# Developments in Electron Beam Processing: Higher Capacity, Better Performance

David A. Meskan

**RPC Industries**

**Hayward, CA 94545**

**Abstract**

New applications and expanding production in existing applications continue to generate new performance demands for electron beam processing systems. These user generated requirements challenge e-beam equipment manufacturers to expand the equipment performance envelope to keep pace with user needs. In the last several years much effort has been directed toward the development of very wide, high product throughput systems, improved nitrogen inerting systems, and increased reliability, maintainability and uptime/availability. Systems incorporating the results of this work, which define the state-of-the-art, are now installed and in production use. Currently, in addition to continued interest in Large systems, there is a renewed emphasis on narrow systems with higher throughput. This paper describes e-beam system advances since RadTech '90, and development work now underway.

## Introduction

The purpose of this paper is to present a snapshot view of the present state of industrial electron beam processing and to suggest which trends will continue for the next several years. It is not possible to present all of the technical details which one might wish because of the need to protect the proprietary interests of the firms engaged in the production applications and technology development. Still, the general picture can be seen quite clearly.

The paper is organized according to the following plan. Three growing applications are described in the next section. Performance requirements for new electron beam processors are. strongly influenced by these applications. Next come sections discussing two principal trends: higher throughput and enhanced nitrogen inerting. These sections are followed by one dealing with reliability, maintainability and uptime, and a concluding summary section.

## Expanding Production

### Silicone Release Coatings

In this application an electron beam curable silicone coating is app4ed to a plastic film or paper web by an offset gravure or smooth roll coater. The coating weight is typically one gram per square meter and electron beam accelerating voltages of 200 kV or less are sufficient to penetrate and cure the product with a typical dose of 2.5 Mrad (25 kGy). The coatings are sensitive to the presence of oxygen during the curing process. Oxygen concentrations above approximately 50 ppm will inhibit curing.

Three significant equipment installations for silicone coatings have been completed since RadTech '90. First was the commissioning of the 72 inch (1,830 mm) BroadBeam® processor, shown in Fig. 1, which is in continuous multiple shift operation at speeds of 1,000 fpm (305 mpm).[1]

Secondly, the 130:inch (3,300 mm) wide, 200 kV BroadBeam® processor, shown in Fig. 3, has recently been commissioned in a new plant.[2] This processor includes a water cooled chill roll and an advanced nitrogen inerting system. The line, which is not yet in full production operation, is designed to operate at 1,300 fpm (400 mpm) with an electron beam dose of 2.5 Mrad (25 kGy).

The third event was the commissioning of the 49 inch (1,250 mm) wide European Demonstration Facility (EDF) in Hamburg, Germany, a cooperative project of RPC, Pagendarm and Th. Goldschmidt.[3] (Fig. 2) This facility was designed for the further development of silicone coating and inerting technology as well as the development of new silicone coating applications. The line has now been successfully run at speeds above the initial goal of 1,500 fpm (450 mpm).

The trends for silicone coating applications can be anticipated from these three installations; higher speeds and wide webs which will require improvements in coaters and inerting systems.

**Cross-linking of Plastic Films**

Cross-linking enhances the physical characteristics of the film, increasing the tensile strength and raising the melting point. Inerting is not required because oxygen doesn't inhibit the process. The state-of-the-art is presently defined by production machines approximately 100 inches (2,540 mm) wide operating at speeds of 1,000 fpm (305 mpm). Chill rolls are generally not used, but specific products may require their use.

The production of the cross-linked film is typically a 20 shift per week operation which demands that the electron beam processors have a high degree of reliability.

At present there doesn't seem to be much interest in wider lines or higher speeds for cross-linking. There are indications that nitrogen inerting may be specified for future machines and perhaps as retrofit packages on existing machines as a means to avoid the environmental problem of ozone disposal. Several companies are examining the trade-offs involved in the equipment and operating costs for nitrogen generation as an alternative to ozone destruction.

