Innovative New Chimney Design for Wet Flue Gas

Paul Nederlof, Msc.
Hadek Protective Systems, Inc.
651 Holiday Drive
Pittsburgh, PA 15241

ABSTRACT

For removal of a large number of flue gas components, wet air pollution control (APC) equipment is often chosen as the best available technology. Low flue gas temperatures produced by these systems warrant the need for consideration of corrosion control in the flue gas systems, downstream of the wet APC-systems.

This paper will present an innovative new chimney design. The design consists of a concrete shell and a glass block lining without an internal flue reducing the outside chimney dimensions and time to build the chimney considerably.

Retrofit of APC equipment to an existing power plant usually poses considerable design challenges requesting scarcely available real estate. A quick to build, smaller foot-print new chimney will add to the solutions available.

Additionally, the same design concept may be used in existing chimney structures. By removing the original flue, the flue gas opening in chimneys originally designed for high velocity hot flue gas evacuation is enlarged, making it suitable for accommodation of low temperature wet flue gases in a limited outage time.

Cost of the different options will be discussed, taking into consideration construction schedules, manpower requirements, and local design restrictions to provide a realistic comparison basis for the respective design options

INTRODUCTION

A typical chimney consists of a foundation to support the chimney and transfer all loads to the earth. On top of the foundation the chimney is built. In power plant construction these are usually reinforced concrete structures that can range in height from a few hundred to more than one thousand feet.

Chimneys are the last structure in the flue gas path and used for emission of residual pollutants resulting from the combustion of fuel. It safeguards people at or close to the plant from high concentrations of those pollutants by providing dilution of the pollutants in the atmosphere.

In present times many pollutants need to be removed from the flue gas before it is emitted into the atmosphere. The methods used for removal usually drop exit temperatures of the flue gas considerably, from a typical 130^{o}C - 150^{o}C (266^{o}F - 302^{o}F) to a typical 50^{o}C - 55^{o}C (122^{o}F - 131^{o}F). The resulting temperatures are below the dew point for sulfuric acids and very often even below the water dew point. This creates a corrosion hazard for the structures exposed to this flue gas. Chimney structures should be able to contain this flue gas without being deteriorated.

The most commonly used method in construction of chimneys is to guide the flue gas through a chimney flue, essentially an extension of the outlet duct leading to the top of the chimney. The flue will protect the concrete from the corrosive flue gases and the annular space around the flue will protect the concrete from thermal stresses. In case of more units using one chimney structure, each unit can still have its own flue and be independent of the other units. One considerable disadvantage of construction materials that are resistant to sulfuric acid is the cost, compared to regular materials of construction.

Therefore if only one flue would be necessary, considerable cost savings could be achieved by eliminating the use of a flue altogether. Not only in materials cost, but also build time.

In the following the new design for a chimney based on this concept and the building of one is discussed.

NEW CHIMNEY DESIGN CONCEPT

The design concept of the new chimney design is to use the reinforced concrete windshield also as a flue. Therefore, only a windshield needs to be constructed. The building of an internal flue and complex support structures inside the windshield is then not required anymore.

To be able to use the concrete windshield as a flue, it should be able to withstand the acidic gases and condensates present in the flue gas and the thermal variations. High temperature differentials over a concrete wall may lead to tensile stresses that cannot be counteracted with extra reinforcement economically. Therefore the temperature differential over the concrete should be limited to acceptable levels as designed.

A common component in flue gas is sulfur tri-oxide which, combined with water, creates sulfuric acid. Commonly used concrete with Portland cement has a very low resistance to sulfuric acid and should be protected from this.

To be able to construct a single flue chimney and at the same time using the concrete windshield as flue the concrete is ideally protected with a lining system that is insulating and acid resistant.

A lining system consisting of Borosilicate Glass Blocks of a closed cellular structure is available and widely used in the industry. Borosilicate Glass Blocks being of closed cellular structure are insulating and being of borosilicate glass, acid resistant. Using this lining system the design can and has been built.

DESIGN ADVANTAGES

The design concept significantly simplifies construction of a chimney, which offers a number of distinct advantages over a conventional chimney design with a separate flue.

