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ELECTRON BEAM ACCELERATOR FACILITIES AT IPEN-CNEN/SP

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ABSTRACT

Electron beam processing is a manufacturing technique, which applies a focused beam of high-energy electrons produced by an electron accelerator to promote chemical changes within a product. At IPEN-CNEN/SP there are two electron beam accelerators Type Dynamitron® (Manufactured by RDI- Radiation Dynamics Inc.) Job 188 and Job 307 models. The technical specifications for the Job 188 energy 1.5 MeV, beam current 25 mA, scan 1.20 m, beam power 37.5 kW and for the Job 307 energy 1.5 MeV, beam current 65 mA, Scan 1.20 m, beam power 97.5 kW. Some applications of the electron beam accelerator for radiation processing are wire and cable insulation crosslinking, rubber vulcanization, sterilization and disinfection of medical products, food preservation, heat shrinkable products, polymer degradation, aseptic packaging, semiconductors and pollution control. For irradiating these materials at IPEN-CNEN/SP, there are some equipments such as, underbeam capstan with speed control from 10 to 700 m/min; a track; a system to roll up and unroll wires and electric cables, polyethylene blankets and other systems to improve the quality of the products.

1. INTRODUCTION

All electron accelerators include a source (of electrons), an evacuated accelerating chamber, and a system for extraction from the vacuum and distribution over the product surface. Most accelerators obtain their electrons from a heated filament source (similar to that of a TV tube), called the electron gun. The energy of these electrons is then increased in one or more stages as they pass through a vacuum with an applied electric field. There are numerous ways to generate this electric field. DC accelerators generate and maintain the full accelerating voltage between just two electrodes. As the voltage is raised to millions of volts, electrical insulation becomes a major engineering problem. Even at low potencies, these accelerators can have dimensions exceeding 15m (45 feet). For systems with the energy and the power needed for industrial irradiation, the most common commercially available models are the Dynamitron®, and Insulated Core Transformer (ICT).[1]

There are two industrial electron beam accelerators at IPEN-CNEN/SP, both manufactured by RDI-Radiation Dynamics, Inc:

- Electron Beam Accelerator JOB 307 (Dynamitron®) energy 1.5 MeV (Figure 1), beam current 65mA, scan 60 to 120 cm , beam power 97.5 kW. It is used for irradiating the wire and cables crosslinked, polyethylene foam, heat shrinkable tubing and plastics, thin film polymer crosslinking, polymer tube crosslinking and other products.

- Electron Beam Accelerator JOB 188 (Dynamitron®) energy 1.5 MeV (Figure 2), beam current 25 mA, scan 60 to 120 cm, beam power 37.5 kW. It is used for irradiating and sterilizing medical products, silicon wafer processing, food, composites modification, polymer modification, shrink wrap sheet products, tire and rubber pre-cure treatment, chemical or biological wastes, and other products.

2. PRODUCT IRRADIATION SUMMARY

The electron beam accelerator imparts high velocities to electrons. The electrons are emitted form a collimated beam that is scanned across the product to irradiate the material. As the electrons penetrate into the material, they make numerous collisions with the atoms they encounter. The atoms generally become excited or ionized by these collisions, gaining extra energy that can initiate chemical changes within the product. Each electron in the beam has sufficient energy to excite thousands of atoms within the material, before coming to rest or being scattered out of the material.

Within the product material, the electron beams are scattered in all directions. Most collisions produce an angle relatively small scattering as the beam electrons interact with the orbital electron in the atom. Some collisions, however, will result in a large back-scattering angle when the beam electron encounters an atomic nucleus. A fraction of the electrons are, therefore, back scattered toward the beam source.

In terms of industrial use, the two main Dynanitron® processing parameters are the accelerator voltage and the beam current. The voltage that affects the depth of the electrons will penetrate into the product. The beam current affects mainly the product dose. A higher voltage means that each electron has more energy and when it penetrates deeper into the material, because it can make more collisions before stopping. The average of energy absorbed per collision is, however, nearly independent of the electron energy, so the accelerator voltage affects mainly the dose distribution within the material, and not the magnitude of the dose.

The beam current, on the other hand, does not change the energy per electron; thus, it has effect on the dose distribution. An increase in the beam current leads only to a proportional increase in the collisions, but it increase the strength of the dose at any depth within the product.

Another important material processing parameters is the line speed of the product as it passes beneath the scanning beam. The higher the line speed, the lower the product dose. The product dose can, therefore, be increased by increasing the beam current [2-3].

Accelerator equipment and peripherals:

- High voltage power supply;
- Beam tube assembly;
- Optical and scan system;
- Vacuum pumping system;
- Control System;
- Utilities;
- Take on and take off (wire and cable system , polyethylene foam system for irradiation);

- Rolling mat;
- Other equipments.

2.1 Energy – Electron Accelerator

When an electron (whose charge is 1.6 x10^{-19} Coulombs) is accelerated in an electric field of 1 Volt, its energy becomes 1.6 x10^{-19} Joules. This is more commonly stated as one electronvolt or 1eV. In electron irradiation processing it is common to quote energies, not in microscopic numbers of joules but simply as electron-volts or millions of electron-volts (MeV), where the "volts" factor is equal to the accelerating potential of the source. Not all electrons in a beam have identical energies and it is common to have a spectrum or range of energies. The spectrum shape depends on the type of accelerator, and how it is adjusted [3].

