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RSCR® SYSTEM TO REDUCE NO_X EMISSIONS FROM BOILERS

Richard F. Abrams
Vice President, Business Development
Babcock Power Inc.
5 Neponset Street
Worcester, Massachusetts 01606
508-853-1140 (Telephone)
508-853-2572 (Fax)
Email: rabrams@babcockpower.com

Robert Faia
Sr. District Sales Manager
Babcock Power Sales Inc.
5 Neponset Street
Worcester, MA 01606
508-248-6996 (Telephone)
508-248-6831 (Fax)
Email: rfaia@babcockpower.com

ABSTRACT

Babcock Power Environmental (BPE), a Babcock Power Inc. company, has developed a new, innovative, high-efficiency NO_X reduction technology designed to greatly reduce the NO_X emissions from waste to energy (WTE) boilers at relatively low cost. This “tail-end” system uses Selective Catalytic Reduction (SCR) to achieve the high reduction performance. Conventional SCR catalyst cannot be used in the traditional “high-dust” location, downstream of the economizer because constituents in the ash would poison the catalyst quickly, rendering it useless. Thus, the Regenerative Selective Catalytic Reduction (RSCR®) system is designed to operate at the end of the plant before the flue gas is discharged to the stack. The process utilizes a reactant (usually aqueous ammonia) to be added to the flue gas stream upstream of the RSCR to reduce NO_X to harmless reaction products, N_2 and H_2O.

The RSCR combines the efficient heat recovery, temperature control, reactant mixing, and catalyst into a single unit and provides the maximum NO_X reduction and heat recovery practical. The paper will describe the overall predicted performance of a typical WTE boiler plant using this new technology. The paper will also provide actual operating data on the RSCR, which has been retrofitted to four biomass-fired units.

INTRODUCTION

There is a need for today’s power plants to meet the growing demand for electricity while, at the same time, achieving efficient combustion, low emissions, and no net CO_2 releases into the environment. Waste to energy (WTE) boilers achieve relatively low NO_X emissions with new combustion techniques to below that achieved by conventional selective non-catalytic reduction (SNCR) systems. However, to achieve even lower emissions, a new, proven emissions control device has been developed to significantly reduce NO_x and CO, thus enabling the industry to meet the challenge of higher energy demands and lower emissions.

A new system for the reduction of NO_X emissions to levels hereby unheard of for US WTE boilers has been developed and commercialized. Emissions are controlled using a system called the “RSCR”, which is a regenerative selective catalytic device achieving NO_x reductions of >80%, applied to the relatively cold gas (after the boiler and scrubber/particulate removal equipment) prior to its discharge to the stack. This paper will provide actual operating data on the RSCR, which has been retrofitted to four existing biomass-fired units. The technology is covered by US patent # 7,294,321.

RSCR® TECHNOLOGY FOR EFFICIENT NO_X REDUCTION

The conventional technology for attaining NO_X reductions of >80% from a combustion process is Selective Catalytic Reduction (SCR). Hundreds of coal and gas fired plants worldwide have had “conventional” SCRs installed between the last heat transfer surface, typically the economizer, and the unit airheater. This location produces flue gas at 600 to 800ºF, which is the ideal temperature for the catalyst. The gas can be laden with ash particles and acid gases due to its location upstream of the scrubber and ESP or baghouse. A conventional SCR is not suitable in processes where the ash may contain poisons such as sodium, potassium, lead, phosphorus, or arsenic. On these problematical applications, the solution is to locate the SCR after the scrubber/particulate control equipment, where the flue gas temperature is much lower than the required 600-800°F.

The primary application of an RSCR system is the reduction of NO_X emissions in the flue gas found at the tail end of the boilers where gas temperatures are cool, typically 300 to 400ºF. In an RSCR, the temperature of the flue gas is temporarily elevated for optimal catalyst performance and the heat is recovered before sending the clean flue gas to the stack. The main advantage of an RSCR system is its high thermal efficiency versus standard tail-end solutions in which a heat exchanger and duct burners are used. The RSCR thermal efficiency can be as high as 95% in contrast to standard tail end solutions that typically achieve 70-75% efficiency. This higher thermal efficiency means that fuel consumption for the RSCR is typically 10- 15% of that consumed by a standard tail-end SCR.

