STRATEGIES FOR REDUCING CEMENT KILN BAGHOUSE CORROSION PROBLEMS

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INTRODUCTION

Corrosion costs big time! The costs associated with corrosion of cement kiln baghouses can be as much as $100,000 to $500,000 per year for each kiln baghouse, depending upon the severity of the problem. Corrosion is caused by acid attack on carbon steel, resulting from the presence of acid producing compounds in raw material, fuels and additives. These compounds typically contain sulfur and chloride. However, weak acids such as carbonic acid can cause slow corrosion over a long period of time.

The costs of baghouse corrosion include:

1. Repair of tube sheets and bag collars
2. Repair of walls/hopper
3. Cost of new, replacement dust collector
4. Kiln downtime
5. Bag replacement
6. Environmental permit non-compliance fines
7. Reduced production
8. Personnel morale due to unpleasant task of bag replacement
9. Safety hazards
10. Management distraction from making cement

This paper explores the causes and costs of cement kiln baghouse corrosion. Typical system arrangements are discussed with a focus on identifying key problem areas for each unique system. Ways to identify the cause of the corrosion as well as strategies to reduce corrosion will be elaborated on. Finally, four case studies will be discussed to detail real world problems and solutions.

CAUSES OF CORROSION

Chemical reactions between acid compounds and carbon steel cause corrosion. The major chemical reactions are as follows:

Agent	Acid	Corrosion	
CO_2	Carbonic H_2CO_3	Iron Oxide FeO	Type of corrosion that occurs in atmosphere
SO_2	Sulfurous H_2SO_3	Iron Sulfite $FeSO_3$	Type of corrosion that occurs in baghouses
SO_3	Sulfuric H_2SO_4	Iron Sulfate $FeSO_4$	
$CaCl_2$	Hydrochloric HCl	Iron Chloride $FeCl_2$	
Cl_2	Hydrochloric HCl	Iron Chloride $FeCl_2$	

These reactions do not take place in the gaseous phase. The presence of liquid H_2O is necessary to cause the reactions to take place. Therefore, three things are needed for corrosion to occur in a baghouse:

1. Acid producing compounds
2. Condensation
3. Plain carbon steel

Eliminating any one of the three will solve the problem. Since the first two items can be at least partially eliminated in most cases, this paper will focus heavily on those. The replacement of plain carbon steel by more expensive alloys or expensive coatings will only be touched upon briefly.

Acid Producing Compounds

The major sources of acid producing compounds are as follows:

1. Pyritic Sulfur in raw materials
2. Sulfur in fuels
3. Chloride in raw materials
4. Chloride from the addition of $CaCl_2$
5. Chloride in fuels

Pyritic Sulfur burns to form SO_2 in the temperature range of 400 – 600°C (750 – 1110°F). The amount of SO_2 from pyritic sulfur that actually makes it to the kiln baghouse is dependent upon the kiln system, kiln efficiency, and the handling of the kiln exit gases. During the combustion of fuels containing sulfur, it is expected to generate a certain amount of SO_2 gases. Again, the amount that actually makes it to the kiln baghouse is highly dependent upon the system design, efficiency, and operational parameters.

Chloride containing compounds require high temperatures to decompose. These high temperatures can be found in the lower stages of a preheater/precalciner system and in the burning zone of the kiln. The gaseous chloride will then circulate throughout the entire system. The amount of chloride that actually makes it to the kiln baghouse is dependent upon the system design and the efficiency of the system.

Condensation

The acid producing compounds need to be in aqueous form to function as an acid, and thereby promote corrosion. Water in the cement process can come from a number of sources.

All kiln gases have H_2O from the combustion of fuel and from the inherent moisture in the kiln feed. In some cases, additional H_2O is added in water spray form. In systems designed to utilize the kiln exit gases for drying in an in-line raw mill, the amount of H_2O vapor to the kiln baghouse can be greatly increased. The total amount of water vapor in the gas stream as well as the temperature of the gas dictates the dew point temperature. If the process gas temperature is within 20°C (36°F) of the dew point temperature, localized condensation of water and acid formation is a potential problem.

Sources of Condensation:

- Operating near or below the acid dew point during normal operation
- Lack of proper insulation of the dust collector
- Improper water spray operation
- Inadequate mixing of cold air with hot kiln gases before entering the baghouse
- Leakage at doors and hatches and discharge devices
- Poor gas distribution in dust collector
- Frequent start-up/shutdown (passing through acid dew point)
- Poor start-up procedures (inadequate fabric pre-coat during initial start-up)
- Frequent isolation of compartments and opening of doors to change bags

Materials of Construction

The third item present to have corrosion is plain carbon steel. As everyone knows, plain carbon steel corrodes slowly in ambient conditions (lying in the maintenance yard) due primarily to weak carbonic acid formed by the reaction of water (condensation) and the CO_2 in the air reacting with the iron. The corroded parts will then lead to shorter lifetimes and require sooner than expected maintenance. This same carbon steel located inside a building will last much longer if it is kept dry.

In a baghouse that same carbon steel even in the presence of acid producing components will last a long time if it is kept hot and dry.

