



Degradation of protective coatings in steel chimneys of flue gas desulfurisation systems

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ABSTRACT

This paper presents problems associated with corrosion of steel stacks and changes in philosophy of corrosion protection when implemented into flue gas desulphurization systems. In-situ tests were taken by means of electrochemical impedance spectroscopy at the stack which discharges flue gas before wet lime/limestone desulphurization. A very quick electrolyte absorption by the spherical infill vinyl ester coating was found using the electrochemical impedance spectroscopy. An analysis of destruction shows a joint effect of mechanical and corrosion factors on the poor resistance of the coating. The poor resistance of the coating is also connected with the method of chimney construction and coating application.

1. Introduction

The chimney is an important element of processes occurring in power plants, stabilising the manufacturing system, releasing flue gases at an appropriate height to the atmosphere. It may occur as a single element in a straight-line system as well as serve a larger number of system units as a collective element. The basic role of a chimney involves possibly the largest amount of air to stimulate the burning process by creating a draught. In other words, it is about obtaining a maximum negative pressure in the exhaust gas – flue gas [1].

There are very specific, highly aggressive corrosion conditions inside the chimney channel. Fossil fuels, together with hard bituminous coal and brown coal, contain sulphur compounds, which are converted into SO₂ and SO₃ during the burning process. These gases easily form sulphuric acid in the presence of steam, which is the main reason for corrosion in flue gas channels and chimneys. The relationship between the occurrence of intensive corrosion and the condensation of acids formed during the burning process was found a long time ago [2]. The SO₃ content in flue gases even in small amounts results in a considerable increase in the dew point temperature. The appearance of sulphur oxide (VI) in flue gases results in an increase in the temperature of up to 110 °C. The best correspondence between the theoretical and measured values is obtained by using the Verchoff – Banchemo equation [3].

$$\frac{1}{T_{DP}} = (2.276 \times 10^{-3}) - (2.943 \times 10^{-5}) \ln p_{H_2O} - (8.58 \times 10^{-5}) \ln p_{H_2SO_4} + (6.2 \times 10^{-6}) (\ln p_{H_2O}) (\ln p_{H_2SO_4})$$

where:

T_{DP} – dew point temperature, K;

p_{H_2O} – partial pressure H₂O, mmHg;

$p_{H_2SO_4}$ – partial pressure H₂SO₄, mmHg.

Rylands Jenkinson's research showed that it is the rate of sulphuric acid deposition on the installation surfaces that is the most significant for corrosion processes, which depends on the difference between the dew point and the surface temperature. He found that the maximum deposition of sulphuric acid occurs when the surface temperature is 30–40 °C lower than the dew point temperature of the acid. A subsequent violent increase in the condensation rate occurs below the surface temperature of 50 °C as a result of reaching the dew point temperature of the steam [3].

This research shows a very high corrosion threat for chimney channels at a flue gas temperature of 120 °C, which is particularly frequent in upper parts of chimneys. A significant threat also occurs for fumes at temperatures of 80–90 °C [4].

More aggressive conditions, as compared with other fossil fuels, occur for heavy oil burning. For power stations using coal, the SO₃ content usually corresponds to 1–2% of the sulphur content in exhaust gases. The situation is different for heavy oil. This fuel usually contains trace elements, such as vanadium, which work as catalysts in the burning process, resulting in oxidation of large amounts of SO₂ into a much more aggressive SO₃. Depending on the burning technology used for oil containing 2–3% of sulphur, more than 150 mg/Nm³ SO₃ may occur in exhaust gases. For such a high SO₃ content in the exhaust gases, the dew point will occur at temperatures above 150 °C. In this situation, each steel surface with a slightly lower temperature will be

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quickly covered by a highly aggressive acidic condensate. At a temperature of 125 °C, the sulphuric acid concentration in the condensate will amount to 75–80%. Such a combination of the temperature and acidity constitutes a significant hazard for a majority of materials [5].

Nowadays, the constantly growing importance of environmental protection makes it necessary to introduce new technological solutions that reduce the release of exhaust gas emissions into the atmosphere by various industries, especially in the energy sector [6]. In the economic policy of industrialised countries of the world, there is a tendency to limit compounds, such as SO₂, HCl, HF, HBr or nitrogen oxides. To achieve this purpose, flue-gas desulfurization (FGD) systems were introduced, owing to which it was possible to reduce gas temperatures in the chimney. Such exhaust gases are more aggressive for the structure than hot exhaust gases from coal. Apart from the lower temperatures, the corrosivity of these exhaust gases results from a higher moisture content and in the case of desulfurized exhaust fumes from coal – from the chloride and fluoride content in the form of ions or HCl and HF acids. It was necessary to install gas heaters to increase the temperature of treated gas to safe high values. The use of by-pass installations is another solution allowing for achieving this objective, where some gases are directed to FGD system, while the remaining untreated part flows directly to the chimney and, by becoming mixed with FGD-treated gases, keeps the gas temperature at an appropriately high level. This method is obviously more harmful from the point of view of environmental protection [1,6].

