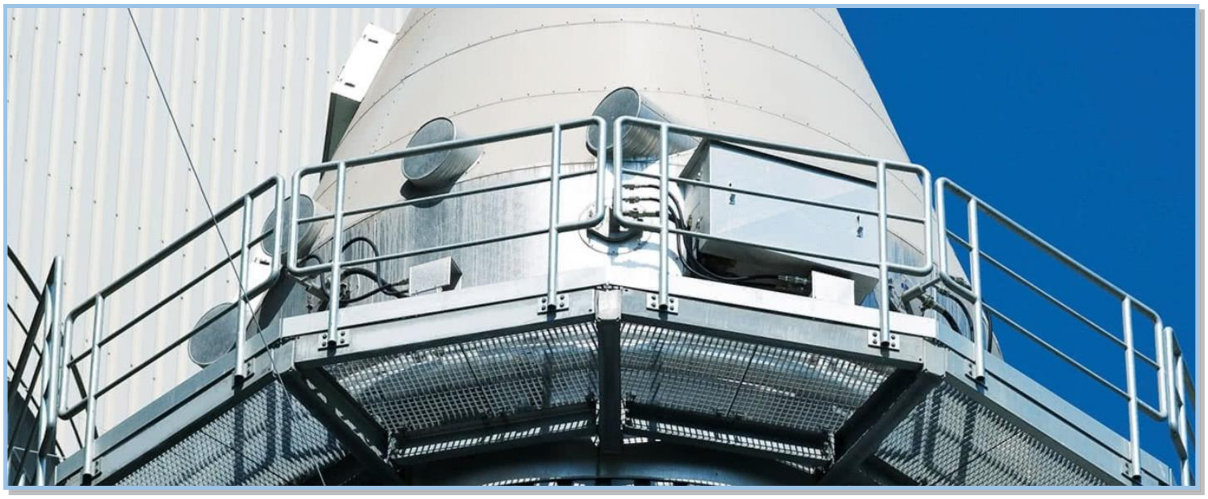
Improving Cooling Performance of Gas Conditioning Towers/Downcomers to Reduce Plant Emissions

Robert Van Durme, P.E.
Lechler Inc.
445 Kautz Road
St. Charles, IL 60174
RobVanDurme@Lechlerusa.com

Marek Serafin, P.E.
Continental Cement
301 E. Front St.
Buffalo, IA 52728
Marek.Serafin@Continentalcement.com



Abstract –
A project was initiated at a midwestern cement plant that needed to improve their cooling capacity of their existing Gas Conditioning Tower (GCT) to reduce the tower outlet temperature and to improve Mercury (Hg) removal downstream in the process. In achieving a lower outlet temperature of the cooling tower, a plant can increase the natural adsorption of Mercury in the plant's equipment, thereby decreasing the amount of Activated Carbon required to meet emission requirements. The plant was hoping to avoid investing in a new cooling tower or other high capital cost equipment. The challenge was to increase cooling without experiencing wetting or buildup in the tower or ductwork. The upgraded tower has been running successfully for approximately 2 years. Before and after results will be presented.

Index Terms –
Emissions, downcomer, efficiency, gas cooling, process improvement, mercury removal, spray nozzles, temperature reduction, tower

I. Nomenclature

Baghouse – Large construction of filter media to capture dust and particles from the cement making process from entering the atmosphere.

Calcination – The process of the decomposition of calcium carbonate (limestone) to calcium oxide (lime) and carbon dioxide in order to create cement.

Downcomer – A long section of duct or pipe that transports process gas towards ground level for processing.

Flue gas – Combustion byproducts from generating heat from the burning of fuels such as coal or natural gas.

GCT – Gas Conditioning Tower. Structure for the cooling of hot flue gases from the production of cement.

Preheater Tower – A series of cyclones that allows the transfer of waste heat from the flue gas to the raw product to reduce fuel consumption.

Heat of Vaporization – The amount of heat needed to turn one gram of a liquid into a vapor, without a rise in the temperature of the liquid.

II. INTRODUCTION

This paper consists of a midwestern cement plant located on a major inland waterway with most shipments and receipt of products handled via barge and rail. The site has 1 kiln that produces approximately 3,000 tons per day of clinker. The plant was built in the 1970's. Fuel (i.e. coal, natural gas) is burned to create heat in the kiln for achieving the proper temperature for calcination of the raw product. The remaining heat from the kiln is partially recovered to increase the temperature of the incoming product. The flue gas from the kiln is directed through the GCT to reduce the gas temperature before it reaches the baghouse and raw mill prior to exiting into the atmosphere. The plant uses a high-pressure water atomization system for cooling of the flue gas that does not require air compressors. They were seeking to improve their cooling capacity of their GCT in order to improve Mercury (Hg) capture.