In some processes where the opportunity to control temperature in the presence of acid producing compounds does not exist, plain carbon steel is eliminated from the equation by:

- Replacing with other material such as stainless steel or various plastics
- Extensive coatings

In most cement kiln applications other strategies can reduce the problem significantly enough to eliminate the need for these extreme measures. These will be discussed further under the section "Strategies to Reduce Corrosion".

DIFFERENT TYPES OF CEMENT KILN SYSTEMS

Different types of cement kiln systems and resulting configurations of the venting system provide different conditions for corrosion and different strategies for reducing corrosion. The major types of kiln systems are as follows (refer to the attached schematics):

- Wet kilns
- Long dry kilns
- Preheater/precalciner kilns
- Preheater/precalciner kilns with all kiln gases passing through the raw mill
- Preheater/precalciner kilns with partial bypass of kiln gases around the mill

The exhaust gases from a wet and long dry system are usually vented directly to a baghouse. Suspension preheater kilns and precalciner kilns typically send their exhaust gases to the raw mill area for drying of the raw materials. In some instances where the raw materials are very dry, a simultaneous bypass of kiln gases around the mill and recycle of mill exit gases is utilized.

In most cases when all the kiln gases are passed through the roller mill, the majority of the sulfur and chloride containing compounds are scrubbed out of the gases due to the intimate contact of raw material and gases found inside a raw mill. Even though the baghouse runs at low temperatures when the mill operates (80 – 100°C / 176 – 212°F), corrosion does not occur as rapidly due to the lack of acid compounds.