System Components

The major components of an RSCR system are:

- Ductwork for diverting the flue gas flow to the RSCR and back to the stack
- Modularized canisters that house the thermal media, catalyst, retention chamber, burners
- A high efficiency thermal media system
- Catalyst for NO_X and optional CO removal
- A burner system including combustion air fan
- Ammonia injection, delivery and storage system
- Hydraulic power system for damper operation
- Flue gas booster fan
- Damper system
- Controls and instrumentation

System Operation

An RSCR system is a combination of two established and proven technologies: Regenerative Thermal Oxidizer (RTO) and SCR. By utilizing the direct contact regenerative heater technology (usually associated with an RTO), in which cycling beds of ceramic media are used to transfer heat, the low temperature issue is resolved. NO_X reduction takes place in SCR catalyst modules positioned above the heat transfer bed, where the flue gas has been heated to around 500 to 600°F and the proper amount of ammonia has been added upstream of the canisters. Either anhydrous or aqueous ammonia can be used.

Simplified, a typical operation sends cleaned flue gas from the scrubber/particulate control device containing NO_X to the inlet of the system and mixes with ammonia. The inlet temperature of the flue gas is not critical and can be saturated or higher. The gas passes up through the preheated heat transfer media bed and it is heated to around 500°F.

Catalyst modules are placed downstream of the heat transfer media bed. The ammonia in the flue gas reacts with NO_X to form nitrogen and water. As the gas leaves the catalyst in the first canister, a burner located in the retention chamber (the space connecting the first and second canister) adds heat. The burner is required to make-up for heat losses through the walls of the canisters and inefficiency in the heat transfer media. It raises the temperature in the retention chamber by about 10°F. The gas flows into the second canister, through the catalyst, and passes through the second media bed. The media in the second canister absorbs heat from the hot flue gas as it cools from 510°F to about 10°F warmer than it first entered the system. A portion of the NO_X reduction takes place as the gas passes through the second canister.

Once this cycle is completed, the flow reverses, so that the second canister (which was heated) becomes the inlet canister and the first canister becomes the outlet canister. Careful operation of the dampers routes the flue gas through the particular canister and is controlled by a central PLC.

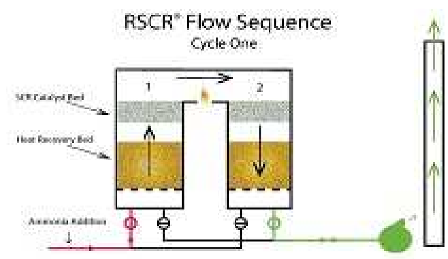

FIGURE 1: OPERATION OF A TWO-CANISTER RSCR DESIGN

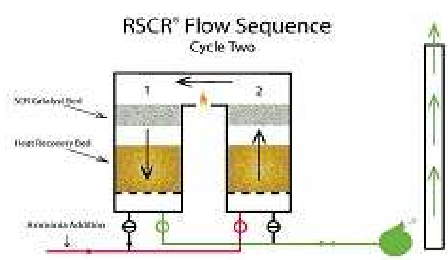

FIGURE 2: RSCR FLOW SEQUENCE – CYCLE TWO

Design Basis

The system design depends upon the inlet flue gas flow, NO_X concentration, temperature and constituents in the flue gas, compounds of chlorine and sulfur, along with trace ash components. Particulate loading in the inlet flue gas is an important parameter in the design of the RSCR system. Properly functioning particle removal technology is mandatory upstream of the RSCR.

The possibility of reaching the acid dew point, which could be corrosive and could lead to ammonium bisulfate formation, means that the SO_3 content in the exhaust gas must be specified. When present in large quantities, the system design may require provisions to account for their removal.

System Description

In order to better understand an RSCR system, it is worthwhile to describe the major system components in detail. The main function of ductwork is to route the flue gas from the particulate control device or ID fan to the RSCR and return it to the stack after treatment. The ductwork is typically made of carbon steel material. The ductwork must take into consideration two important design features: it must allow sufficient distance for ammonia to mix and it must be adequately sized to minimize pressure drop.

