TIME AND COST EFFECTIVE REPAIRS TO BOILER IN-LEAKAGE

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AN INTRODUCTION AND A REVIEW TO THE ECONOMICS OF AIR IN-LEAKAGE

Air in-leakage into balanced draft boilers and their associated ductwork has been prevalent for many years. It can be a particular problem for older boilers and boilers which have many tube penetrations through the boiler furnace and convection pass pressure boundaries. Air infiltration into a boiler setting after the flue gases have been cooled below about 1,600F (ignition point of carbon char) provides absolutely no benefit to combustion and constitutes an efficiency loss. The most directly calculable efficiency penalty is the air heater exit gas temperature. For example, if there is 5% leakage on a 400MW boiler through the penthouse, direct costs can modestly be estimated by heat losses over the course of a year as follows:

Basis:

- 8,000 hour/year of operation
- 60% capacity factor
- 3,200,000 lb/hr total airflow at full load
- 1,920,000 lb/hr airflow at 60% load
- 80F ambient air around the boiler
- 300F flue gas temperature
- Specific heat of air = 0.24 Btu/lbm/F
- 5% air in-leakage through the penthouse and convection pass
- Fuel cost = $2.00/mBtu

The dollar savings by eliminating the 5% air in-leakage through the penthouse may be calculated:

BTU/Year loss = (Airflow)(operational hour per year) (leak rate)(ΔT)(Specific Heat =
(1,920,000)lb/hr)(8,000hour/year)(0.05)(300-80F)
(0.24 Btu/lbm/F)
= <u>4.05×10^{10} Btu/year</u>

Direct cost of leakage =
(4.05×10^{10}
Btu/year)($2.00/mBtu)(1mBtu/1,000,000Btu)
= <u>$81,000</u>

One reason air in-leakage has not been more aggressively attacked is that the major costs involved are more abstract.

Other hidden costs of air in-leakage include:

- Poor low NOx burner performance
- High carbon in flyash or Loss on Ignition (LOI)
- Overloaded ID Fan capacity from leakage which limits fan capacity
- Secondary combustion at the superheater with consequent tube metal overheating and slagging
- Desuperheating spray water flow changes
- Fan horsepower losses
- Electrostatic precipitator performance deterioration
- Steam temperatures different from design
- Flyash accumulation in the penthouse or header enclosures interferes with outage repairs, and requires expensive and time consuming removal.
- Safety as related to header enclosures and penthouses that overhang areas below which personnel may be working.

These "other costs," although less obvious, have been very significant and tend to overshadow the direct cost of air leaking into the boiler. These costs usually exceed that of simply heating and discharging tramp air up the stack.

Case Studies of Three Plants

This paper presents case studies of three plants: Duke Marshall, CP&L Mayo and SCE&G Urquhart. Tube penetrations were sealed in the penthouses of two of the plants (Marshall and Urquhart) and the hot side electrostatic precipitator (Mayo) on the other. These examples show the success of the Isomembrane® Application.

WHAT IS ISOMEMBRANE®?

Isomembrane® is a Danish invention which was developed and is the property of Hasle/Isomax®; Isomembrane® is protected technology. Used in power plants sizing from 8MW to 2,200 MW, it is applicable to boilers of any size. It is sandwich construction of layers of high density fibers, special mesh, high temperature adhesive and a sealing castable to finish the surface. This system allows for sealing of problem areas that have been traditionally sealed with refractory and metal seals. The problem with these other methods is that they do not last in an environment where thermal changes cause a lot of movement between the different components. Other methods tend to deteriorate in a short period of time due to this cyclic expansion. Some methods such as high crown seals prove effective and durable, but are costly and require certified welding skill for installation. Another large advantage of the Isomembrane® method of sealing is that tube spacing changes are more easily accommodated than with scalloped seal plates, which