Figure 1 – Long Dry Or Wet Kiln System

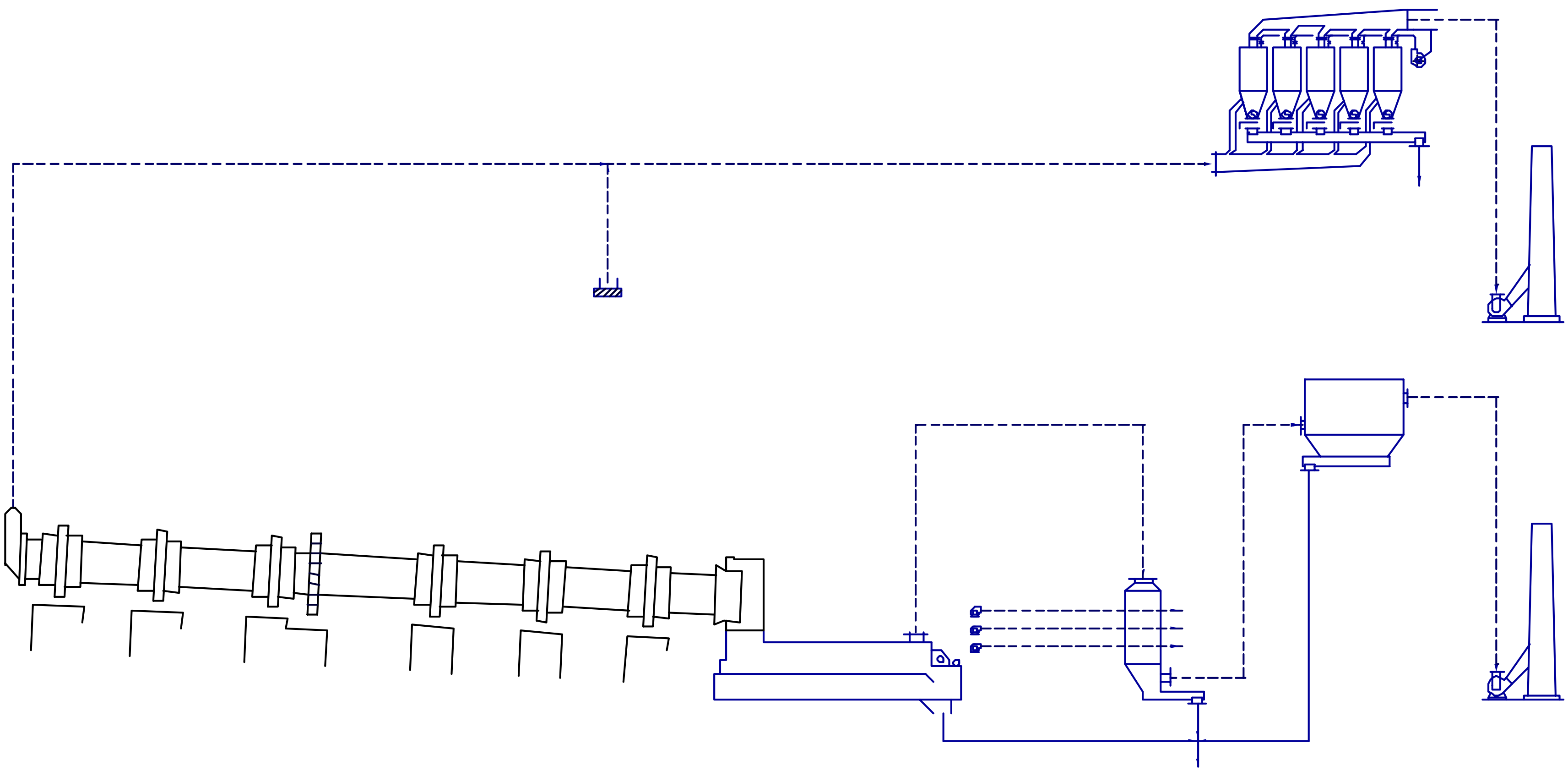


Figure 2 – Preheater System

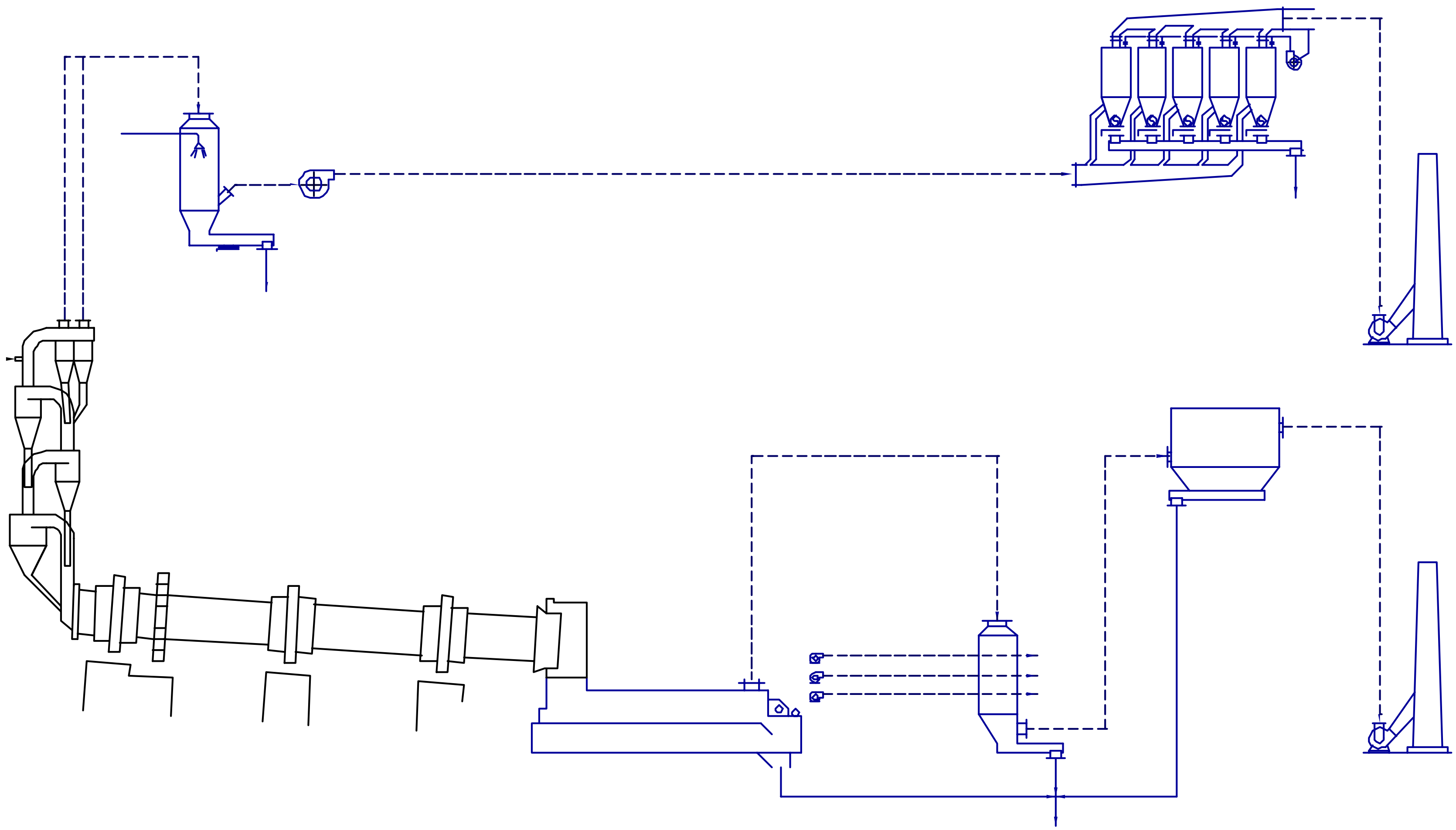


Figure 3 – Preheater/Precalciner Kilns With All Kiln Gases Passing Through The Raw Mill

