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60 kW ELECTRON ACCELERATOR FOR A PAINT-CURING FACILITY

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Summary

Compared with radioactive isotopes, electron accelerators are very powerful sources of radiation. Due to the limited penetration depth of the electrons, these accelerators can only be applied for the radiation processing of surfaces or thin materials. Of special interest is the utilization of low-energy, high-power electron accelerators for the curing of paint coatings on wood, metal, and plastic surfaces. A paint-curing facility was built with a 600 keV electron accelerator with an output power of 60 kW. During the first year of continuous operation, important improvements were made in the entire process, particularly in developing suitable paint and maintaining a pure nitrogen atmosphere in the radiation chamber.

Industrial Electron Irradiation

While inducing reactions by means of energy-rich ionizing radiation has been investigated intensively for a long time in fundamental research, the exploitation of electron-beam energy for industrial irradiation processes has become of great interest only recently. This is primarily because of the lack of suitable beam generators with sufficient output capacity and high reliability, two requirements which are essential for the production process. Today, such accelerator installations are offered by various manufacturers. Also, the development of individual irradiation processes has led to industrial results.

The following is a review of the important features for accelerated electron applications in contrast to γ-radiation of Co and Cs sources, although these forms are not basically different in their radiation chemistry effects. An important difference between these two types of radiation concerns their absorption in the irradiated material (see Fig. 1 and Fig. 2).

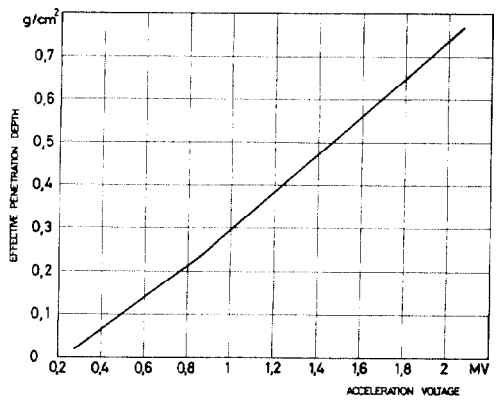


Fig. 1: Effective Electron Penetration after Deduction of Losses in the Window and in 10 cm of Air

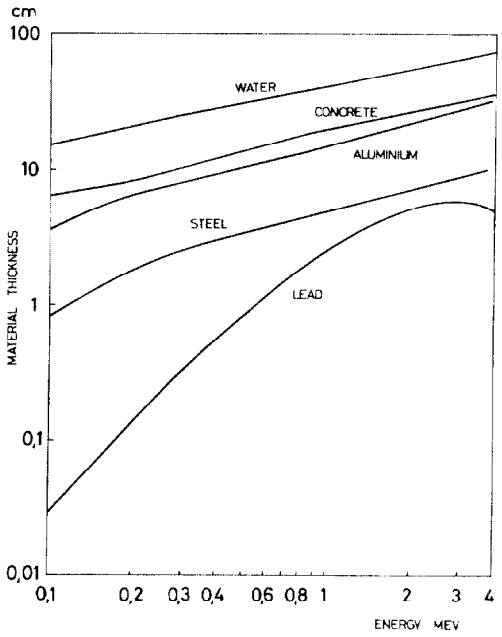


Fig. 2: X-ray Absorption (attenuation by a factor 10)

The useful penetration depth of electrons at 1 MeV, with a material density of 1, amounts to only a few millimeters. To irradiate a section with a thickness of 1 cm, an energy of approximately 2.5 MeV is required. However, the γ-radiation of Co^{60} penetrates similar material to a thickness of approximately 30 cm.

The second important difference between γ and electron radiation concerns the available capacity of the sources and, thus, the production capacity for a given irradiation level. The beam power of an electron accelerator can be expressed in kW as the product of beam current and accelerating voltage. Today, the maximum available capacities of such installations lie in the range of from 50 to 100 kW. An increase in beam power by increasing the beam current is readily possible and is primarily a design problem. In any case, the price of the electron accelerator does not increase correspondingly. On the other hand, in radioactive sources the irradiation capacity and the price of the irradiation installation

are predominantly proportional to the activity of the Co^{60} employed. Thus, an increase of the source output means a corresponding increase of the required investment. For comparison, it must be added that the output power of the source of 1000 kCi Co^{60}, which is already extraordinarily large, corresponds to an electron-beam output of only 15 kW.

