Production of a liquid de-icer by evaporation of FGD waste water at Nordjyllandsværket, unit 3

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Abstract

The Elsam-owned, Danish 380 MW_e pulverized coal-fired power plant "Nordjyllandsværket, unit 3", commissioned in 1998, is equipped with a limestone-based Mitsubishi Heavy Industries (MHI) flue gas desulphurisation plant. After six years of operation the rotary regenerative gas-gas heater had to be replaced due to corrosion and increased pressure drop. At the same time, intensified environmental regulation on the FGD wastewater outlet forced Nordjyllandsværket to evaporate all liquid effluents.

The retrofitting/upgrading of the FGD unit have been carried out during short outage periods within the last year with the removal of the gas-gas heater as the first step. The upgrading has almost been completed in September 2005 with the commissioning of an evaporator for the FGD waste water. The final product, ie a concentrated calcium chloride solution – brine – will be sold as a liquid de-icer. The production of brine and the thermodynamic coupling are covered by a PCT patent application.

1. Introduction

1.1 The plant at commissioning

Nordjyllandsværket, unit 3 (NJV3) is a 380 MW_e pulverized coal-fired power plant commissioned in 1998. It is equipped with a limestone-based Mitsubishi Heavy Industries (MHI) co-current, flue gas desulphurisation plant. The flue gas cleaning train at NJV3 – when commissioned – was very traditional. The hot flue gas from the boiler/SCR was cooled in a rotating air preheater from 375 °C to 128 °C and the fly ash was removed in an electrostatic precipitator. The flue gas was then cooled further down to around 85 °C in a rotary regenerative gas-gas heater. After flue gas cleaning in the FGD plant the flue gas was reheated to 80 °C and emitted through the stack.

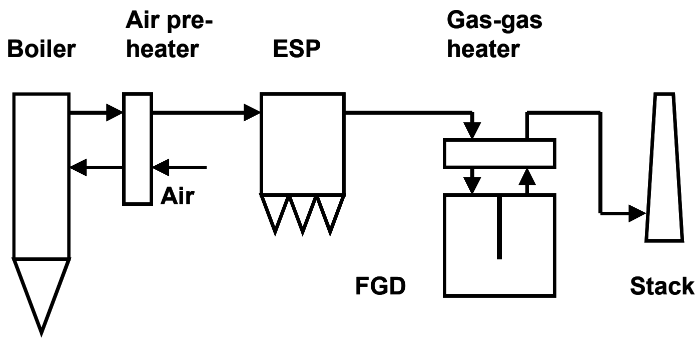

Figure 1: Air and flue gas layout of Nordjyllandsværket, unit 3

Since commissioning the NJV3 FGD plant has used chalk as absorbent. The chalk is delivered from a nearby cement factory, and the resulting gypsum is returned as a raw material for cement production. Details on Elsam's experience in chalk absorbents in wet FGD scrubbers are given in ref. /1/.

1.2 Consequences of the use of SDAP at NJV3

In 2003 Elsam decided to use spray dry absorption product (SDAP) as absorbent at NJV3 because of a substantial surplus in the Elsam area. The main components in SDAP are calcium sulphite and calcium carbonate/calcium hydroxide. Besides, there is a chloride content of approx 2 per cent in SDAP and a small amount of sulphur-nitrogen (SN) compounds.

The SN compounds are produced in the SDA plant in a reaction that involves NO_x and SO_2 and form a variety of sulphur-nitrogen (SN) compounds as indicated in figure 2. These SN compounds are extracted from the SDAP into the waste water of the wet FGD plant.

The technology of how to use SDAP in wet FGD plants is well-described in ref. /2/, as the Elsam power plant ESV3 has used SDAP as the sole absorbent for the last 5 years. However, the use of SDAP at NJV3 would increase the chloride load in the FGD waste water beyond the current legislation of 3 tons/day. Another obstacle would be the amount of non-biological degradable SN compounds in SDAP as described in ref. /5/, which – according to Danish legislation – would prohibit discharge of the waste water to municipal wastewater treatment.

After careful considerations Elsam concluded that the environmental conditions for using SDAP at NJV3 would require evaporation of the FGD waste water. Although there was an obvious economic incentive for using the SDAP at NJV3, it would be necessary to find a very cost-effective way of evaporating waste water in order to make the project viable.

