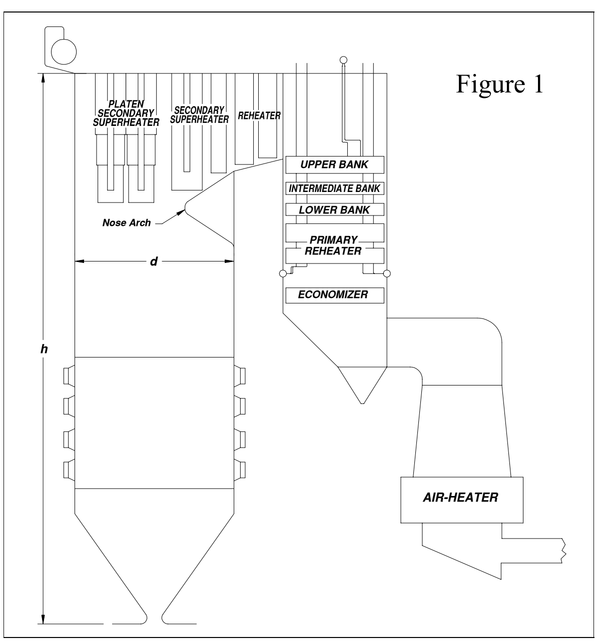


Figure 1

Furnace Heat Release Rate: $\left[\dfrac{heat\ \ release\ \ BTU\ /\ HR}{furnace\ \ flat\ \ projection\ \ area\ \ FT^2}\right] \ldots BTU\ /\ FT^2\ \ HR$

Let's review some of the fundamentals of typical USA boiler furnaces. Interestingly, the furnace volumes, heat release rates and literal tons of steel for a given capacity boiler are very similar. Most pre-CAAA pulverized coal designs are sized for a furnace heat release rate of between 75,000 - 85,000 Btu/ft²/hr.

First, let's discuss furnace heat release rate. Figure No. 1 shows the definition of how the furnace heat release rate is determined. "New" boilers designed for severe slagging, low NO_x, and with overfire air systems tend to have heat release rates between 60,000-70,000 Btu/ft²/hr. As discussed earlier, the designs of 30 years ago were more like 80,000 Btu/ft²/hr. Figure 1 shows how the furnace heat release rate is calculated.

What should the furnace exit temperature be? Once the furnace projected area is calculated and the heat release rate determined by the definition and calculation, as shown in Figure 1, then the bulk furnace exit gas temperature (FEGT) can be estimated by the graph in Figure 2 below.

