3. Application of Electron Accelerator Worldwide

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Sueo MACHI,
FNCA Coordinator of Japan, JAIF

1. Introduction

Electron accelerator is an important radiation source for radiation technology application, which covers broad fields such as industry, health care, food and environmental protection. My paper over-viewing these applications published at International Meeting Radiation Processing in 1997 is useful reference for broader information. My presentation today is focusing on commercial electron accelerator applications.

2. Electron accelerator and Co-60 irradiator

There are about 1,000 electron accelerators for radiation processing world-wide[1]. Electron accelerator has advantages over Co-60 irradiator in terms of high dose rate and power, assurance of safety, and higher economic performance at larger volume of irradiation in addition to better efficiency of radiation absorption and free of recharge of Co-60. Penetration range of electron, however, is much shorter than photon from Co-60 gamma radiation.

Accelerator generating higher energy in the range of 10 MeV and high power electron beams is now commercially available, which can be used for wide range of applications including sterilization of medical product and foods.

Application of X-ray generated by conversion of electron beams seems not very feasible because of low conversion efficiency and damage of accelerator by backscattered X-ray[2].

Medical Products Irradiation

Currently about 40% of medical products are sterilized by radiation. Sterilization of medical products has been carried out mainly by Co-60 because of high penetration range of gamma rays. There is a trend to use high energy electron accelerator replacing Co-60 in case of large through-put of products.

One typical irradiation system using 10MeV electron beam designed by Titan Scan Co. was shown in Figure 1. High energy accelerators of 5-10MeV are provided by several companies in Belgium, France, Japan, U.S.A. and Canada.

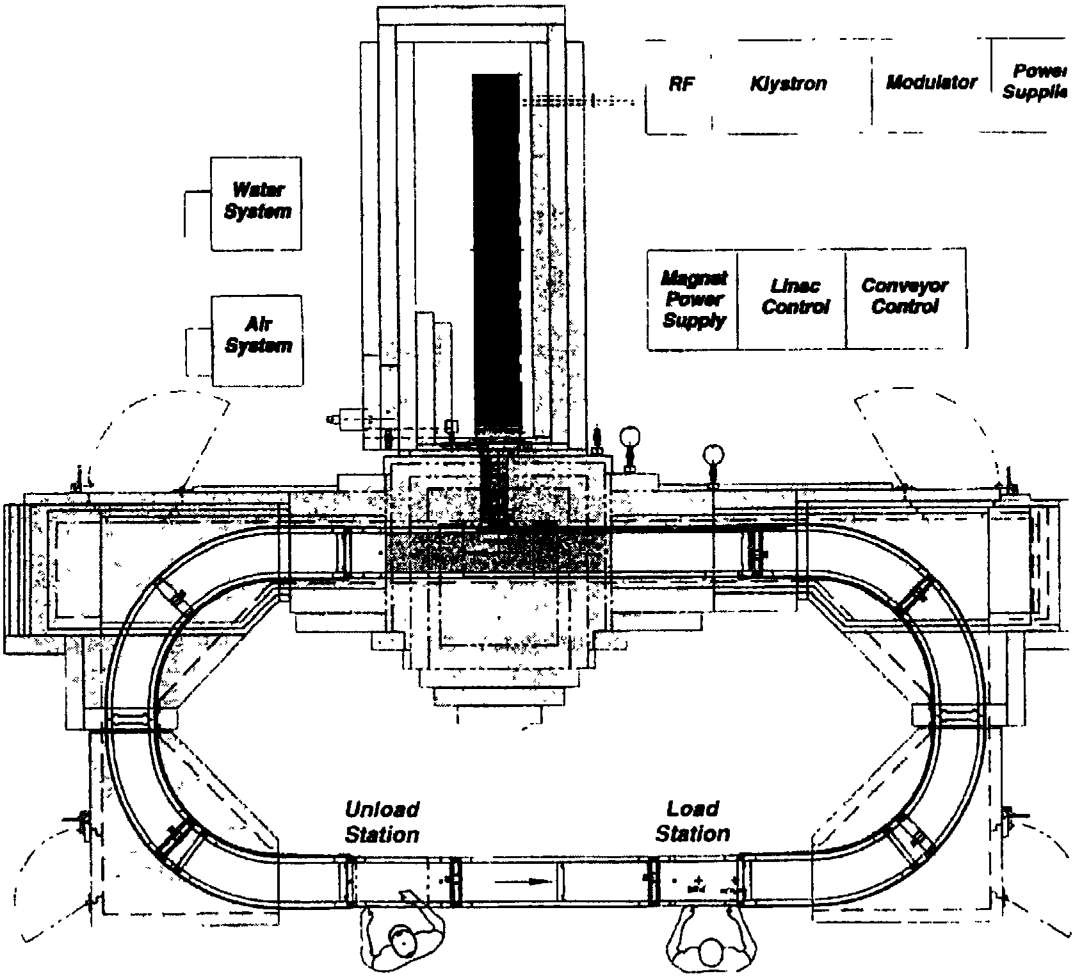


Fig.1 Plan view of the Surebeam On-Site System utilizing single sided processing and conformal steel shielding.

