Getting Started with EB

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Electron beam technology can be applied to a wide range of processes. Integrating an electron beam into a new or existing process line requires attention to a series of steps to define and test whether the technology is adaptable to the process. The rewards for carefully planning an installation will include long-term, dependable operation.

Electron Beam Applications

The range of voltage of an electron beam machine is dependant on the application for which it will be used. The applications mentioned below utilize electron beam machines rated for 80 to 300 kV.

Crosslinking – A common application for this technology is crosslinking of plastic film. Crosslinking occurs when a material is bombarded by a stream of electrons causing the chemical bonds in the material to rearrange. This alters the physical properties of the material to make it stronger, shrink uniformly and more heat resistant.

Curing coatings - Electron beam processors can also be used to cure coatings. The most common of these are coatings applied to paper and film substrates, but the process can also be used to cure coatings on non-wovens, metal and building products. These coatings can be decorative (paint), functional (silicone release) or both. Substrates can be fed through the machine sheet by sheet or as a continuous web.

Ink drying - Lower voltage processors can be applied to ink drying processes. Higher voltage machines are not necessary because the layer of print is very thin and does not require higher energy to penetrate it.

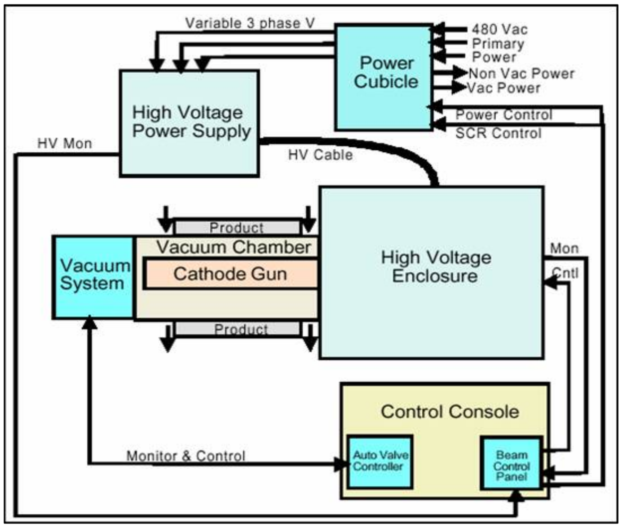
Adhesives and laminates - Adhesives and laminates form the final major group of products that are commonly electron beam cured. This family includes film to film adhesion, film to paper, or film to paperboard. Laminate furniture pieces can be fed through a processor to cure the adhesive between the surface and the board. Laminates can also be applied over print with the ink and adhesive cured simultaneously. Electron beam processors can be used in tandem with other processes (such as UV lamps) to produce unique effects. Some processes combine an ultraviolet cured prime coat with an electron beam cured finish coat. Additional new, creative uses for electron beam technology are currently being evaluated and developed.

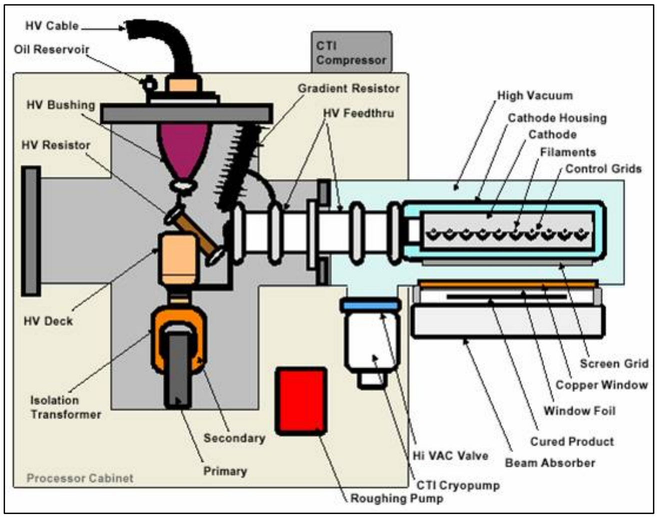
Electron Beam Advantages

Instantaneous curing makes the electron beam process extremely efficient. The machine requires minimal process line space, especially compared to conventional drying ovens. Product waste is minimized by the ability to start and stop the machine quickly. This also allows for immediate quality control checks. The electron beam process is highly consistent, scalable and repeatable and allows radiation curing of multi-layer materials, thick coatings and opaque materials. The total cost of operating an electron beam machine compares favorably to alternative technologies. The electron beam curing process is also environmentally friendly in that little or no Volatile Organic Compounds (VOCs) are produced.

Machine Components

The electron beam processor generates a wide cloud of electrons from electrically heated filaments within a cathode. The electrons are accelerated by an applied high voltage. The field of accelerated electrons delivers a continuous beam through the window into the reaction chamber. A titanium window foil supported by a water-cooled copper window is used to isolate the vacuum environment of the cathode from the reaction chamber. Excess electron energy that passes through the reaction chamber is absorbed by the beam absorber which can be a chill roll or cooling plate on a lift table assembly. The beam absorber is also water cooled.





