Applications of Industrial Electron Accelerators at Samsung Heavy Industries

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ABSTRACT

An industrial electron beam accelerator has been developed at Samsung Heavy Industries with the collaboration of Seoul National University and Russian Budker Institute of Nuclear Physics. The accelerator is a high voltage accelerator using rectifiers and able to deliver 40 mA of 1 MeV electrons in CW mode. Functionally, the accelerator is an electron irradiation processing device and an electron beam scanning system is employed for the uniform irradiation of the electron beam through the extraction window of the size 980 mm x 75 mm. The industrial applications of the electron irradiation processes include combustion flue gas purification process, treatment of industrial waste water containing refractory pollutant, treatment of semiconductor devices, and radio-chemical processes. The major features of the device and its industrial applications will be described.

I. INTRODUCTION

Samsung Heavy Industries Daeduk R&D Center is a part of SAIT (Samsung Advanced Institute of Technology) Daeduk site which is located at the central part of Korea. The accelerator laboratory at Daeduk R&D Center is devoted for the development of accelerator technologies and applications. Current research activities include the development of electron accelerators for irradiation processing purpose, applications of electron irradiation processing and the development of a synchrotron light source.[1]

As an initial step, an industrial electron accelerator[2] has been developed with the collaboration of Seoul National University and Russian Budker Institute of Nuclear Physics. The electron accelerator is designed for electron irradiation processing and it is a part of an electron irradiation processing facility. Practically, most of electron accelerators for irradiation processing are used for radio-chemical processes, which include treatment of heat-resistant electric cable, automobile tire, textile, polymer tube for heating purpose, foam sheet and thermo-shrinkable tube. Another interesting application is semiconductor treatment. After the electron radiation treatment, the switching speed of IGBT (Insulated Gate Bipolar Transistor) is improved by order of 2 magnitude. Though there are many other possible applications such as sterilization of food and medical waste, our major research object is focused on the application of the electron accelerator to environmental engineering. The combustion flue gas purification process is one of the actively studied subject for environmental applications. This technology could be a major impact on the flue gas purification technology for incineration plants and coal power plants. The treatment of industrial waste water containing refractory pollutant is also actively studied.

II. ELECTRON IRRADIATION PROCESSING FACILITY

The industrial electron beam accelerator developed at Samsung Heavy Industries is a high voltage accelerator using rectifiers. The original design of the accelerator was developed at Russian Budker Institute of Nuclear Physics. The nominal energy and current of the electron beam is 1 MeV and 40 mA, respectively. As a matter of fact, the electron accelerator is a part of the electron beam irradiation processing facility and an additional scanning system is required for the uniform irradiation of the electron beam to a certain area.

After a frequency converter changes the frequency of input current from 60 Hz to 480 Hz, a transformer coil system is employed to convert the voltage. The transformer system consists of one primary coil of 30-turn and 44 secondary coils of 3000-turn. In order to prevent discharge, the transformer coil system is filled with SF_6 gas. Each secondary coil generates the DC voltage of 20~25 kV with its own rectifier system from the input voltage of 360~390 V. In order to produce the high voltage for the acceleration of electrons, the outputs from 44 secondary coil systems are connected in series and 0.7~1 MV is delivered to an accelerating tube which is positioned at the center of the transformer coil system. The accelerating tube is made of 88 ceramic tubes and 87 stainless steel disks by alternately stacking them up and being bonded together. The pressure of the accelerating tube is maintained below 10^{-7} torr. The voltage distribution of the accelerating tube is manipulated by connecting appropriate resisters between stainless steel disks. The scanning system is used for the uniform spread of the accelerated electron beam through a Titanium extraction window. The physical size of the electron extraction window is 980 mm X 75 mm and the scanning frequencies of horizontal and vertical directions are 55 Hz and 925 Hz, respectively. Figure 1 shows the simplified diagram of the electron accelerator.