4. Food Irradiation

Irradiation reduces spoilage, improves hygiene and extends shelf life of foods. Food irradiation can also contribute to increase export potential for quarantine purposes without using methyl bromide fumigation which depletes the ozone layer. Irradiation of deboned poultry meat to reduce contamination with Salmonella and Staphylococcus has been commercially used in France since 1990. An electron accelerator (LINAC) of 10 MeV, 10kW has been used for irradiation.

In Odessa in Ukraine, the electron accelerator plant to disinfest grain to avoid loss after harvest eliminating insect pest using electron beams of 1.2~1.5 MeV with the power of 40kW. The grains are irradiated during continuously flowing in a pipe under beams as shown in Figure 2. [3]

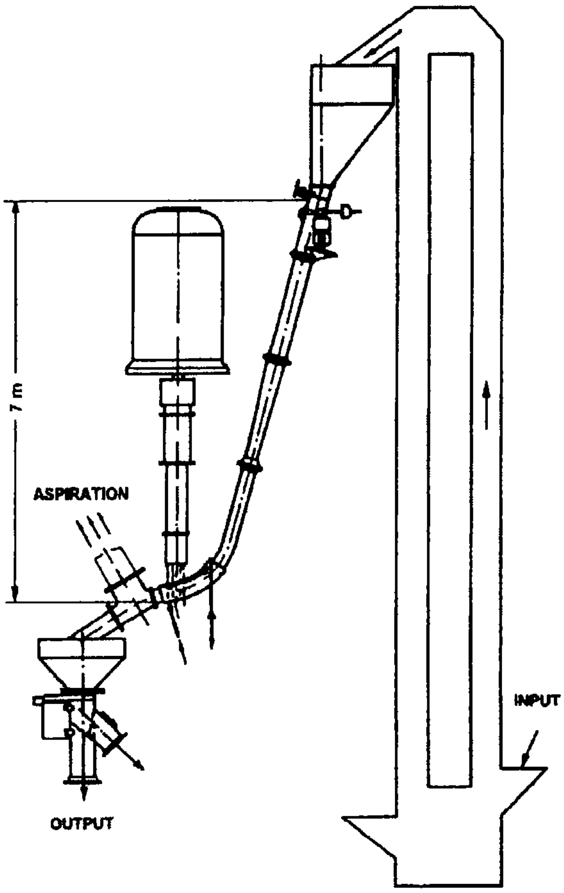


Fig.2 The operational scheme of the technological line

Food borne diseases increasingly affect the health of populations. In the United States for example, food derived pathogenic bacteria such as Salmonella, E. Coli, Listeria, Campylobacter, Vibrios, Trichinella and other parasites claim an estimated 5,000 lives annually and between 24 and 81 million cases of diarrhea of various kinds. Food irradiation has been increasingly recognized by health authorities as a means of countering this health problem. Currently 250 supermarkets in the USA are selling irradiated ground beef for hamburgers.

Irradiated foods, in particular species, are on the commercial market in 35 countries worldwide.

5. Polymer modification

Electron accelerator is used efficiently and economically for production of new or modified polymeric materials through radiation-induced cross-linking, grafting and polymerization reactions.

The advantages of radiation processing over chemical methods are:

- Savings in energy consumption
- Improved product quality or new products
- Reduction in emissions of environmentally harmful substances
- Elimination of harmful chemical residues in products.

Owing to these cross-linking technology properties of plastics such as polyethylene, polyvinylchloride and rubber can greatly be improved in terms of thermal resistance, chemical resistance and mechanical strength. Examples of commercial products manufactured by electron accelerator are listed in Table 1.

Cross-linked insulation shows increased resistance against heat, chemical attack and cuts, and is more compact being used in the automobile industry, telecommunications, the aerospace industry and in home electrical appliances.

In the automobile industry, electron accelerator is used to cross-link rubber molecules in the production of radial tires. For example, Michelin in France, Goodyear and Firestone in the USA, Bridgestone and six other tire manufacturing companies in Japan and a company in Korea have been producing tires using electron accelerators.

Heat shrinkable polymeric materials produced by radiation processing are unique products widely used for food packaging, electrical insulation at junctions and corrosion protection of underground pipeline welds.

