LASTRON - SECOND GENERATION ACCELERATORS AND CHEMICAL REACTORS FOR EBFGT FACILITIES

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Abstract

Commercializing reliable affordable electron beam flue gas treatment technology requires both, the optimization of accelerator technology and chemical reaction chambers. Moreover, this engineering process involves the integration of beam specific characteristics, such as dosage distribution and penetration of electrons into the flue gas stream. In consideration of the treatment economy, it might be required to calculate the overall process performance without merely limiting the evaluation to accelerator efficiency. For example, a higher energy beam, 1MeV to 2 MeV, reduces the losses in the beam window and penetrates further into the gas stream and, therefore, increases the overall process economy. The energy distribution should be optimized with respect to the configuration of the chemical reaction chamber in order to treat the flue gas uniformly. All these measures are required to achieve high removal rates in large flue gas streams. Today removal rates of more than 99% SO_x and more than 80% SO_x are required to be compliant with future emission legislations. It is planed to establish a 100,000m³ electron beam flue gas treatment facility that can achieve constant removal rates of higher than 99.4% SO_x and more than 80% NO_x. The high removal rates would allow us to place CO_2 capture technologies down stream of the EBFGT facility.

1. INTRODUCTION

Since the 1970s, laboratories and pilot demonstrations by the Japan Atomic Energy Research Institute (JAERI), the University of Tokyo, have known the treatment of industrial flue gases by exposure to electron beams (EBFGT). Since then, a number of installations have been built world wide, leading in 2000 to the most recent facility - treating up to 270 000 Nm^3/h of flue gas - at the Pomorzany power station in Poland. This installation has provided technical information that allows formulating requirements on the next generation of EBFGT facilities.

Analyzing the operational data of existing EBFGT facilities, a number of technical modifications can be applied in order to increase the reliability of the EBFGT. Such changes are focusing on the electron beam accelerator and the support systems. Chemical reactor and electron beam system are required to interface directly, in a way to match the footprint of existing plants and to optimize the dosage. Electron beam steering and electron beam windows are directly related to the dosage delivered to the flue gas stream and, therefore, determine the over all process efficiency.

In order to achieve wider acceptance in industrial facilities, reliability is of highest priority. Assuming that preventive maintenance is required to operate a facility, redundancy is one solution to achieve a high availability of the system. Moreover, industry is looking for turnkey solutions in order to apply the EBFGT process in the same way as competitive technologies. EBFGT systems need to be maintained and operated for a minimum of 10 years, realistically looking at a lifetime of 15 to 20 years.

Dynamically changing legislation, such as green house gas legislations, will require the implementation of CO_2 capture options down stream of EBFGT installations. Research should consider “electron beam multi pollution control processes” as being capable to treat flue gases in preparation for any down stream CO_2 treatment. Thus, it might be required to focus on specific pollutants, such as SO_x, in order to allow alternative down stream procedures to take place. It is known that CO_2 sequestration or catalytic reactions will require the removal of SO_x at very low concentrations. In addition, sequestration technologies (such as CO_2 compression) will require a very low temperature up stream of the flue gas compressor.

2. MAIN DISCUSSION

Existing EBFGT facilities show that electron beam accelerators have a large potential to increase the process reliability and the treatment economics. The second-generation design of accelerators will fundamentally differ from past systems. In order to achieve this improvement, the accelerator and the chemical reactor will be matched in order to

- Optimize dosage distribution in the reactor
- Increase net energy delivered into flue gas stream
- Reduce footprint of EBFGT facilities.

The following chart is a risk management analysis of possible failure points in an EBFGT facility, utilizing DC accelerator technology. Dr. Zimek [7] from the Institute of Nuclear Chemistry and Technology in Warsaw presented possible EBFGT failure points in May 2007, representing operational data collected by the institute. The chart does not differentiate between failures related to the accelerator hardware or failures related to the design of the facility.

