Online Chemical Engineering Information

Effective Temperature Control for Cement Kiln Off-Gases

(Special Shared Content with Turbonsonic)

Introduction

Effective off-gas temperature control without unwanted side effects can be achieved in many cement plants with state-of-the-art evaporative spray technology.

Gas temperatures have elevated in recent years from as low as 180°C to over 370°C. This is coincident with a higher proportion of "dry" operation kilns. Evaporative cooling water sprays in conditioning towers, ducts or at the kiln exit have proven an effective alternative to infiltration air. Typical installation locations are shown in the dry cement process schematic.

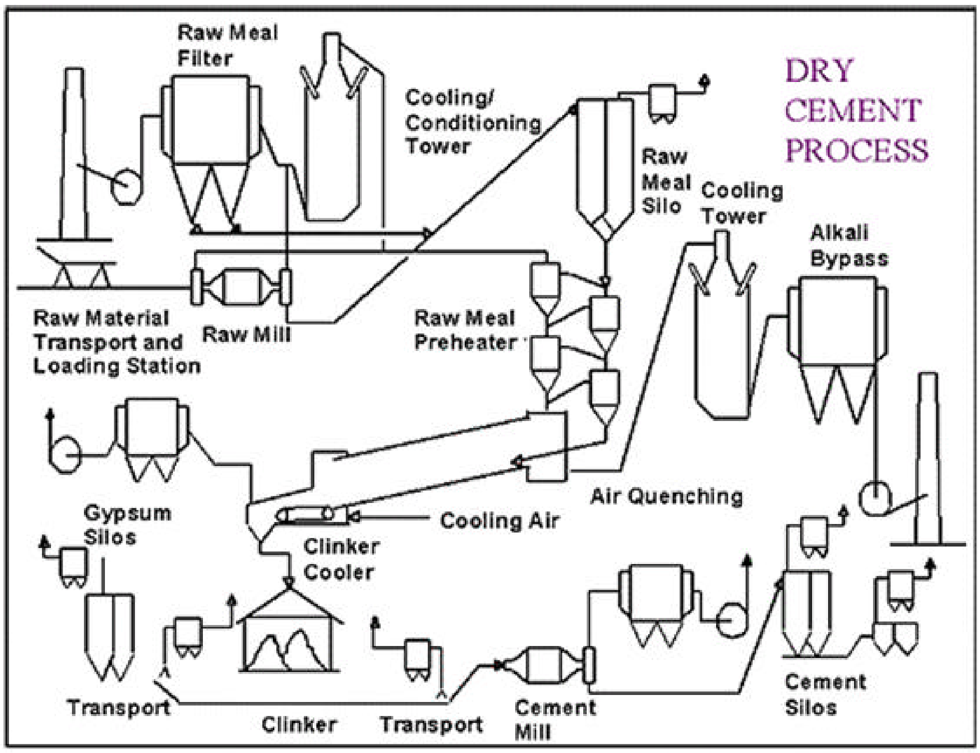

Figure 1: Evaporative spray cooling applications for the dry process

Why Use Water Sprays?

There are several compelling reasons for controlling either the gas temperature and/or water content in optimum ranges.

One relates to the composition and amount of particulate. As much as 5-7% of the feed tonnage can be carried through to pollution abatement equipment (PAE). The melting point of some of the particles in the hot gas stream are as low as 260°C. They can cause sticky deposits in ductwork, on fan blades and downstream particulate removal devices. This effect can be minimized by controlling temperatures to below 200°C. It is imperative, however, to simultaneously ensure 100% evaporation in the particulate/dust-laden environment or wet deposits will occur. Typical dust loadings will range from 10-40 grains/cfm even after cyclones. Deposits will build up causing high pressure drops, and eventually break free and damage equipment.

As many of the fuels used in kilns today have increasingly high sulfur levels, temperatures must be kept above the sulfuric acid dewpoint so as to prevent corrosion in the ductwork, towers, baghouses or electrostatic precipitators (ESP). Chlorides in the gas phase or combined with particulate will dissolve in condensed water forming hydrochloric acids. Under deposits these acids cause severe corrosion; therefore, accurate temperature control must be achieved. This can be done with water sprays producing fine droplets of 50 µm (micron) Sauter Mean Diameter (SMD) or less.