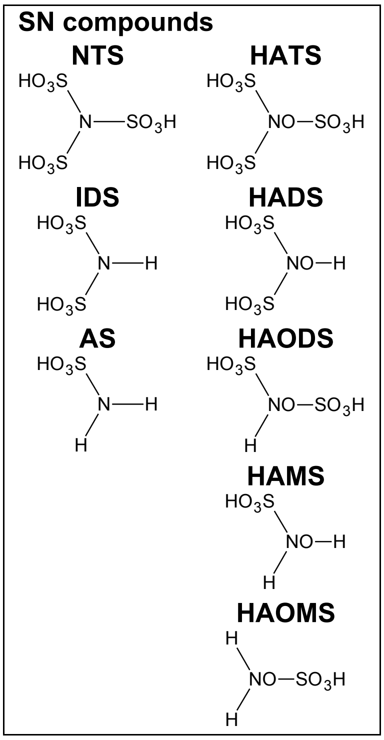

Figure 2: SN compounds

At Elsam we looked at both conventional multi-effect evaporators and spray dryers. Multi-effect evaporators are very energy-efficient, but because of the chloride content, extremely corrosion-resistant materials have to be used. For spray dryers the situation is just the opposite. Spray dryers can be made of low-alloy steel because the evaporation takes place in a gas phase without material contact, but spray dryers are very energy-consuming – typically the consumption exceeds 1.5 MJ pr MJ water evaporated.

1.3 Revamping of the gas-gas heater

At the same time, Elsam considered a revamping of the gas-gas heater (GGH), which was totally worn out. One of the ideas was to scrap the GGH and replace it by a water spray for cooling of the flue gas and subsequently reheat the clean flue gas by hot air from the air preheater.

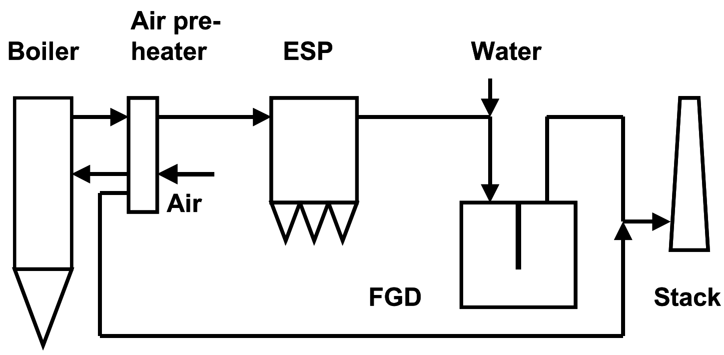

Figure 3: Air and flue gas layout after removal of the gas-gas heater

1.4 Combination of individual projects

During the project development phase, Elsam examined whether the different projects could be combined in order to optimise both energy consumption and capital expenditure. In the final layout Elsam choose the capital inexpensive spray dryer solution, but improved the energy economy by using the spray dryer outlet to reheat the flue gas from the FGD *(see fig. 4).* During the planning of the construction phase, a fast introduction of SDAP and the availability of the power plant were the main focus points. To make the timetable of the total project fit together, a wastewater pond was established.

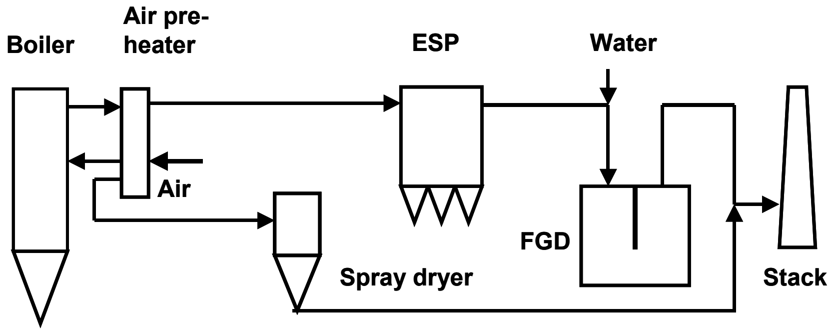

Figure 4: Air and flue gas layout of the upgraded NJV3 FGD system

2. Detailed description of the five sub-projects

The upgrading of the flue gas desulphurisation plant was divided into five 5 individual projects with different timetables. Four of the five sub-projects are roughly described in the above introduction, but the fifth project – filtration of fly ash and gypsum from the brine – was somewhat unexpected.

Individual sub-projects	Commissioning
Removal of the gas-gas heater	July 2004
SDAP storage and dosing	September 2004
Waste water and brine storage facilities	September 2004
Evaporation plant	September 2005
Filtration of brine	January 2006

Table 1. List of the individual sub-projects

2.1 Removal of gas-gas heater

After six years of operation the rotary regenerative gas-gas heater (GGH) had to be replaced (or removed), primarily due to corrosion and increased pressure drop. The condition of the GGH ultimo 2003 was:

- 6 years old and heavily attacked by corrosion.
- Increasing pressure drop due to extensive deposits.
- Increasing raw to clean flue gas leakage resulting in a decrease in desulphurisation rate.
- High maintenance costs.
- Frequent problems with aluminium fluoride blinding of the absorbent, because the GGH was placed on top of the absorber and the water from cleaning of the GGH ended in the absorber.