Electron beam curing occurs as the result of energy transfer from the accelerated electrons. Electrons penetrate the product resulting in free-radical polymerization of coatings, inks or adhesives, causing instantaneous curing.

An electron beam processor is controlled by an HMI control console. A high voltage power supply provides voltage for the cathode, which is contained in a vacuum chamber. The beam absorber is housed in a rollback system or lift table which is self-shielded.

Integrating an Electron Beam into a Process Line

Carrying an electron beam process line from concept to reality requires a number of steps from running initial trials to engaging engineering resources to configuring the final arrangement. A potential electron beam user must consider the long-term needs of the process line and how to design a new machine or adapt a current machine to fit that process. Physical requirements of electron beam equipment, the path of the material or substrate through the machine and safety considerations must also be taken into account.

From Concept to Reality

- Perform lab trials/pilot line trials
- Evaluate new vs. existing line
- Engage qualified engineering resources

The application of electron beam technology to a current process line begins with a concept. Is it possible to incorporate an electron beam into an existing line? Is the material being handled compatible with electron technology? How painful will the conversion from one technology to another be? Lab tests and research can help answer these questions.

In many cases, it is possible to incorporate an electron beam into an existing process line. For some applications, it is most beneficial to retain the ability to switch between the old process and the new one. The decision to incorporate an electron beam into an existing line or to create an entirely new line is based on the product mix that will be processed and the condition of the existing line. After determining that electron beam technology is compatible with a process, the proper engineering resources are engaged to integrate an equipment solution. These resources could be internal or external and, ideally, should be involved early in the conceptual phases of the project. The purpose of the engineering team is to evaluate the impact an electron beam processor will have on the existing process and develop a comprehensive project plan to apply the technology. The team must consider future needs that may arise in the production process and allow for flexibility to adapt.

A major goal of the engineering process is to avoid being painted into a corner. An electron beam processor can be expected to provide 20+ years of operation and long term production needs should be anticipated to avoid costly upgrades in the future. Although many aspects of an electron beam can be upgraded or changed to fit new production needs, some are much more expensive than others to implement. High-dollar upgrades include changes in voltage, throughput, width of materials and inerting systems.

Voltage levels affect the high voltage power supply rating, shielding thickness and component design. Maximizing the voltage rating now will limit the ability to handle future process needs including thicker coatings, more layers or a wider range of substrate thicknesses. In order to increase voltage ratings later, the machine could require thicker radiation shielding, upgraded electrical components and, possibly, an entirely new power supply. This can be very costly.

Long Term Needs

- Voltage Rating
- Throughput (dose vs. line speed)
- Width
- Inerting

Throughput must also be considered. Will the electron beam rating limit future line speed increases? Will it limit anticipated process changes? In addition to throughput, the width of the product will have a major impact on the electron beam design. A change to a narrower width is relatively easy to accommodate, but increasing the width of the product will necessitate an increase in the width of every component along the web path.

A final consideration for the long run is the inerting system. Some processes may require nitrogen inerting, especially with certain coatings. Nitrogen inerting and ozone exhaust require different equipment designs. The level of inerting (allowable oxygen content) also impacts the design of the processor.

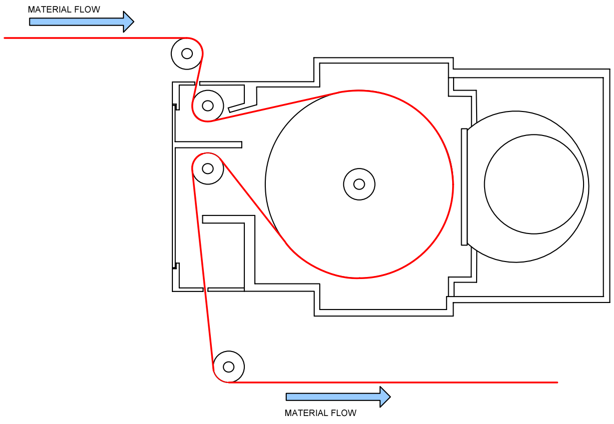
Once these variables have been carefully considered and levels and variations for future applications have been pinned down, the design work can begin. The next major decision lies in whether a used machine can be refurbished to meet the requirements of the process or whether a new machine needs to be built. Both options have advantages and disadvantages.

Refurbished vs. New Electron Beam Equipment

The immediate advantage of refurbishing an existing electron processor is the cost. Utilizing a used machine could cost between 40 and 60 percent less than building a new one. Refurbishment takes less time than building machines from scratch and obsolete components can be replaced with the latest technology. Unfortunately, there is a limited supply of electron beam machines available for refurbishment. It may be difficult to find a used machine to fit the voltage, throughput, and width requirements of a product. It may be necessary to compromise on desired machine features in order to fit the process with the available machine.

