Wet Position Booster Fans for Reduced Power Consumption and Optimized Environmental Performance of Power Stations with FGD and Wet Stack

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1. Introduction

ALSTOM Power Italia has been contracted to design and build wet FGD for the Rovinari 4 x 330 MW lignite fired power station in Romania. In order to minimize the running cost of the FGD system, the booster fans will be placed in the "wet position" (i.e. between the wet FGD scrubber and the wet stack), where they will consume significantly less power. Alden Research Laboratory has investigated the combined environmental effect of the wet booster fans and the thermally insulated, Pennguard lined wet stacks, taking into account that the wet booster fans will impart a small temperature increase on the treated flue gas stream.

2. Executive summary

The FGD booster fans for the 330 MW lignite fired units at Rovinari Power Station will be placed in the wet position (i.e. between the wet FGD scrubber and the wet stack), where they will consume significantly less power than in the more common "dry position" (i.e. in the hot, dry flue gas upstream of the FGD scrubber). In order to function well in the environment of desulfurized, water saturated flue gas, the booster fans are fabricated from corrosion resistant materials and cleaned during operation through a regular wash cycle.

Alden Research Laboratory has performed a study into the environmental benefits of using wet booster fans, considering that these heat up the treated flue gas by 3 to 5 degrees C. The study included both thermodynamic calculations and physical tests using a laboratory scale model. The study showed that, at nominal unit load, (a) the booster fans will have the capacity to evaporate small diameter droplets contained in the wet gas including all of the water from the fan wash cycle and (b) raise the flue gas temperature sufficiently to enable the thermally insulated, Pennguard lined chimneys to maintain the flue gas temperature just above the water dewpoint, effectively eliminating condensate formation in the wet stacks. A properly designed liquid collection system in the outlet ducts and the chimney breeching will still be needed, to collect bigger droplets that may not have enough time to evaporate.

3. Overview of Rovinari Power Station FGD project

The Rovinari Power Station has four, 330 MW lignite fired boilers, constructed in the period between 1976 and 1979. The units fire a local lignite coal with a sulfur content that ranges between 0.5 and 1.35

%. Following the accession of Romania into the European Union, Rovinari Power Station will have to meet the EU emission limit for SOx of 400 mg/Nm3 dry 6%O2. To achieve this limit ALSTOM will retrofit separate wet limestone FGD systems to Unit 3 (2009) and Unit 6 (2010), possibly followed by Unit 4 (2011) and Unit 5 (2013) (Figure 1).

