In-line Electron Beam Sterilization for Aseptic Beverage Packaging

By Josh Epstein

Electron beams, along with gamma radiation, have been used for decades for niche applications in the pharmaceutical, medical device, food and beverage packaging sectors. Large, high voltage (500 kV to 10 MV) electron beams used commercially for the bulk sterilization of closures, films and, in some instances, the direct treatment of food. While high voltage, electron beam technology is appreciated for its high efficacy and predictability, the size and expense of the systems have relegated the use of this technology to bulk sterilization at contract irradiation centers. With the evolution of compact, cost-effective, low voltage (80–150 kV) electron beams over the past five years, a new class of in-line applications is now possible. The benefits of high-speed, high efficacy sterilization, with no chemicals and at room temperature, are now realized across a variety of packaging applications.

The beverage industry is particularly well positioned to take advantage of this technology. Adoption of aseptic and extended shelf life (ESL) packaging is growing in popularity as consumer beverage demand moves away from carbonated soft drinks toward functional beverages, ready-to-drink teas and coffees and dairy-based drinks. Furthermore, increased competition, energy costs and a push toward more sustainable packaging combine to drive the development of alternative beverage packaging concepts. With the development of aseptic packs, cartons, pouches and polyethylene terephthalate (PET) bottles, packaging sterilization technology is evolving to address new performance and system integration requirements.

Advanced Electron Beams (AEB) offers low energy electron beam emitter technology that is integrated into a wide range of beverage filling equipment for aseptic packaging applications. In addition to developing the technology, AEB is active in co-developing new applications and new markets with leading filling equipment manufacturers.

The Technology

Electron beams work by directing a shower of accelerated electrons through a high voltage emitter toward a target (Figure 1). The electrons are generated from a tungsten filament and directed by a high voltage source inside of a vac-

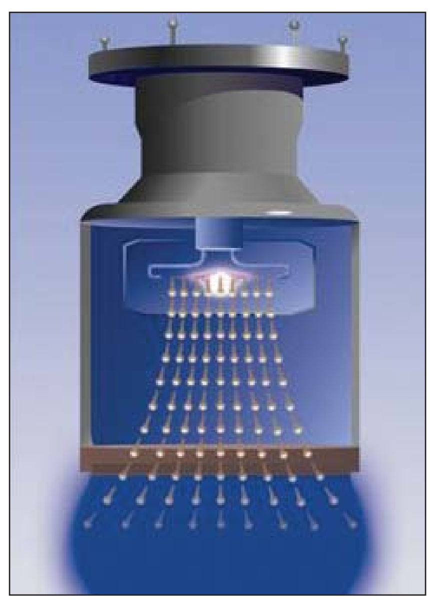

Figure 1: Illustration of Advanced Electron Beams Emitter

uum chamber. The energetic electrons pass through a metallic foil that is thin enough to allow electron transmission but strong enough to hold a high level of vacuum. While traditional forms of the technology required a dedicated vacuum pump and a large power supply to generate industrially useful electron beams, AEB's emitter technology is hermetically sealed–no vacuum pump required–and operates with a rack mountable power system.

As the energetic electrons enter the atmosphere, they collide with air molecules and scatter (Figure 2), creating an atmospheric plasma that acts as an electronic "brush"–delivering sterilizing energy directly to surfaces as well as around product contours, such as a bottle cap threads. Additionally, electron beams will penetrate through thin packaging materials, allowing for in-line sterilization of the interior of many beverage pouches or other flexible packaging types. As surfaces are exposed to electron beams, energy is absorbed according to the intensity of the beam and speed the product moves through the treatment zone. The most common metric used to measure the amount of absorbed electron energy is the Kilogray (kGy).

Figure 2: Electron and Air Molecule Collision and Scatter

Sterilization Efficacy

As a form of ionizing radiation, the microbiology of electron beam sterilization is well understood. Since electron beams have a long history of use for sterilization, the relationship between microbial kill-rate and absorbed energy dose is well characterized.[1] The industry uses *Bacillus pumilus* as the challenge organism for bioburden studies associated with ionizing radiation. Low voltage electron beams have the advantage of depositing energy at or near the surface, resulting in an extremely high rate of dose delivery. This enables aseptic levels of sterilization (i.e., log reduction in bioburden) in milliseconds. In practice, this means sterilization is not the bottleneck in determining the speed of the production line.

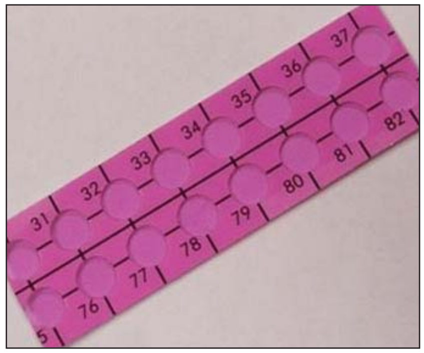

Figure 3: Radiachromic film measures the amount of electron beam energy absorbed into a surface point, helpful in evaluating new applications, calibration and performance monitoring.

The dose delivered to any surface point can be measured using a radiachromic film, which changes color in precise proportion to the amount of electron beam energy absorbed (Figure 3). This serves as a valuable tool for evaluating new applications, calibrating newly installed systems and performing periodic monitoring. Compared with conventional chemical sterilization methods, electron beam sterilization is simple, dramatically reducing the number of critical control points that need to be monitored in order to ensure asepticity.

A Profitable Path to Sustainable Beverage Packaging

Low-voltage electron beams offer a room temperature, chemical-free alternative to the conventional sterilization technologies that are used in the beverage industry. This technology is already being designed into a range of aseptic filling lines including single serve dairy, beverage pouch, bag-in-box and PET bottles. There are several key benefits that are driving the industry towards rapid adoption of this technology:

1. Reduced energy costs. With no requirement for heating or steam generation, there is a drastic reduction in energy consumed.
2. Smaller process footprint. Electron beam sterilization eliminates the need for non-value added process steps that consume manufacturing floor space, such as preheating and rinsing.
3. Eliminated need for rinse water. By eliminating the need for chemicals, electron beam sterilization also eliminates need for rinse water.
4. Removed risk of chemical residuals. Electron beams leave no residue on the packaging materials, eradicating the risk of chemical contamination of the product.
5. Lowered packaging weight. By removing heat from the process, it is possible to lightweight the package design offering significant savings in resin costs.

Low voltage electron beams promise to deliver operating cost savings, sustainable manufacturing solutions and high levels of sterility assurance. ■

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