Further, sulfur has been shown to encourage calcium carbonate formation in the 370-980°C range and this can lead further to calcium sulfate (gypsum) formation, both of which are very hard cementitious deposits.

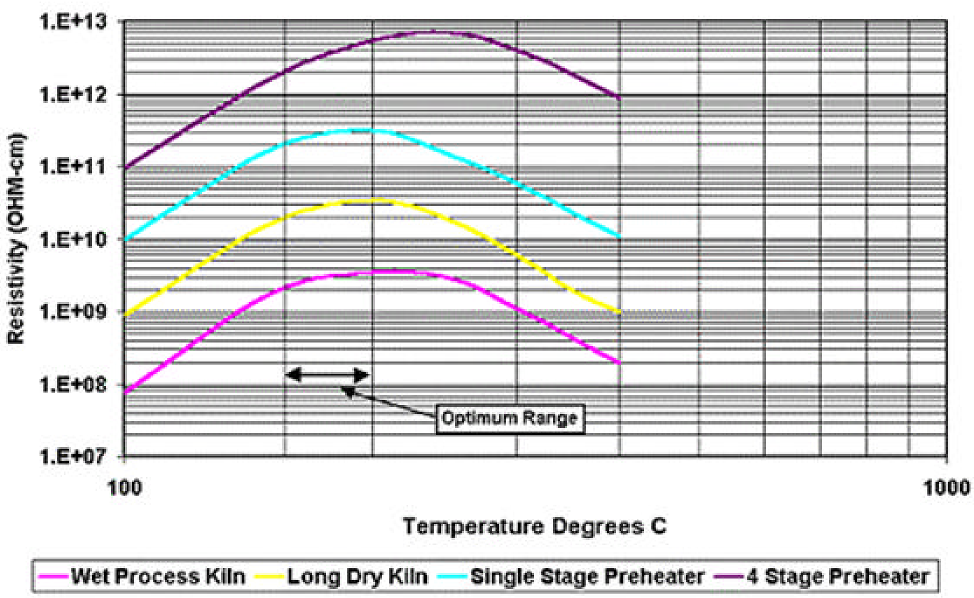

Figure 2: Typical dust precipitator - resistivity vs. temperature

Another reason for effective temperature control is that pollution control regulations continue to be tightened. As ESP efficiency and, therefore, stack emissions are directly influenced by dust resistivity, conditioning the gas stream ahead of an ESP to optimize temperature and humidity is a critical factor. Optimum moisture content can be achieved through judicious injection of water. These charts show typical resistivity curves for different kiln operations. Operating in the range of 10^7 - 10^{10} OHM-cm is usually most effective for dust removal. Above 10^{10} operation and design are more critical.

Resistivity curves like these should be developed for each system so target temperatures and humidity can be set. Water sprays can then be controlled by temperature and/or humidity sensors. Figures 2 and 3 show how adding moisture can reduce resistivity into a better operating range. Caution must be exercised not to go too low in temperature.

