Low Temperature SCR Cost Evaluation in Solid Waste Incineration Power Plant

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Abstract. To meet the increasingly strict emission control requirement, low temperature selective catalytic reduction (SCR) system is adopted in some waste incineration power plant because of the limited denitrification capability of selective non-catalytic reduction (SNCR) system in boiler furnace. The article evaluated the increased cost per ton of waste when SCR system is equipped on a $2 \times 400t/d$ waste incineration power plant in Henan province. The total cost of SCR system, including construction period and operation period, per ton of solid waste is about 37 yuan.

Keywords: Waste Incineration, SCR, Cost.

1. Introduction
According to GB18485-2014, standard for pollution control on the solid waste incineration, the nitrogen oxides (NOx) control limits at hourly average emission is 300 mg/Nm$^3$, which can be met by SCNR system. However, due to the environment and public pressure, some local government has issued more strict regulations to control pollution emission. In February 2020, the Office of the Leading Group for Pollution Prevention and Control in Henan Province issued the “Implementation Plan for the Pollution Prevention and Control Strategy in Henan Province in 2020” [1], requiring the emission concentrations of incinerator flue gas particulate matter, sulfur dioxide (SOx), and NOx (1 hour average) under the condition of standard oxygen content of 11%, not higher than 10, 35, 100mg/Nm$^3$ respectively. So the NOx emission limits should be below 100 mg/Nm$^3$ in Henan Province.

Low temperature SCR system [2] is necessary for new-build solid waste incineration power plant. The increased cost per ton of waste is an important value for investors’ decision making.

2. Technical Introduction of the Project
The designed waste treatment capacity of this project is 800t/d with the annual designed waste treatment capacity of $29.2 \times 10^4t/a$. $2 \times 400t/d$ waste incinerator and $1 \times 15MW$ medium temperature and medium pressure condensing steam turbine + $1 \times 18MW$ generator set are equipped.

The flue gas purification system of this project adopts a combination of "SNCR + semi-dry FGD Absorber + Dry Deacidification + Activated Carbon Spray + Bag Filter + SCR" process (Figure 1).
2.1. Design Input
The original emission of NOx in the incinerator (grate furnace) is around 350mg/Nm³ and the actual SNCR system efficiency is around 30%~60% [2] due to different operation conditions. The theoretical SCR efficiency is up to 95% while in present operation experience the efficiency is around 85% [3]. Here we define the original NOx as 400mg/Nm³ and after SNCR process decreased to 200 mg/Nm³, which is the input NOx concentration of SCR system and the final emission control limit is 100mg/Nm³. Refer to Table 1 for basic input.

| NO. | Item                                                                 | Set/Description          |
|-----|----------------------------------------------------------------------|--------------------------|
| 1   | Number of Incinerator                                               | 2                        |
| 2   | Type of Incinerator                                                 | Grate furnace            |
| 3   | SCR Inlet Flue Gas Flow (Standard Condition, Wet, 100% MCR)         | 76000Nm³/h               |
| 4   | SCR Design temperature                                              | 190°C                    |
| 5   | SCR operation temperature                                           | 180~220°C                |
| 6   | Inlet NOx Concentration (SNCR in operation)                         | 200 mg/Nm³               |
| 7   | Inlet NOx Concentration (SNCR out of operation)                     | ≤400 mg/Nm³              |
| 8   | Outlet NOx Concentration                                             | 80 mg/Nm³                |
| 9   | SCR yearly Operation time                                           | 8000 h                   |

2.2. SCR system main equipment list
The SCR system consists of an SCR reactor, ammonia evaporation system, ammonia injection system, detection and control system, etc. Each incineration line is equipped with 1 SCR reactor. The SCR reactor adopts a fixed bed form where the low temperature catalyst (180~220°C) is placed in modules. The number of catalyst layers in the reactor depends on the required catalyst reaction surface area. The
reactor is initially equipped with two layers of catalyst and a backup layer. Refer to Table 2 for main equipment list of SCR system.

Table 2. SCR Process Main Equipment List.

