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Technical/Commercial Budget Proposal

Topsøe SCR DENOX Unit

Client: State of Florida

Project: Waste Incinerator

Table of Contents

1. Introduction

This Technical/Commercial Budget Proposal is in response to inquiry received on 9 January 2002 and subsequent e-mail of 16 January 2002.

2. Design Consideration

Reducing Agent

Please note that anhydrous NH_3 has been foreseen as the preferred reducing agent. Alternatively, the unit can be designed for the use of aqueous solution of urea or aqueous NH_3. The price difference is insignificant.

Minimum Operating Temperature

The minimum operating temperature for the SCR DENOX unit is determined by the dew point of ammonium bisulphate (NH_4HSO_4). Condensation of ammonium bisulphate (ABS) on the active catalyst surface area causes some deactivation of the catalyst, and although later operation at a higher temperature may reactivate the catalyst, a certain permanent deactivation must be expected over time. An additional implication of severe condensation of ammonium bisulphate is an increased pressure drop due to clogging of the DNX catalyst channels.

The condensation of ABS is a simple thermodynamic gas phase phenomenon. The dew point temperature is only dependent on the concentration (partial pressure) of ammonia (NH_3), moisture (H_2O) and sulphur trioxide (SO_3):

$$NH_3 + H_2O + SO_3 \rightarrow NH_4HSO_4$$

A higher partial pressure of any of the reactants will lead to an increase in the dew point temperature of ABS.

When determining the minimum catalyst operating temperature, a distinction must be made between the dew point for ABS in the bulk phase and in the catalyst pores, because the vapour pressure of ABS is lower in the micropores than in the bulk phase. This effect is normally referred to as capillary condensation, and implies that the dew point temperature in the micropores is higher than the dew point temperature in the bulk phase. As a consequence, the first condensation of ABS will take place in the micropores of the catalyst.

Several references exist in the literature where the bulk phase dew point temperature of ABS is determined. The formula used by Haldor Topsøe A/S for calculation of the dew point for ABS in the catalyst pores is based on literature studies, in-house laboratory experiments, pilot tests and industrial feedback. We have found that the dew point

temperature for ABS in the micropores is approx. 35 - 40°C higher than the dew point temperature in the bulk phase. This is in general agreement with figures reported in the literature by others.

It is normally recommended to operate the SCR DENOX catalyst at a minimum temperature of 10°C above the dew point of ABS in the catalyst pores in order to account for lateral temperature differences in the SCR reactor. The minimum operating temperature is calculated for each case based on project specific operating conditions.

Finally, it should be mentioned that condensation of ABS is a thermodynamic phenomenon and will therefore be harmful to any type/manufacture of catalyst

With an assumed SOx content of maximum 1 ppm_v after the bag filter and with an assumed maximum SO_2 to SO_3 oxidation of 3%, the minimum inlet temperature for the SCR catalyst is in the order of 270-280 (520-540°F).

Layout

In order to cope with the above minimum inlet temperature for the catalyst and also in order to ensure an acceptable catalyst activity per volume of catalyst, the flue gas has to be heated up before entering the SCR unit.

The cold non-cleaned flue gas exchanges heat with the cleaned hot flue gas in a gas/gas heat exchanger, and then the non-cleaned gas is further heated to the operating temperature of the catalyst by means of a gas or oil heater. After the heater the NH_3 is injected into the hot flue gas, and the flue gas is passed through the catalyst where the NH_3 and the NOX will react on the surface of the catalyst and form free nitrogen and water vapour. The cleaned flue gas is then passed through the heat exchanger and the cold cleaned flue gas is routed to the stack.

3. Design Data

The design is based on the data given/assumed below:

Flue gas source:		Waste Incinerator
Flue gas mass:	ACFM	170,000 (ref. t = 300°F)
Pressure:	mmWG	800
Temperature:	°C	149
O_2 content:	vol-%	10
H_2O content:	vol-%	10
SO_2 content:	ppm_v	< 30 (at 7% O_2)
SO_3 content:	ppm_v	< 1 (at 7% O_2)
NOx content, inlet:	ppm_v	260 (at 7% O_2)
NOx content, outlet:	ppm_v	< 150 (at 7% O_2)
NH_3 slip:	ppm_v	< 5

All data at actual O_2, wet gas, unless otherwise specified.

4. Consumption Figures

At the conditions specified in Section 3 above the expected consumption is as follows:

NH_3	kg/h	< 10
Electric Power:	kW	5 - 7
Instrument air:	Nl/min	30 – 40
Oil/Gas:	MWh/h	< 2.8

5. Scope of Supply

5.1. Battery limits

Flue gas system:

- inlet/outlet heat exchanger
- inlet/outlet preheater
- inlet/outlet NH_3 injection nozzle system
- inlet/outlet mixer elements
- inlet/outlet reactor

NH_3 piping:

- inlet/outlet skid-mounted NH_3 evaporator and flow control assembly
- inlet/outlet NH_3 injection nozzle system

Control system:

- inlet/outlet locally placed transmitters
- inlet/outlet analyser
- inlet/outlet control cabinet

5.2. Equipment per unit

- one (1) charge of proprietary Topsøe deNOx catalyst type DNX 950.
- one (1) catalytic reactor (exclusive of inlet pipe).
- one (1) gas/gas heat exchanger
- one (1) oil/gas fired preheater
- one (1) NH_3 injection nozzle system for installation in the rectangular inlet pipe
- one (1) pre-fabricated NH_3 evaporator and flow control assembly fitted electrical heated evaporator, flow meter, flow control valve, indicating instruments, valves and fittings.
- one (1) NOx analyser, complete with transmitter/receiver unit, measuring probe, purge air unit, analog input/output, strip chart recorder, etc.
- one (1) control system, complete with PLC with digital/analog, input/output cards, metering pump frequency converters and control gear, flow relays, main switches, MCBs, terminals, etc.
- one (1) lot of instruments, piping, valves etc., as required within the battery limits.