2.2 X-Ray Sources

X-rays produced by bombarding heavy metals with electrons have energies which cover a wide range, but never exceed the maximum energy of the parent electrons. It is common to refer to an X-ray spectrum by the nominal energy of the electron beam which generated it.

For example, a 5 MeV electron beam is said to generate 5 MeV X-rays, even though the parent electron beam and daughter X-rays include a range of energies. For X-Rays, this "energy" is a useful label for comparing the penetration of X-Ray sources and for ensuring that the source will meet the international guidelines for maximum energy.

The S.I. unit of radioactivity (1 disintegration/sec.) is the Becquerel (Bq). However, the Becquerel is so small relative to the size of industrial sources that an old unit, the Curie (Ci) or the mega Curie (MCi) are almost always used. For a cobalt-60 source, 67.578 Ci, (a number derived from adding the energies of each of the gamma ray emissions, as known in basic physics) emit one watt of radiation power. Thus, 1 kW of electron or X-ray radiation is equivalent to 67,578.00Ci (1Ci= 37GBq), 1MCi of cobalt 60 is equivalent to 14.8 kW of electrons or X-rays.

Note that the above equations relate to the power equivalence of the sources only. In practice, the efficiency with which the radiation is absorbed by the product is different for each source Thus, the amount of material processed by 1 MCi is not the same as that by 14.8 kW of electrons or 14.8 kW of X-rays [1].

2.3 Electron Beam Applications and their Corresponding Doses

Uses	Material	Process	Doses
Sterilization	Medical and biological products, virus, bacterias, packaging, etc.	Radio-sterilization e-beam or ^{60}CO	10 – 30 kGy 25 kGy (standard)
Polymers	Polyethylene, Nylon, composites, etc	Crosslinking of plastic, wire, cable, foam, etc	~ 200kGy
Polymers	Teflon	PTFE Degradation	~ 500 kGy
Environment	Chemical or Biological wastes, gases NOx, SOx	Radio sterilization	10 – 30 kGy
Food	Herbs, spices, red meat, fruits, potatoes, etc	*Control of salmonella in meat ** disinfectations of herbs, spices, etc	• 1.5 kGy • 10.0 kGy
Gem stone	Topaz, semiprecious stone, etc	Gemstone coloring	~100000kGy

2.4 Electron Beam Accelerators Facilities at Ipen-Cnen/SP

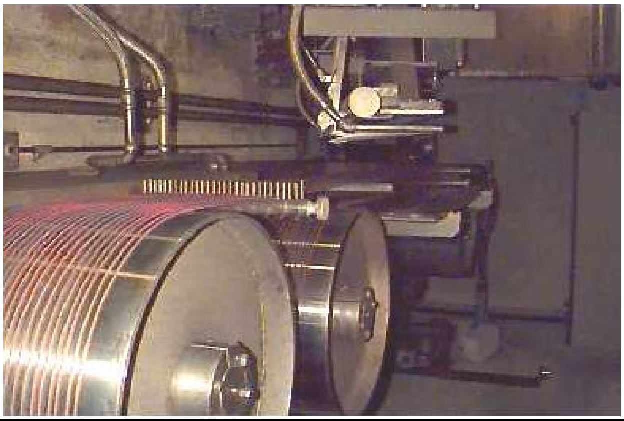

Figure 1. Irradiation system for wires and cables, of the electron beam accelerator JOB 307

Figure 2. Electron beam accelerators at IPEN-CNEN/SP – JOBs 188 and 307

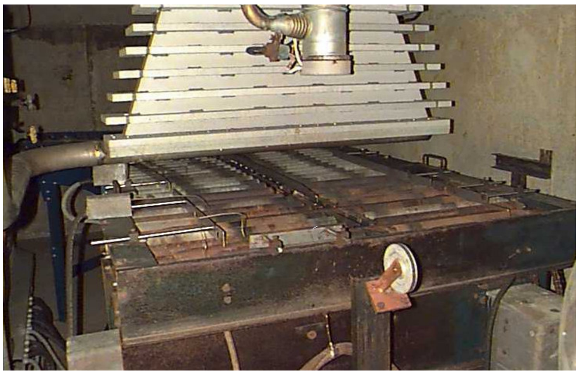

Figure 3. Electron beam Accelerator JOB 188 irradiation system.

3. CONCLUSIONS

Today, the environment is an important matter of concern for man's own survival in this planet. The inattention, during decades, brought us to such an alarming situation that we should join all the means and efforts to preserve what it still remains. For this purpose, the Radiation Technology Center (CTR) of the Nuclear and Energy Research Institute (IPEN) develops researches and make services, using electron beam accelerator to find solutions to eliminate or, at least to decrease the toxins and pollutants from wastewater, flue gases and chemical and biological wastes until acceptable levels. The irradiation of pollution sources by itself or together with other conventional processes, can bring solutions before unimaginable.
IPEN doors are open for all those who want to find solutions or even some new ways of solving problems affecting on environmental and also for those who want to develop new products or new techniques using radiation.

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