Although the cost and longer lead time associated with building a new electron beam may seem daunting, this option also has advantages. The size and shape of the machine can be tailored to precisely match the orientation of materials, physical space available, dose level and web path to fit a current process line. Working from scratch makes it easier to accommodate both current and future needs. New components provide the latest technology and advancements in engineering.

The next design consideration involves material handling. What impact does your new product formulation have on the electron beam process equipment? Will the product be fed through the machine via a web (continuous application) or sheet fed (discrete pieces, batch)? The allowable deflection of the product, substrate and coating must be determined along with the shielding design. Shielding must provide multiple surfaces for the radiation to “bounce” in order to absorb the x-rays and there must be no line of sight to the processing zone. These decisions are made based on the allowable wrap angle of the product.



The angle of entry into and exit from the reaction chamber (wrap angle) is determined by the flexibility of the substrate. Properties of the coating and substrate material as well as line speed and web tension impact web path design. These properties also determine the roll diameters, number of rolls, number of driven rolls and wrap angle approaching and leaving the rolls. The web tension control scheme, material path lengths, and materials used are all important in laminating applications. These factors impact the characteristics of the cured product and must be calculated to eliminate wrinkling in the coating.

The surfaces of the rolls or conveyors transporting the product through the machine have to be compatible with both the product and the electron beam exposure. For example, Teflon cannot be used for the roll coating because it degrades when exposed to an electron beam. The grade of finish (smoothness) of the rolls needs to be considered. Material choices for rolls range from anodized aluminum to stainless steel to carbon fiber. If ozone exhausting is used, the impact on all exposed surfaces must also be considered.

Electron Beam Equipment Requirements

Electron beam equipment requires adequate physical space, utilities and maintenance to function properly.

Machine sizes vary greatly depending upon the machine rating, application and manufacturer. A typical electron beam processor will require 80 to 120 inches of length in the web/line direction. The width of the machine is determined by the width of the web or product that is running through the machine. The high voltage power supply can be up to 100 inches square and 100 inches tall. Control enclosures must be given enough space for mounting and proper access, and clearance around the machine is necessary for routine maintenance.

Machine Design Considerations

- Continuous vs. batch process
- Flexible vs. rigid substrates
- Process needs vs. shielding requirements
- Allowable wrap angle
- Materials for roll surfaces

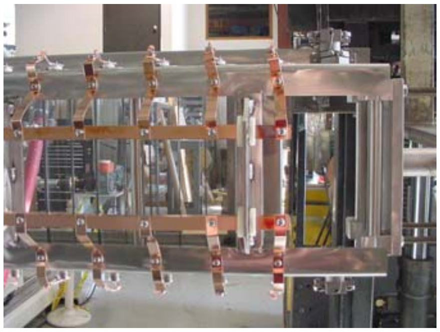
A self-shielded electron beam processor can weigh from 10,000 to 40,000 pounds. The high voltage power supply can weigh an additional 7,500 to 20,000 pounds. A standard concrete floor will support the weight of the machine; no special foundation is needed, and the power supply can be installed outdoors in some cases if necessary.

The orientation of the beam can be configured to fit the space available and the demands of the process line. Beams can be horizontal (side fire), vertical (down fire), or at an angle. Most electron beams have integrated shielding and subsystems, making them self-contained.

Proper utilities must be in place to operate the electron beam processor. Machines require a power feed for 480V, 3 phase / 200-800 amps. An outside exhaust vent for nitrogen (approximately 60 cfm for inerting) or ozone (approximately 1200 cfm) removal is necessary as well as a cooling water supply (100 gallons/minute) for the copper window, chill roll/beam absorber, and the cryogenic pump for the vacuum system. Compressed air is also needed to operate the clamps and activate the vacuum system gate valve.

Installation of an electron beam processor requires portable lifting equipment and clear access to the process line.

Regular preventative maintenance and calibration checks including periodic replacement of consumable materials in the machine help to reduce unplanned downtime. Foils and filaments are replaced every few months to every few years depending upon the application. Most other components only require service after multiple years. Calibration checks help to catch component failures early to avoid allowing them to cascade.



Electron beam technology has been widely used and safely applied in industry for more than 30 years. However, it is important that owners and operators of this equipment are aware of the potential risks. Appropriate measures can then be followed to ensure safe operation.

<u>Long Term Needs</u>

- Consumable items
    - Foils
    - Filaments
- Calibration Checks
- Regular preventative maintenance
- Trained service technicians

Preventative maintenance checks range from weekly to annually and depend upon run time and company practices. Generally, checks include water and nitrogen flows, cooling water temperature, water and SF6 pressure, vacuum readings and checks on the color of the insulating oil in the high voltage power supply. Trained contracted or in house service technicians can be called upon for repairs or more technical maintenance.