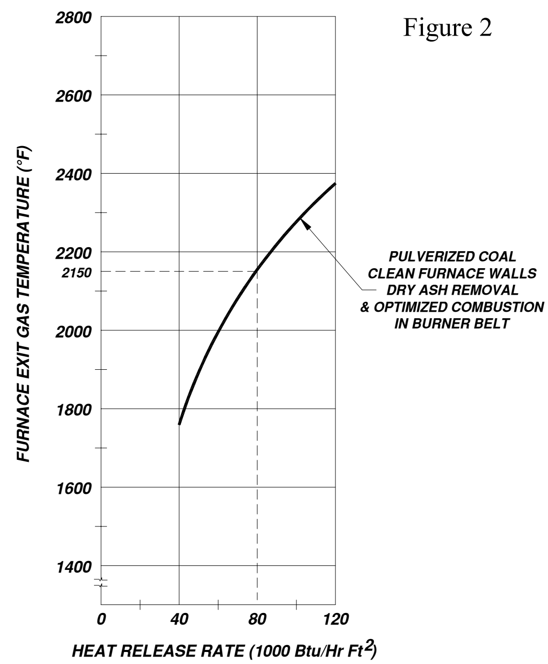


Figure 2

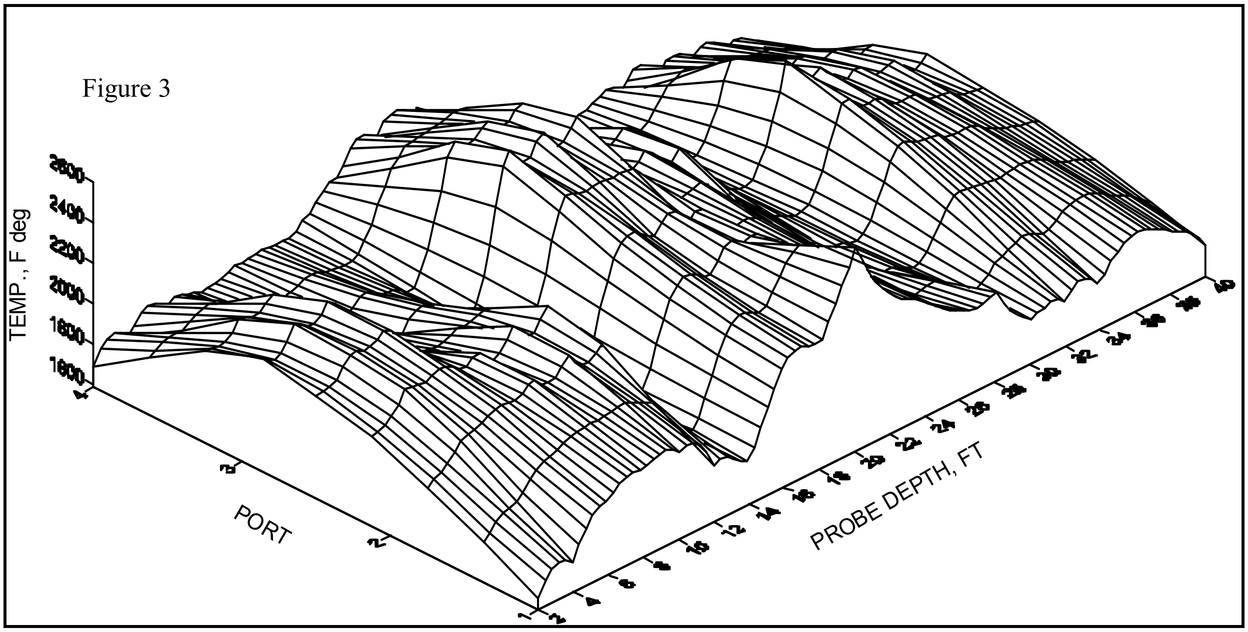
Caution: The "Bulk FEGT" is based on the following three major factors:

1. Commercially clean tube surfaces
2. Combustion optimization so that secondary combustion is not occurring in the upper furnace
3. "Bulk FEGT" means the average flue gas temperature. So, some localized high temperature lanes can be offset by equally low temperatures from the mean, which can result in a satisfactory "average", but unsatisfactory metals overheating or slagging in localized areas.

An important point to make here is that "Bulk" gas average temperature is not the same as "Peak" temperatures. Please note the example below in Figure 3 that shows extreme "peaks".

An example of "stratified" temperatures is shown on Figure 3 below.

Figure 3



Burner Zone Heat Release Rate

This is crucial regarding the performance of in-furnace NO_x reductions. A very concentrated burner zone heat release will generate significant thermal NO_x. Thermal NO_x, is formed from the breakdown of the oxygen and nitrogen that comprise air. This disassociation of N_2 and O_2 to form various forms of NO_x occurs at temperatures above and/or about 2,800ºF.