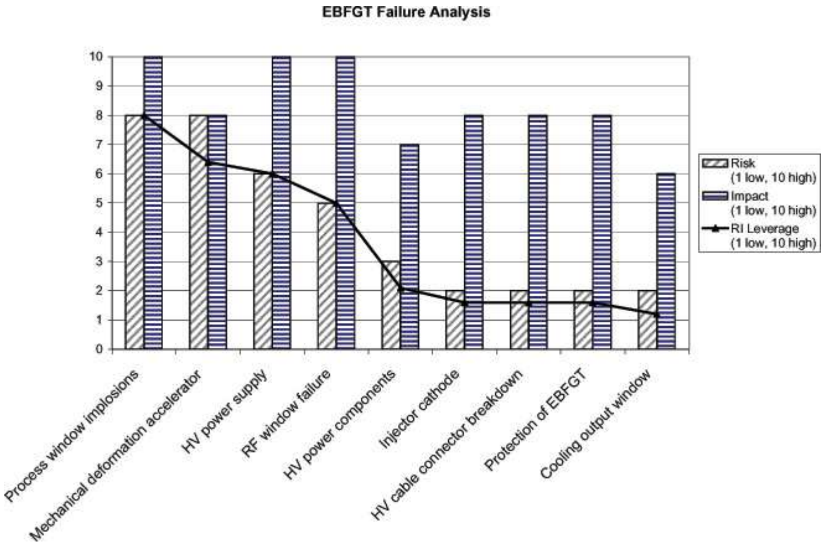

FIG. 1. Risk management analysis of possible failure points in an EBFGT facility, utilizing DC accelerator technology

The chart characterizes each failure point with a risk and an impact number; whereas 1 is low and 10 is high. Thereafter, the Risk-Impact leverage is calculated in order to allow a better identification of failures. In order to utilize the existing results and experience from current EBFGT operations, the design of accelerator and chemical reactor must be reviewed. Design iterations will allow improving the pollution removal rates and prolong mean time between failures. A possible first step is to decide upon an accelerator technology that integrates all requirements and allows future upgrades.

The accelerator will operate at 1.0 to 1.5 MeV, allowing the beam to transit efficiently through a segmented beam window. High beam current acceleration methods such as microwave cavities or induction cells should

- have mechanical stability at high energy levels; analytical results of surface stresses in the cavity or induction cell require technical solutions
- allow heat management to ensure optimal operation at various modes
- be flexible in order to allow retrofit into existing facilities; all power transmission must be cables
- allow future growth to increase the beam power to 1 MW

The design of the accelerator must be reliable and accessible for preventive maintenance; a mean time between failures of 2000 to 6000 hours is required. Preventive maintenance will allow exchanging parts before failure, limiting the mean down time to 16 hours or less. Preventive maintenance considerations require that the beam accelerator can be de-energized in order to service. A full scale EBFGT facility will allow each accelerator to be designed with its own power supply and chemical reaction chamber. Subsequently, the flue gas stream will be divided into sub streams of 100 000 m^3 each.

The major advantage of splitting the main gas stream is the ability to shut down one system for maintenance, without disrupting the treatment process. Each reactor has an in-flow guiding the gas stream and exposing the gas to the electron beam for a prolonged period. The electron beam will scan across the gas stream and is pulsed in order to

- allow optimized energy control
- synchronize the scan with the segmented beam window.

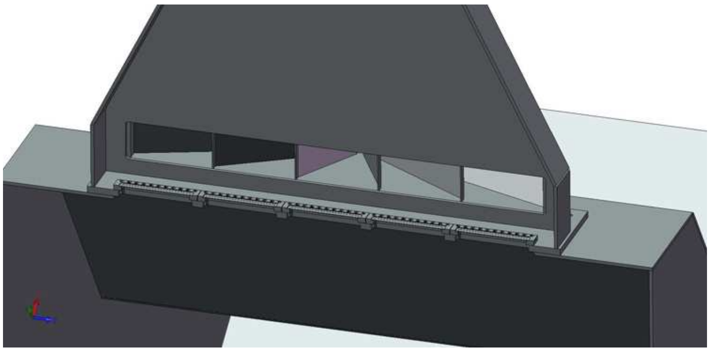

FIG. 2. Segmented beam windows of accelerator interface

The reaction chamber will have either a square flue gas inflow opening or a round pipe. The size of the inflow will be designed to reduce the flue gas velocity to approximately 7.5 m/s. The accelerator will be interfaced with an angular incident to the gas direction in order to allow full penetration across and along the gas stream. The accelerator interface has segmented beam windows as shown in Figure 2 (above), which allows the electron beam to transit from the beam generation section into the flue gas chamber. The window-segment is a key component in increasing system reliability by less mechanical stress and better temperature control of the window. To ensure optimal facility up-time, the beam window will be replaced on a preventive maintenance schedule.