Stress caused by temperature changes is a considerable problem in the effective protection of steel ducts. The adoption of stationary heat exchange and a straight-line temperature course inside the chimney lining, while defining stress in the lining, may prove to be erroneous in some situations. It will be so when the temperature inside the lining increases more quickly than it can be redirected to its internal side by thermal conduction [1].

The formation of the so-called “thermal bridges” is a serious threat to the steel chimney durability. “Thermal bridges” may be caused by faulty or moist external insulation. They can also occur at places, where the steel structure was reinforced externally. “Thermal bridges” continuously release heat from exhaust gases resulting in the formation of acidic condensates at these places. They can constitute a problem in all systems for the exhaust gas extraction, regardless of the type of fuel and the flue gas temperature [7].

The chimney cap, where exhaust gases are mixed with air, is part of the chimney, which is the most exposed to corrosion, as this process is connected with reduction in the temperature of exhaust gases. This process depends on the following factors: the temperature and the exhaust gas flow rate, the speed of wind, exhaust moisture content and atmospheric pressure. The combination of these factors may result in an exhaust gas condensation in the cap, which is hazardous from the point of view of corrosion threats [1].

This means that continuous condensation occurs under the conditions of the operation of the flue gas desulfurization system and in the chimney channel [6].

This article presents a case of damage to the coating protecting the internal surface of the chimney releasing the treated flue gas after desulfurization using the limestone scrubbing method. Hard bituminous coal is the fuel used at the power station, where the problem occurred. The chimney had been used for approx. 1.5 years. As a result of the damage to the coating, disastrous corrosion occurred at the chimney casing made of S355JR structural steel (0,24% C, max. 1,6% Mn, max. 0,55% Si). A vinyl ester coating filled with spheroid-shaped pigments was used to protect the chimney against corrosion. The product data sheet provided by the manufacturer of the coating contained information that some nanomolecule was added as a filler; however, it was not specified more accurately.



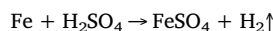
Fig. 1. The coating protecting the area of joining two chimney segments.

2. Destruction of coating and chimneys wall

The chimney described in the publication constitutes an integral part of the flue gas desulfurization system, thus it releases the treated flue gases into the atmosphere at a relatively low temperature, which does not exceed 70 °C under normal operating conditions. The chimney was built by preparing the individual segments at the ground level, which were subjected to blasting on the internal side in accordance with the specified profile (approx. 90 μm). An overlap necessary for connecting the segments was left. After welding, the connected surfaces and the adjacent areas as well as the previously applied coating were ground. Next, the coating was added to reach the specified thickness. The condition of the internal part of the chimney presented in the publication corresponds to approximately a one-year operation.

During an inspection of the internal part of the chimney channel, poor adhesion of the coating to the surface and to the previously applied coating was found at joint areas. The adhesion between the paint coats was particularly problematic. At some places, there was no adhesion between the coating and the paint (Fig. 1).

At the joint sites of individual chimney segments, places showing the cracking of the coating can be observed. This leads to the formation of places deprived of the coating and very strong general corrosion occurs in an acidic environment:



When the damage to the coating is local, the loss of coating is characterised by greater depth (Fig. 2).

Places were identified on the entire surface area of the tank with disastrous corrosion leading to the perforation of the chimney channel. Mineral wool, constituting thermal insulation of the chimney channel on the external part, can be seen in Fig. 3.

Further damage to the coating confirming the wrong selection of the coating material for the conditions in the chimney includes blister-covered areas, which were identified at several sites. Blisters were filled with liquid, which shows they were osmotic in nature. Such damage results from both wrong selection of the coating and the lack of cleanliness inspection of the steel surface before applying the coating. Soluble salt contamination probably occurred on the surface, which promotes osmosis (Fig. 4).

The upper part of the chimney, where the greatest threat of the acidic condensate formation occurs, was made of stainless steel. There are some reports in the literature on strong corrosion caused by condensing gases [8]. No corrosion problems were found there, apart from local superficial discolourations.

After an inspection of the internal part of the chimney channel,

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