EBG - THE ELECTRON BEAM ENGRAVING OF GRAVURE CYLINDERS

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Summary

A new approach to the preparation of gravure printing cylinders using electron beam technology is described herein. An electron beam engraving machine generates by melting and evaporization of copper, gravure cells of variable size and depth at high-speed from digitally stored picture and text information. The "EBG" engraving machine is compatible with existing gravure copper cylinder technology, and will offer substantial productivity improvement through a high level of machine automation. Through real-time image processing techniques with deflection of the electron beam quality, improvements in type and picture information can be obtained which will set new quality standards for the gravure printing cylinder.

Introduction

It may be a surprise to you if I tell you that the roots of the three physical methods for gravure cylinder preparation we have talked about in the last few years all go back to the beginning of the 1960's. In that year, the first tests with the diamond stylus engraving of copper cylinders were completed. At the beginning of the 1960's, that means after the invention of the laser, Dr. Hell got his patent for cylinder preparation with the laser beam. And in 1961, the first laboratory tests were made with electron beams. This is a long history, and gives me the opportunity to start with a historical overview.

Picture 1

(1) History of EBG.

(2) EBG, compared to laser gravure in copper.

(3) Shape of EBG engraved gravure cells.

(4) Construction of the EBG machine.

(5) Prospective specification of EBG machine.

(6) Productivity of the EBG machine.

(7) Some quality improvements.

(8) Input to EBG machine.

(9) EBG and existing Helio-Klishographs.

(10) Time schedule for prototype and pilot installation.

The additional points of my agenda are:

- Electron beam gravure compared to laser gravure in copper.

- The shape of the electron beam engraved gravure cells.

- The construction of an EBG machine.

- Prospective specification of an EBG machine.

- The productivity of the electron beam process.

- Some quality improvements achievable only with the electron beam.

- The input to the EBG machine.

- The electron beam gravure and existing Helio-Klischograph technology.

- The prospective time schedule for pilot installations at the beginning of the series.

History

The potential of high-power electron beam material treatment has been known for several decades to the scientific and engineering world, with some applications for cutting, welding and tooling. Compared to the precise generating of the gravure cells with micrometer tolerances, those applications at that time were rather rough and coarse.

Picture 2

HISTORY OF ELECTRON BEAM ENGRAVING

About 1962	IBERA Battelle Institute, Frankfurt, and Technical University Delft in the Netherlands, initiated by ERA. Not successful.
1972	Steigerwald, Germany initiated by Burda. Feasibility was proven on principle.
1976	Hell starts EBG project using some existing Steigerwald know how.
1981/82	Operational function model proves potential for high speed and high quality. First rotational proof printing.
1984	First demonstrations for customers.

Nevertheless, some European gravure printers planning with the long view and with confidence in the fast-moving technical advance, reacted consequently and took the first initiative. They founded the IBERA, the International Beam Engraving Research Association in the early 1960's, in order to investigate the application of the electron beam for gravure cylinder engraving. About 1962, the research work was performed at the Battelle Institute in Frankfurt, Germany and, later, at the Institute of Applied Physics of the Technical University of Delft, in the Netherlands. At that time, copper was used as well as zinc and brass material. The project failed. In the discussions with the leading scientists in this project, Professor le Poole and Dr. Fonteyne saw the main handicap in not having the electron optical means to produce sufficiently short pulses of high electron energy concentration with the right energy distribution in the cross section of the beam when hitting the surface of the cylinder. Today, we think they were right in these statements and with the tools of that time, they had no realistic chance.

Some years later, when the IBERA group had given up, there were numerous sensational and spectacular papers on the potential of laser beam engraving in metal, among others, from the RCA laboratories, and other people. At the end of the Sixties, I had to investigate the chances for laser beam engraving of gravure cylinders and I saw no chance to get a sufficient result if we wanted to get speed and efficiency.

In spite of this somewhat confusing situation, and I think this has to be acknowledged, the Burda Company started a cooperation in 1971 with the Steigerwald Company in Munich for electron beam material treatment. The Steigerwald Company was specialized in electron beam cutting and welding. The first tests were done with modified machinery at engraving frequencies of five kilodots per second. This is a little more than the engraving speed of a mechanical engraving head today. The tests showed, in principal, promising results and this was a task of the feasibility study. But this EBG project, in spite of a lot of interest of several gravure companies in Europe, was not actively continued. Remembering those years, I feel finally, that it became more and more obvious that a huge dimension of time and financial resources really would be required to come to an economical production unit.