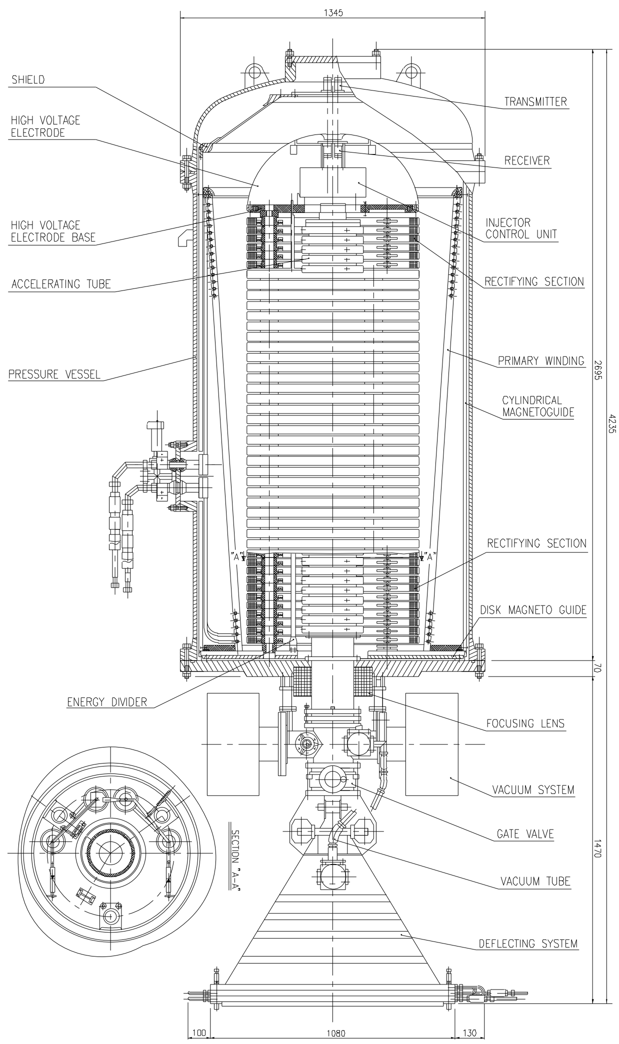

Figure 1. Simplified diagram of the electron accelerator.

III. COMBUSTION FLUE GAS PURIFICATION

One of the most prominent environmental applications is the combustion flue gas purification process[3] for the treatment of the flue gas from incineration plants and coal power plants.

Figure 2 shows the simplified schematic of the flue gas treatment. The irradiation of the electron beam produces radicals from the steam vapor inside the reactor, which react chemically with SO_x and NO_x gases and produce acids such as H_2SO_4 and HNO_3. The neutralization of the acids is the final process of the electron irradiation method. There are advantages of the electron irradiation method over conventional methods. Since the electron irradiation process is a dry process, no secondary waste water is produced as the by-product of the process. When ammonia gas is fed as the neutralizer, the by-product can be used as a fertilizer. The reduction of SO_x, NO_x, and HCl also can be done simultaneously and the fact that the area of the facility is much smaller than that of the conventional facility could be the most attractive advantage.

Bench scale tests using the flue gas with the flow rate of 4 Nm^3/hr promises the simultaneous reduction of SO_x and NO_x up to 90 % and 80 %, respectively. A pilot plant able to treat the flow rate of 200 Nm^3/hr is under construction for the treatment of the flue gas from a municipal incinerator.

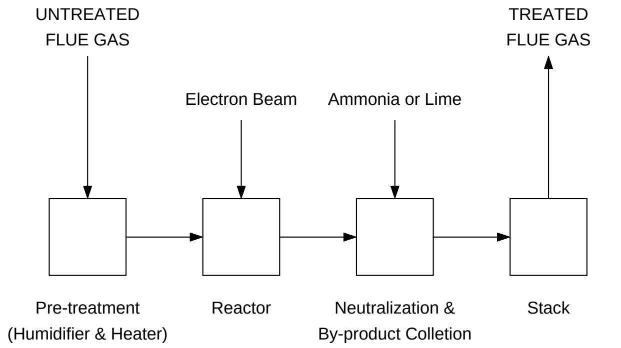

Figure 2. Simplified schematic of the combustion flue gas purification process.