**Web Offset Printing**

The use of electron beam "dryers" to cure 100% solid inks and coatings in the web offset lithographic printing process continues to be the largest single industrial application for electron beam processors operating below 300 W. Most of the first generation processors have been about 40 inches (1,020 mm) wide; the overall range is from 28 to 52 inches (710 to 1,320 mm). Press speeds are 800 to 1,000 fpm (245 to 305 mpm) and ink is printed wet-on-wet on the top of a horizontally moving web. The inks and coatings are solventless and the absence of VOC's gives added importance to this printing process. Electron beam doses of 2 to 3 Mrad (20 to 30 kGy) at voltages less than 200 kV are typically required to cure the inks and coatings.

Several press manufacturers are now introducing a second generation of presses. The printing speeds of the new presses range from 1,200 to 1,500 fpm (365 to 450 mpm) and web widths from approximately 20 to 57 inches (520 to 1,450 mm); some of the new presses print on the bottom side of a horizontal web.

The higher speeds have stimulated the development of higher performance electron beam processors which will be further discussed in the next section.

**High Throughput**

Summarizing the preceding information, we see that until recently "typical" maximum throughput requirements corresponded to 1,000 to 1,200 fpm (305 to 365 mpm) with delivered doses of 3 Mrad (30 kGy), or 3,000 to 3,600 MRFPM (Mradfpm) (915 to 1,100 MRMPM).

**Silicone Release coatings**

Future requirements are suggested by the development work being done at the European Demonstration Facility. The BroadBeam® processor is rated at 3,280 MRFPM, (1,000 MRMPM) and the initial goal was to successfully cure uniform silicone coatings on plastic film at speeds up to 1,500 fpm (450 mpm). It was reported at RadTech '91, Edinburgh, that success had been achieved at 1,640 fpm (500 mpm); we can now report that success has also been achieved at 2,000 fpm (600 MPM).[4] Fortunately for electron beam processor suppliers, the coating supplier has formulated a coating requiring less than 2 Mrad (20 kGy) so that 3,600 MRFPM (1,100 MRMPM) is sufficient even at these higher speeds. It thus appears that throughput-will not be a limiting parameter for these applications during the next several years.

**Web Offset Printing**

Presses running at 1,500 fpm. (450 rnprn) impose a throughput requirement of about 3,750 MRFPM. (1,145 MRMPM) for doses of 2.5 Mrad (25 kGy). Therefore, processor throughput of 4,000 MRFPM (1,220 MRMPM) should be adequate for the second generation presses. In order to achieve reliable performance under conditions of continuous operation at 4,000 MRFPM (1,220 MRMPM) and higher, with acceptable window foil lifetimes (which we define as a minimum of 2,000 hours at full beam power) it has been necessary to redesign the windowfoil/support-plate system.

We are now able to supply an optional high performance window with the 4,000 MRFPM (1,220 MRMPM) and 2,000 hour performance specification. The design is based on water cooling of the foil support plate and conductive heat transfer from the foil to the plate. No convection cooling of the foil Is required; we have found that the high gas velocities required across the foil for effective convective cooling are a significant complicating factor when efficient nitrogen inerting is required at high web speeds. We have also investigated different foil materials and foil coatings but have found them to be unnecessary for achieving our design objectives. The study of these different foil materials is continuing in anticipation of still higher throughput requirements in the future.

**Nitrogen Inertin**

Nitrogen inerting requirements have not changed much in the last several years: oxygen concentration should be below 50 ppm for silicone coatings and below 150 pprn for web offset lithography. "Typical" nitrogen consumption at speeds below 1,000 fpm has been around 0.025 standard cubic feet per square foot of web (scf/sq. ft.), (0.008 scm/sq.m).

**Silicone Release Coatings**

This application continues to be the most demanding in terms of nitrogen inerting requirements because of the combined requirements of speeds above 1,500 fpm (450 mpm), oxygen concentration below 50 ppm and economically reasonable nitrogen consumption rates. As reported at RadTech '91, Edinburgh, RPC and various industrial partners are working together to develop efficient high speed inerting; 0.020 scf/sq. ft. (0.006 scm/sq. m) at a speed of 1,640 fpm. (500 mpm) was achieved at the European Demonstration Facility.

