

INFORMATION ONLY

ASHWIN PATNI, LECHLER INC., USA, OUTLINES THE BASIC DESIGN CONSIDERATIONS FOR A FLUE GAS COOLING SYSTEM AND THE POTENTIAL ADVANTAGES OF A LOWER TEMPERATURE OPERATION FOR CEMENT PLANTS.

WATER COOLING SYSTEM

Introduction

Gas cooling is an integral process component for most cement plants around the world. Traditionally, it serves to protect baghouses from damage due to hot gases. However, under current NESHAP regulations, the performance of gas cooling using water sprays can be critical to plant operations.

Cooling gases close to dew point approach temperatures can have many advantages. A cooler temperature in the presence of moisture can reduce lime consumption for SO₂ control. Mercury adsorption is also more efficient at lower gas temperatures; using powdered activated carbon and, in some cases, a well-designed gas cooling system can help in lowering activated carbon usage while maintaining the level of mercury capture. Lower gas temperatures also have positive effects on ID fan energy consumption by reducing overall gas volumetric flow rates, which decrease with cooler temperatures.

As is well known, cement manufacturing is a high-temperature process. The temperature required to produce clinker is in the range of 1500°C. The flame temperature required to heat the raw material is typically 2000°C. These hot combustion gases pass through the process stream counter current to material flow and this transfers heat from gases to material as they cross each other. There is additional process equipment, including cyclones or chains in long kilns, which make heat transfer more efficient. Typically, the exit temperature of the gases downstream of cyclones for new plants is about 325°C and for older technology temperatures are slightly higher. These gases have a very high dust load, which consists mainly of raw meal materials. To capture this dust a baghouse is utilised. Today's filter media can handle continuous gas temperatures of up to 260°C. To protect these bags, typically, a spray injection system is installed to cool the gases to a lower temperature below the

normal operating temperature of filter media. In newer kilns, the spray injection location is either in a downcomer duct or inside a gas conditioning tower. A gas temperature of around 120°C can offer potential advantages, which may reduce some costs associated with reagents required for emissions control and also possibly reduce the power draw by ID fans. This article discusses the basic design considerations for a gas cooling system and the potential advantages of a lower temperature operation.

Benefits of gas cooling in the cement manufacturing process

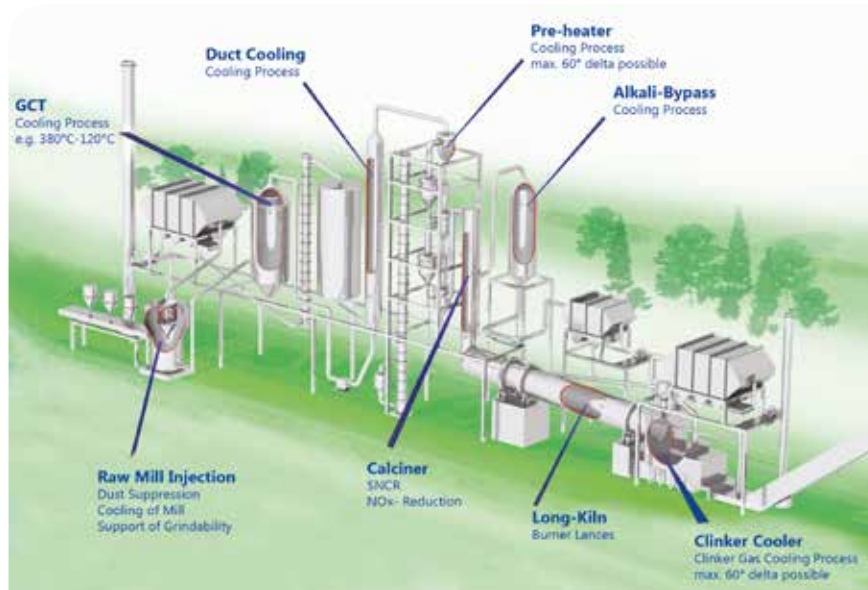
Modern cement manufacturing is almost completely a dry operation. Water sprays are one of the few wet operations within the cement manufacturing