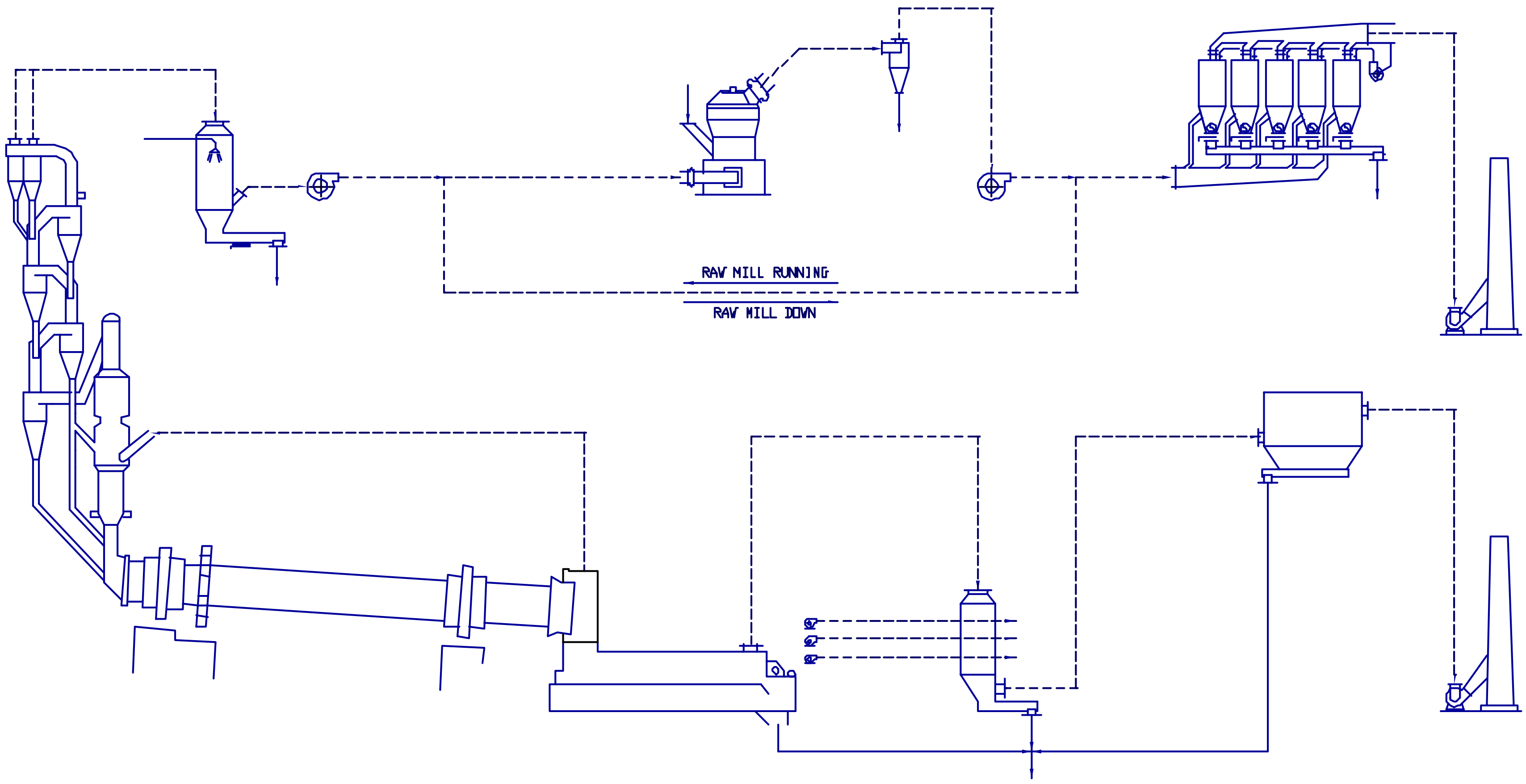
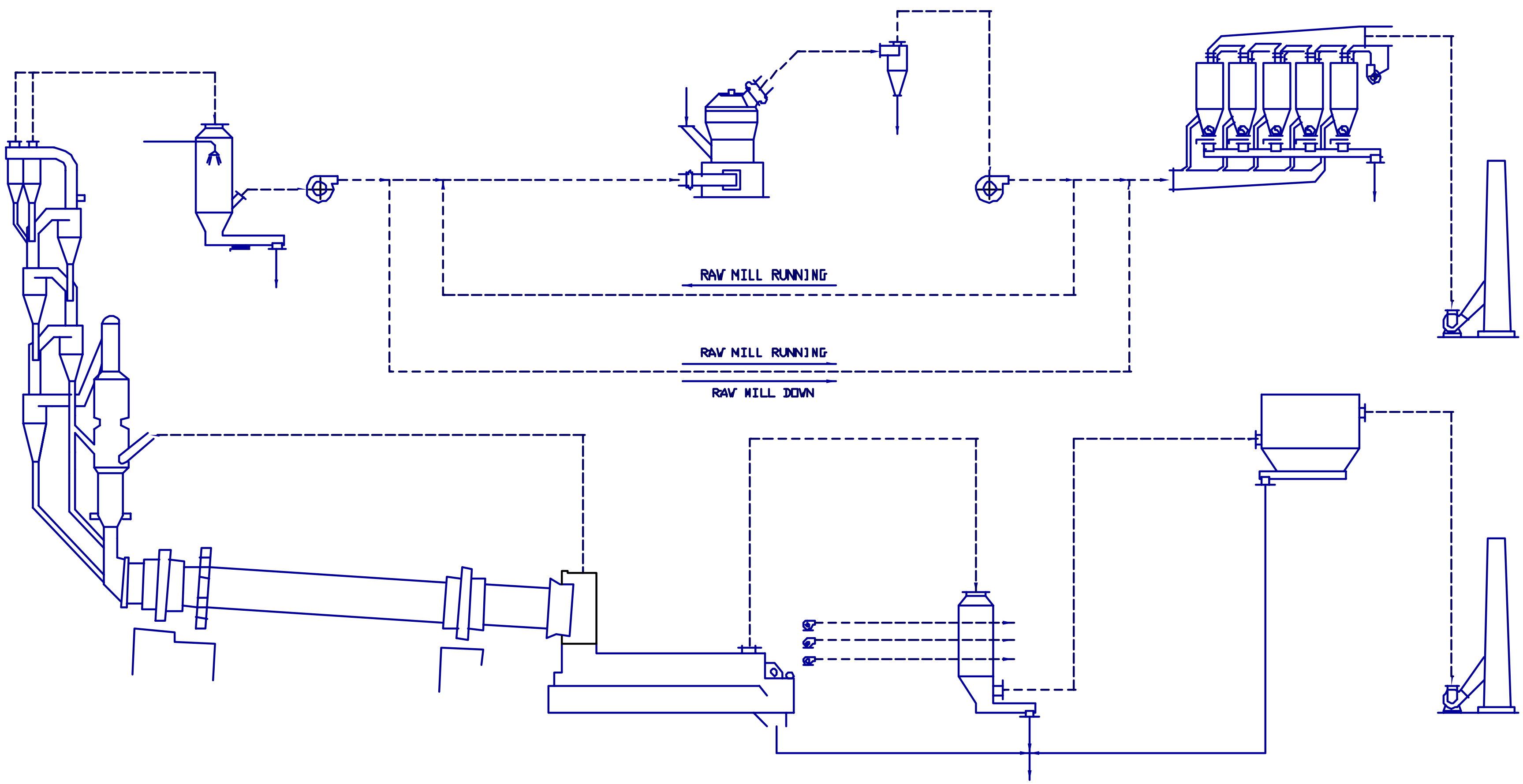