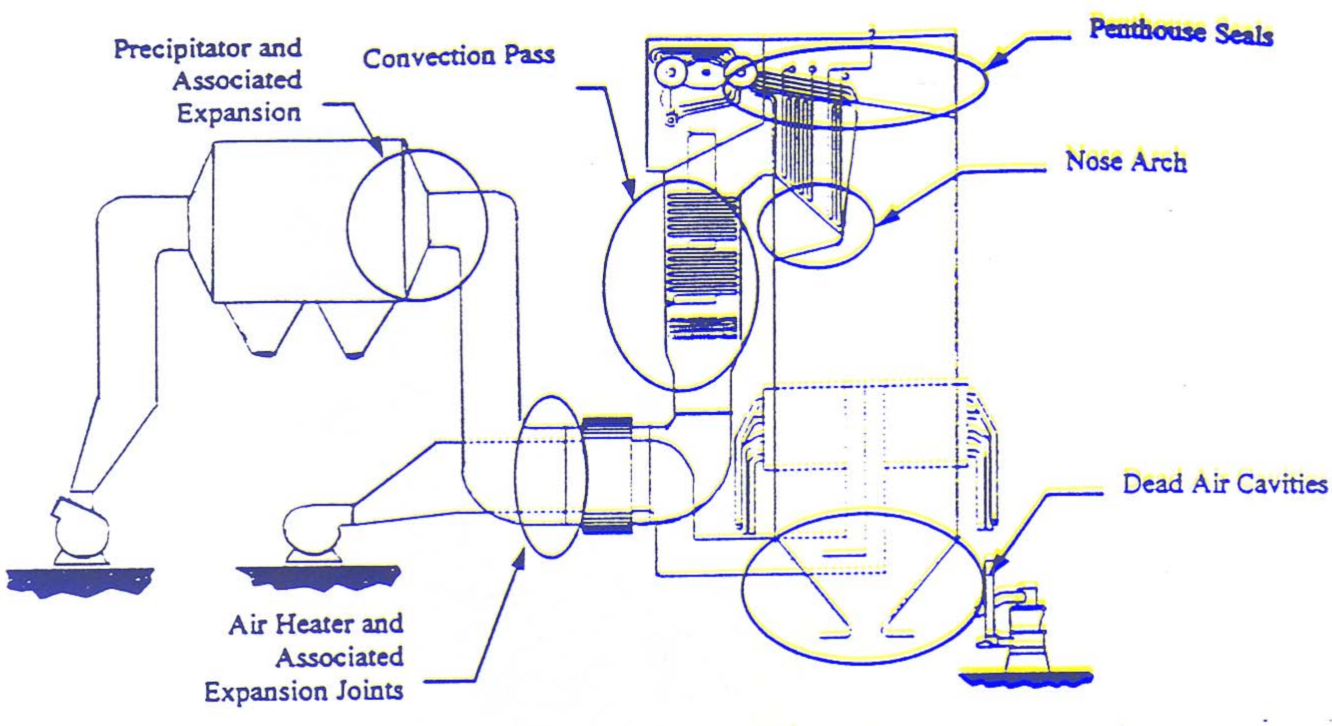

Figure 1 - Typical Areas for In-Leakage Through the Boiler

require very tight clearances. A reasonably priced seal was needed, and Isomembrane® has met that need.

HOW IS THE NEED FOR ISOMEMBRANE® IDENTIFIED?

Isomembrane® is a cost effective way to reduce air in-leakage into the boiler. Typical areas for air in-leakage are outlined above in Figure 1.

Considering all of the opportunities for leakage, air in-leakage throughout the boiler has many adverse affects, which are further explained in the following paragraphs:

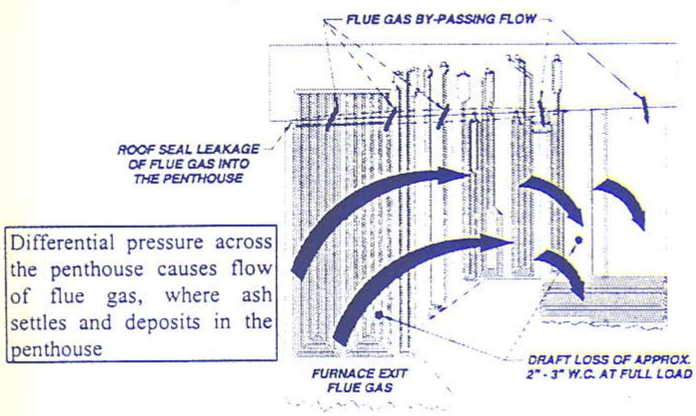

Figure 2 - Ash Accumulation in the Penthouse

Ash Accumulations

In boiler operations, there has long been a need for a cost effective method of sealing leaks in and around the furnace. Most involved in boiler operations can identify with ash accumulations into the penthouse. This common problem can pose serious safety risks, as well as continued financial burden. It poses a safety risk by stressing structural members and pressure parts, as well as burn hazards for personnel. Cooling down and removal of ash provide an additional cost of time and money.

Ash accumulations become an increased safety hazard during a tube failure. A tube leak causing levels of moisture in the penthouse will cause the ash to absorb many times its weight in moisture. Increased weight further endangers structural members not designed to withstand that load.

Some ash has been identified as a health risk. Costs involved in ash removal are significant, and when all environmental concerns are addressed, costs are expected to escalate proportionally.

Reduced Fan Capacity

One consequence of air in-leakage is reduced fan capacity. During operation, many plants become limited by ID fan capacity, often due to excessive air infiltration into the furnace through the convection pass and penthouse seals. Increased fan power consumption is costly in itself. Finding ways to minimize air in-leakage can reduce auxiliary power

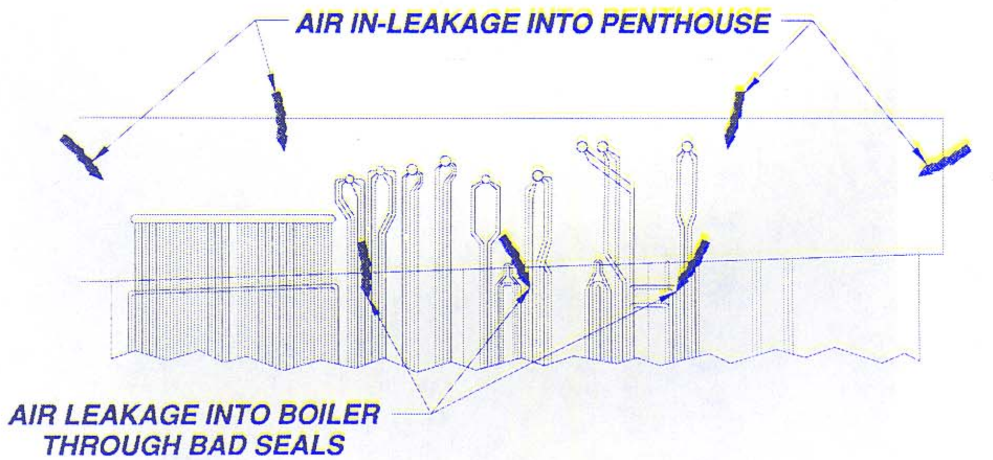

Figure 3 - Air In-leakage through the Penthouse

by lowering fan consumption. Continued overloading of ID fans with tramp air will result in a subsequent unit derate.

Secondary Combustion

Secondary combustion into the convection pass may be noted during normal operation. This is an indication that air, other than that being introduced in the furnace, is finding its way to unburned fuel. Due to the combination of tramp air and excess air, erroneously high oxygen indication generally results in an oxygen starved furnace by disrupting the fuel and air balance. Secondary combustion occurs when fuel rich flue gas migrates at temperatures above 1,600F through the furnace and finds tramp air. Mixing of the fuel rich flue gas and the tramp air in a high temperature environment will cause combustible products to ignite. This can cause overheating of the tubes, and flame quenching, which results in increased carbon in ash, as a well as slag accumulations.