After careful and straight forward comparison of the potential and laser and electron beam engraving in metal, preferrably in copper, not allowing too spectacular assumption of some future technology breakthroughs in the laser field, the Hell Company in 1976, made the decision to develop an electron beam engraving system. Some parts of the Steigerwald know-how were, indeed, usable for the start of the project, to have a first basis for further intensive research and of the electron optical design and control electronics.

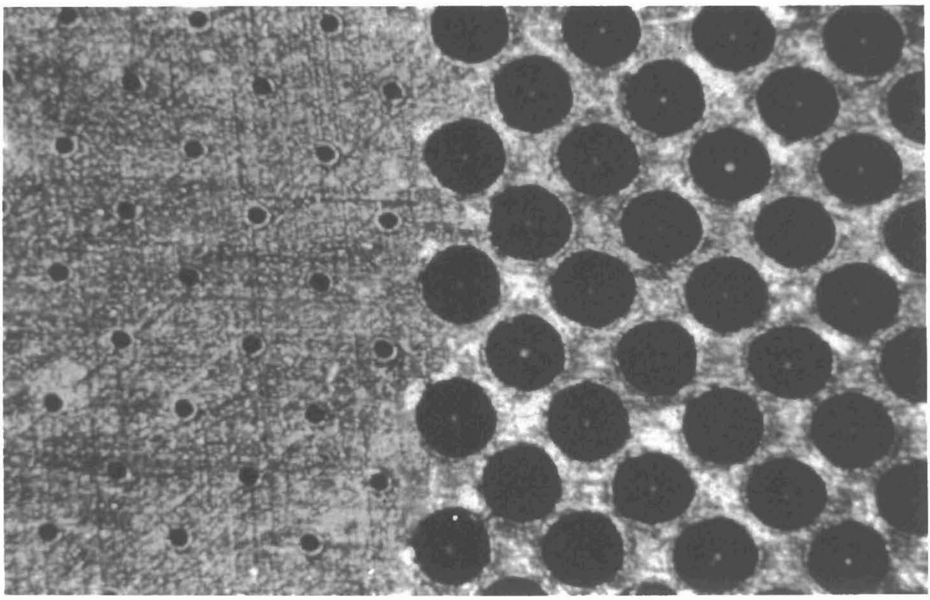
Applying the Steigerwald know-how, we were just about able to generate the comparatively low speed, a few thousand dots per second some sizes of heavily built gravure cells within the necessary overall gradation of volume range with unacceptable tracking at black and white borders and we still had a long way to go in R & D for a high-speed variable and economic production machine for top quality gravure cylinder engraving in copper. A young team of highly qualified and engaged physicists carried this project through with substantial overall progress so far in spite of all throwbacks in within the first years of this project.

In 1982, an operational function model proved potential for high speed and high quality. We got the first rotational proof printings. At the end of 1984, we had the possibility to show a small group of customers the laboratory model and made a live demonstration of the cylinder engraving. In mid-January 1985, a group of European rotogravure printers from the ERA and a few American customers saw the first operating laboratory model.

How to Compare EBG to Laser Gravure in Copper

We know that only a powerful laser can guarantee a high engraving speed and the most powerful lasers are working in the infrared with 10.7 micrometers. In this area of wavelengths, copper is a very good reflector of the laser beam. To avoid this problem, it is possible to change to a plastic gravure cylinder, but we have good reasons to believe that copper is a well-approved printing cylinder material for gravure in future years. I make this statement under consideration of not expected environmental problems in agreement with major experienced gravure printers in Europe and America.