Figure 4 – Preheater/Precalciner Kilns With Partial Bypass Of Kiln Gases Around The Mill



In the case of partial by-pass of kiln gases around the mill, the acid components in the bypass gases are not scrubbed out by the raw mill. When this gas is mixed with the low temperature mill exit gases, the resulting gas mixture is below the acid dew point and corrosion occurs.

COST OF CORROSION

The cost of corrosion goes beyond the obvious such as replacing corroded tube sheets, walls in hoppers and the actual replacement of the entire dust collector with the required kiln shutdowns. 7

They include other costs that are not so obviously caused by corrosion. These other costs manifest themselves in short bag life. This short bag life leads to other items listed in the introduction of this paper.

- High bag replacement costs
- Environmental fines
- Curtailed production
- Personnel problems due to the difficult task of replacing bags
- Safety hazards
- Management distraction from making cement

The causes of short bag life differ, depending upon the type of collector.

Reverse Air Collectors:

1. Anti-collapse rings in bags corrode thereby causing wear of the bags from the inside out (Figure 5).
2. Corrosion of tube sheet, collars and tensioning devices causes inadequate bag tensioning and accelerates bag wear (Figure 6)
3. Crystallization of acid compounds in between the glass fiber causes etching and wearing of the glass and advanced wear.

Figure 5 – Bag Ring Corrosion

Figure 6 – Tube Sheet Corrosion

Jet Pulse Collectors:

1. Corrosion of cages causes wear of the bags inside out
2. Corrosion of tube sheet holes around bag seal causes leakage of dust around bag. Resulting dust on tube sheet gets blown into the clean side of the bag causes advanced wear
3. Crystallization of acid compounds in glass fibers causes etching, wearing and shortening of bag life.

This advanced wear of bags due to corrosion often starts a downward spiral. As bags begin to have holes, emissions go up, frequent isolation of compartments and opening of doors accelerates corrosion and wear. If bags are not replaced quickly enough and tube sheets are not cleaned, the dust on the top clean side of the tube sheet is blown back into the bags causing advanced wear. Bag wear caused by corrosion could make bags that should last 4-6 years, wear out in 4-6 months. The results can be disastrous for the plant in many ways.