60 kW Paint-Curing Facility

Of particular interest is the curing of paint coatings on wood, metal, and plastic surfaces. In light of general considerations outlined in the first portion of this paper, it is obvious that paint-curing is an ideal application for electron accelerators. Plant production capacity is very high, necessitating powerful radiation sources. The thickness of the coating is in the order of a few tenths of a millimeter; therefore, penetration requires electron energies of only a few hundred keV.

High production rates require that the electron accelerator have the reliability of an industrial machine, because of the extremely high cost of breakdown periods.

When price comparisons are made between different types of accelerators, the most economic one is the accelerator which gives trouble-free performance and provides continuous output.

With the special objective of higher reliability in mind, an industrial electron accelerator was built with a maximum accelerating voltage of 600 kV and a beam power of 60 kW. In the low-energy region, all accelerators are of similar design; but the high-voltage generators are based on different circuits and principles.

For the paint-curing facility, a pressurized 600 kV dc power supply was used; it can be connected, through one or two shielded high-voltage cables, to either a 100 mA accelerator or two 50 mA systems. A slightly modified symmetrical cascade generator was used for the generation of the accelerating voltage, from the 1000 V and 2 kHz input voltage, which is delivered by a frequency-converter set. As insulating material, sulfur-hexafluoride (SF_6) under a pressure of 60 lbf/in^2 was chosen rather than oil, which would provide better dissipation of the power losses. The more expensive SF_6 insulation, however, provides easier access to the generator in the tank, facilitates checks and maintenance, if necessary, and would considerably shorten the time required for repair work.

The accelerator utilizes a conventional design and is encapsulated under SF_6 in an aluminum tank. In the electron gun on top of the accelerator tube, a Lanthanum-Hexaboride cathode is used for the production of the electron beam. The cathode is energized from

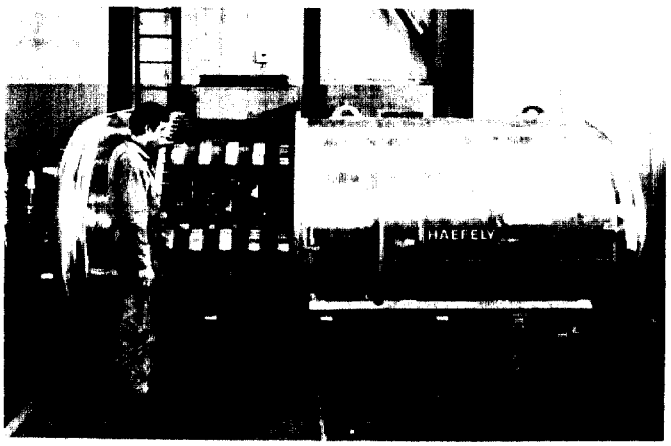


Fig. 3: DC-Power Supply, 600 kV / 100 mA, in Pressurized Tank

a small generator in the high-voltage terminal which is driven through an insulating shaft by a motor at ground potential. The beam current can be set from the control desk by remote control.

A magnetic scanning system, which has a special 1 kHz power supply, is used to achieve a uniform distribution of the dose over the full width of the scanner. The system can be used with scanning widths of up to 2.3 m.

A fast-reacting protective system is incorporated which prevents the fractions of the titanium foil from getting into the vacuum system and the accelerating tube, should the beam-exit window break. The flange of the window is designed for easy replacement to shorten the time required to change the titanium foil during maintenance. In cooperation with the Swiss company, Ulrich Steinemann Ltd, St. Gallen, a complete paint-curing plant was built, the principle of which is shown in Fig. 4. The accelerator was installed in a small room surrounded by 60 cm concrete walls. The conveyor system for the coated panels to be irradiated is designed to prevent the passage of X-rays through the inlet and outlet slots, either directly or by reflection. An automatic radiation-protection system securely locks the radiation-processing room when the accelerating voltage is switched on.