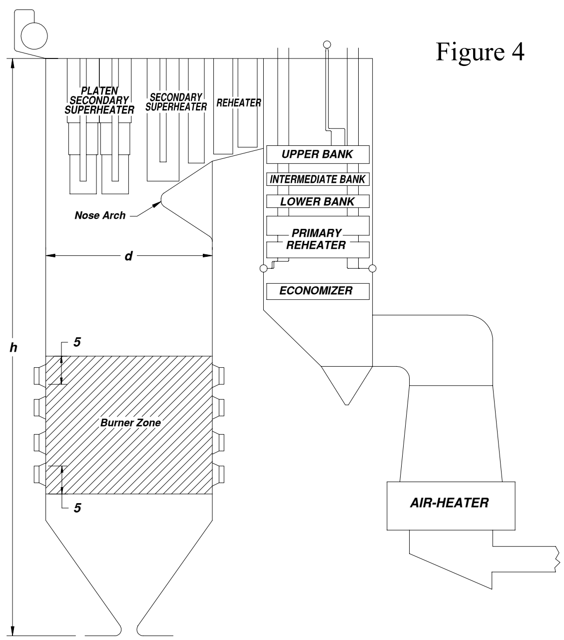


Figure 4

So, the burner belt heat release rate is an extremely large and important factor in the production of thermal NO_x. The burner zone heat release rate is figured on using the shaded area as shown, to the left, in Figure 4. New low NO_x burners may be as low as 200,000 Btu/ft²/hr. Some Pre-Clean Air Act Amendment Boilers have been over 400,000 Btu/ft²/hr. burner zone heat release rate. Spreading out the burner zone heat release of combustion has a marked reduction on thermal NO_x production. This is not something easily corrected on an existing boiler, but a very important factor regarding NO_x production.

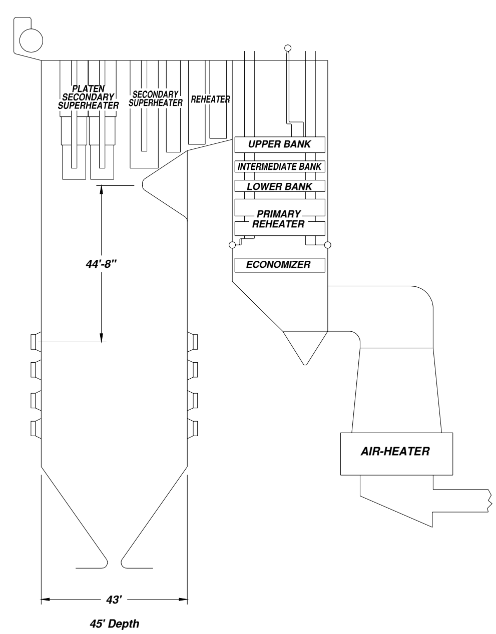
Burner Zone Heat Release Rate: $\left[\dfrac{heat\ release\ BTU/HR}{effective\ burner\ zone\ area\ FT^2}\right] \ldots BTU/FT^2\ HR$

Residence Time

If combustion is to be "optimized", then the products of combustion must be completely combusted before the flue gases pass the plane of the nose arch. Please note the 44'-8" dimension on Figure 5A. This is 44'-8" from the centerline of the top burners to the apex of the nose arch. As lower NO_x levels are achieved by retro fitting low NO_x burners, or overfire air systems, precious time for combustion is sacrificed for lower furnace flame intensity, and consequently, lower NO_x. However, there is only so much time to get this accomplished. The following calculation on page 5, in Figure 5B, shows how to approximate residence time.

Figure 5A

364 MW UNIT



Calculation of Furnace Residence Time — **Storm Technologies, Inc.**

Figure 5B

Based on:

Mass Flowrate of Steam	2,500,000	lb/hr
Average Funace Temperature, T_F	2800	°F
Distance from Top of Burners to Superheater Inle, d	45	ft
Furnace Width, W	43	ft
Furnace Depth, D	45	ft
Furnace Plan Area (W x D)	1935	ft^2