Another important application of electron beams is the curing of surface coatings in the manufacture of products, such as wood panels, adhesive tapes, surface coats for printing, floppy discs, and decorative steel plates. A major advantage of electron beam (EB) curing is that no organic solvent is emitted into the environment during the process. This process is more friendly to the environment. Wound dressing, deodorant polymers, membrane for battery separator are more recent products sold in market.

Table 1: Commercial Application of Electron Accelerator

1. Modification of polymeric materials (commercial products)
Heat-resistant wire/cable Hear shrinkable materials for food packaging, insulation, etc. Formed polyethylene Automobile tires Cross linked nylon and polyurethane for automobile parts Cross linked polyethylene tubes for floor heating, drinking water Membrane for battery separator Hydrogel for wound dressing Deodorant polymers Surface coating
2. Sterilization of medical products
Japan, the U.S.A., Canada
3. Treatment of foods
Deboned separated poultry meats, France, 10MeV, 10kW Disinfection of grain, Ukraine Odessa, 1.2~1.5meV, 20kW Meats, frozen patties, USA, Calif., 10MeV, 4kW[4)]
4. Environmental protection (Industrial plants, large pilot plant)
Cleaning flue gas from coal burning power station, Poland, 0.8MeV~1.2MW Cleaning flue gas from coal burning power station, China, 0.8MeV Cleaning flue gas from heavy oil burning power station, Japan, 0.8MeV, 24MW Cleaning waste water from dyeing factory, Korea, MeV, 40kW

6. Cleaning environment

Electron accelerators of large capacity are used for cleaning exhaust gases in industrial scale in China, Japan and Poland and for waste water cleaning in pilot scale in ROK, the U.S.A., Austria and Brazil.

Innovative technology using electron beams to simultaneously remove SO_2 and NO_x by irradiation was first developed in Japan Atomic Energy Research Institute by the research group that I was heading and further followed by research groups in several countries. The mixture of ammonium sulfate and ammonium nitrate, which is a by-product of the process, can be used as agricultural fertilizer. As shown in Figure 3, the flue gas is exposed to electron beams while it passes through an irradiation chamber. A small fraction of gaseous ammonia is injected into the chamber. As a consequence of reactions induced by radiation, SO_2 and NO_x are converted into a mixture of ammonium sulfate and nitrate particulates.

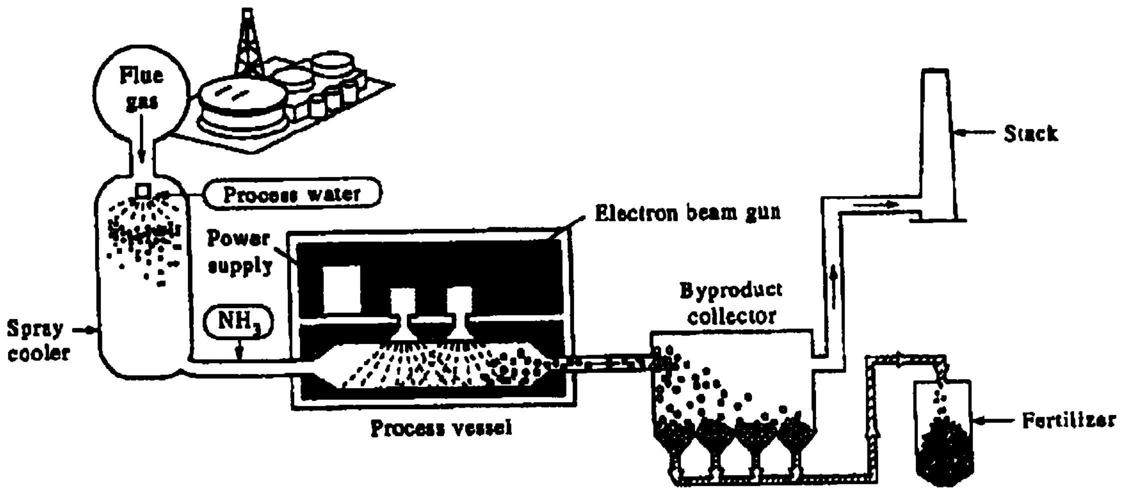


Fig. 3. Flow diagram of electron beam process for flue gas treatment.

The advantages of this technology over conventional processes for treating flue gases are:

- It is the only process to simultaneously remove both SO_2 and NO_x.
- The by-product of the process can be used as agricultural fertilizer.
- The process does not require large amounts of water.
- It can meet the stringent requirements for removal efficiency of SO_2 and NO_x.