The speed has been successfully increased to 2,000 fpm (600 mpm) with no increase in nitrogen consumption. Using the cost figures (for Germany) from Reference 4, the nitrogen cost at 2,000 fpm (600 mpm) would be only 0.77% of the total cost of BOPP film, silicone coating and nitrogen (TABLE 1).

TABLE I. Relative cost of nitrogen, silicone coating and substrate. Substrate material, 15 µm BOPP; coating weight, 1 gm/m$^2$; web speed, 600 m/min.

| | Cost per 1000 m$^2$ (DM/1000 m$^2$) | Percentage (% of total) |
|---|---|---|
| Substrate | 110.00 | 76.87 |
| Coating | 32.00 | 22.36 |
| Nitrogen | 1.10 | 0.77 |
| TOTAL | 143.10 | 100.00 |

It is difficult to predict the requirements which will arise in the next several years because it has yet to be shown that uniform coatings can be achieved at 2,000 fpm (600 mpm) and higher speeds with webs wider than 49 inches (1,250 mm). Nonetheless, the encouraging results from the EDF suggest that the new inerting techniques will be adequate for the near term.

**Web Offset Printing**

The usual BroadBeam® Processor configuration for web offset printing applications includes two high velocity nitrogen manifolds at the infeed and a low velocity manifold near the processing region. Nozzle angles, flow- velocities, etc. have been studied to determine optimum settings for reduced nitrogen consumption as the web speed increases. Various types of hybrid systems are also in use. For example, a hybrid system that has been in multi-shift production operation for over 5 years uses air instead of nitrogen in the first high velocity nozzle. This particular configuration consumes approximately 0.020 scf/sq. ft. (0.006 scm/sq.m) at speeds up to 1,000 fpm (305 mpin).

The high printing speeds of the new presses are within the range of already demonstrated inerting capabilities. Reduction of nitrogen consumption continues as an important objective. it has yet to be demonstrated that some of the new techniques which have proven effective for silicone coatings can also be implemented on web offset presses. Differences between printing press and silicone coating line equipment configurations may prevent the direct transfer of the inerting technology.

**Reliability, Maintainability and Uptime**

Now that electron beam processing has moved from laboratories and pilot lines into high volume production factories, uptime has become a major requirement. For example, of the 22 RPC BroadBeam® processors most recently delivered for production operations, 19 operate 3 shifts per day.

High available uptime is achieved by design and construction of the equipment and by proper maintenance. The design and construction must not only produce a machine with high reliability, but also one which does not need frequent maintenance and can be easily and quickly serviced when necessary.

RPC's goal is to deliver production machines which exceed 98% available uptime. There is one BroadBeam® processor that has exceeded 99% available uptime during 5,000 hours based on the users' production records. The favorable available uptime experience of the last few years permits us to guarantee uptime for some standard production applications.

The factory recommended preventative maintenance schedule places very Little burden on the users; it is routinely performed during scheduled maintenance shifts or when the line is down because of other equipment or material problems.

We are now attempting to move beyond preventative maintenance to predictive maintenance. A program is underway with a major equipment user to develop a methodology for logging and analyzing machine parameters which will be indicative of the need for maintenance. Ideally, predictive maintenance would eliminate unnecessary 11preventative" maintenance, increase the available uptime, reduce overall maintenance costs, and point the way to improved designs for future electron beam processors.

The predictive maintenance project anticipates that more comprehensive equipment performance monitoring wil1 become increasingly available in future production lines. This trend places a requirement on electron beam equipment manufacturers to incorporate control and data logging systems compatible with other systems on the production line. Our response to this need is the introduction of control systems based on programmable logic controllers (PLC's) which provide compatibility with state-of-the-art factory systems yet are simple enough to be operated as remote on/off systems in less sophisticated environments.

