Chapter 11
Flue Gas Desulfurization: Processes and Technologies

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ABSTRACT

Most of the total quantity of sulfur oxides (SOx) emitted to the atmosphere come from the combustion of fossil fuels, whose preponderance in the energy mix is expected to prevail in the years to come. In order to avoid the damaging consequences that this supposes, the improvement of the removal methods has been the topic of many researches. In this sense, the majority of abatement processes have always been based on wet Flue Gas Desulfurization (wFGD) technologies. In this chapter, the origin, development, deployment and enhancement of the wFGD processes is thoroughly revised. From the early studies on sulfur absorption for commercial purposes to the maturing of the technology fostered by environmental regulations, the chapter covers the aspects that have accompanied FGD research, including the reaction mechanism studies, the main types and configurations, and extending the analysis on the variables, parameters and technical aspects conditioning the process.

INTRODUCTION

The 80% of the total quantity of sulfur oxides (SO_x) are regarded to be emitted from anthropogenic sources through the combustion of fossil fuels during energy production processes (Pandey & Malhotra, 1999). In this sense, the predictions from the Energy Information Administration (EIA), the World Energy Council (WEC) and the International Energy Agency (IEA) agree that fossil fuels will play a key role in the energy consumption mix in the future (EIA, 2013; WEC, 2013; IEA, 2014). Particularly for oil, the EIA reference case shows that the total primary energy consumption is going to grow a 0.4% per year until 2040. As for coal, its consumption is expected to increase at 0.3% per year, remaining the second-largest energy source worldwide (EIA, 2013). Therefore, the continued great dependency

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on fossil fuels entails damaging consequences to the environment and the global climate (IEA, 2014). In order to overcome these prejudicial effects, Air Pollution Control Policies have aid fostering the research on SO_2 removal at a worldwide level since the 1970s (Chang, Song, & Wang, 2011). Today, the techniques to reduce SO_2 emissions can be divided in three categories (Crnkovic, Milioli, & Pagliuso, 2006; Lee & Huffman, 2007):

1. Pre-combustion technologies (including fuel desulfurization and coal gasification or liquefaction);
2. Simultaneous combustion of coal and limestone mixtures (removal is carried out during combustion); and
3. Post-combustion technologies or flue gas desulfurization (FGD).

For more than 50 years, the majority of removal methods have been based on FGD technologies, which are scrubbing processes where the flue gas at the outlet of the combustion process is put into contact with an alkaline component (Siagi & Mbarawa, 2009; Taylor, Rubin, & Hounshell, 2005; Y. Wu, Li, & Li, 2007). Furthermore, FGD methods can be classified as once-through or regenerable (Mathieu et al., 2013). In the former type, the SO_2 is predominantly bound to the sorbent, which must be managed as a waste or by-product. As for the latter, no waste is generated as the substances produced can be reused as absorbents after a proper treatment. Once-through and regenerable FGD methods can be of the wet or dry type depending on the quantity of water used in the process as well as on the moisture content of the residue obtained (Taerakul et al., 2007). Wet FGD technologies have been predominantly selected over the dry type because of their high desulfurization efficiency, low investment, compact flow sheet and less land occupied, rare fouling, high utilization rate of reagents and a stable operating environment (Chang et al., 2011; Frandsen et al., 2001; Tomas Hlincik & Buryan, 2013; Kiil, Michelsen, & Dam-johansen, 1998; Shen et al., 2013; Taerakul et al., 2007). Limestone is used as the alkaline component in more than 90% of the installed desulfurization capacity in the world because of its natural abundance and low cost (Hrastel, Gerbec, & Stergaršek, 2007; Kallinikos, Farsari, Spartinos, & Papayannakos, 2010; Kiil et al., 1998; Ryu, Grace, & Lim, 2006). During the last years, the research over more efficient removal technologies has been fostered by the tightening of emission control policies and the expected increase in fossil fuels. The aim of this chapter is to summarize the main aspects and characteristics of FGD processes: from the description of the particular nature of SO_2 that has historically promoted environmental legislation to the revision of the basic concepts concerning the abatement techniques and the management of the effluents obtained. By this manner, the reader would be able to obtain an overall description of the FGD process before go in depth with the subsequent chapters.

THE PROBLEM OF SO_2

SO_2 Effects

The negative effects of SO_2 are both to human health and the environment. Once in the atmosphere, a series of photochemical or catalytic reactions promote its oxidation to SO_3 before being hydrated and again oxidized by air humidity into sulfuric acid (H_2SO_4) (Electric Power Research Institute [EPRI], 2006b; Phillips, Canagaratna, Goodfriend, & Leopold, 1995):

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