Paints cured by conventional methods (heat or ultraviolet light) cannot be cured by electron bombardement. In cooperation with paint manufacturers, suitable paints for radiation treatment were developed and improved at the plant.

This paint-curing process employing special paints will not give satisfactory results, i.e., an acceptable surface quality of the coated panels, when a small percentage of oxygen (atmospheric air) is present during the short irradiation period. Inert gases

must be used to achieve a high-quality surface finish on the coated material. In the demonstration plant at St. Gallen, the panels pass through a chamber under the scanning system in which a nitrogen atmosphere is maintained. During the initial tests, atmospheric air may considerably deteriorate the surface finish of the panels. Since the nitrogen chamber cannot be hermetically sealed, traces of air are permanently brought into the chamber at the surfaces of the panels. The design of a suitable conveyor system and nitrogen chamber to maintain a nearly pure nitrogen atmosphere under the electron beam constitute an extensive development program which resulted in many improvements.

The large quantity of ozone produced by the influence of intense electron and X-ray radiation poses another problem. The ozone is very reactive and causes severe corrosion to metallic components and a number of organic materials. Ozone is removed from the radiation room by a powerful exhaust system leading to the open air.

The prototype and demonstration model of the paint-curing facility was used, not only to collect performance data on the components, but also to make tests on the reliability and lifetime of those components which require maintenance, such as the cathode and beam-exit window. The plant was operated at full production conditions. The high production capacity achieved at low costs, compared with conventional methods, and the high surface quality of the treated panels have proved that the plant meets the high economic requirements of industrial production. A paint-curing facility of the same design will be installed at a furniture-manufacturing plant, and production will commence in the autumn of 1973.

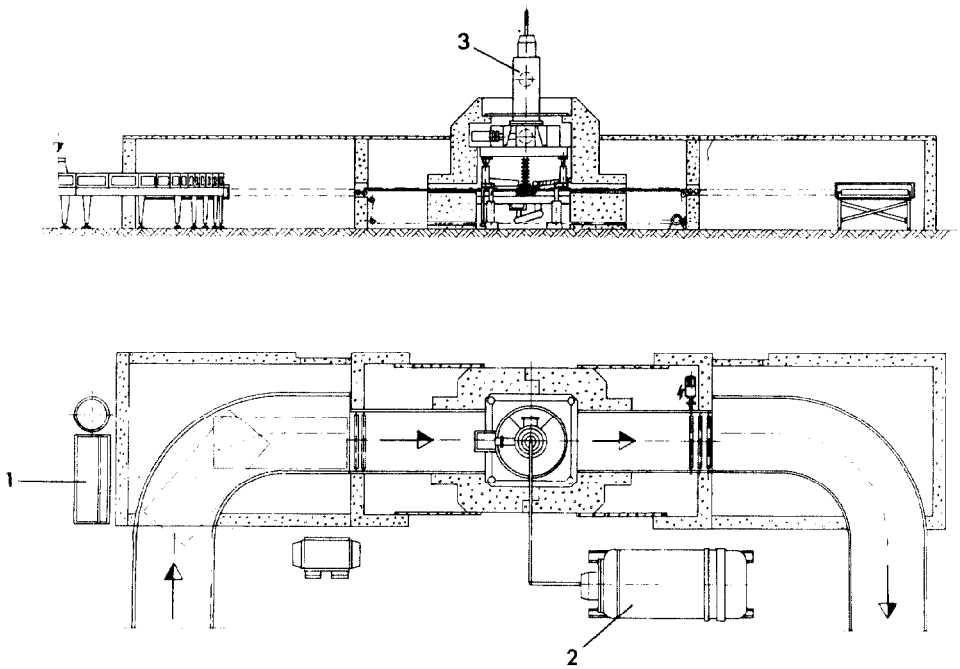


Fig. 4: Irradiation Facility for Curing Paint with Electron Accelerator, Radiation Shielding, and Transport System.
(Drawing, Ulrich Steinemann Ltd, St. Gallen, Switzerland)

1. Control Desk 2. DC Power Supply 3. Electron Accelerator