**Summary**

As always, it is the user's needs which determine which equipment will be successful. The current List of needs is familiar - high speeds, effective and efficient inerting, reliability and uptime - but the specific requirements represent a significantly higher level of performance.

What will be needed two years from now? It seems improbable that there will be a large demand for processors wider than 130 inches (3,300 mm). Coaters and web offset presses probably won't be running faster than the new generation. Nitrogen consumption will still be higher than desired (zero) but acceptable.

Perhaps the next broad-based need will be for small, less expensive electron beam processors with medium-to-high performance for a multitude of narrow web.-applications. If this trend develops, electron beam equipment suppliers will be presented with a very difficult challenge and rare opportunity.

References


1. Douglas Hanson Company, Hammond,Wisconsin, USA
2. Mobil Chemical Company, LaGrange,Georgia, USA
3. Pagendarm GmbH, Hamburg, Germany, Th. Goldschmidt AG, Essen, Germany
4. David A. Meskan and Alan F. Klein, "Developments in Inerting Systems for Electron Beam Processors", RadTech Europe Edinburgh 1991 Conference Papers, p. 93

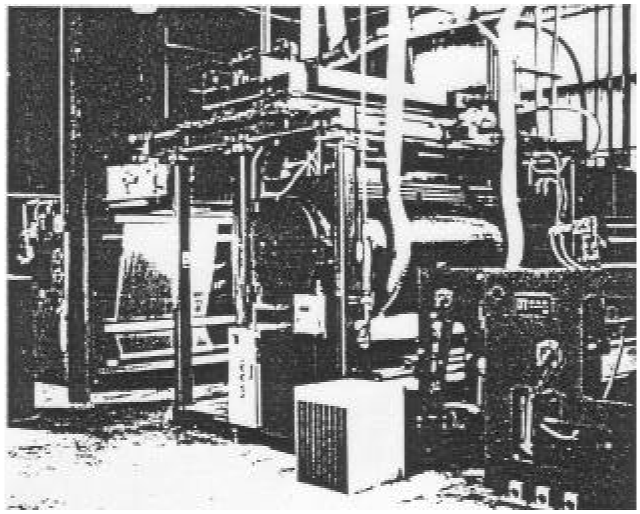

FIGURE 1. Electron beam processor on silicone coating line. Web width 72 inches (1,839 mm), line speed 1,000 fpm (305 mpm), 200 kV.

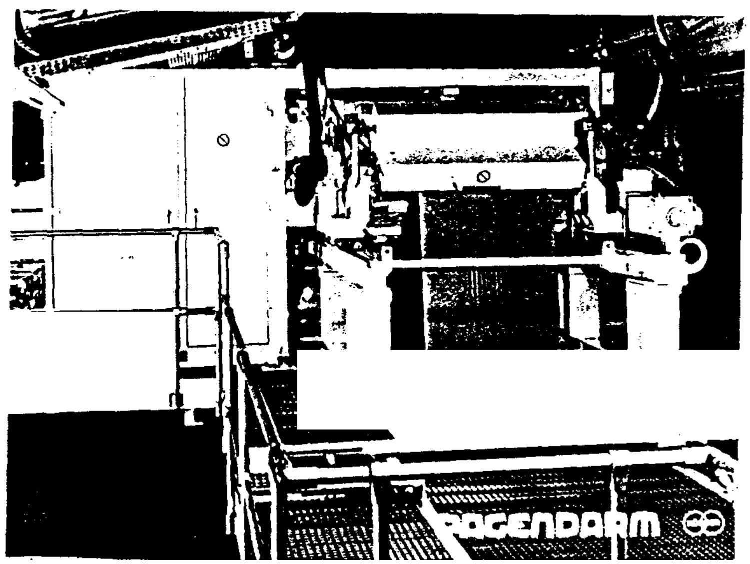

FIGURE 2. Electron beam processor on European Demonstration Facility. Web width 49 inches (1,250 mm), line speed 2,000 fpm (600 mpm), 200 kV.