process. Water sprays pose multiple challenges to a cement plant operator, including maintaining a stable and trouble free operation. In most cases, spray nozzle performance is the root cause of many issues. The challenge for a cement plant is to assess spray performance. Performance assessment is typically associated with an understanding of the droplet size being produced at various operating conditions. A spray nozzle manufacturer should have detailed data regarding droplet size information for any operating condition. Estimated droplet sizes have been known to deviate considerably from the actual produced droplet sizes, especially when the nozzles have worn over time or have had scaling issues.

The droplet assessment can be a challenge when it is impossible to see the sprays interacting with flue gas inside the tower or duct. Any diagnosis has to be based on the spray nozzle manufacturers' droplet size data and measured by process parameters in the field. The droplet size for most air atomising nozzles is a combination of air to liquid flow ratios and other parameters such as liquid viscosity and operating pressure. Compressed air pressure is not a good parameter for measuring a nozzle's performance. Droplet size cannot be estimated on pressure alone and, therefore, it is important that air and water flow rates are measured to determine optimum sprays. Cement plants should also be aware of their compressed air usage as it can be very costly.

Most systems in the US operate with dual fluid nozzles. These systems require more energy to operate in comparison to a hydraulic system. However, a dual fluid atomisation design is much more resilient in terms of increasing flow capacity or altering the produced droplet size. This can be easily accomplished by adding more compressed air and replacing pumps. A hydraulic spillback system is not very resilient in terms of a capacity increment or changing the droplet size while using the same equipment. However, it has the lowest operating cost, as a hydraulic system does not require any compressed air.

The purpose of any spray nozzle is to produce the most liquid surface area for efficient gas-liquid interaction for heat and/or mass transfer by utilising minimum energy to generate such surface area. Typically the energy input rises



VarioSpray application in a cement kiln.



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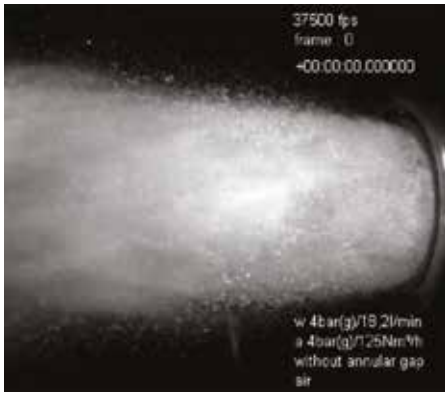
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Left: Typical Air Atomizing Nozzle with large droplets exiting the nozzle orifice from the edge. Right: RingGap™ nozzle with Annular Air shearing large droplets from the nozzle edge to create a very tight droplet spectrum.

near the spray injection plane, which can cause massive dust buildup that can fall under gravity and damage downstream components.

Water quality

Well or quarry water, which has very high dissolved solids, is typically used. Some nozzles have very high propensity to scale internally with this type of water. This leads the nozzle efficiency to go down and cause hopper wetting. The droplet size is usually based on new

exponentially as we try to generate smaller and smaller droplets. For a cement plant, this phenomenon is similar to the increase in energy input that is required to grind smaller and smaller particles from a rock.

Design criteria of a gas cooling system

Available residence time

Available residence time is defined as the straight available evaporation distance that can be utilised to achieve complete evaporation of spray droplets. It is the most important consideration when calculating droplet size and selecting the type of spray nozzle. It is typically calculated by dividing the duct volume of available straight evaporation distance by the actual flue volumetric flowrate at process temperature.

Process condition

This involves a study of detailed process conditions, including variations in inlet temperature and changes in volumetric gas flowrates. If all other variables are held constant, the rate of water evaporation slows as the gas temperature approaches closer to the boiling point of water. This parameter also has an effect on droplet size and type of nozzle selection.