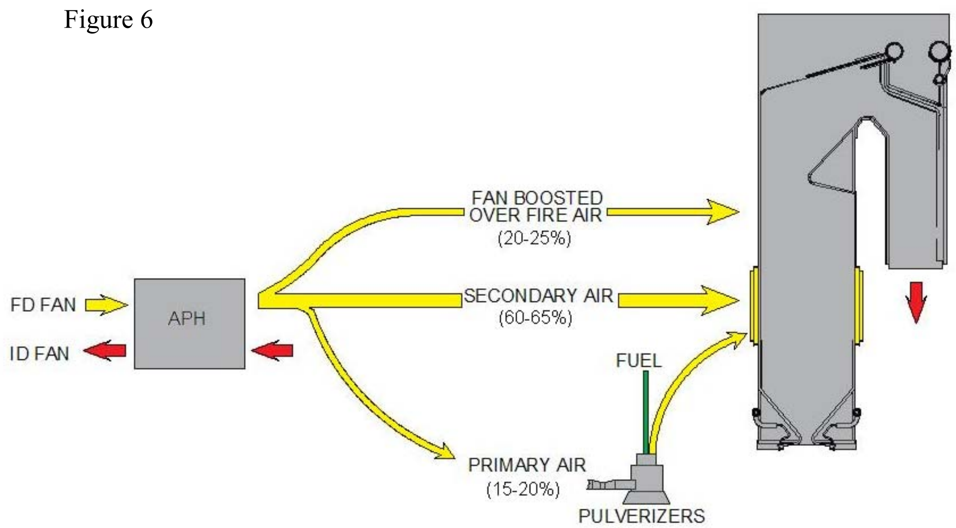
Step 1 **Calculate Mass Flowrate of Gas, W_{gas}** *CALCULATED VALUE*	W_{gas} = 3,261,000 lb/hr
Step 2 **Calculate Density of Flue Gas** Density (lb/ft^3) = $\frac{530}{460 + 2,800}$ x .078	Density = 0.0127 lb/ft^3
Step 3 **Calculate Volumetric Flowrate of Flue Gas, Q_{gas}** Q_{gas} (ft^3/min) = $\frac{3,261,000}{\text{Density of Gas x 60}}$	Step1 / Step2 / 60 Q_{gas} = 4,279,528 ft^3/min
Step 4 **Calculate Vertical Velocity in fps, v** v (fps) = $\frac{4,279,528}{\text{Furnace Plan Area x 60}}$	Step3 / Plan Area / 60 v = 36.9 fps
Step 5 **Calculate Residence Time, t** t (sec) = $\frac{d}{v}$ or $\frac{45 \text{ ft}}{36.9 \text{ fpm}}$	Superheater Distance (d) / Step 4 t = **1.22** **seconds**

Based on a 364 MW eastern bituminous coal fired boiler.

Overfire Air

Overfire air, when utilized, applies some of the combustion air above the burners. Usually, for optimum tuning the OFA is nearly all of the "excess air" added to the furnace. In other words, if the boiler is operating at a burner belt stoichiometric ratio of 1.0 or 100% of theoretical air with no excess air, and the economizer exit is 20% excess air or 120% theoretical air, then assuming no air in-leakage, the OFA is providing about 20% of the total combustion airflow. This can be shown schematically in Figure 6 below.

Figure 6



The residence time for this OFA is changed (reduced), because the OFA ports are located above the burners, and thus a shorter distance from the furnace exit. Therefore, there could be considered two residence times - R_1 - to the OFA, and R_2 - from the OFA to the furnace exit as shown below in Figure 7.

