ELECTRON ACCELERATORS FOR CLEANING FLUE GASES AND FOR OIL LIQUEFACTION*

Sergey Korenev#, Roland Johnson,

Muons, Inc., 552 N. Batavia Avenue, Batavia, Illinois 60510, USA

Abstract

High-power electron beams can be used to reduce the environmental impact of coal and oil-fired power generating plants by removing harmful materials from flue gases. This technology has been tested in the laboratory and at smaller industrial levels, but to make it economically attractive, the accelerator costs must be reduced and the efficiency must be increased for removing toxic components with low concentrations. We propose a simple electron accelerator with a wide beam to reduce costs. To remove toxic materials we propose a plasma reactor for desulfurization and selective catalytic reduction. The designs of 0.5 to 1.0 MeV accelerators with 20 to 100 kW average power are considered along with the design of a plasma reactor for flue gas treatment. The design of a pilot facility for the oil industry is also presented.

INTRODUCTION

The progress in radiation technologies link with destruction of toxic components of flue gases from power stations had shown the understanding of physical and chemical processes.

The pilot stations based of electron beam treatment were tested in Japan, Germany, Poland, USA, Russia [1, 2, 3]. The main concept of radiation decomposition of toxic components in flue gases consists in the using of electrons for starting of chemical reactions with following chemical processes leading to solid fractions of component of SOx, NOx. The main problem consists in the low concentration of toxic components such as SOx, NOx in flue gas from electrical power stations. The main advantage of electron beam technologies consists in the creation of conditions for chain reactions and forming of solid components, which easy to take off.

The current problem of this technology for treatment of flue gases consists in the low efficiency. This problem combines of the high efficient electron accelerator and plasma reactor. The question of increasing efficiency of this technology is subject of this paper.

The question of increasing efficiency for electron beam for creaking of heavy oil is other topic for this paper.

Other subjects of this paper are new approaches for design of simple and reliable electron accelerator.

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#sergey@muonsinc.com

STRUCTURE OF ELECTRON ACCELERATORS

The main concept of electron accelerator consists on the DC electron accelerator with large cross section of electron beam and vacuum insulation of high voltage components [3, 4, and 5]. The general structure of electron accelerator is given on Figure1.

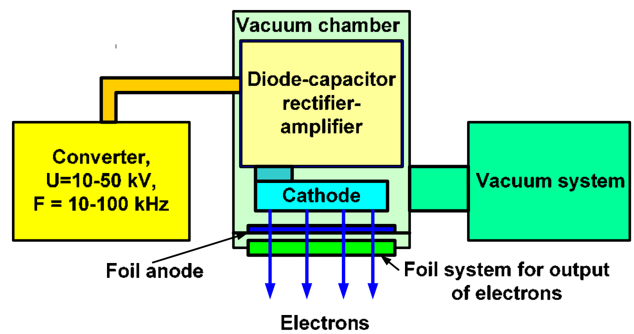


Figure 1: The structure of electron accelerator.

The main parameters of electron accelerators are following:

1. Kinetic energy is 0.5-1.0 MeV
2. Beam power is 20-100 kW.
3. Beam dimensions are 40x100 cm^2.
4. Power efficiency is 60%.

The large cross section of electron beam leads to low current density 5-25 μA /cm^2. It decreases the thermal conditions for foil anode and foil system for output of electrons. Also this low value of current density allows to use field emission cathodes [6, 7] and plasma cathode with partial discharge.

The vacuum chamber presents the metal vessel with vacuum pump and pressure of residual gas is 10^{-6} Torr.

The foil system for output electron beams from vacuum chamber to air based on Be foil with DLC (Diamond-Like-Carbon) coatings with thickness 1-2 microns [9].

MAIN COMPONENTS OF ACCELERATOR

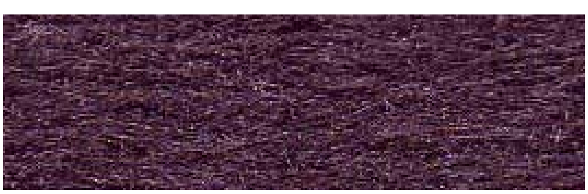
Power supply source consists from high frequency converter (10-100 kHz) and Diode-capacitor rectifier-amplifier. The Diode-capacitor rectifier-amplifier locates in vacuum chamber. The recent progress in semiconductor industry and high power electronics allows to realize these systems for high power 20-100 kW in reasonable scale. The relative low high voltage 10-25 kV leads to simple primary high voltage insulators. The study of vacuum electrical insulation for elements of Diode-capacitor rectifier-amplifier was shown reasonable vacuum conditions for surface electrical discharge. The pictures of ceramic capacitors and diodes are given in Figure 2.

Figure 2: The pictures of ceramic capacitor and rectifier diode.

The vacuum conditions on the level of 10^{-6} Torr allow to increase the threshold voltage in to 3-4 times in compare with air for atmosphere pressure. The limit of voltage for ceramic capacitors determines the breakdown voltage inside of ceramic.

The cathode connects with last capacitor of Capacitor-diode rectifier-amplifier. The cathode fabricates from conducting carbon fiber material, see Figure 3 a, b.

a) Carbon-Fiber Cathode.



b) The surface of Carbon-Fiber Cathode.

Figure 3.

The beam current corresponds to Child-Langmuir Law. The field emission for carbon-fiber cathode with large cross section is table to till beam power 20 kW. The increasing of power leads to effect cathode spots and evaporation of carbon-fibers in these places. The increasing of beam power to till 100 kW realizes by carbon-fiber cathode with partial vacuum discharge. The design cathode includes the current reducing resistors, see Figure 4.