1. A shorter construction time: Building of the chimney consists of construction of the concrete column only. When a slip form is used for construction, time to build the column may be reduced to less than 2 months for a typical 200 meter high chimney. Since no additional supports for a flue need to be incorporated in the concrete shell, the design is further simplified, aiding reliability of the construction process.
2. Lower maintenance: Due to the simplification of the design, there are fewer items to maintain. Together with the chimney flue, flue supports, insulation, expansion joints are eliminated.
3. Greater suitability for seismic regions: Elimination of the internal flue removes a large mass from the chimney. A steel liner in a typical 200 meter high chimney would weigh about 500 tons, while a borosilicate glass block lining on the concrete shell would only weigh about 80 tons sharply reducing the horizontal loads induced by earthquake movements. Even when the concrete would be loaded beyond its tensile force and develop small cracks, the chimney would be kept gas tight by the lining system [(i)].
4. Flexibility in operating conditions: Borosilicate glass is one of the few materials that is completely resistant to sulfuric and hydrochloric acid without limitation for

temperature or concentration. A power station may therefore choose to run at full wet stack operation or full by-pass and switch between the two.

5. The borosilicate glass block lining system consists of borosilicate glass blocks of a closed cellular structure, cut to a typical size of 6”x9”x2”. Cutting the blocks leaves a roughened surface structure that aids in reduction of the condensate film thickness. This reduction of the condensate film thickness reduces the chance of re-entrainment of droplets into the gas stream, allowing higher wet flue gas velocities [(ii)].
6. Lower cost: All advantages mentioned earlier will result in a chimney that requires lower initial investment costs and lower maintenance cost during its service life.