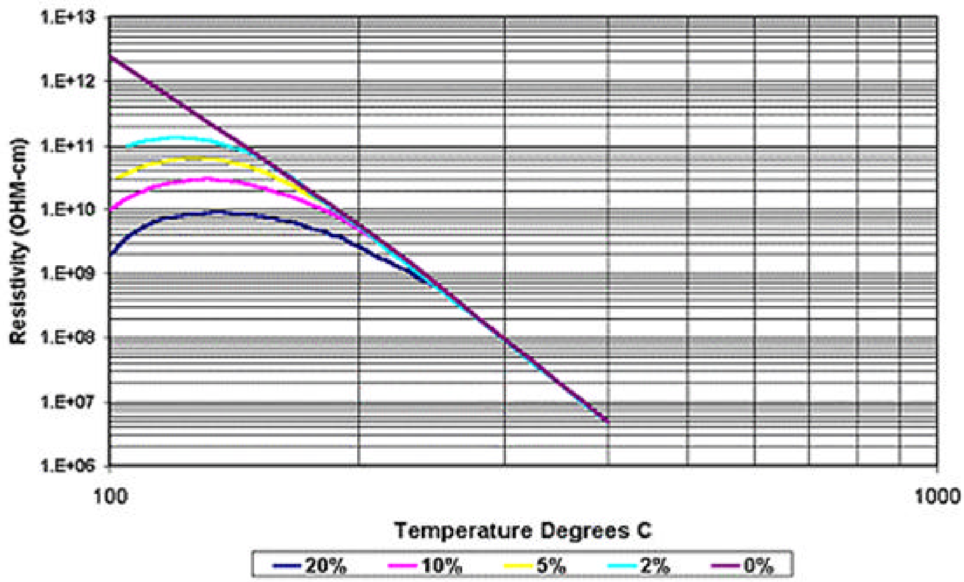

Figure 3: Typical impact of temperature and % moisture on resistivity

A third reason to control temperature by evaporative cooling relates to power consumption. Cooling the gases with water sprays as opposed to injecting dilution (infiltration) air will reduce the volume of gas to be moved by the induced draft fan. Energy savings can be achieved by reducing fan load. As well, less air volume reduces baghouse capacity requirement.

Maintenance

Maintenance of spray systems can be a significant factor and must be considered in equipment selection. Operating costs and maintenance of high pressure, 450 psi plus, hydraulic water systems must be balanced with the low pressure, 60-80 psi air atomized approach using compressed air. Nozzle and lance design are key factors in minimizing wear. Water used for these applications can often be highly loaded with abrasive particulate, which can deteriorate nozzle tips, compromising performance and increasing replacement costs.

Operating Criteria

After determining the required degree of cooling, the gas flow, desired control setpoint temperature, particulate type and quantity, the amount of water to be sprayed can be calculated. Droplet size is one of the most critical criteria to be achieved. This is because evaporation time for the droplets, given the temperature difference (?T) driving force between the hot gas and water temperatures is an exponential function. The drop size is set so evaporation occurs in available or design residence time in the duct/tower. For example, a droplet size of 100 µm with an evaporation driving force of 200°F will take 0.7 sec for complete evaporation (see graph below).

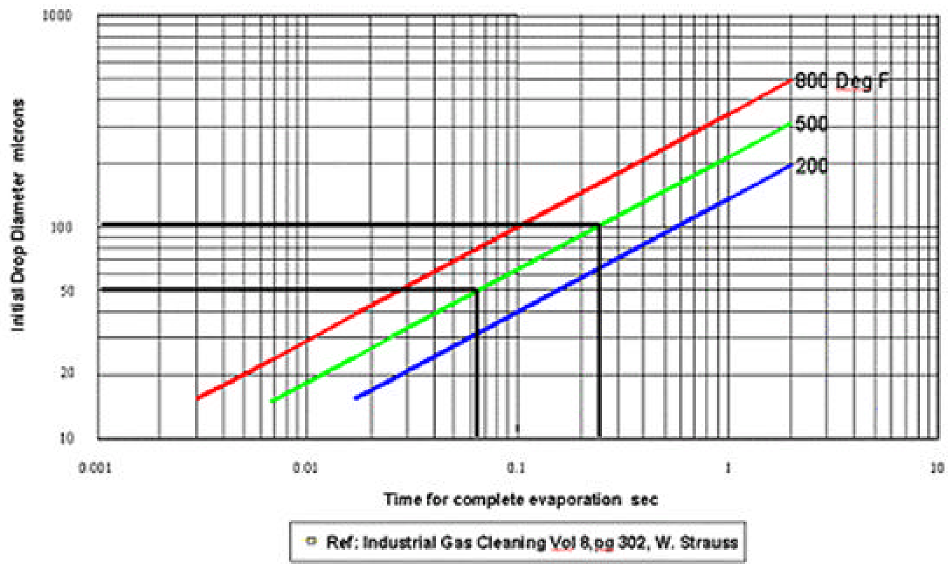

Figure 4: Evaporation lifetimes for pure water drops

Reducing the diameter in half to 50 µm, exponentially increases the surface area and reduces time for evaporation to 0.1 - 0.2 seconds. Droplets generated in the sprays are usually measured in mean diameters (Sauter Mean Diameter - SMD) and are distributed in a bell curve fashion. Although the spray average drop size is important, the maximum drop size and percentage of drops in that high range need to be considered. Evaporation times for these will be exponentially much longer. Further, the effects of spray interactions with the dust is important as wetted particulate will require much longer drying times than water alone.