Elsam considered two different options to change the GGH, either replacement by a new GGH with a larger bore or a complete removal. Based on a technical and economical evaluation Elsam decided to remove the GGH completely as shown in fig. 2.

2.1.1 Water consumption

In the new improved layout the flue gas was cooled from 128 °C to 95 °C by injecting water in the original GGH area. For a 380 MW_e power plant it results in an increased water consumption of 0.6 m^3/°C/h or for NJV3 approx 18 m^3/h.

2.1.2 Reheating of clean flue gas

At NJV3 we did not want a wet stack because of the risk of droplet fallout in the neighbourhood as is often associated with wet stacks. We therefore decided to reheat the flue gas by using hot air extracted from the air preheater. A reheat of 4-5 °C was expected to be adequate, which would need the addition of 4-5 kg/s of 360 °C hot air at full load. After extraction of an additional amount of 5 kg/s, that means 1½% of the total flow in the air preheater – the temperature in the air preheater changes slightly:

Original temperature data				Temperature data after extraction of 5 kg/s air			
Flue gas, in	373 °C	Combustion air, in	35 °C	Flue gas, in	373 °C	Combustion air, in	35 °C
Flue gas, out	128 °C	Combustion air, out	363 °C	Flue gas, out	125.2 °C	Combustion air, out	362.2 °C

Table 2. Temperature data of the air preheater at plant commissioning and after extraction of 5 kg/s air

The energy penalty for extraction of the 5 kg/s of air is the decrease of 0.8 °C in the combustion air temperature. To compensate for this, the amount of coal must be increased slightly. The extra amount of coal can be calculated to approx 40 kg/h or 250 tons of coal pr year or a cost of approx 15,000 €/year.

The main reason for the low energy costs for reheating the flue gas is that extraction of extra air not only reduces the combustion air temperature by 0.8 °C but also reduces the flue gas outlet temperature by 2.8 °C. The result is that it is possible to extract 1 MJ of hot air by increasing the fuel load by less than 0.2 MJ.
As the extracted air has a dust content of approx 100-200 mg/Nm^3 it will increase the dust emission in the stack by approx 1-2 mg/Nm^3. In addition to this, we have seen an additional increase in the dust emission, as the GGH used to be an efficient dust trap. All in all we have seen an increase in the dust emission from the original 8 mg/Nm^3 to 12 mg/Nm^3.

2.1.3 Lining in gas-gas heater area

In the original design,the area below the GGH was glass flake-lined. This is a lining which is sensitive to temperature stress cracking and has a max working temperature of 130 °C when dry. As the GGH has been removed, the flue gas temperature could now reach 150 °C during oil-firing. To insure all material and handle temperature-related conditions, Elsam decided to install a teflon lining and water cooling in the GGH area.

2.2 SDAP storage and dosing

As Elsam has used SDAP as an absorbent for the last 5 years, this part of the project was straightforward. It included erection of a 1500 m^3 SDAP storage silo and an agitated tank to produce batches of SDAP slurry, which was pumped to the original dosing station for chalk slurry. Elsam's experience in the use of SDAP in wet FGD plants is described in ref. /2/ and /3/.

2.3 Waste water and brine storage facilities

There was a substantial economic incentive for a very fast introduction of SDAP into the FDG plant. However, as the time of delivery of the evaporation plant exceeded the time of delivery of the SDAP storage and dosing unit by 6-9 months, it was decided to "store" the waste water from the FGD plant until the evaporation plant was operationable.

The wastewater pond was constructed as 4 individual basins with a volume from 3,000 to 20,000 m^3. On a long-term basis the basins will be used for storage of drainage water from the surrounding fields and will play an important role in the future water supply to the power plant.

Sale and delivery of the end product –brine – will take place from a 3,000 m^3 covered concrete tank.

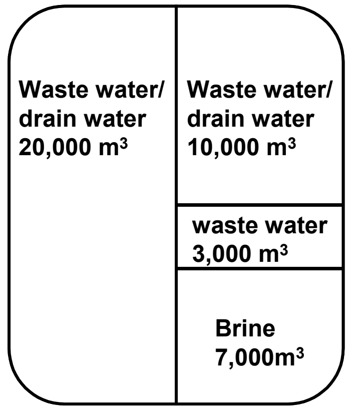

Figure 5: Sketch of the waste water ponds at Nordjyllandsværket

2.4 Evaporation of waste water

The evaporation of the waste water takes place in the spray dryer, which is delivered by the Danish company Anhydro A/S. At full load approx 18 kg/s of hot preheated air is needed to evaporate approx 6 m^3 of the FGD waste water per hour. The outlet from the spray dryer is a mixture of dry powder and air at 140 °C. The powder is collected in the subsequent bag house filter, and the outlet air is used to reheat the flue gas after the FGD plant by approx. 4 °C. The dry powder, which is a mixture of predominantly calcium chloride, gypsum and fly ash, is dissolved in a side stream of the waste water. The target of the end product is a 25 – 30 % salt solution. The main mechanical problems have occurred in the salt dissolution area during commissioning of the plant.