Spray coverage/distribution

It is very important to have optimum spray distribution based on nozzle design for an evaporative spray cooling application. Improper distribution can cause issues such as sticky dust, which can stick to vessel walls. Spray coverage also plays a vital role in efficient evaporation.

Flue gas flow distribution

This parameter is one of the most important and least studied from a spray injection system design standpoint. The ideal gas distribution for efficient and trouble-free evaporation is less than 20% RMS velocity distribution. A mal-distribution can cause wall wetting

and clean nozzle performance and certain safety margins are utilised to work with upset conditions, such as scaling or nozzle wear. Once the droplet sizes produced by the spray nozzle increase beyond the design envelope, wetting occurs.

Direct vs compound operation

Spray nozzles, like any other type of process equipment, have a best efficiency operating point. For a dual fluid spray nozzle with a constant air-to-liquid ratio, the droplet size produced is smaller at higher operating pressures. Typically, in direct mode, nozzles are efficient and require a lower air-to-liquid ratio than running the spray injection system in compound mode. Certain nozzle designs have worse outcomes under compound mode. Nozzles are selected to cope with a large variation in turndown. It is very important that the effect of droplet size is studied carefully for such large varying conditions.

Benefits of lower flue gas outlet temperature

SO₂ control

Various cement plants in the US are required to control SO₂ emissions. The preferred reagent to scrub SO₂ is lime and there are two common methods of injecting lime into the system. The first method is to introduce lime into the conditioning tower or downcomer mixed with cooling water in a slurry form. The second method is to inject lime as powder just upstream of the ID fan. In both cases the reaction between lime and SO₂ is much more efficient closer to dew point temperatures. Lower temperature reduces the actual volume of the flue gas, increasing overall available residence time of the system and providing higher interaction potential between lime and SO₂ molecules. As the outlet temperature of gas decreases, the lime injection rate falls. This method alone can save the plant thousands of dollars in lime costs. These

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reactions have been well studied and proven in power plants.

Mercury capture via dust shuttling or activated carbon

Elemental mercury is typically adsorbed on a high surface area particle, such as powdered activated carbon. Cement dust can also adsorb mercury. In physical adsorption, temperature is also a factor that determines adsorption. At lower temperatures the adsorption rate is higher and cooling the gases increases the residence time of the system. Reducing the temperature also improves the pollutant's concentration of inert flue gas, which provides a conducting condition for removal while achieving higher efficiency.

Improved particulate control device performance

Cooling of gases also improves air-to-cloth ratios within a baghouse. At a lower temperature, the actual flue gas volume reduces the inlet velocities in a baghouse and improves its air-to-cloth ratio. In ESPs, humidity and lower temperatures reduce dust resistivity while improving ESP performance. At lower temperatures, the residence time inside an ESP increases, which could be beneficial for overall dust removal performance.

Over the years, Lechler has been successful in designing new and efficient nozzles. Once the system has been designed, the spray nozzles are the easiest component to replace without significant modification to the existing system. In other words, by using an efficient spray design, more water can be injected to cool the gases without upgrading compressors to achieve the desired outlet temperature and avoiding wetting the hopper. Another potential benefit of high efficiency nozzles is that they can be installed in smaller vessels, which reduces overall construction costs – if installing new GCT towers.

It is commonly believed that in a cement plant a hydraulic spray injection system can be difficult to operate. Lechler has installed many hydraulic spillback systems, including a recent plant installation located in Florida, which was designed to inject approximately 150 gpm of water. This is made possible by selecting the correct droplet size and matching it to variation in process conditions. Hydraulic systems have much lower operating costs due to a lack of required compressed air.

If a gas cooling system is designed properly, it should not experience wetting in any condition, unless there is an equipment malfunction.