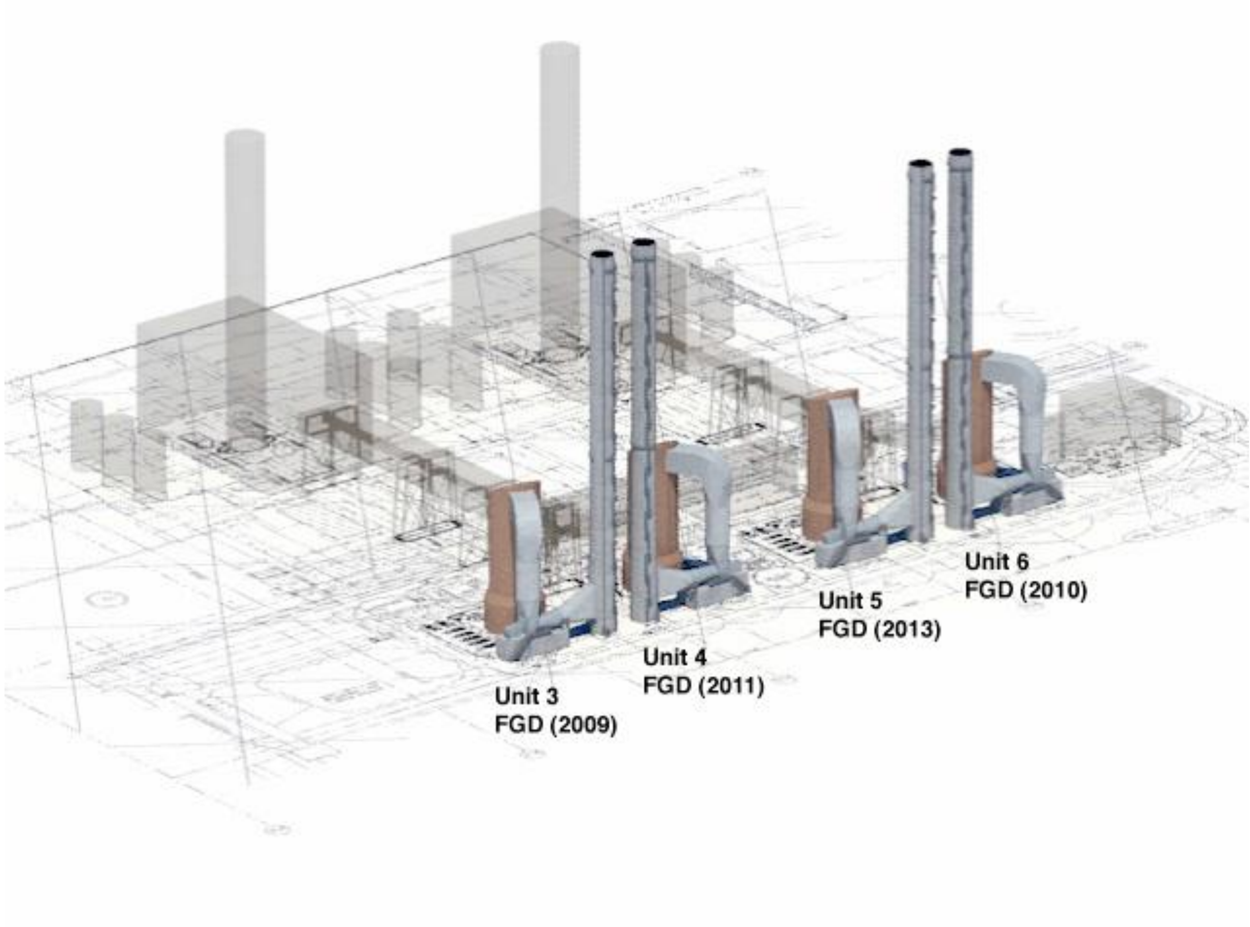

Figure 1: Overview of Rovinari Power Station FGD project – planned situation.

For each of the four units, the gas flow volume (at nominal load, in Nm3/h, wet) will be over 2,000,000 cubic meters per hour.

Following treatment in the FGD absorber, the flue gas stream enters the FGD outlet duct at a temperature of 61 °C and saturated with water. In order to minimize the droplet content of the flue gas entering the FGD outlet duct, the absorbers are equipped with two stages of mist eliminators, placed in series.

4. Economic considerations related to location of the booster fans

For most FGD plants constructed worldwide in recent decades, the location of choice for the booster fans has been upstream of the FGD scrubbers, in a high temperature non-saturated gas stream. The obvious advantage is, that the booster fans can be constructed of mild steel or a Corten type steel, keeping the cost of the booster fan itself low. However, the disadvantage is that at temperatures of 120-150 °C, the gas stream has a high volume and lower density, significantly increasing the energy consumption of the booster fans.

In recent years, the cost of energy has increased strongly and consequently, power plant owners are motivated to look for ways to minimize the energy consumption of the generating plant itself, maximizing the electricity output available for delivery to the grid.

At the same time, the technology of corrosion resistant materials and of booster fan design has been developed to a level, where booster fans can reliably be used in the wet corrosive gas stream (Figure 2). To avoid ash or gypsum buildup on the fan blades, special spray systems and wash cycles have been developed that keep the fan blades clean during operation.

Considering the need for maximum net power production and the availability of modern booster fan technology, the designers of the Rovinari FGD system found that the use of wet booster fans was highly desirable, significantly reducing the estimated power consumption per booster fan.