The selection of thermal media is a critical feature of RSCR design. Factors that need to be taken into consideration during the design process are: gas-side pressure drop, thermal efficiency and cost. A large bed face area reduces the pressure drop and operating cost but increases capital cost. Figure 3 shows a photo of a typical thermal media used in this type of application with a cross section area of 6" by 6" and a height of 12".

FIGURE 3: A BLOCK OF MONOLITH CERAMIC THERMAL MEDIA

The NO_X reduction catalyst, supplied by Cormetech, Inc., is installed downstream of the thermal media where the flue gas temperature is sufficient for the catalyst to operate. The factors taken into consideration are: sufficient catalyst volume for NO_X reduction and minimizing ammonia slip and pressure drop. The presence of alkaline metals like sodium or potassium or metals such as arsenic can irreversibly deactivate the catalyst. Proper selection of catalyst pitch is necessary to mitigate the possibility of pluggage. The useful catalyst life, NO_X reduction and ammonia slip are guaranteed. A layer of precious metal CO oxidation catalyst can be provided on top of the SCR catalyst to achieve >50% CO reduction simultaneously with NO_X reduction.

A burner is required to compensate for the small inefficiencies in heat recovery and to make up for heat loss through the walls of the RSCR. The burners are located in the headspace of the RSCR in the retention chamber. The number of burners required is one less than the total numbers of canisters. Therefore, one burner is required for a two-canister system. View ports are provided in the retention chamber for visual inspection of the burners (see Figure 4).

FIGURE 4: PHOTO OF RSCR SYSTEM BURNERS IN OPERATION

A small fan is required to supply combustion air for the burners. During the start-up process, the burners help bring the system to the desired operating temperatures from the cold condition. The burners can be designed to use natural gas, propane, low sulfur fuel oil, or biodiesel, depending upon specific plant requirements. The retention chamber and canisters are internally insulated to minimize skin temperature for a given ambient temperature and wind speed. Skin temperature generally does not exceed 120°F.

The ammonia delivery system consists of ammonia pumps, storage tank, interconnecting piping and a control system (See Figure 5). The size of the tank depends upon injection rates, hours of operation and typical delivery truck volume. The small, redundant ammonia pumps use a variable speed drive that can vary the quantity of ammonia in response to changes in NO_X as detected by the plant CEMS monitor.

FIGURE 5: AMMONIA SKID/STORAGE TANK -50 MW RSCR

The key to the operation of the RSCR is the ability to cycle the valves every two to three minutes. The valves used in the main gas flow are metal-seated butterfly dampers, up to 90" diameter. The dampers must cycle from fully open or closed to the opposite condition in three seconds or less, without slamming. To accomplish this, hydraulic actuators are used. The actuators move the damper blade through 95% of its travel very quickly, and then move the last 5% more slowly, until stopped by a proximity switch. A high pressure hydraulic power unit provides the motive force for the actuators, and includes an accumulator which has sufficient volume to move all dampers to their "failsafe" positions in the event of a system upset.

A heavy-duty fan is provided to offset the pressure drop through the RSCR system, and to permit the RSCR to heat up or cool down while off line. The fan size depends upon the gas flow and pressure drop through the system and care is taken to optimize its design. Alternatively, the system ID fan can be used to overcome system pressure drop.

Three dampers are provided to ensure smooth operation and maintenance of the RSCR system. Two isolation dampers are provided in the ductwork connecting the RSCR system to the boiler and to the stack, and one bypass damper is provided in the main ductwork connecting the boiler to the stack. During normal operation, the bypass damper in the main ductwork is closed and the other two dampers are open to route the gas flow through the RSCR system. To bypass the RSCR system, the two isolation dampers in the RSCR inlet and outlet duct are closed and the main bypass damper is open. There is also a damper for supplying fresh air during start-up and allows the RSCR to operate when isolated from the process. All the dampers are fail-safe in case of power loss or system upset.

A standalone PLC with a touch-screen interface terminal is provided for controlling the operation and monitoring of the RSCR system. The panel also includes communication modules, diagnostics screens for all instrumentation/controls/field devices, a modem and other instrumentation.

