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SCR deactivation in a full-scale cofired utility boiler

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Abstract

The Energy and Environmental Research Center installed a portable slipstream selective catalytic reduction (SCR) reactor in the convective pass of a utility boiler cofiring wood waste and Powder River Basin (PRB) coal. Catalyst sections were removed after 43, 128, and 171 days of operation. SCR catalytic activity was determined for each section, and a sample of one section was examined under a scanning electron microscope to look for signs of catalyst blinding and/or poisoning. The catalyst deactivated at an apparently inverse rate with an initial deactivation rate of 18% every 1000 h. The major mode of deactivation appeared to be pore blocking by combined alkali and calcium sulfate deposition and growth.
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Keywords: Biomass; SCR; PRB; Cofire

1. Introduction

This paper details full-scale work conducted by the Energy and Environmental Research Center (EERC) related to bench-scale results published previously [1]. The bench-scale paper should be consulted for details regarding scanning electron microscopy (SEM), X-ray diffraction (XRD), and thermogravimetric analysis (TGA) results.

Cofiring biomass with coal is an attractive short-term option for reducing CO_2 emissions. Existing coal-fired stations may be able to blend biomass into their coal feed without significant changes in operating conditions or equipment, eliminating the need for construction of new installations to handle 100% biomass feedstocks [2]. In addition to reduced CO_2 emissions, cofiring may also offer benefits in reduced emissions of NO_x and SO_2 [3]. Some working experience is available for biomass cofiring [4–7]. However, little is known of biomass cofiring with low-rank US coals, such as North Dakota lignites and Powder River Basin (PRB) coals. Before biomass can be cofired with these coals on a large scale, several technical issues must first be addressed. One of the issues to be resolved is the effect of biomass cofiring on ash behavior and selective catalytic reduction (SCR) unit performance.

European and Japanese utilities have been installing SCR units to curb their NO_x emissions since the 1980s [8], and at least 75 coal-fired plants in the United States have installed SCR units in direct response to the US Environmental Protection Agency's (EPA's) NO_x Budget Trading Program [9]. SCR systems may be installed in a variety of locations in the flue gas stream depending on catalyst type, but they are most often installed in the high-dust environment before the air preheater. The higher temperatures in this region allow use of more efficient zeolite and vanadium or titanium dioxide catalysts [10]. This efficiency comes with a cost: because the flue gas upstream of the air preheater has not yet passed through an electrostatic precipitator (ESP) or baghouse, all of the fly ash must pass through the SCR unit and may blind the catalyst by plugging passages or covering surfaces and thus reducing the catalyst's reactive surface area. Blinding of the catalyst reduces the amount of NO_x that can be converted to N_2 and H_2O and also allows ammonia, which is added to

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the flue gas to react with NO_x, to slip through the catalyst unreacted and escape as a pollutant as well as contribute to air preheater deposition.

Much research has focused on better understanding and reducing blinding in SCR units installed at coal-burning power stations, but little is known of the effects of biomass combustion on SCR performance. Research on the effects of alkali and alkaline-earth metals on catalyst activity suggests that biomass, which contains high levels of these elements, could be very detrimental to catalyst lifetime when cofired with coal. These elements are likely to form sulfates that deposit on catalyst surfaces and cause blinding or catalyst poisoning [4,11,12]. Similar alkaline-earth-based sulfur deposits have been observed to form rapidly in the SCR units of diesel vehicles running on a blend of diesel fuel with small percentages (less than 1%) of high-ash lubricating oil [13]. In addition to alkali and alkaline-earth metals, phosphorous is also a known SCR catalyst poison found more abundantly in biomass than in coal [5].

As high-dust SCR seems likely to remain the technology of choice for reducing NO_x emissions, SCR catalyst manufacturers must be able to design SCR catalysts that either resist blinding and poisoning from cofired ash or can be cleaned online. The objectives of this study were to provide a greater understanding of how various factors contribute to SCR catalyst deactivation in a cofired power plant and how those factors can be mitigated by examining mode and degree of catalyst blinding and poisoning in a cofired utility boiler.

2. Experimental

A portable SCR slipstream reactor was installed by the EERC in a utility boiler cofiring wood and coal. This reactor is illustrated in Fig. 1. The reactor chamber, seen in Fig. 2, connects to round piping and transitions to a section with a square cross section to hold the catalyst in an electrically heated section kept at 700 °F. Above and upstream of the catalyst, the reactor chamber houses the flow straightener, which is seen in Fig. 3. The flow straightener, just as its name implies, is used to reduce turbulence in the gas flow and to attempt to drive any ash particles entrained in the gas straight through the reactor, reducing the amount of ash settling onto the catalyst. The final assembly of this equipment can be seen in Fig. 4. Here, gas comes into the reactor chamber from above, turns 90° through the elbow at the bottom, then turns upward after a few feet to pass through an orifice meter and into the induced draft (ID) fan before being blown back into the duct work of the boiler.

The boiler is a stoker-fired unit that burns 80% wood waste with 20% coal. The wood waste is primarily hog fuel (tree bark), with some sawdust. The coal is a mix of PRB

Fig. 2. Reactor chamber.

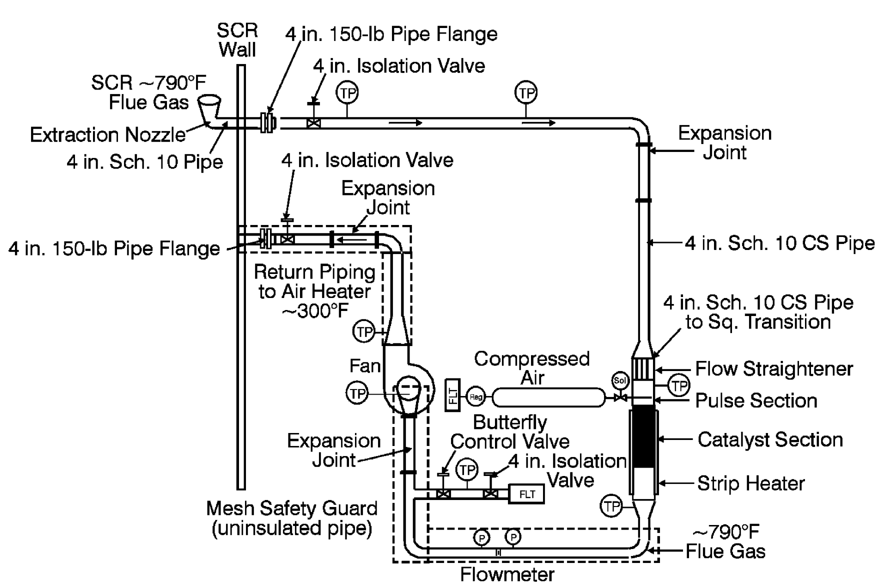

Fig. 1. Schematic of the slipstream SCR reactor.