STRATEGIES TO REDUCE CORROSION

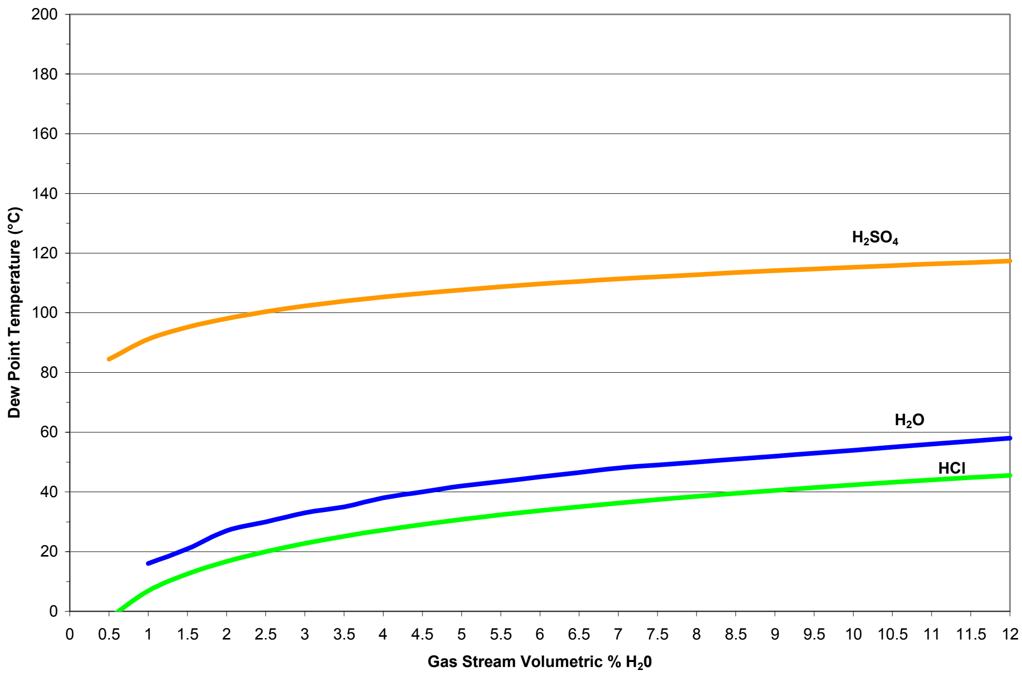
If baghouse corrosion is suspected, the inside of the baghouse should be inspected. During the internal inspection, careful notation must be made about the location of all corrosion sites. A detailed corrosion inspection along with other plant data will often answer what is causing the corrosion. In general the following advice can be considered as an effective guide to minimize kiln baghouse corrosion.

Keep it hot or get it out! That is, keep the cement kiln baghouse well above acid dew point or get rid of the acid producing compounds.

Keep it hot!

Dew point is the temperature where water vapor condenses out of the gas stream. The dew point is highly dependent upon the percentage of water vapor and temperature of the gas stream. Very small amounts of water in terms of percentage of the gas stream build up to large quantities of water in the baghouse over a period of time. Acid dew point is the temperature where water that contains acid producing compounds condenses. The Sulfuric acid dew point is usually much higher than the water dew point, whereas the hydrochloric acid dew point is typically lower than that of water.

Figure 7 – Typical Hydrochloric Acid, Sulfuric Acid and Water Dew Points



Strategies to Keep the Baghouse Hot:

1. Proper control system, training and discipline of the operators
2. Process modification
3. Proper insulation
4. Leakage prevention
5. Proper start-up/shut down procedures
6. Proper system design from the beginning

Controls should be adjusted to keep the dust collector hot, well above acid dew point. Fiberglass bags and membranes on glass bags can tolerate temperatures around 260°C (500°F) but last longer around 250°C (480°F). Operators should control temperatures as close to 250°C (480°F) as possible to prevent corrosion if they have acid producing compounds.

Some regulations require a maximum temperature of 205°C (400°F) to control dioxin/furans. In this case, operators should run as close to 205°C (400°F) as possible to prevent acid dew point problems.

Actions needed to accomplish this are:

1. Proper types and adjustment of controls to prevent the necessity of large safety factors.
2. Proper location, design and operation of bleed air dampers and water spray systems
3. The thermocouple at the inlet to the baghouse should be properly located to insure that all gases have had adequate time to mix.
4. A thermocouple should be located at the exit of the baghouse to insure the temperature drop over the baghouse is kept to a minimum. A high temperature difference over the baghouse would indicate excess leakage into the baghouse.
5. Training and discipline of the operators

<u>Process Modification</u>

In some cases the original plant process designers sized the baghouse fan to operate at low temperatures to minimize the capital cost and power consumption of the system. If nothing can be done to remove the acid containing components it might be necessary to increase the baghouse and fan size in order to operate at a higher temperature. An alternative to increasing the baghouse size is to replace the filter bags with e-PTFE membrane material which can filter a higher volume of gas, provided the inlet and outlet dampers are large enough to handle the higher gas flow.

The only other alternatives are:

1. Live with corrosion problems
2. Use special coatings or alloy materials to prevent corrosion

<u>Proper Insulation</u>

Even when the gas passing through the baghouse is hot enough, if the baghouse is not insulated properly the steel surfaces will usually be cold enough to cause condensation. It is absolutely necessary to insulate all process baghouses venting products of combustion.

During start-up conditions this condensation will be at such large quantities that the hoppers and material handling equipment may fill up with water.

The details of insulation are very important in preventing condensation. The areas around doors and on doors may be the most difficult. It is an advantage to have a double door arrangement - one door to seal the dust collector and another door to seal the insulation around the dust collector (see Figure 8).