Efficiency Penalties

Testing can also reveal air in-leakage into the furnace. A High Velocity Thermocouple (HVT) traverse incorporated with an air heater test can reveal oxygen rise through the boiler. Air infiltration through the convection pass will be indicated by a rise in oxygen from the furnace exit to the air heater inlet. This rise in oxygen is proportional to the percent leakage through the boiler.

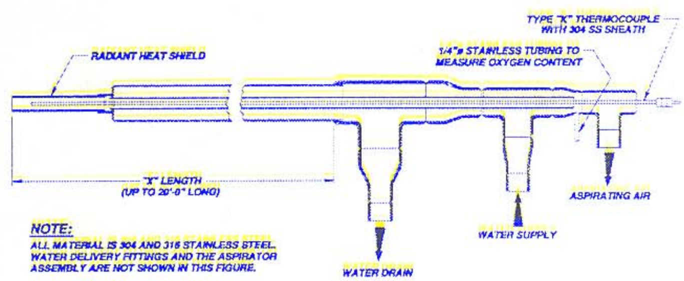

Figure 4 - High Velocity Thermocouple

Boiler inspections reveal air in-leakage into the boiler by showing visual ash deposits and tube discoloration. Leakage through the penthouse and the rest of the boiler provide an economical penalty by decreasing boiler efficiency. Simply put, it requires more fuel to produce the same amount of steam. The magnitude of this penalty is proportional to the amount of air in-leakage. Indirect heat rate or efficiency penalties are usually greater as the in-leakage increase.

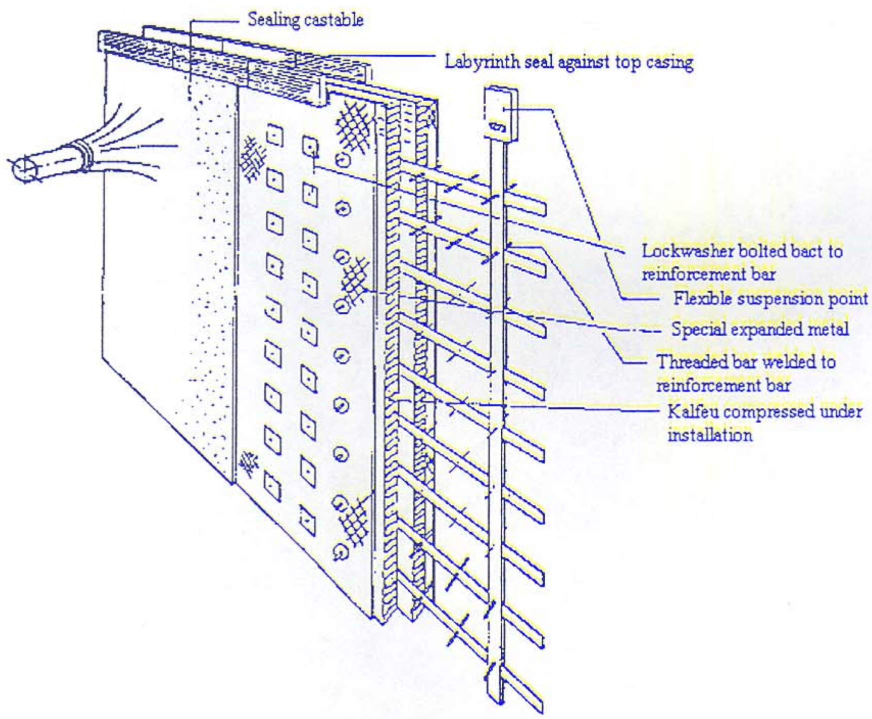

Figure 5 - Isomembrane® Application on a Wall

Opacity and Precipitator Problems

Precipitators are sensitive to in-leakage, both through the furnace and through the precipitator itself. Air leakage causes an increase in the mass flow through the precipitator. Since precipitators are sensitive to mass flow, this often causes an degradation in the performance of the precipitator.