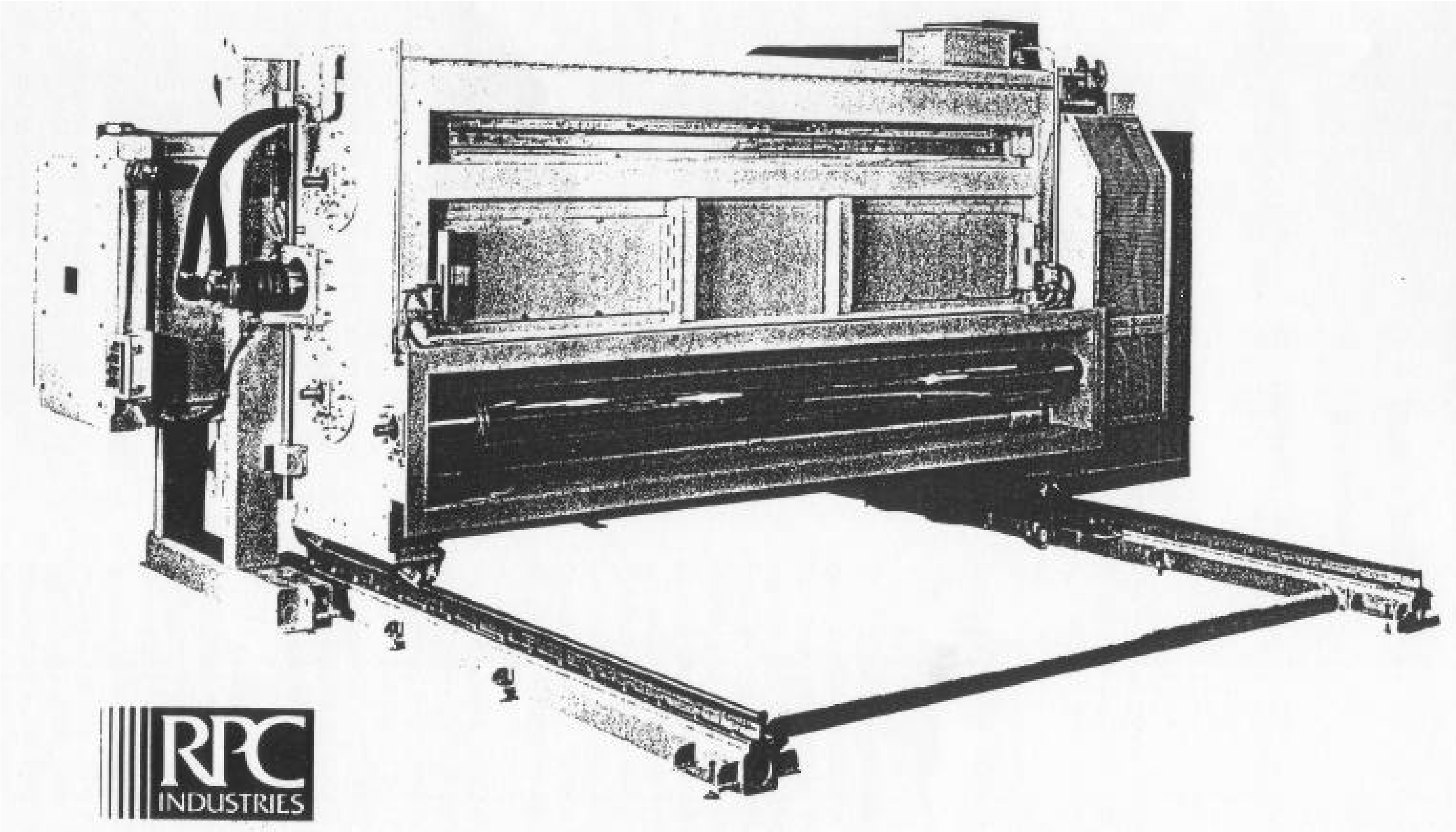


FIGURE 3. Electron beam processor for silicone coating line. Web width 130 inches (3,300 mm), 1,300 fpm (400 mpm), 200 kV.