Comparisons of the energy costs to atomize the drops can be made. Two typical approaches are single fluid, water only, sprays operating at 450-650 psi. These will typically create droplets in the 100 µm SMD size. Pumping costs and maintenance issues can be excessive. Usually excellent water filtration needs to be included. Compare these costs to the alternate approach of air atomized sprays which generate 50-60 µm SMD drops. These calculations of compressed air usage operating in the 60-80 psig range, can show air atomization to be attractive from a performance and cost perspective.

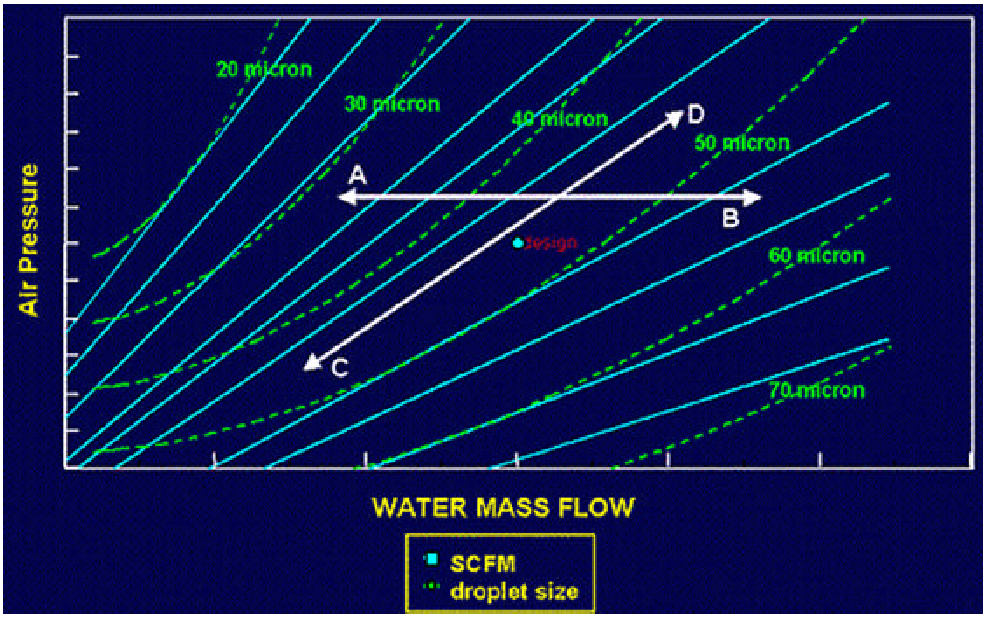

Figure 5: Turbotak atomizing nozzle performance curve

Operating control logic parameters are very important. As can be demonstrated, referring to the performance curve below, an air atomized system can be controlled with either a constant pressure (A to B) or constant air flow (C to D) scheme. As the water flow varies based on automated temperature setpoint, flows will change along the bottom "X" axis. The air and liquid pressure can be varied as shown on the Y axis. Resultant drop sizes are indicated by a set of dotted line curves. Compressed air consumption is shown on the solid series of curves. Monitoring of two or more of these variables allows the operator to troubleshoot nozzles in operation to ensure that proper drop size is being achieved at all times and with all sprays.

Example Applications

Case 1

A 4500 ton/day cement manufacturer was having wetting problems in the cooling towers ahead of his electrostatic precipitator. Inefficient cooling water atomization and drop size control was experienced with 580 psi hydraulic nozzle operation. Short nozzle life due to high wear on the nozzle internals was a secondary problem. Eventually wet bottoms and under deposit dewpoint corrosion resulted in severe damage of the base of the tower. From the pollution perspective, precipitator performance was not optimum as humidity and temperature were not being effectively controlled by the sprays.

A two-phase air/water Turbotak spray nozzle system was installed and set to control temperature at 140°C. Multiple orifice sprays and lances were used as in the attached sketch. These were operated at 40-60 psi, creating 40-60 µm droplets. With the multiple orifice spray nozzle, fewer lance assemblies were used thus minimizing maintenance efforts. The tower diameter of 21 feet required only 8 multiple orifice sprays versus the previous 16 single orifice nozzles, while still providing complete coverage of the tower. The system has operated well for several years.