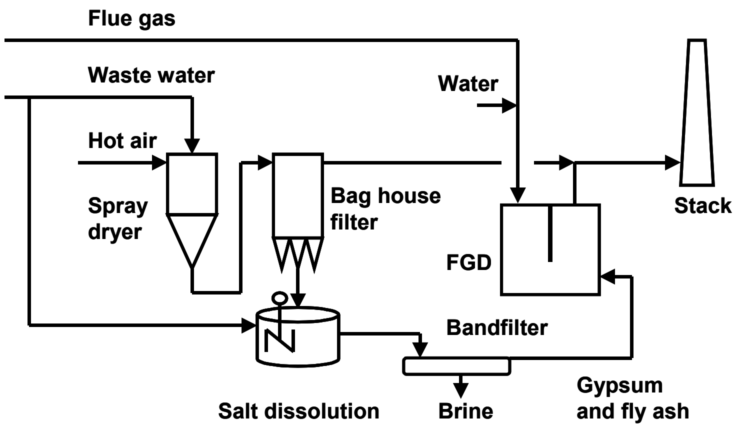

Figure 6: Flowsheet of the extended FGD plant at NJV3

2.4.1 Energy consumption in evaporation plant

Temperature data after extraction of 5 kg/s air				Temperature data after extraction of 18 kg/s air			
Flue gas, in	373 °C	Combustion air, in	35 °C	Flue gas, in	373 °C	Combustion air, in	35 °C
Flue gas, out	125.2 °C	Combustion air, out	362.2 °C	Flue gas, out	118 °C	Combustion air, out	360.2 °C

Table 3. Temperature data of the air preheater after extraction of 5 kg/s and 18 kg/s of air

The energy penalty for increasing the extraction of air from 5 kg/s to 18 kg/s is a further decrease of 2.0 °C in the combustion air temperature. To compensate for this, the amount of coal must be increased. The extra amount of coal can be calculated to approx 110 kg/h or 650 tons of coal per year at a cost of around 35,000 €/year or approx 1€ per m^3 evaporated. This means that the total fuel penalty for evaporation of the waste water and reheat of the flue gas is 850 tons of coal per year at a cost of approx 50,000 €/year.

2.5 Filtration of produced brine

The produced brine contains from 2 – 10% of suspended solids due to the fly ash in the drying air and degradation of SN compounds in the waste water. Originally it was anticipated that sedimentation of the brine was sufficient to remove the solids. However, it turned out that the degradation of the SN compounds was far more efficient than originally anticipated. A belt filter will be installed at the end of the year, and it is expected that this will be adequate to produce a saleable brine / de-icer.

3. Product quality

The brine will be as specified in table 4.

The production is expected to be from 5-8,000 m^3/year depending on coal quality and the received amount of SDAP. A production of 8,000 m^3 will cover the market for liquid de-icers within a distance of 25 – 50 km from Nordjyllandsværket.

Density	1,250 kg/m^3
Dry matter	25%
Freezing point	< 20 °C
Chloride	15 – 16%
Calcium	2 – 8%
Sodium, magnesium, potassium	<7%
Total nitrogen	<0.25%
Heavy metals: Cd, Hg, Cu, Ni, Zn, Cr, Pb	< 5 mg/liter

Table 4: Specification of the liquid de-icer

4. References

/1/ Skriver, A.E., Fogh, F., Knudsen, N.O.; *Chalk – a Cheap and Efficient SO_2 Absorbent for Wet Scrubbers;* Power-Gen'99, Europe; Frankfurt, 1-3 June 1999.

/2/ Fogh, F.; *Converting SDAP into Gypsum in a Wet Limestone Scrubber*; Power Plant Chemical Technology 1996; Kolding, 4-6 September 1996.

/3/ Fogh, F.; *SDAP – an Efficient Absorbent for Wet Desulphurisation*; VGB-Konferenz, Kraftwerk und Umwelt 2000, Leipzig, 4-5 April 2000.

/4/ Gutberlet et al; *Bildung von Schwefel- und Schwefel-Stickstoff-Verbindungen in Rauchgasentschwefelungsanlagen und ihr Einfluß auf Oxidationskinetik von Sulfit*; VGB Kraftwerkstechnik 76, 1996, Heft 2.

/5/ F. Fogh, E.F.Smitshuysen; *Nitrogen Speciation in FGD Wastewate*r; VGB PowerTech 7, 2003