Air in-leakage has caused localized corrosion, high sparking, thermal stress, discharge plate bowing and discharge electrode failure. In the case of a hot side precipitator, air in-leakage combined with localized dew point corrosion can accelerate corrosion of metal components and cause thermal fatigue cracking. This cold air causes localized cooling and thermal fatigue cracking. The Mayo plant experience is an example of an economical and durable solution.

WHAT IS THE PROBLEM?

Air in-leakage through the boiler has been identified at the root of many problems with combustion in the boiler. **Isomembrane® is one cost effective solution:**

Isomembrane® is a five step process:

1. Boiler structural supports and tube alignment must be repaired. Some original metal seals also provided tube pendant mechanical support. Support must be repaired to restore load carrying integrity. This product must never be used in a manner to conceal a structural defect.
2. Cleaning and preparation of the surface. Tubes must be cleaned and any major gaps in the surface must be filled prior to installation. Gaps are filled with the appropriate refractory or ceramic fiber insulation.

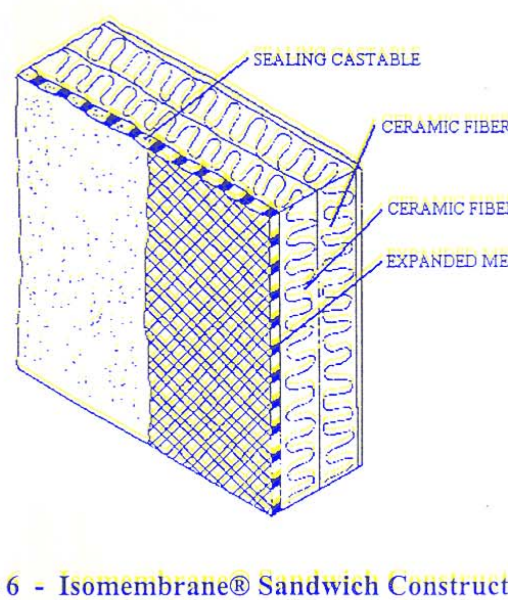

Figure 6 - Isomembrane® Sandwich Construction

3. A ceramic fiber is installed over the surface to provide fill and allows for expansion.
4. Expanded metal is attached to the pins, and over the ceramic fiber.
5. A sealing castable is spread over the expandable metal to provide the final step. This provides a gas tight seal. By forming of the casting around tubes, it allows for expansion of the membrane type seal. Elasticity of the Isomembrane® allows for thermal expansion, which is critical in a furnace environment. No asbestos is involved in the installation of Isomembrane®.

Isomembrane® can be used in many applications. It is especially suited for penthouse applications, nose arch, convection pass tube penetrations, dead air spaces and expansion joints.

Direct benefits of the Isomembrane® system include the following:

- Avoiding costly weld repairs, or new seal installation
- Eliminates vacuuming, both time and expense
- Reduced safety risk of ash accumulations, both personnel and structural
- Efficiency savings
- Conservation of fan horsepower

Other benefits include:

- Improved precipitator performance
- Reduced slagging
- Lower furnace exit gas temperatures
- Better NOx performance
- Improved flyash carbon content with better combustion airflow management

SPECIFIC EXAMPLES OF ISOMEMBRANE® APPLICATION

Duke Marshall #4

Marshall plant has been one of the most efficient power plants in the United States for 25 years. It burns pulverized coal and provides 3,500 PSIG Steam to a 700,000 kW tandem compound turbine. The boiler has two stages of reheat and the rated temperatures are 1,007F, 1,000F and 1,000F respectively. Unit heat rate averaged 8,912 Btu/kWh for the plant's past thirty years.

This plant had a history of flue gas bypass in the penthouse (See Figure 3). Large ash accumulations as high as 5 ft were common in the penthouse after a shutdown. This ash required considerable time to cool down after shut down and before it could be vacuumed. Estimated weights of the flyash accumulation in the penthouse reached 100 tons, a structural concern. The problem of ash accumulation in the penthouse was a continuous expense in time and money. After consideration and research, it was decided to try the Isomembrane®. This system was new to the United States, but had been successful in Europe.