5.3. Engineering and Documentation

- Project time schedule
- Layout and general arrangement
- Detailed engineering and detail drawings
- Arrangement and installation drawings
- Erection documentation
- "As built" drawings and documentation including material certificates, inspection and test reports
- Operation and maintenance manuals including sub-suppliers' documentation and specifications
- Spare parts list

5.4. Erection and Commissioning

Our scope of supply is exclusive of erection and commissioning, but we can offer supervision assistance during erection and commissioning of the unit by one of our engineers at a per diem rate as specified in Section 7.2 below.

Travelling costs, board and lodging for our supervisor will be invoiced at actual cost.

We estimate the minimum supervision assistance required to be approx. 10 man-days. The man-days are inclusive of training of personnel (see below).

In connection with the above, please note that in order to maintain our guarantee terms, as specified in Section 10.2 below, loading of catalyst into the reactor as well as commissioning of the unit must be supervised by one of our experts.

5.5. Training and Education of Operators

During commissioning/hand-over of the unit, we recommend a two-day seminar to be conducted by our supervisor giving detailed instructions on how to control, operate and maintain the unit.

6. Client's Supply

- Design and supply of equipment foundations
- Connection lines for utility supply to the unit
- Piping, power and control cables between various equipment, as per the documentation and cable list of Haldor Topsøe A/S
- Lighting and earthing installations
- NH_3 storage facilities
- Inlet pipe to reactor
- Manpower for erection, tools and assembly materials
- Manpower for insulation and cladding of the reactor
- Manpower for catalyst loading
- Manpower for commissioning
- Insulation and cladding material for the reactor.
- Flue gas fan (if applicable)

7. Budget Price

7.1. Equipment, Catalyst and Engineering

The total price of the supply of one (1) SCR DENOX unit, complete with associated equipment, accessories, materials and services, as specified in Section 5 above, is:

EUR 1,500,000.00

- The above price includes delivery of all equipment EXW Copenhagen (Incoterms 2000).
- The above price is exclusive of any duties and value added tax (VAT).
- The price is exclusive of installation, erection and supervision.

7.2. Per Diem Rates

We can offer supervision assistance by one of our engineers for erection, catalyst loading and commissioning of the unit at a per diem rate of:

EUR 950.00

for days out of office in 2002. Travelling costs, board and lodging will be charged at actual cost.

8. Terms of Payment

The price given in this proposal is based on the following terms of payment:

a. 30% on signing of technically and commercially clarified contract
b. 30% within 3 months after order
c. 30% within 30 days after delivery (prorata)
d. 10% after commissioning of the unit; however, not later than 3 months after mechanical completion.

9. Delivery Time

Our normal delivery time for one (1) SCR DENOX unit, as specified above, is 5 - 6 months.

10. Guarantees

10.1. Mechanical Guarantee

The equipment and machinery supplied are guaranteed against faulty material and bad workmanship for a period of 12 months after commissioning/acceptance; however, max. 18 months after delivery of equipment.
In case of failure to meet this guarantee, the client shall inform Haldor Topsøe A/S in writing without delay, and if it can be excluded that the failure is due to:

a) normal wear and tear
b) maloperation
c) repairs, changes or replacements made by the client without consent of Haldor Topsøe A/S,

Haldor Topsøe A/S shall without delay repair or replace the faulty part. Replaced parts under the guarantee shall on request be returned to Haldor Topsøe A/S.

10.2. Performance Guarantee

At the conditions specified in Section 3 above and on the condition that the entire equipment for the unit is constructed and installed in accordance with the instruction manuals and recommendations issued by Haldor Topsøe A/S, it is guaranteed that the concentration of NO_x in the reactor outlet gas will not exceed the value, as specified in Section 3 above, at steady load conditions i.e. at stable exhaust flow rate, temperature, composition and pressure.

The guarantee period is 16,000 operating hours; however, maximum two years starting from the day the exhaust gas is passed through the unit for the first time.

The unit is designed for an NH_3 slip of less than 5 ppm_v (wet gas, actual O_2), and during steady operation this can be maintained. However, at sudden changes of load, minor overshooting may occur.

The above-mentioned performance shall be attained and proven by a performance test not later than 3 months after completion of installation of the unit. If it turns out during the initial start-up period or during the performance test run that the guaranteed performance cannot be obtained, Haldor Topsøe A/S will make good, i.e. will modify the installation or change the catalyst, at own cost.

If the performance test, due to no fault of Haldor Topsøe A/S, cannot take place within 3 months after completion of the installation of the unit, the performance test shall be deemed to have taken place, and the final instalment falls due.

If the catalyst has to be replaced or additional elements have to be added during the subsequent guarantee period in order to obtain the guaranteed performance, a prorated discount is given on the price of the replacement catalyst calculated as:

$$\frac{(16{,}000 - X)}{16{,}000} \times 100\%$$

where X is the number of actual operating hours achieved from initial start-up of the SCR unit.

11. Limitations of Liability

Haldor Topsøe A/S is under no circumstances responsible for indirect or consequential damage due to non-fulfilment of any guarantee or for any other reason.

12. Validity

This proposal is a budget proposal only and as such valid for 60 days from the date of issue.

HALDOR TOPSØE A/S

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