CONSTRUCTION

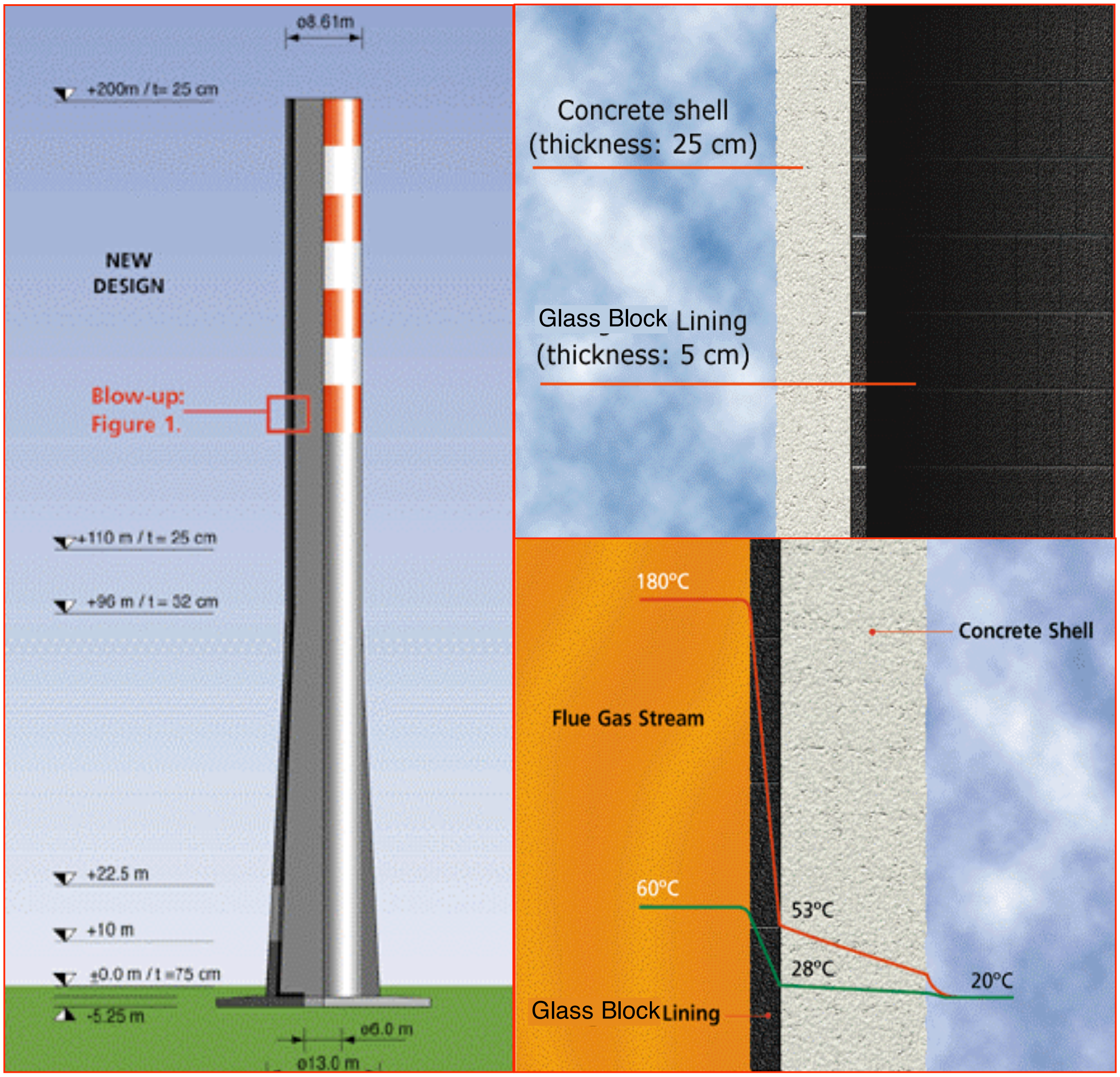


Figure 0 Sketch of new chimney design with details

The construction of the new chimney design is a concrete shell with a borosilicate glass block lining system directly applied to the concrete. This will necessarily place all elevators and access platforms for regulatory measurements on the outside of the chimney shell. In Figure 0, a sketch of the chimney and close up of the lining system is shown.

Eliminating the internal flue and also eliminates the annular space, thereby reducing the outside diameter of the concrete shell considerably. Wind loads are therefore significantly reduced compared to a similar chimney designed according to the conventional design.

This reduction in loads is not shown in the foundation though, since dead load is reduced significantly as well, requiring extra piles or a larger foundation area to counteract the overturning moment [iii].

The annular space in a conventional design provides isolation from the higher temperature in the flue gas and therefore there will be hardly any temperature drop over the chimney shell. In case of the new chimney design, the lining system will insulate the concrete shell from a large temperature drop, but it will be larger than in the conventional design. To counteract the thermally induced stresses in the concrete shell, more reinforcement is required [iii].

CONCEPT APPLICATIONS

The design concept as described in aforementioned paragraphs may be used in new power units with air pollution control equipment and could facilitate short wet duct systems by building the chimney very close to the APC equipment.

In retrofit situations, the concept may be used on the existing concrete shell of the existing chimney at the plant. Two problems are solved at once, using this approach. Usually older chimneys were designed with high flue gas velocities, to facilitate dispersion. These velocities are too high for flue gases running at or below the water dew point since condensate will be carried out of the chimney. By using the extra space provided in the annular space, the chimney diameter is increased and consequently the flue gas velocity may be decreased to acceptable levels for a wet stack.

The second problem solved is outage time. Inherently a retrofit of APC equipment to an existing plant is built while the plant is running. However, the lining system may be applied to the concrete shell while the chimney is operating since ventilation is easily established in a chimney structure. Removal of the flue may be done during the APC tie-in outage or any earlier suitable outage.

CASE HISTORIES

Considerable experience exists with the design concept using a borosilicate glass block lining system directly on the concrete shell. One of the earlier uses was at a paper plant in Georgia where a brick flue did not perform in the environmental conditions it was exposed to after about 3 years of operating.

It was decided to remove the upper 23 meters (75 feet) of the brick lining and instead of rebuilding the liner with brick, a 38 mm (1-1/2”) thickness of the borosilicate glass block lining system was applied directly to the inside of the concrete shell. A positive seal was made between the juncture of the borosilicate glass block lining and the top of the remaining brick liner using a fabric seal.

A large percentage of the borosilicate glass block lining could be applied before the actual plant shutdown. Tearing out of the upper section of brickwork and the placement of fabric seal and new stainless steel cap was accomplished in a six (6) day plant outage.

This particular chimney at the Oglethorpe paper mill serves flue gasses from three boilers, an oil and waste wood boiler, a black liquor recovery boiler and a calciner. Flue gases from the oil fired boiler and calciner are scrubbed with flue gas temperatures around 70°C. Flue gas temperature from the recovery boiler is around 200°C. Normal operating temperatures in the chimney are between 88°C-121°C (190°F-250°F) depending on the load of each boiler. Maximum upset temperature conditions to 232°C (450°F) for a maximum 2-hour duration.

Three years after this work was completed, the brick liner exhibited significant cracking and it was decided to continue the earlier restoration approach and in September of 1987, the borosilicate glass block lining system was installed on the remainder of the concrete shell and all but the lower 12 m (40 feet) of the brick liner was removed.

In 2001 the chimney was completely inspected by specialists. The chimney was found to be still in good structural condition although the target wall area had seen numerous problems over the years [iv].

According to plant personnel the chimney is still operating in the same condition as in 2001, except for the installation of another target wall in the breeching area in 2004.