| NO. | Equipment                        | Specification                               | #1 Unit | #2 Unit |
|-----|----------------------------------|---------------------------------------------|---------|---------|
| 1.1 | SCR Steel Flue Gas System        | Inlet Flue Gas Duct Support Steel Structure | 1       | 1       |
| 1.2 | Flue Gas Damper                  | Motor: 2.0kw                                | 3       | 3       |
| 1.3 | Damper Sealing Air Fan           | Flow: 2000m³/h, Pressure: 3000Pa             | 1       | 1       |
| 1.4 | Sealing Air Fan Heater           | Power: 3kW                                  | 1       | 1       |
| 2.1 | SCR Reactor                      | 3.5m × 3.5m × 5m                            | 1       | 1       |
| 2.2 | Low Temperature Catalyst         | Honeycomb type, 36m³, 180-210°C, “2+1” layer, | 1       | 1       |
| 2.3 | Ammonia Injection Grill          |                                            | 1       | 1       |
| 2.4 | Sonic Soot-blower                | Compressed air: 0.48-0.6MPa, 2Nm³/min       | 1       | 1       |
| 2.5 | Electrical Hoist                 | 3t, H=20m                                   | 1       | 1       |
| 3.1 | Evaporator                       | Inlet medium: 20% (wt) ammonia , 20kg/h,    | 1       | 1       |
|      |                                 | Heat source: Steam                          |         |         |
| 3.2 | Dilution Fan                     | High Temperature Centrifugal Fan, 120Nm³/h, 5Kpa, 2.2Kw | 2       | 2       |
| 3.3 | Dilution Fan Heater              | 30kW                                        | 1       | 1       |
| 3.4 | Ammonia-Air Mixer                |                                             | 1       | 1       |
| 3.5 | SCR Regeneration Fan             | 12000m³/h, 3000Pa, 30kW                     | 1       | 1       |
| 3.6 | SCR Regeneration Fan Heater      | 900kW                                       | 1       | 1       |
| 4.1 | SGH Steam Heater                 | Shell: Q235B,                               | 1       | 1       |
|      |                                  | Coil: 20G                                   |         |         |
| 4.2 | Drain Tank                       | 24m³, φ3.0m × H3.5m                          | 1       | 1       |
| 4.3 | Drain Pump                       | Centrifugal Pump, Q=10m³/h, H=50m; P=3Kw   | 2       | 2       |
| 5    | Ammonia Pump                     | Centrifugal Pump, Q=1m³/h, H=50m             | 3       |         |

When SCR is in operation, it will consume the steam from steam drum and electricity as well as ammonia and catalyst. Table 3 shows the raw material and source consumption for SCR system.

Table 3. Raw material and source consumption for SCR system.

| NO. | Item                      | Unit | Data |
|-----|---------------------------|------|------|
| 1   | 20% (wt) Ammonia          | kg/h | 40   |
| 2   | Steam (4.6MPa, 260°C)     | t/h  | ~4   |
| 3   | Catalyst Consumption      | m³/year | 24 |

3. Cost Evaluation
Considering that the SGH steam source is extracted from steam drum, the flow of super heated steam entering the steam turbine under the SCR operation mode is reduced, of which the power generation decreased by about $5.12 \times 10^6$ kWh by year. Besides, SCR system will increase the plant power consumption by $3.95 \times 10^6$ kWh annually.
Table 4. Cost Evaluation with SCR in Operation.

| NO. | Item                                                                 | Price (¥) | Unit     | Hourly Consumption | Annual Consumption | Annual Cost (10000 ¥) | Cost (¥/t waste) |
|-----|----------------------------------------------------------------------|-----------|----------|--------------------|--------------------|-----------------------|------------------|
| 1   | Income loss on decrease of power sales                               |           |          |                    |                    |                       |                  |
| 1.1 | Steam consumption of SGH (kwh)                                      | 0.65      | kwh      | 640                | 5120000            | 332.8                 | 11.40            |
| 1.2 | Power consumption increase                                            | 0.65      | kwh      | 494.4              | 3955200            | 257.09                | 7.12             |
| 1.2.1| Increased power consumption by ID FAN                                 | 0.65      | kWh      | 392                | 3136000            | 203.84                | 6.98             |
| 1.2.2| Increased power consumption by Air Compressor                        | 0.65      | kWh      | 22.4               | 179200             | 11.648                | 0.40             |
| 1.2.3| Increased power consumption by SCR System                            | 0.65      | kWh      | 80                 | 640000             | 41.6                  | 1.42             |
| 2   | Raw Material Cost                                                    |           |          |                    |                    |                       |                  |
| 2.1 | Ammonia                                                             | 750       | t        | 0.04               | 320                | 24                    | 0.82             |
| 2.2 | Catalyst                                                            | 50000     | m³       | /                  | 24                 | 120                   | 4.11             |
| 3   | Maintenance Cost                                                     | /         | /        | /                  | /                  | 60                    | 2.05             |
| 4   | Financial Cost                                                       | /         | /        | /                  | /                  | 160                   | 5.48             |
| 5   | Depreciation and amortization                                       | /         | /        | /                  | /                  | 133                   | 4.55             |
| 6   | Sum                                                                 | 1+2+3+4+5 |          |                    |                    | 1086.89               | 37.22            |

Note: The cost data is estimated with the suppliers’ reference price and present solid waste incineration power plant operation experience in Henan Province and the feed-in price of solid waste power plant is 0.65 yuan/kwh [4].

After the SCR system was put into operation, the consumption of ammonia and catalysts caused an increase in annual operating costs of 1.44 million yuan (2.1+2.2 in table 4), and an electricity increase of 2.57 million yuan (1.2) besides the income loss on power sales of 5.12 million yuan (1.1). Considering 15-year depreciation period of SCR system equipment, the construction and operation of the SCR process resulted in an increase cost of 37.22 yuan per ton of waste disposal.

4. Conclusions
Based on a 2 ×400t/d solid waste incineration power plant in Henan Province, the cost evaluation of SCR system is conducted in this article. The total cost of SCR system for disposing 1 ton of solid waste, including construction period and operation period, is about 37 yuan, which should be taken into consideration by investors in the early stage of project.

References
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