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INTRODUCTION

This paper is concerned with four problems associated with non-condensible gas contamination of steam that can reduce dry kiln performance. The sources of non-condensible gas contamination will be discussed and some of the methods available to reduce or eliminate the impact of these contaminants.

The four problems include:

- 1) impeded heat transfer through dry kiln fin pipe
- 2) depressed steam temperatures in dry kiln fin pipe
- malfunctioning steam traps due to non-condensible gas locking
- corrosion of condensate piping from oxygen pitting or low pH condensate

For the purposes of this paper we are most interested in the effects of oxygen, carbon dioxide, and nitrogen. These are noncondensible gases which are readily available in air and boiler make-up water.

Heat Transfer

The dry kiln is a condition controlled room utilizing steam coils as a heat source to dry lumber. The rate at which heat flows from steam to the conditioned air in the kiln depends on a number of factors. The heat (contained in the steam) must first pass through a film of condensate and non-condensible gases, then possibly a layer of rust or scale, the metal tube, usually a layer of metal oxide on the outside of the fin pipe, a layer of stagnant air, and finally the air for which heat was originally intended.

The film of air (non-condensible gases) in the dry kiln fin pipe is a poor conductor of heat and it is therefore a very effective insulator.

The table below compares the thermal conductivities of several common materials.

	Thermal Conductivity
Material	Btu/hr-ft ² - ^o F/in
Copper	2620
Iron	340
Water	5
Air	. 2

This table demonstrates that a one-inch thick air film is as resistant to heat transfer as a wall of copper 1,000 feet thick. For the operation of dry kilns it is extremely important that fin pipes have as little condensate and air film as possible. If air and condensate films do build on internal fin pipe surfaces, the rate at which the kiln will heat is greatly reduced. Depressed Steam Temperatures

The previous paragraphs indicated that the rate at which heat was transferred from the steam to the kiln was negatively impacted by non-condensible gases. This is not the only negative aspect of contamination of steam with gas. It is possible that the actual temperature of the steam can be reduced.

Dalton's Law of Partial Pressures states that in a mixture of gases or vapors (steam is a vapor) the total pressure of the mixture is the sum of the partial pressures exerted by each vapor in the mixture. This physical law has impact on dry kiln operations.

Example: The total pressure in a steam coil is 100 psi but the vapor gas mixture is 3/4 steam and 1/4 gas.

Partial pressure of steam = 3/4 (100) = 75 psi Partial pressure of gas = 1/4 (100) = 25 psi TOTAL PRESSURE 100 psi

The temperature of dry saturated steam at 100 psi is 328° F and this is the steam temperature expected for the operation of our example dry kiln. Unfortunately if the steam coil contains 1/4 gas, the actual steam temperature would be that of 75 psi steam or 308° F, a reduction of 20° F.

Gas Locked Steam Traps

The above problems dictate that an important aspect of steam trapping is the elimination of non-condensibles (air) in the condensate. Certain types of steam traps will remove such air as reaches them with the condensate. If the shape of the steam coil is such that the general direction of steam flow is towards the trap and if the trap selected has good air discharge capabilities most of the air will get out through the trap. If, however, the shape of the coil allows condensate to get to the trap before all the air is discharged then the trap alone cannot reduce the percentage of air and further venting may be required.

There are only three characteristics that differentiate the way steam traps operate.

- Density The density of steam and hot condensate is different and therefore a float can be used, sink in steam and rise in water.
- Temperature There is a difference in temperature between steam and sub-cooled condensate or for our discussion, between saturated steam and air contaminated steam.
- 3) Impulse If condensate is discharged at full steam temperature there will be a maximum of flash steam formed at the trap outlet. This causes a local build-up of back pressure and closes the trap. The trap which best eliminates air in the steam coil will operate on the principal of temperature control. Balanced thermostatic traps or vents are preferred.

Corrosion of Condensate Piping

There are two methods of corrosion in condensate systems and non-condensible gases are involved in each.