IV. WASTE WATER TREATMENT

The treatment of municipal and industrial waste water becomes a more important subject in the field of environmental engineering.[4,5] The treatment of the industrial waste water containing refractory pollutant is actively studied in Samsung Heavy Industries.

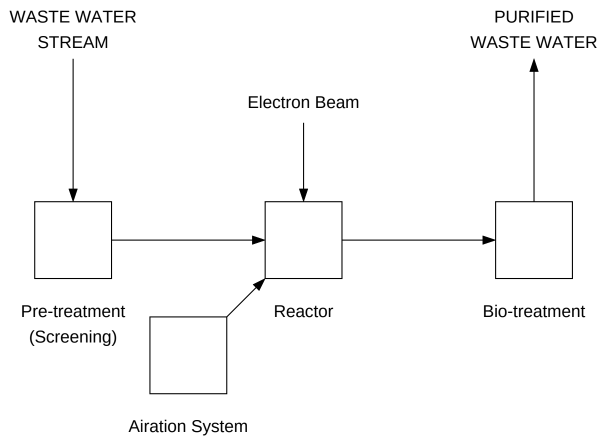

Figure 3. Simplified schematic of the industrial waste water treatment process.

Figure 3 shows the simplified schematic of the industrial waste water treatment. The irradiation of the electron beam to waste water produces radicals such as e^-_{aq}, H•, OH•, H_2•,

H_2O_2•, H^+, OH^-_{aq}, H_2O•, and O_2^-•. In order to improve the penetration depth of the electron beam to water, an air bubbling system is employed to help the effective distribution of the radicals. The radicals react chemically with chlorinated organic compounds and generate by-products such as H_2O, CO_2, chloride, aldehyde, and formic acids. The fact that the interaction by the radicals are effective to a wide range of pollutant is the one of advantages of the electron irradiation method. The effectiveness in biological sterilization and decolorization of dyes is another advantage. The method also shows the improvement in sedimentation and coagulation.

Figure 4 shows the preliminary result of application to dye waste water. The solid line shows the reduction of TOC (Total Organic Carbon) and the dotted line shows the efficiency of decolorization as functions of absorbed dose. The sampling of the waste water is performed from dyeing industry complex. As the dose increases, both of the decomposition of compounds and the bio-degradability increase.

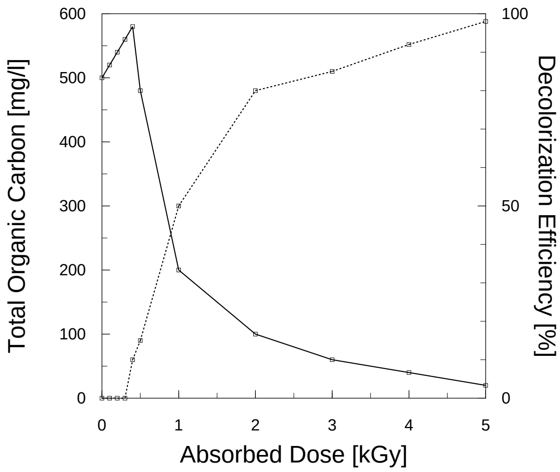

Figure 4. Effectiveness of the electron irradiation method for dye waste water. The solid line shows the reduction of TOC (Total Organic Carbon) and the dotted line shows the efficiency of decolorization as functions of absorbed dose.

V. CONCLUSION

The electron accelerator developed by Samsung Heavy Industries Daeduk R&D Center is used as a part of the electron irradiation processing facility. Our major applications of the electron irradiation processing facility are the subjects related with industrial and municipal waste management. The preliminary result of the flue gas treatment shows the possibility that the technology could become a major impact on the flue gas purification process for incineration plants. The bench scale test of the waste water purification process is also successful. However, both of the applications need more research works for practical applications. The research subjects of other radio-chemical processing techniques are performed by the collaboration with other institutes and industries.

VI. REFERENCES

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