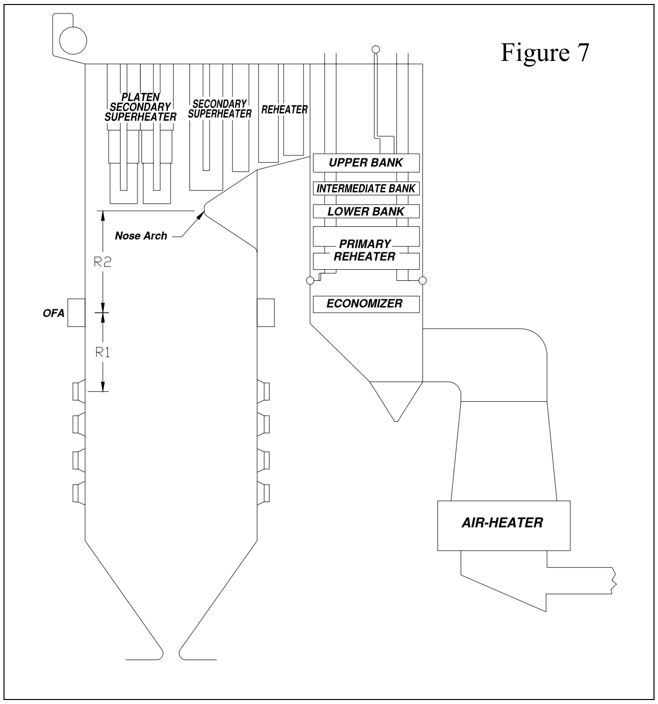


Figure 7

Summary

As you can see, as low NO_x burners, OFA, and lower quality fuels are utilized, after a while, the "Furnace Forgiveness" is used up. It is at this point (when the extra margin in the furnace size is used up) that serious attention to the precision of the inputs must be applied. Precision of the burner belt inputs is also referred to as the 13 Essentials of Optimum Combustion. These, as well as, the 11 Furnace Performance Advances as listed on pages 1 and 2 are what have made boiler furnaces designed in the 60's and 70's, perform magnificently!

We hope this description of some furnace definitions is a helpful refresher. Should you desire test gear or performance improving components, we would be pleased to hear from you.

For more information on our company, visit our web site at www.stormeng.com.

Sincerely yours,

Dick Storm
Consultant

Three test gear kits that are very useful for getting inputs right.

For more test gear information call and ask for our current catalog or visit our website.

A complete HVT probe kit typically includes the following items:

- Standard HVT probe
- Stainless steel armored lead wire for the type "K" thermocouple
- Portable digital thermometer to accurately measure the temperature
- Clear tubing to go from the HVT probe to the gas sample conditioner
- STORM custom gas sample conditioner
- ECOM-AC Gas Analyzer that measures O_2, CO, and NOx

Isokinetic Coal Sampling Kit
Includes:

Stainless steel coal sampler w/filter canister, cyclone separator, Orifice Aspirator Assembly, H.D.P. Sample Container with O ring, Extra Filter Paper, 10ft section of reinforced tubing w/clamps, 1) coal sampling probe, 1) calibrated dirty air probe, 1) temperature and static probe w/ type "K" thermocouple, 2) dustless connectors, digital manometer, 10" vertical incline manometer w/18" pitot tube and steel carrying case, 1 lot of required heavy wall 3/16" tubing, 1) 8ft type "K" thermocouple lead wire with connections, labels and spare seals.

Unit Price: **$6,500.00**

Insitu Flyash Sampler includes:

Sample canister, nozzle tip, perforated cylinder, 100 Reg. filter paper, aspirator assembly, optional pipe length, required air connection fitting and procedures.