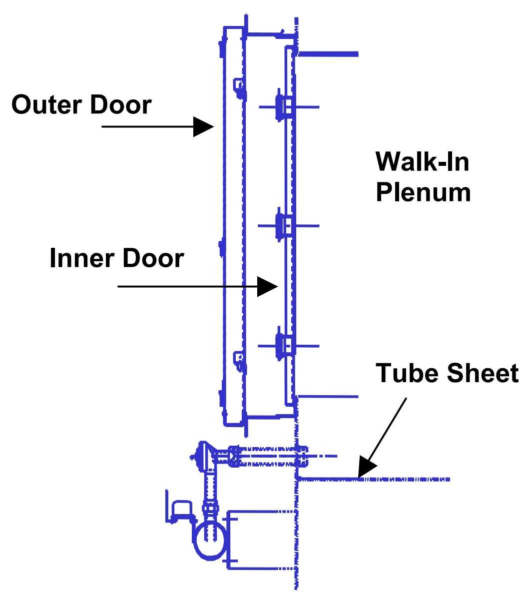


Figure 8 – Insulated Double Door

Preventing Leakage

One of the causes of corrosion in baghouses is leakage around access doors and discharge devices. Strategies to reduce leakage are:

1. Have good double sealed doors
2. Have a minimum number of doors. A top access collector has much more area to seal than a walk in plenum collector. The corrosion problem associated with top access can be a primary reason to choose a walk-in plenum collector instead of a top access collector/walk-in plenum.
3. Proper sealing of all doors.
4. Use the proper seal material for the temperature.
5. Replace the seals when hard and worn out.
6. Start-up/shut down procedures:
    a) Protect bags from condensation during initial start-up by pre-coating them
    b) Vent refractory dry-out gases through another method or don't put the bags in the collector until refractories are dried out.

Occasionally kilns are started up and expected to run at reduced capacity for some time and the dampers of some of the compartments of the baghouse are isolated until needed for full capacity at a later time. Usually these dampers are not completely airtight and some of the kiln gases leak into an unused cold compartment causing severe corrosion and ruining the bags. Unused compartments should be positively blanked off to prevent this from happening.

Get It Out!

In other words, get rid of acid causing compounds. Without acid containing compounds even at low temperatures (like roller mill exit gas temperatures) corrosion will be minimized or eliminated.
Strategies to eliminate acid producing compounds:

1. Run all the kiln gases through the mill. The mill is an effective scrubber of acid producing compounds due to the intimate contact of raw material and gas.
2. Change raw material if economically feasible. Individual testing of each raw material component can be performed to determine what the bad actor in the mix is. If the pyritic sulfur is an outside purchased component that makes up a small percentage of the raw mix, it may be feasible to change sources.
3. The same lime injection sometimes needed to reduce SO_2 will also reduce corrosion.
4. If $CaCl_2$ is added to help alkali removal, inject it into the kiln burning zone instead of adding it to the raw mix. This will minimize chloride carryover to the kiln baghouse.

When all else fails!

If none of the above strategies to reduce corrosion causing conditions can be achieved, there are options available to reduce the effects of corrosion:

1. Change materials of construction
2. Purchase bag materials that are more acid resistant
3. Use special alloy bag accessories like reverse air anti-collapse rings, cages on jet pulse and bag hardware.
4. Use acid resistive coatings

Materials of Construction

Stainless steel resists sulfuric acid attack but not hydrochloric acid. Additionally, stainless steel is corrosion resistant, not corrosion proof. Eventually, if the acid compounds are present and condensation is occurring, the stainless steel will corrode as well although the process of corrosion will be much slower than plain carbon steel. For larger process collectors, stainless steel can be very costly. An evaluation of capital investment as compared to operating life must be made.

Acid Resistant Bags

Some suppliers have acid resistant fabrics using certain fabric finishes that coat the glass fiber better. Also, some suppliers can supply alloy rings and sew them into the bag so that they don't move and cause fabric wear when corroded.

Alloy Bag Accessories
Stainless steel and other alloys sometimes coated with Teflon are used in bag rings, collars, suspension devices and cages to minimize corrosion.

Coatings
There are new coatings available that are designed for service at the temperatures of a kiln baghouse. These coatings typically require costly surface preparation in addition to the cost of the coating material itself. There is limited experience with the use of these coatings so the long term benefits of corrosion resistance are not clear yet.

CASE STUDIES

Four case studies where severe corrosion problems were solved will be discussed:

1. **Case A** – A lime kiln baghouse improperly insulated
2. **Case B** – A roller mill was installed in a plant where a preheater kiln and a preheater/precalciner kiln were vented to one dust collector. The new lower mixed gas temperature accelerated the destruction of an older dust collector.
3. **Case C** – A new plant with a preheater/precalciner kiln and a roller mill experienced severe corrosion and bag life problems.
4. **Case D**– A new baghouse on a wet kiln suffered severe corrosion problems.

Case A – A jet pulse baghouse was installed on an older lime kiln. The dust collector was not insulated and severe corrosion problems occurred above the tube sheet on the clean air side. The lime dust below the tube sheet on the dirty side prevented corrosion. The unit was properly insulated to prevent condensation above the tube sheet. Consequently, without condensation, the acid attack was minimized and the corrosion stopped.