Wetting problems have been virtually eliminated, maintenance reduced and improvements in precipitator performance achieved.

Case 2
The main gas conditioning tower of a large cement manufacturer measured 23' diameter. At an effective height of 70' the residence time was 7-8 sec. The gas flow of 240,000 acfm, gave a gas velocity of 570 ft/min. Inlet gas temperature of 400°C was to be controlled at 130°C. Dust loading measured at about 30-40 gr/acfm. For this system, six Turbotak 9 orifice by 6 mm diameter nozzle/lance assemblies were used to spray a total of 100 US gpm at 70 psi. A Sauter Mean Diameter of 40-45 µm is achieved with a maximum drop size of 160 µm. Due to the straight through liquid path design of the Turbotak spray nozzles, nozzle wear and thus maintenance has been significantly reduced. The six assemblies have replaced fourteen previous air assisted nozzles, which operated at 100 psi. Total compressed air flow is 1100 scfm.

Case 3
A western cement plant at high elevation was challenged to:

a. Maintain temperature control under varying production conditions such as raw mill on/off.

b. Maintain stack opacity

c. Provide low temperature control without "wet tower bottoms"

d. Reduce compressed air usage

Previous experience with 17 air assisted nozzle/lances in the top of the 15' diameter tower had not met these objectives. A retrofit consisted of installing 8 Turbotak 6x6 mm cluster nozzles in the 15' diameter tower to cool 200,000 acfm of gas from 1100°F to a 250°F setpoint. Compressed air differential pressures were reduced to balance with water pressure, and objectives have been met.

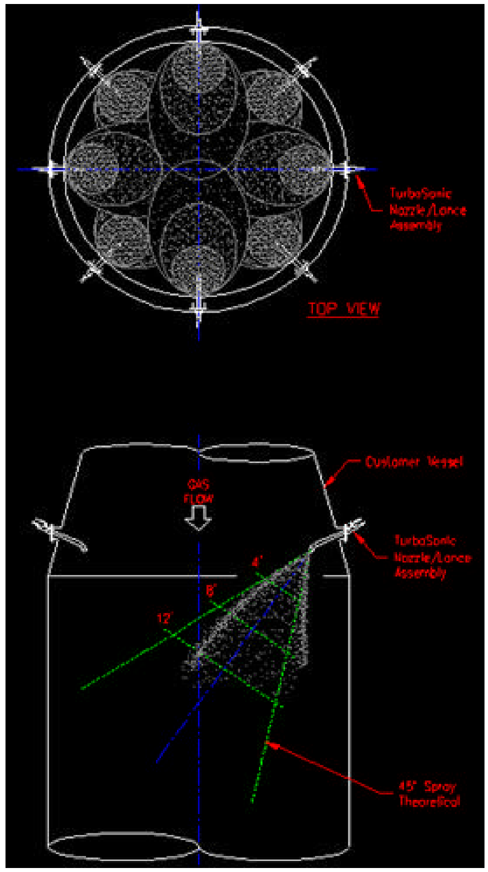

Figure 8: Cement kiln conditioning tower with Turbotak nozzle installation

Case 4

A 1,700,000 ton/year plant in Canada operated a vertical "calciner" duct ahead of an induced draft fan. Cooling was being done by air assist sprays giving drop sizes of 130 µm SMD. This resulted in wetness and then deposit build-up on the duct walls. Deposits fell regularly into the fan inlet.

A retrofit with 3 Turbotak 6x8.5 mm sprays was installed and set to produce 45 µm SMD drops. These smaller drops allowed effective cooling in the short residence time, 1.4 seconds, high velocity 4500 ft/sec flow of 280,000 acfm. Deposits have been eliminated despite the dust loading of 29 grains/acfm.

Conclusions

Effective temperature control can be achieved by a properly designed and controlled water spray system. This allows dry operation with minimal deposition, ease of ash handling and no corrosion. The resultant optimization of pollution control equipment can allow operational flexibility in meeting pollution control standards without costly modifications or capital expenditures. Finally, nozzle design is critical in minimizing maintenance and operating costs.