Two new reinforce concrete chimney shells were slip formed in Poland at the Patnow Power Station in 2006. In April and June of 2007 these two chimney shells have been lined with a borosilicate glass block lining system of 54 mm (2”) thickness.

At the Patnow power plant two scrubbers had to be added to clean flue gases from the 6 units. The existing chimneys could not be turned into wet stacks because of space constraints for ductwork into the chimneys and 3 units feed into each chimney.
The scrubbers were built at such a place in the plant that it was more economical to build two new chimneys than construct new ductwork leading to a common chimney. Due to the corrosion resistant materials necessary in ductwork downstream of scrubbers, ductwork is very expensive.

It was therefore decided to build two new chimneys close to the scrubbers. The building of the chimney is visualized in pictures 1 thru 7. First the chimney shell was slip formed.

Picture 1 Slipforming of the concrete shell

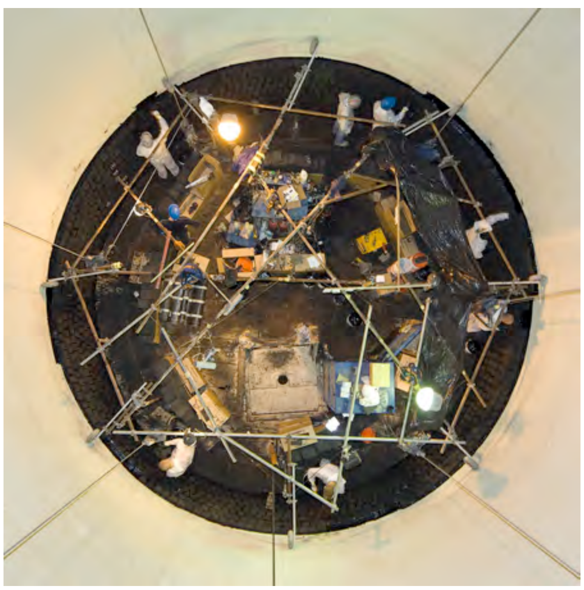
When concrete left the slip form, it was screeched and a vapor retaining primer applied to the smoothened surface. The borosilicate glass block lining system would be directly applied over the vapor retaining primer.

Picture 2 Screeching the surface

Picture 3 Applying vapor retaining primer

Picture 4 Concrete out of slipform, screeched concrete, primed concrete.

The breeching opening in the chimney is at the same height as the top of the scrubber vessel. This way, the area of concrete to receive a lining can be greatly reduced making the design of the chimney even more economical. A false floor would be installed, just below the breeching.



Picture 5 Application of borosilicate glass block lining system

Picture 6 Floor, just below breeching

Picture 7 Power station with two new chimneys going up between existing

DISCUSSION OF COST SAVINGS

In this section an economical comparison is made between the new chimney design concept and a chimney designed according to the conventional design using a flue inside a reinforced concrete shell. The comparison can only be qualitative, since pricing is strongly influenced by availability of labor, equipment and scheduling.

Building time of a new chimney design is greatly reduced and may be 5 months (excluding the foundation) instead of 7 or more for a new chimney. An almost 30% cost savings.

Elimination of the internal flue and structural details is currently (due to the high price of steel) about a 60% savings compared with the lining system alone. The difference in size of the concrete shell only counts to about 10% savings due to extra reinforcement. The same is true for the foundation.

During its service life the chimney would require less maintenance.

CONCLUSION

The new chimney design is a reliable, quicker and cost effective way of building a chimney for wet flue gas emission. Two new chimney designs may even be more economical to build than one, depending on location, space availability and cost of ductwork.

i) PENNGUARD® Block Lining System, Seismic Test Performance, Department of Civil and Environmental Engineering, University of Melbourne, Melbourne University Private (MUP), January 22, 2002
ii) Evaluation of PENNGUARD® Stack Liner material for Application in Wet Stacks**,** Gerald B Gilbert, Lewis A. Maroti**,** August 20, 2001
iii) FaAA project-Nr: DUS0324: Two Concrete Chimneys h = 200 m Brick Lining vs. Pennguard Lining Detailed Chimney Designs, Comparison of Masses, Labor, Constrction Costs, Dr-Ing P. Noakowski, Dipl.-Ing M. Breddermann, Dipl.-Ing. Th. Rauscher, June 28, 1998
iv) FaAA project-Nr: DUS0508: Inspection report Paper Mill Oglethorpe, Reinforced Concrete Chimney h =106 m, Dipl.-Ing M. Breddermann, Dr-Ing P. Noakowski.