Actions Taken:

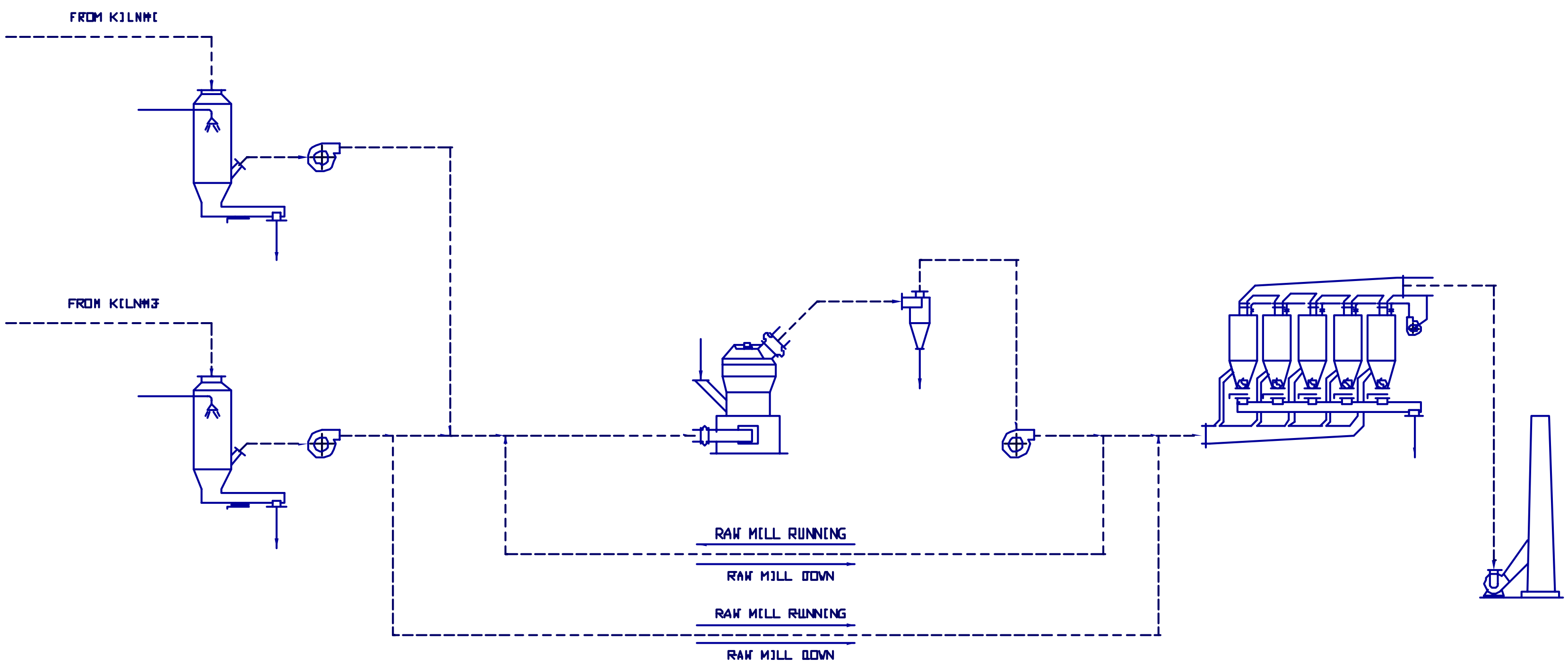
1. A complete analysis was done on the gas and material flows and temperatures.
2. The unit was properly insulated to prevent condensation above the tube sheet.

Case B – After a new roller mill was installed in a plant where a preheater kiln and a preheater/precalciner kiln were vented to one dust collector (see Flowsheet Figure 9), the corrosion problem that was already evident was accelerated by the lower mixed gas temperature from mill gases and partial mill bypass.

Actions Taken:

1. A complete analysis was done on the gas and material flows, temperatures and pressures of the plant.
2. A new process flow was designed to keep the kiln gases above 205°C (400°F) at all conditions.
3. A new jet pulse dust collector was installed as well as new plant ductwork with new dampers and controls.

Figure 9 – Flowsheet, Case B



Case C – A new kiln and roller mill were installed with the kiln gases partially bypassed around the mill. Within two years after start-up, the metallic portions of the reverse air collector were corroded and very short bag life was experienced.

Action Taken:

1. A complete analysis of gas and material flow was done to determine the problem.
2. The problem was determined to be chlorides in the kiln gas and a continuous partial bypass of the mill causing the worst case scenario: a low dust collector temperature with the presence of acidic compounds.
3. A process flow was designed to take all the gases through the mill thereby scrubbing the chlorides. Corroded parts of the tube sheets, collars and bag hardware were replaced to allow the proper tensioning of the bags.
4. New woven fiberglass bags were installed with a better acid resistant finish The anti-collapse rings were alloy coated and sewn in a way to prevent movement.

Case D – A new dust collector was installed on a wet kiln with too low of a back end temperature. Corrosion of doors and walls became evident almost immediately.

Action Taken:

1. Increased back end temperature of the kiln.
2. Improve insulation around doors.

CONCLUSIONS

The cause of corrosion of kiln baghouses is quite simple – a chemical reaction between iron and acid.
The cures are also simple in principle – ***"keep it hot"*** or ***"keep it out"***, but the actual execution of the cure sometimes is much more complex and difficult. An experienced baghouse supplier or consultant with cement process experience may be required to properly analyze the causes and the most cost effective solution.

Special alloys and coatings are the ***"last ditch"*** efforts only if the ***"keep it hot"*** or ***"get it out"*** approaches cannot be executed.

It is hoped this paper gives the operators and designers of cement plant venting systems a better understanding of cause and cure of baghouse corrosion.