III. EVAPORATIVE COOLING IN THE CEMENT MAKING PROCESS

The production of clinker requires a significant amount of heat generated in the calcination process. Cement plants continually search for methods and processes to capture the heat and re-use it to improve the efficiency and reduce fuel costs. In almost all cement plants, the flue gas requires to be cooled to a temperature that is within specification of the particulate control device in order to not ignite the filter media that is being utilized to clean the flue gas of dust and contaminants. The flue gas enters a downcomer or GCT where water is injected for cooling of the flue gas. The downcomer or GCT is typically located downstream of the kiln outlet and just upstream of the particulate control device to help control the temperature of the flue gas. In this area, the water droplets are heated until they reach boiling and they evaporate. The energy that is used to bring the water droplets to evaporation is removed from the flue gas and the resulting effect is a reduction in the flue gas temperature and increase in water vapor. This is known as the Heat of Vaporization. Imbalances in this process can produce wetting inside the duct or downstream equipment resulting in costly downtime and clean-up of the wet dust.

The two most common atomization technologies utilized in the evaporative cooling process are high-pressure atomization and twin-fluid atomization. High pressure atomization uses elevated pump discharge pressures in the range of 500-600 psig to supply a spray injection nozzle/lance to introduce the water droplets into the flue gas. Twin fluid technology utilizes compressed air to atomize the water into droplets via a spray injection nozzle/lance as well. The water and compressed air (the two fluids) combine inside the nozzle and exit into the flue gas stream. The typical operating pressure of these systems is 60-80 psig.

Both technologies are used world-wide. Most installations in the United States utilize the twin-fluid technology. The merits of this systems in comparison to high pressure atomization is that they produce smaller droplets at lower operating pressures. This allows for shorter evaporation distances and smaller construction costs in fabrication of a cement plant. The drawbacks to this system is that they require a constant supply of compressed air capacity that adds to the operating and maintenance costs of a cement plant.

IV. Current operation

In the 1990's, the plant constructed a GCT to reduce plant emissions and utilize a baghouse for the collection of particulates. The system utilizes a high-pressure atomization system for cooling of the flue gas. The plant has continued to benefit from this technology by not requiring to use air compressors for droplet atomization. The tower has a diameter of approximately 6.4m with 18 openings along the circumference close to the top of the tower where the hot flue gas enters and flows vertically downward (See Figures 2 and 3). A diffuser plate is located at the inlet of the GCT to help distribute the gas evenly in the vessel (See Figure 1).

Fig. 1. Flue Gas Diffuser at top of GCT

In the past operation with the raw mill off, the flue gas entered the tower at approximately 388° C and exited at approximately 250° C. The pump system supplying the injection lances was found to have no additional capacity to inject more water into the process. Attempts to reduce the outlet temperature of the tower via increased water resulted in wetting of the material and ductwork. This led to forced outages for the plant. With the new regulations in the market, the plant was seeking to reduce their GCT outlet temperature.

Some of the possible approaches to reduce their GCT outlet temperature considered were: Physical tower modifications, conversion from a high pressure to twin fluid atomization system, pump modifications to increase operating supply pressure, and improvement of their current system utilizing their current equipment.

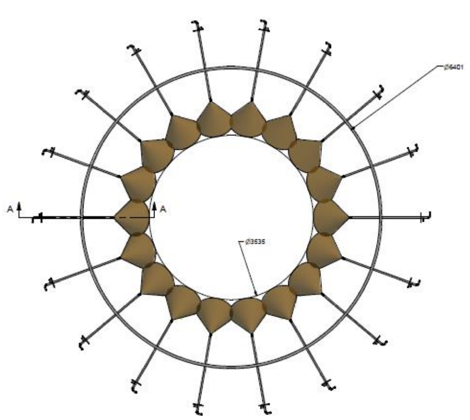


Fig. 2. Original Lance Layout in Tower (millimeters)

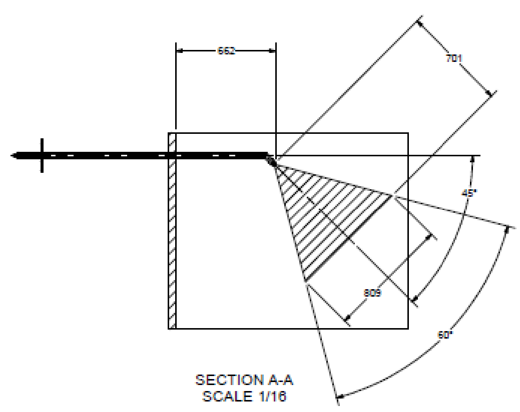


Fig. 3. Original Lance Design (millimeters)

V. FLUID APPLICATION ENGINEERING

In review of the possible solutions, the plant wanted to pursue the least cost option which was reviewing the current water injection system and determine if it could be improved to achieve the results they were looking for. Physical tower modifications, the additional of air compressors, or upgrading their current pump equipment were all determined to be the least attractive due to the significant capital costs involved. The hope was that a thorough engineered analysis of their current water injection system would give the ability to improve their cooling capacity.