Installed Base

The RSCR system has been installed on four wood-fired boilers in the US – two 15 MW units in New Hampshire and 50 MW units in Maine and Vermont. These units use feedstocks consisting of whole tree chips, waste wood, and, in one case, construction and demolition wood as fuel for the boilers. The goal of all installations was to qualify for Connecticut Renewable Energy Credits (REC). The state requirement for qualifying for RECs is achieving a NO_X level of 0.075 lb/MBtu (approximately 60 ppmv) or less on a quarterly average.

The inlet NO_X levels at the sites are typically in the range of 0.25 to 0.28 lb/MBtu (200 ppmv). While designed to reduce NO_X levels by 70 to 75%, the two systems have been able to reduce NO_X levels significantly below 0.075 lb/MBtu. Because the RECs are based on reductions averaged over the quarter and not on instantaneous values the plants are able to "catch up" their averages should the RSCR be out of service for any reason.

The RSCR system for the first 15 MW unit has been in continuous operation since October 2004, and the 50 MW system has been in continuous operation since the beginning of the first quarter of 2005. The newest unit on a 15 MW boiler started up in October 2007. The owners of the three plants have been able to qualify for Connecticut RECs every quarter since start-up because of the RSCR operation, demonstrating the reliability and performance of the technology.

See Figure 6 for the first 15 MW unit under construction showing the catalyst in two canisters and thermal media in one canister. Figure 7 shows the completed system for a 50 MW boiler in which two trains of 5 canisters each were used to meet the emission reduction requirements.

FIGURE 6: A THREE-CANISTER SYSTEM UNDER CONSTRUCTION

FIGURE 7: AN RSCR SYSTEM SHOWING TWO TRAINS OF 5 CANISTERS EACH

Biomass applications compared to WTE

The experience to date for the technology has been on biomass plants. It is interesting to compare typical stack emissions from a WTE plant after the scrubber/particulate device to that of a modern conventional biomass plant. Table 1 shows the values for various pollutants.

- NO_X, CO, SO_2, and PM levels are somewhat higher for biomass plants
- SO_3, HCl, and VHM may be higher for WTE plants

While there are differences, they are not significant with the exception of PM, which is considerably higher for biomass. This is one of the pollutants of interest for the catalyst because of the concern for the potential for catalyst poisoning. Even with these higher levels of PM, the original catalyst is still operating, over 4½ years after initial start up. Furthermore, one of the operating units uses construction and demolition debris as a feedstock. BPE has measured the VHM concentrations in the particulate matter in the bottom of the RSCR, and the values are reported below. The system was clearly challenged with significant levels of VHM. This unit also has the original catalyst and recent testing of the catalyst indicates life expectancy of 5 to 10 years.

Since the RSCR has high removal efficiency, the users do not need to buy or operate SNCR systems, saving capital and significant operating cost. The RSCR is capable of reducing the uncontrolled NO_X out of the boiler to <50 ppm.

Because of this information, the RSCR has direct applicability to WTE facilities. It has been selected currently to be used on a 2 x 1100 TPD RDF plant in Ohio and a 37MW C&D facility in Massachusetts.

TABLE 1: TYPICAL EMISSIONS

	WTE –after DFGD	**Biomass**
	At 7% O_2,dry	*at 7% O_2,dry*
NO_X	190 ppm/90 ppm (SNCR)	192 ppm
CO	100 ppm	316 ppm
SO_2	<14 ppm	28 ppm
SO_3	<5 ppm	Very low
HCl	<20 ppm	10 ppm
HF	<4 ppm	
VHM	<0.1 mg/dscm	*
PM	13 mg/dscm	18 mg/dscm-150 mg/dscm
		*Ph 43,110 ppm Zn 27,100 ppm As 1,710 ppm

CONCLUSIONS

The RSCR system has proven to be an effective, reliable, and economical means to achieve very low NO_X emissions from biomass plants.

The feature that differentiates the RSCR from other tail-end SCR technologies is high thermal efficiency. Normally the thermal efficiency of the RSCR in a given application is guaranteed at 95%. Competing technologies that utilize regenerative or plate type heat exchangers for heat recovery and duct burners to reach the catalyst operating temperature are typically in the range of 70-75% thermal efficiency and therefore can be expected to require five times the auxiliary fuel as the RSCR.

The technology can be applied to WTE facilities to achieve very low levels of NO_X emissions while offering low energy consumption.

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