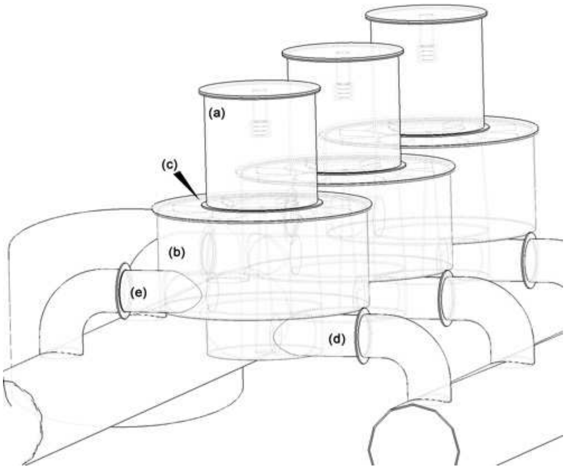

FIG. 3. Reactor design

Figure 3 shows a round reactor design; it has an in-flow (d) that will guide the gas stream in a cyclonic motion, and expose it to the electron beam for a prolonged period. This circular gas flow allows the steering of the electron beam in a very efficient way and, therefore, optimizes the exposure of the gas stream. The electron beam is steered digitally and can be modified online. Thus, the deflection pattern and the beam intensity can be regulated in real time by monitoring the SO_X and NO_X

sensors. The implementation of this control loop will result in the optimization of the electric energy consumption of the electron beam accelerator.

After exposure to the electron beam, the flue gas will flow in a propagation chamber, which allows the chemical reaction to form the NH_4NO_3 and $(NH_4)_2SO_4$ particulate. The dead-time chamber is designed in such a way that all acids form inside a vessel which is corrosion-protected. As a result, an increase in corrosion down stream from the reactor outlet (e) is not expected. Hence, the accelerator-reactor system can be retrofitted into existing facilities with carbon steel piping.

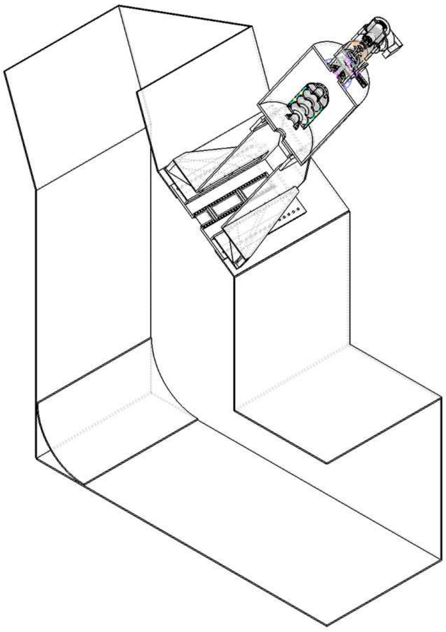

FIG. 4. Rectangular reaction chamber

Figure 4 shows the rectangular reaction chamber and the angled accelerator interface. The inflow of the flue gas is at almost vertical direction on the upper side of the chamber. The cut away view shows the accelerator interface in angular configuration with the segmented beam windows. Each reaction chamber and accelerator will treat 100 000 m^3/h and, therefore, larger EBFGT facilities will have between 2 to 6 reaction blocks. This configuration will allow redundant operation; thus, maintenance can be scheduled without interruption of the flue gas treatment. Flue gas flow rates, plant layouts and space availability on site will determine reactor configuration and size.

In light of the worldwide focus on CO_2 as man made cause of global warming, EBFGT is an important technological solution. Most CO_2 capture procedures require the removal of SO_x (sulfur) in order not to impact down stream CO_2 reactions or sequestration technologies.