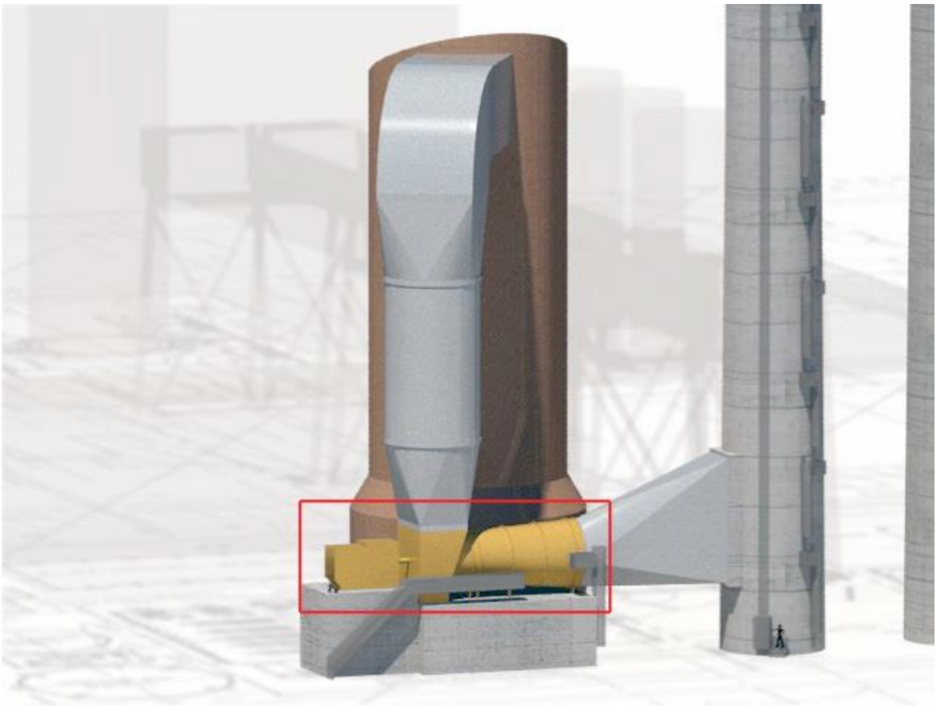

Figure 2: Location of the wet booster fan.

5. Effect of axial flow type wet booster fan on flue gas conditions

The main objective of any booster fan is to increase flue gas pressure to promote its flow through the ducts and to the top of the chimney. Due to the compression effect and to fan inefficiency, a booster fan will slightly warm the flue gas as it passes through the fan. In the case of the Rovinari booster fans, the fan supplier has specified a temperature rise of 5.5 °C at nominal load and 3.0 °C at minimum load.

In a water saturated gas flow, as seen in an FGD system without reheat, this slight warm-up of the flue gas stream could be very significant as it would lift the flue gas temperature above its water dewpoint, potentially eliminating the constant formation of flue gas condensate in the flue gas ductwork and the wet stack. As such, the use of wet booster fans could be an important tool in reducing the risk of liquid carryover from wet stacks.

The flue gas from the Rovinari FGD scrubbers is 61 °C and water saturated. It will also contain up to 50 mg/Nm3 of fine droplets, even after passing through the mist eliminators.

To evaluate the effects of the flue gas temperature rise by the booster fan, the evaporation of the 50mg/Nm3 liquid load must be considered. In addition, the wet booster fans have a 2 minute wash cycle running 12 times per hour, during which water is injected at a rate of 400 liters per hour. The evaporation and flow of this washing water downstream of the fan also has to be considered.

Based on a set of thermodynamic calculations, Alden Research Laboratory concluded that at nominal load, the temperature rise in the wet booster fans should be sufficient to (a) evaporate the 50 mg/Nm3 of droplets in the gas flow, (b) evaporate the washing water from the wash cycle while at the same time (c) raising the gas flow temperature 1.95 °C above its water dewpoint.

During the minimum load case, assuming the same volume of water in the fan wash cycle, the heat added to the gas flow by the wet booster fans would not be sufficient to both evaporate all droplets in the flue gas and raise the temperature of the gas stream above its water dewpoint.

In addition to the above findings, which are based on the energy balance of the total gas stream, Alden concluded that for a portion of the droplets from the fan wash cycle, the residence time in the outlet duct would be too short for these droplets to evaporate before the chimney breeching. On the one hand, this is a positive because this leaves more heat in the flue gas to warm up above its dewpoint. On the other hand, the presence of unevaporated droplets in the chimney breeching creates the need for liquid collectors and sumps in the lower zone of the breeching and lower zone of the stack. Moreover local, unpredictable cold points (i.e. expansion joints) may result in localized condensate formation, further confirming the need for a liquid collection system.

6. Design of the Rovinari wet stacks

Each of the new FGD systems at the Rovinari Power Station will be equipped with its own free standing, 120 m high, 7 m diameter chimney.

These chimneys have been designed in accordance with the New Chimney Design (Figure 3), as developed by Hadek Protective Systems bv. They consist of a 120 m high concrete shell, protected internally by a 41 mm thick Pennguard Block Lining System applied directly to the concrete shell. The New Chimney Design does not use any internal flue, which allows it to be relatively slender and which also keeps construction cost and construction time to a minimum.