Unit Price **$1,850.00**

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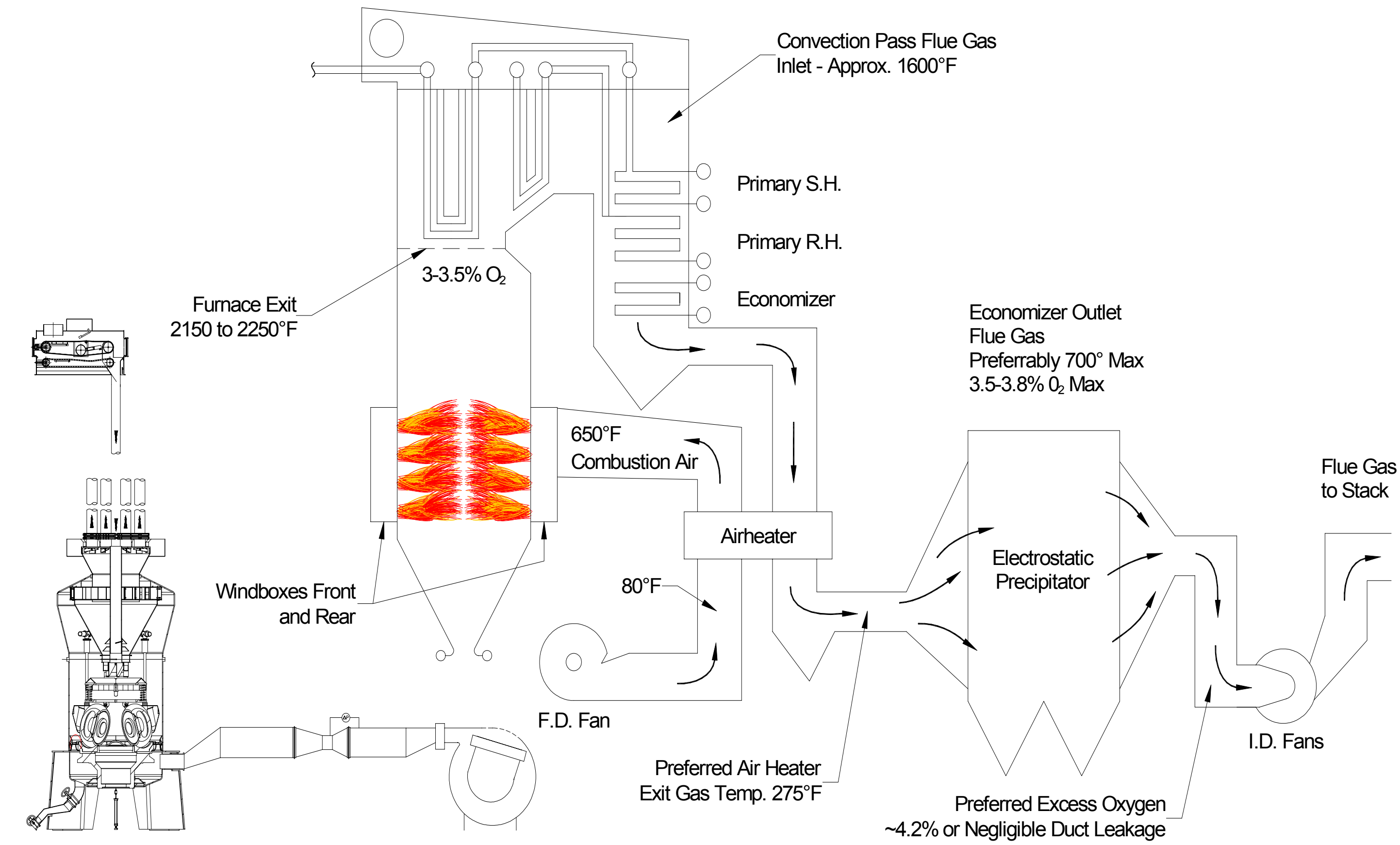
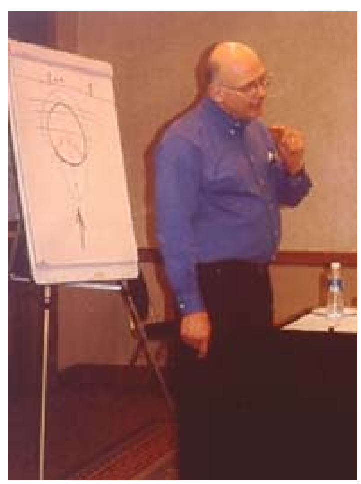
Air in leakage continues to be a problem with 20-40 year old balanced draft boilers. The numbers shown are ideal.



Large Electric Utility Boiler Combustion and Performance Optimization 2 Day Short Course



16 PDH's

Date: February 8-9, 2005

Time: 8:00am to 5:00pm

Location:

Hyatt at Southpark

5501 Carnegie Boulevard

Charlotte, NC 28209-3462

Phone: (704) 554-1234

Fax: (704) 554-8319

To register contact Julie Curlee, Marketing and Sales Coordinator at (704) 983-2040, or for more information visit our website at www.stormeng.com.