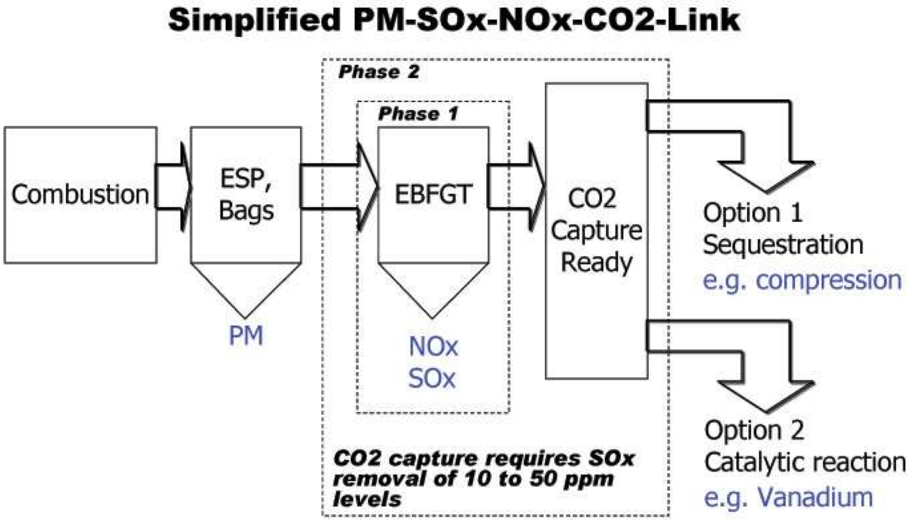

FIG. 5. Integrated flue gas treatment solution

Figure 5 outlines (in simplified version) the steps for an integrated flue gas treatment solution, targeting multi pollution removal. Our current scope of work for implementing EBFGT technology is staged in 2 phases. In phase 1 we are targeting the removal of SO_x and NO_x emissions in order to comply with future emission legislations. The EBFGT facility will be optimized to have a maximum emission of 150 mg/Nm^3 SO_x and NO_x. After establishing the base operational data, we will start phase 2: optimization of removal rates for SO_x. The high removal rate of SO_x will allow accommodating down stream of the EBFGT CO_2 capture technology such as sequestration or catalytic reactions. Integrating CO_2 capture technologies down stream will allow us to test the economic viability of CO_2 procedures.

Concurrently with the development of technical solutions for the EBFGT technology, we will focus on the value proposition to the end user (such as power plants), thus meet their business objectives. Electron beam technology can establish significant financial and economic benefits in many ways. Some of the key benefits are the more efficient utilization of plant infrastructures, possible lower overall fuel costs, and the selling of a by-product (fertilizer). Moreover, the management has to evaluate the importance of delivering an improved product, such as clean energy, at a higher price.

Stabilizing spot market prices of fuels will improve the sustainability of the operation. In the past, fuel prices experienced considerable fluctuations due to seasonal cycles, and escalated on account of unforeseen events such as hurricanes and other natural disasters. EBFGT might allow to combust locally available dirty fuels, such as high sulfur fuels, without exceeding emission limits. Emission regulations are expected to become more restrictive and will be enforced by Governments. Emission caps will result in the restriction of facility outputs, in particular of facilities lacking emission control technology. The incurring costs of such shut downs can be expressed as “costs of lost opportunity to deliver the product”.

The successful integration of Electron Beam Flue Gas Treatment will require an analysis of the financial impact of said technology on industry. Based on the financial results, including short- and mid- term cash flow, a number of financing strategies can be developed. In light of the worldwide focus on CO_2 and other pollutants (such as SO_x and NO_x) as man-made cause of global warming, emission control equipment will attract venture capital, other environmental oriented funds and the public markets.

3. CONCLUSIONS

EBFGT technology is a building block towards a multi pollution control procedure that provides economic viability. Current design efforts target the reliability of the equipment and the affordability of environmental technology. The treatment of flue gas and the removal of sulfur oxide and nitrogen oxides are key steps towards pollution reduction, and are achievable technological goals with minimized financial impact to current operations. In addition, this technology is perfect for already existing plants as retrofit application as well as for new facilities.

The biggest question regarding environmental pollution control is not the technology, but more the willingness to integrate such procedures in industrial operations. Without enforced emission laws, it will be very difficult to motivate key polluters to clean up their operation and, therefore, governments are asked to react accordingly.

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