The Pennguard Block, a closed cell borosilicate glass block, is the main component of the Pennguard Block Lining System and it has a thermal conductivity of 0.087 W/m.°K at a mean temperature of 38 °C. As a result, Pennguard lined chimneys are well insulated and the temperature losses of a flue gas stream flowing from the bottom to the top of these chimneys will be low.

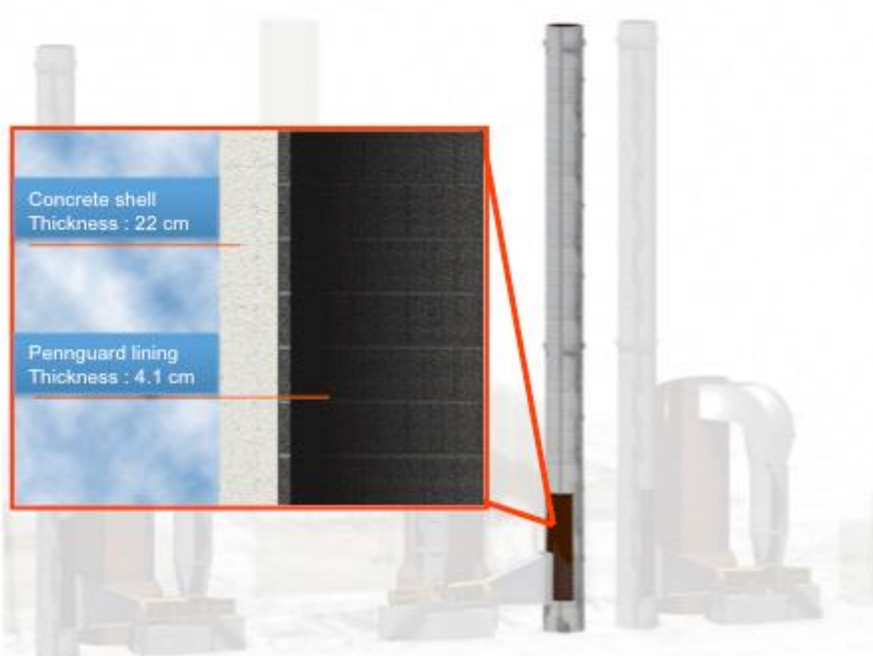

Figure 3: The Rovinari wet stacks have been designed in accordance with the New Chimney Design. The Pennguard lining will be applied directly to the concrete shell, eliminating the need for an internal flue.

7. Combined effect of wet booster fans and Pennguard lined chimneys

The study performed by Alden Research Laboratory shows, that at an ambient temperature of minus 10 °C, the temperature of the flue gas is reduced by 1.6 °C as it flows from the booster fan outlet duct to the top of the chimney.

This means, that at nominal load the temperature increase of 1.95 °C created by the wet booster fans is greater than the temperature decrease experienced by the flue gas as it flows to the top of the chimney. As a result, both the thermal condensation rate ("cold wall condensation") and the adiabatic condensation rate (resulting from pressure loss) are kept at zero, effectively eliminating condensation in the wet stack.

It is important to consider that this finding is conservative because a portion of the fan wash water will not evaporate, effectively allowing a slightly stronger warming of the gas flow. It is also important to consider that in addition to their calculations, Alden Research Laboratory have developed and designed a system of liquid collectors and drains, both in the FGD outlet duct between the FGD scrubber and the wet booster fan (for liquid carryover from the FGD scrubber) and in the outlet duct and chimney breeching downstream of the wet booster fans (for non-evaporated droplets from the fan wash cycle). As usual for wet stack projects, Alden built a detailed scale model of the FGD plant, outlet duct and chimney breeching to develop, test and validate their proposed liquid collector and drain system (Figure 4).

Figure 4: Detailed scale model of the FGD plant, outlet duct and chimney breeching to develop, test and validate the proposed liquid collector and drain system.

8. Conclusion

The study has shown, that in addition to the fan efficiency increase achieved by placing FGD booster fans downstream of the FGD scrubber, this design choice can have environmental advantages as well. The combination of the temperature rise of the flue gas in the booster fans and the excellent thermal insulation offered by Pennguard lined chimneys can reduce or effectively eliminate condensate formation in the wet stacks. Nevertheless, the use of a well designed system of liquid collectors and drains both in the FGD outlet ducts and in the chimney breeching is still required.

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