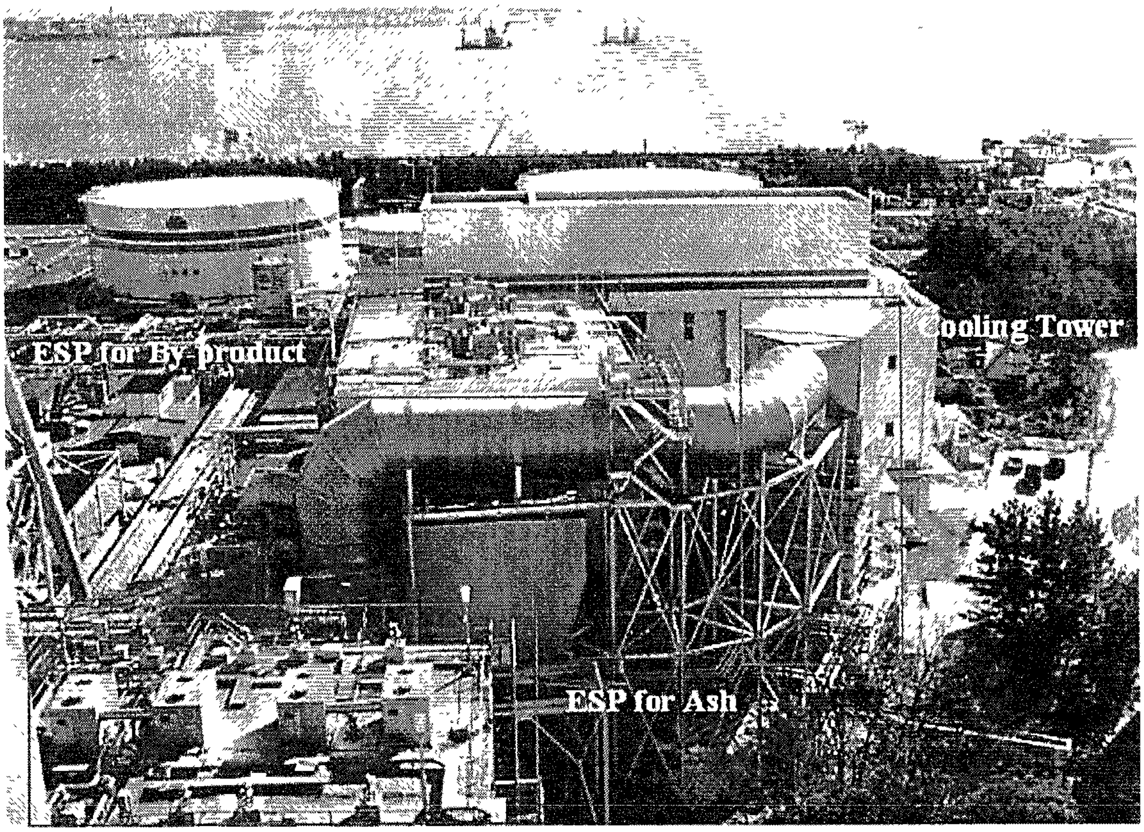
A large demonstration plant with the capacity to clean 270,000 Nm^3/hour of coal burning flue gases has been in operation in Poland using accelerator of 0.8MeV, 12MW under an IAEA/Poland Technical Co-operation project since early 2001.

In China an industrial demonstration plant to remove SO_2 from flue gas of a coal burning power station is in operation. In Japan a demonstration plant in Chubu Power Co. (Figure 4) to clean oil burning flue gases of power station 220MWe is about to start operation in 2002.

Economic feasibility studies of this electron beam process have shown that this technology is more cost effective than the conventional process. It should be noted that the conventional limestone process produces gypsum as a by-product, which cannot be used in some countries. By contrast, the by-product of the electron beam process is a valuable fertilizer.

In Japan Atomic Energy Research Institute (JAERI) will soon start operation of pilot plant to remove dioxin from flue gas of municipal incineration plant.

In Korea a commercial company has been extensively studying treatment of wastewater from dyeing factory using pilot plant of 1,000m^3/day capacity showing promising results.



Plant Capacity: 62,000m^3/h (220MWe) , SO_2 Removal > 92%, NOx Removal > 60%
Electron Accelerator: 800keV, 500mA × 6units
Fig.4. EB Plant to Clean Flue Gas of Heavy Oil Burning Power Plant of Chubu Electric Power Co.

1) S. MACHI, Atomic Energy Week of the Philippines, Dec.11, 2001
2) Y. AIKAWA, Radiation Physics and Chemistry, 57(2000) 609
3) R.A. SOLIMOV, et al., Radiation Physics and Chemistry, 57(2000) 625
4) K.G. CARLSON et al., Radiation Physics and Chemistry, 57(2000) 619

4. Country Reports