Safety Considerations

Radiation – Radiation is only produced by an electron beam processor when the machine is running. When the machine is turned off, radiation ceases to be produced. Radiation emission levels are very low and are managed by the equipment design and operating practices. Most electron beam processors are self-shielded, meaning that the radiation is contained in the reaction chamber and integral shielding. This is accomplished through the use of lead lining and having no line of sight into the processing area.

Electron beam machines are designed to be fail-safe. Radiation monitors are installed on the machine to monitor radiation levels. These monitors are wired directly into the operating system to automatically disconnect power to the machine when an alarm is tripped. Potential radiation exposure points occur at openings in the machine near the product path or maintenance access areas.

Radiation safety is best handled by being aware of the dangers of exposure and properly training all personnel who will be working with or around the machine. A radiation safety officer should be designated and trained through available training classes. Common means for reducing the risk of exposure include decreasing the time that personnel are in the immediate vicinity and maintaining an appropriate distance away from an operating machine.

Ventilation - A byproduct of an electron beam in air is ozone. Depending on the material being processed, ozone can be safely diluted and exhausted or the processing zone can be inerted with nitrogen and ventilated.

Ozone in a non-inerted processing system is diluted with air before being evacuated outdoors. Emissions for an electron beam processor are relatively low compared to EPA standards and regulations. Ozone filtration systems are an option that is available to further decrease emissions.

Ozone

- Generated in reaction chamber
- Ventilation hood and dilution air
- Low emissions
- Optional filtration systems

Nitrogen

- Used to displace oxygen
- Present in reaction chamber
- Ventilation hood

Nitrogen is used in many electron beam processes to displace oxygen and reduce ozone generation. Nitrogen inerting is mostly used with curing processes and is entirely contained in the reaction chamber of the machine. A ventilating hood carries the gas outdoors where it dissipates.

High voltage – As with any high voltage system, specialized training is required to run an electron beam processor. Machine voltages range from 80,000 V to 300,000 V depending on dose level and throughput. Service, repair or handling of the high voltage system should only be carried out by qualified electricians, engineers or service technicians.

High Voltage

- Voltages from 80,000 to 300,000 present
- Requires trained maintenance staff and operators
- Qualified service technicians available from Manufacturer

Lead – Most electron beam processors use lead as the most efficient way to absorb the radiation dose within the reaction chamber of the machine. Lead is more cost effective than heavy steel plates for shielding and takes up less space. All lead in an electron beam processor is encapsulated within a lining, typically made of stainless steel, to ensure that it is totally protected from contact with the user or the product running through the machine. This cladding also makes the machine safe for use with food packaging products.

Lead

- Used for shielding around reaction chamber and processor cabinet
- Efficient material for absorbing x-rays
- Clad with lining material
- Exposure concerns

The risk of exposure to lead is minimal and occurs specifically when machining, drilling or cutting the lead to build or modify the machine. Appropriate handling measures should be followed when working directly with lead.

SF6 gas – SF6 gas can be found in the high voltage mechanical enclosure of an electron beam processor surrounding the vacuum chamber, high voltage deck, etc. In some designs the high voltage power supply is also insulated with SF6. This gas is used to absorb voltage and prevent arcing in the enclosure. There is no industry substitute for SF6. The high voltage enclosure or power supply is sealed to prevent the gas from escaping and causing health risks via inhalation. SF6 has extreme greenhouse gas effects and reclamation equipment should be used if it is necessary to access the high voltage enclosure or the high voltage power supply.

SF_6 Gas

- Used to prevent arcing in high voltage enclosure and/or power supply
- High voltage enclosure and power supplies are sealed
- Inhalation and environmental concerns
- Reclaim

Regulations on the operation of electron beam processing equipment vary from state to state and country to country. Before integrating an electron processor into a production line, the user should have an awareness of local regulations and radiation certification procedures. Depending on the geographic location of production, ozone or nitrogen stack permits, SF6 reclamation systems or special certifications may be necessary. Other general industrial machine design standards such as NEC, UL or CE Mark may also need to be taken into account.

Regulatory Issues

- Vary by state/county
- Radiation certification
- Emissions standards for ozone
- Reclamation systems for SF6
- NEC/UL/CE Mark/etc.

The Next Step

The addition of an electron beam processor can bring significant benefits to a production line. Finding the right machine to fit your demands involves several steps:

- Define and test process plans – Ensure that an electron beam is compatible with the product and represents a good investment for future product needs.
- Consider available options – Explore equipment design options, refurbished machines and how to integrate the electron beam into an existing line.
- Target a machine to fit process needs – Engineer a machine that is suited to provide several years of beneficial operation.

The successful integration of electron beam technology can benefit your operation in several ways and provide many years of reliable performance.

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