Typical operational issues with gas cooling systems

Hopper wetting

The most common issues that can cause hopper wetting are caused by the nozzle or an interruption in the compressed air supply. These issues can also be caused by an increase in droplet size beyond the design

envelope, which is required for complete evaporation. Wetting can not only cause a plant shutdown but can also damage equipment, such as screw conveyors or ID fans. Cleaning of buildup and material accumulation due to wetting requires significant plant resources, which can be time consuming and costly.

Often the system is not designed properly, either from lack of compressed air or improper selection of droplet size. This is a fairly common issue within cement plants. This problem should not occur if the droplet size produced during system operation matches the droplets selected according to system design.

Plants that experience hopper wetting will react by raising the outlet temperature by reducing the water injection rate as a first step. This step solves the wetting issue, but only for the short-term. For the long-term it increases the operating cost, and plants do not generally benefit from cooler gases that can result in operating cost savings. To achieve a stable lower outlet temperature without wetting under all process scenarios, a gas cooling system must be carefully designed. Droplet estimates based on formulas and extrapolation of inadequate data more often result in inaccurate droplet size selection, which is the root cause of most issues.

Advances in spray nozzle technology

New regulations require some plants to reduce HCl and SO₂ and, as a result, lime injection has become important to scrub these acid gases. In the US, plants that required acid gas emission controls quickly ran into nozzle wear and wetting issues due to poor nozzle design and material of construction. In certain nozzle designs, very little wear can rapidly deteriorate nozzle performance and cause severe hopper wetting. The slurry velocity can approach 300 – 400 fps inside the nozzle, which is very high for common alloys, such as stainless steel, from an erosion standpoint. Any deviation or obstruction in the slurry path will cause severe nozzle erosion. The nozzle design and correct choice of construction material are critical for superior nozzle performance and trouble-free operation using slurry sprays. There are nozzle designs available with appropriate material of construction that can provide guaranteed nozzle wear life of 2 years or more if lime slurry is used. Lechler has had operating experience with slurry applications at three cement plants located in the US. These lances have now been in operation without any observable wear for over a year. Another cement plant in California had severe nozzle wear issues. The nozzle tips were wearing within three to four days of operation and this prompted the plant to find an alternate design. Lechler installed Laval nozzle lances at this plant and no nozzle wear has been observed for over a year. It is expected that the same nozzles will continue to operate for more than three to four years without replacement due to wear.

Another issue where new technology can improve the operation is by preventing nozzles from scaling

and plugging during operation times. Typically, in cement plants, a high amount of dissolved solids are present in the process water. This causes scaling at the wet-dry interface inside the spray nozzle. Scales alter the nozzle performance, which leads to hopper wetting. A new technology is available that can clean the nozzles onsite without any manual input or labour. The Lechler Online Cleaning System, or LOC[®], has been proven to completely eliminate manual cleaning requirements, which are present with both lime slurry injection and hard water usage. The LOC[®] system is a trouble-free operation and is virtually guaranteed when using lime slurry and/or hard water. This online cleaning system can also guarantee zero wetting with such liquid media.

Another important area where new spray nozzle technology has created an impact is the capacity to produce superior droplet sizes. It is critical to produce small droplets by using less compressed air. Lechler has found that the droplets for most nozzles generated at the edges produce the largest droplets. There is a new generation of nozzles that can reduce these large droplet sizes to a very fine mist. The RingGap[™] nozzle is very efficient and produces a very narrow droplet size spectrum.

Conclusion

Spray nozzles play an important role within cement manufacturing operations. Under current regulations, a well-designed spray gas cooling system can reduce maintenance issues and the cost of using expensive chemical reagents required for emission control. However, in order to design and achieve cooler temperatures, a careful analysis of the design is required. The droplet size at various design and operating points must be measured carefully, as estimates have been proven to be very unreliable. It is very important that plants ask nozzle manufacturers to describe the methods they use for nozzle droplet testing.

Spray nozzles should provide a high surface area for heat transfer between hot gases and water or slurry. If design calculations are carried out correctly and encompass all design conditions, then a spray gas cooling system should not cause any operational issues. 🌐

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