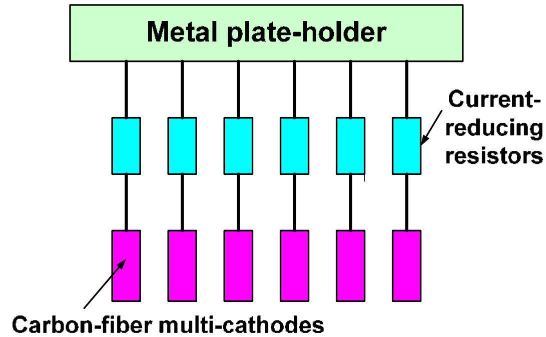


Figure 4. Cathode with partial vacuum electrical discharge.

SYSTEM FOR CLEANING OF FLUE GASES

The new concept of system for cleaning of flue gases SOx, NOx, COx is next:

1. The system includes electron accelerator and chemical reactor max using of electron beam for full chemical processes.
2. The electron beam after reactor uses for production of ozone and free radicals from ionization of water and hydrogen peroxide.
3. The ozone and free radicals increases the efficiency of chemical reaction for catalytic effects and oxidation.

This system allows to increase the efficiency of chemical processes and decomposition of low concentration toxic gases.

The structure of system for cleaning flue gases is given on Figure 5.

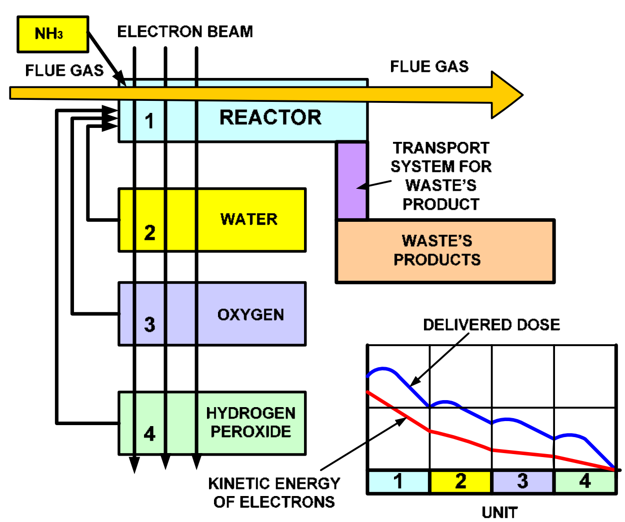


Figure 5.

The delivered dose distribution in flue gas for electron beam with kinetic energy 1 MeV and power 200 kW is given on Figure 6.

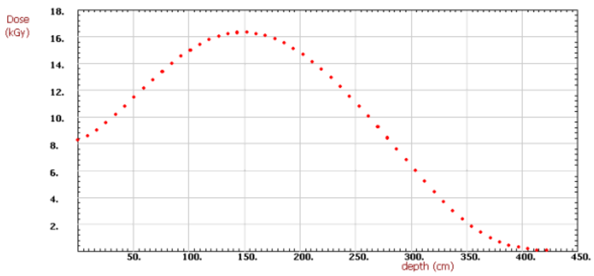


Figure 6.

SYSTEM FOR OIL LIQUEFACTION

The radiation treatment of heavy oil presents the hot topic in the radiation technologies and oil industry. The ideas and concepts [10.11] allow to improve the properties of heavy oil. The study of radiation cracking in liquid hydrocarbons showed the high level of delivered dose for low temperature. The simulated distribution of delivered oil in the liquid hydrocarbons is given on Figure 7.

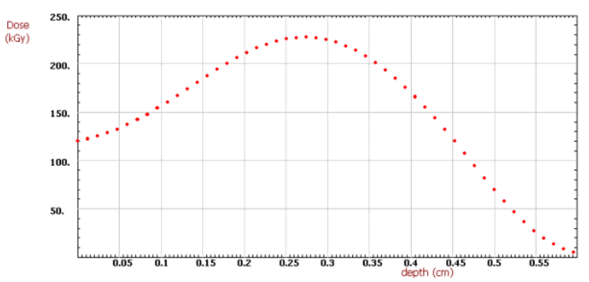


Figure 7.

The plate channel for oil with water cooling chamber allows to satisfy these requirements (Figure 8). The small gap in plate channel determines by kinetic energy of electrons.

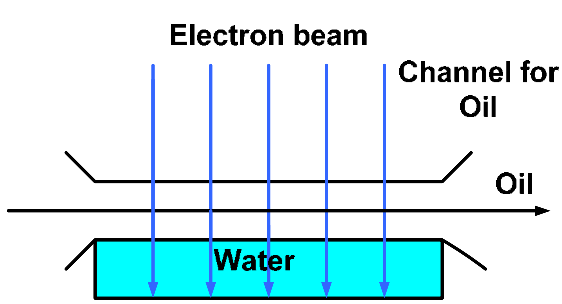


Figure 8: The plate channel for radiation cracking of oil.

CONCLUSIONS

1. The suggested technical solutions for units and components of electron accelerators allow an increase in the efficiency of electron accelerator in total power.
2. The using of broad electron beam allows a decrease in the thermal loads on the foil window for output electron beam from vacuum chamber to air and input to plasma reactor.
3. The suggested system for cleaning of flue gases allows an increase in the efficiency of decontamination of low concentration of toxic gases from power stations.
4. The high power of electron accelerators permits radiation cracking for heavy oils.
5. The increased effectiveness of electron beam technology permits an improvement in radiation processing.

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