Oxygen Pitting

Oxygen pitting is severe if a source of oxygen is available to the moist iron rich environment of dry kilu fin pipe and condensate return systems. The corrosion reaction for dissolved oxygen is illustrated as follows:

> $4Fe + 6H_{20} + 3 O_2 = 4Fe (Oh)_3$ Iron + Water + Oxygen = Ferric hydroxide

Carbon Dioxide

Carbon dioxide is another non-condensible gas, dissolves in water and forms carbonic acid. This is a weak acid but produces corrosion as illustrated.

Fe + 2 H_2 CO₃ = Fe (HCO₃)₂ + H₂ Iron + Carbonic acid = Ferrous bicarbonate + Hydrogen

This reaction occurs rapidly at a pH of 5.9 or less.

SUMMARY OF PROBLEMS

The above discussion indicates that any non-condensible gas will impede heat transfer, depress steam temperatures, and cause many steam traps to perform less than optimally. In addition, the specific non-condensibles of oxygen and carbon dioxide will cause corrosion which destroys our capital investment in dry kiln fin pipe and condensate return systems. The remainder of the paper discusses sources of the non-condensibles, oxygen and carbon dioxide and some of the solutions.

Sources of Dissolved Oxygen

Oxygen may originate from boiler make-up water or enter at various points in the condensate system. Oxygen is present in most make-up waters and unless properly scrubbed and vented in a deaerator will remain in the boiler feedwater. While condensate that is returned under pressure will usually be free of oxygen, infiltration can take place in dry kilns when they are intermittently turned on and off.

Sources of Carbon Dioxide

Carbon dioxide is the leading cause for condensate corrosion. The main source of carbon dioxide is the bicarbonate and carbonate alkalinity of the boiler make-up water. The carbon dioxide generation is illustrated as follows: Ca (HCO3)2 + Heat - CaCO3 + Calcium bicarbonate + Heat yields Calcium carbonate + CO₂ + H₂O Carbon dioxide + Water

There is further breakdown as illustrated below:

CACO₃ + H₂O Heat ---> Ca(OH)₂ Calcium carbonate + Water + Heat yields Calcium hydroxide + CO₂ Carbon dioxide

Corrosion in piping is proportional to the carbon dioxide concentration in condensate. For plants located in areas of hard water we can anticipate that all of the previously discussed problems will be magnified.

Solutions to Non-Condensible Gas Contamination

Realizing that the two major sources of gas are boiler makeup water and air infiltration in the condensate system, several methods for eliminating or reducing their impact are:

- Deaeration Many dry kiln boilers are equipped with deaerators but frequently only the boiler make-up water is deaerated and the return condensate is returned to the storage section of the D.A. tank. Because air can easily be introduced in modulating dry kiln systems the deaerator should be sized to scrub all the plants feedwater.
- 2) The condensate piping should be large enough to insure good flow towards the steam trap. While the primary condensate handling trap may be a float or bucket, a thermostatic trap should be plumbed in parallel to insure maximum gas venting capacity.
- 3) Reduction of carbon dioxide in make-up water can be accomplished with equipment such as a dealkalizer or a degassifier. A dealkalizer takes softened make-up water and passes it through a second ion exchange unit which removes the anions of bicarbonate and carbonates. These anions are replaced with chloride. A degassifier takes softened make-up water and acidifies it with sulfuric acid. The acid frees carbon dioxide from the bicarbonate and carbonate ions which is scrubbed from the solution, the non acidified make-up water is neutralized with caustic soda, and pumped to the deaerator.

CONCLUSIONS

Gases in steam can cause significant dry kiln problems. Each plant requires its own system analysis, but if efficiency and reliable operation are of paramount importance to the dry kiln operation then consideration of the following is important.

- 1) Location and selection of steam traps
- 2) Full deaeration of all boiler feedwater

- Improved condensate return system to reduce quantity of boiler make-up water required
- Pre-treatment of boiler make-up water to remove carbon dioxide

BIBLIOGRAPHY

- Betz Laboratories (1962). "Betz Handbook of Industrial Water Conditioning."
- Liberty Bell Corrosion course, 1969.

Locke, R.C. "Condensate Corrosion Control."

Northcroft, L.G. and Barber, W.M. (1968). "Steam Trapping and Air Venting."

Sarco Hook-up Designs, 1974.