The spray technology selected and applied in these applications play a critical part in the capabilities of the entire process. Several factors are to be considered in selecting the proper nozzle. These include material of construction, flowrate, spray angle, operating pressure, placement, droplet size, maximum free passage, and many more. New developments in spray nozzle technology are allowing powerplants to have better control and achieve/maintain the tighter regulations on key emissions in the plants [1]. A review of the current layout of injection points utilizing the nozzles' known spray pattern, droplet size, spray plume and location highlighted areas in the tower showing maldistribution of the water in the flue gas. This created dead zones of untreated gas and an excess flux of water in the nozzle locations. This was a primary contributor to wetting of the ductwork and tower when attempts to increase the cooling capability of the GCT was performed.

In order to create a more uniform distribution of water through the tower, new lances were designed with two nozzles per lance instead of the original lance that only had one nozzle. Care had to be taken to ensure that when the lances were fully inserted, the additional coverage did not create oversaturation in a localized area. In addition, the design had to account for a proper distance away from the inside walls of the tower where potential wall wetting could occur from overspray (See Figures 4 and 5). The spray pattern and spray angle of the entire spray distribution was evaluated for even coverage across the cross section of the tower. Based upon the engineering analysis of the tower, the plant proceeded with the new spray lance design.

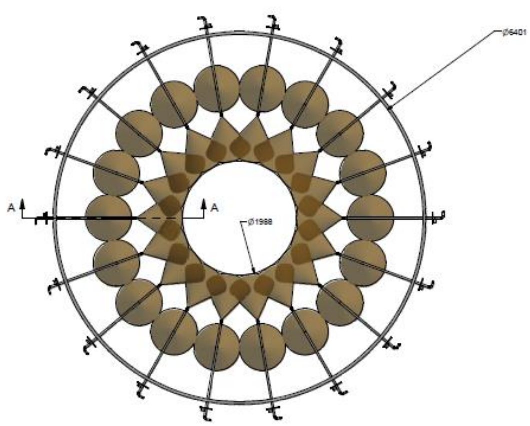


Fig. 4. New Lance Layout in Tower (millimeters)

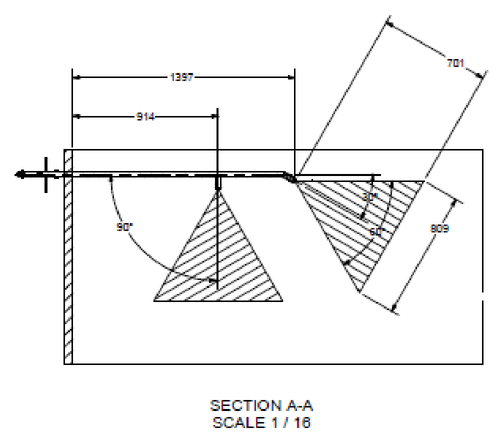


Fig. 5. New Lance Design (millimeters)

VI. IMPROVED COOLING PERFORMANCE

The improved water injection allowed the plant to achieve better cooling capability in their GCT with no wet bottoms. In order to install the new lances, the existing ports had to be increased to allow for lance insertion and removal in a confined area. The lances were extended in length in order to accommodate more uniform placement of the water in the tower. The lances were supplied with new hoses and connections to facilitate easier maintenance. No changes to the existing pump system needed to be made.

In achieving a lower inlet temperature at the baghouse, additional Mercury capture was realized. This allowed for greater Mercury removal in their process. The plant was able to achieve reduction in Mercury emission in excess of 30% during a recent trial (See Figure 6).

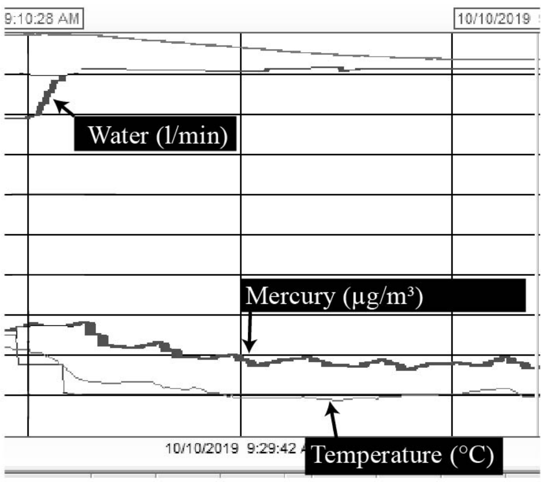


Figure 6. Mercury reduction as a result of lower gas temperature

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions of Continental Cement and their employees on the original version of this document.

REFERENCES

[1] Robert Van Durme, P.E.,"Spray Technology is Critical in Helping a Plant Achieve Optimal Performance," in *Proc. 2009 ASME Power 2009 Conf.*, pp. 1.