Three years since the installation of the Isomembrane®, there has only been a light dusting of ash in the vast majority of the penthouse . There has been one small area in the front corner where it appears to continue to leak. This area will be addressed during the next outage. There is only nominal ash deposits where 5 ft. dunes were common. Costs for vacuuming, and seal repair during each outage are avoided. Other benefits include overall efficiency and auxiliary power savings. Based on the success of the Isomembrane® in the penthouse, Marshall Unit 2 chose to have Isomembrane® installed to seal the air pre-heater (APH) inlet expansion joint. Although only installed in October 1996, the seal appears to be a success.

CP&L - Mayo

Located north of Roxboro, North Carolina, on the Mayo reservoir, these Foster Wheeler, opposed burner units burn pulverized coal supplied by five D-9-5 ball tube mills. Two boilers of 2,750,000 lb/hr capacity each provide superheated steam at 2,700 lb steam at 1005F to a 750 MW turbine.

The existing roof seal is actually a common precipitator design, where the cold roof slides over the hot roof, and is packed with asbestos. Over the years, expansion has caused the seal glands to bow and leak. This air in-leakage resulted in casing cracks, where additional air in-leakage exacerbated the problem. Consequently, introduction of cold air through the cracks caused localized cooling of the precipitator collector plates and localized sparking of the discharge electrodes. Bowed plates resulted in a high spark rate, which affected performance and reliability.

This plant incorporates hot side precipitators for particulate control. Over the years, expansion movement has caused repeated cracks into and around the precipitator and associated duct. Once started, small in-leakage and the hot environment intensified the problem and accelerated the failure. CP&L staff considered rebuilding the precipitator, replacing the original seals, and some other costly repairs. Isomembrane® was researched and accepted as a solution.

Since the installation of the Isomembrane®, there has been no noticeable cracking in the seals. What is most noticeable is the improved reliability of the precipitator, and the ability to maintain satisfactory opacity. Plant personnel have stated that they are satisfied with the product, and its performance.

SCE&G Urquhart #2

Urquhart is a 75 MW CE tangentially fired boiler that can run on either pulverized coal, natural gas or fuel oil. Pulverized coal is supplied to the four levels of tilting burners on the four corners with exhauster equipped CE Raymond Bowl mills.

Urquhart # 2 was scheduled to be fitted with low NOx burners. During a comprehensive inspection prior to baseline testing, suspicions of excessive air in-leakage were verified. These were noted by ash accumulations and tube discoloration.

Before baseline testing could continue, problems had to be addressed, which included the following:

- Sealing boiler in-leakage paths and related ductwork
- Balancing air and fuel
- Ensuring good pulverizer operation
- Repairing and stroking all dampers, nozzles, etc., for consistent and accurate positioning

Air in-leakage can compromise low NOx operation. For successful low NOx operation, it is mandatory that air be staged and distributed in measured and controlled quantities. Uncontrolled air introduced into the furnace causes an imbalance in this operation. Air infiltration interferes with the furnace stochiometry, excess oxygen indication, as well as contributing directly to thermal NOx. To address air infiltration, the Hasle Isomembrane® was suggested and accepted as a tool for sealing the penthouse.

After the installation of the Isomembrane®, the unit's in-leakage was considerably less. The unit was able to meet the requirements of baseline low NOx testing. Testing also revealed the following reduction (top of next column)in air leakage through the boiler:

Test Date	Boiler Leakage
3/3/93	39.16%
5/30/96	17.88%

This table shows a remarkable reduction of 21.28% in leakage through the boiler. This unit has a sloping roof penthouse, and no conventional methods have been successful in sealing the tube penetrations. Ten feet of ash accumulation has been common in the penthouse. Ash also found its way into the skin casing causing bulging and structural damage. Two years after the installation of the Isomembrane®, there has been only a slight dusting of ash in the penthouse. Fan amps have been reduced and the unit is not fan limited any more.

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