Picture 3



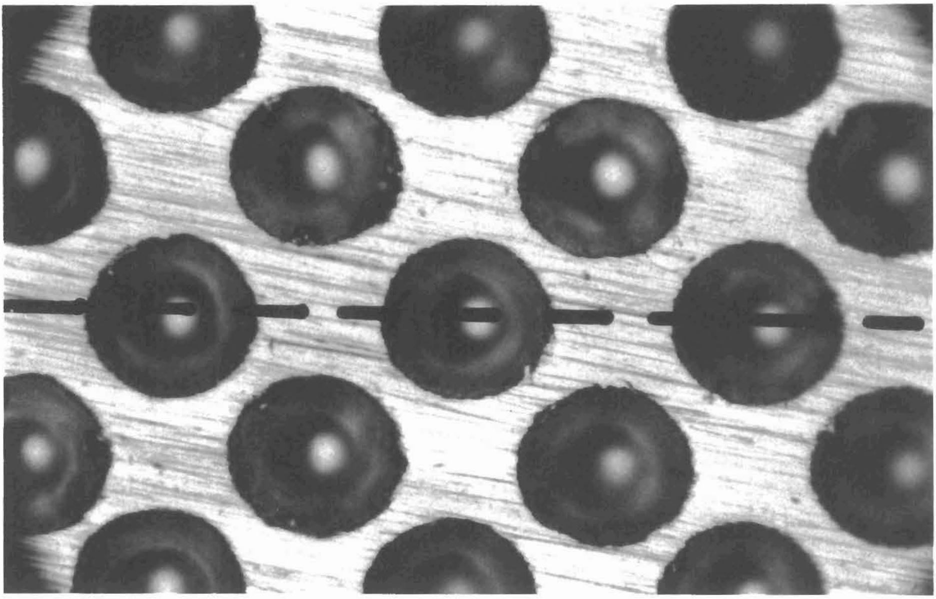
What is the shape of EBG engraved gravure cells? Picture 3 shows an unground ballard skin. The engraving direction is from right to left. The full volume engraved cells at the right side give 2.05 proof printing density with cell dimensions of 125 micrometer diameter and 58 micrometer depths. The small volume cells at the left side give 0.05 printing density with cell dimensions of 28 micrometer diameter and 6 micrometer depths.

By electronic optical control within the electron beam gun, the circular cell shape can be somewhat optimized between a spherical and a more cylindrical form. Its final shape will also depend on best achievable printing results and real production speeds. The cell volume is modulated by changing its diameter as well as its depth. After superheated copper has been melted and the vaporized copper has been forced out of the cell volume by a high plasma pressure, the EBG generated cell is left with a rather smooth inner surface. For that reason, we can expect very good ink transfer out of the cell to the paper at high speed. As the duration of the electron shots is only a few microseconds, the heat is given no time to travel away into the neighborhood of the cell. So we have shots which are too short to allow heat migration; therefore, nearly no walls of vacant copper are building up around the cell. The recrystalizing surface of the EBG generated cell has a thickness of less than 4 to 5 micrometers.

The remaining recrystalizing material at the border of the cell is taken away by a diamond cutter similar to the Helio-Klischograph technology. In this way, perfect walls between the cells are left for carrying the doctor blade even when engraving maximum cell volume. The cylinder will leave the EBG machine ready for chroming or proof printing.

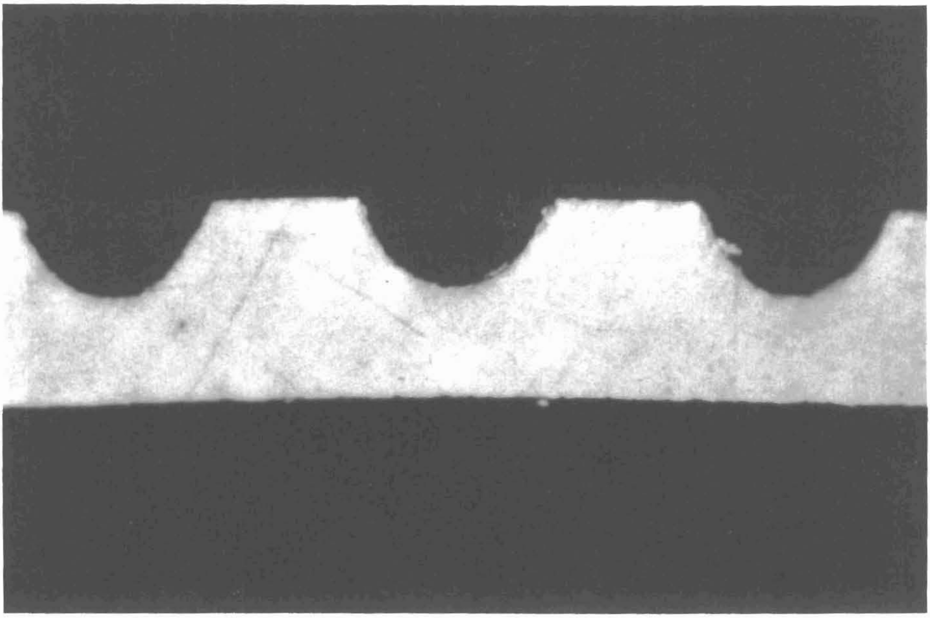
As a key aspect, I would like to say that the same copper requirements are applicable to either the Helio-Klischograph 202 or EBG engraving. That means no investments for different plating technology are necessary.

Picture 4



Picture 4. The ballard skin shows the cut lines for grinding and a broken line for a cross-sectional view. We have large dots with 125 micrometers diameter.

Picture 5

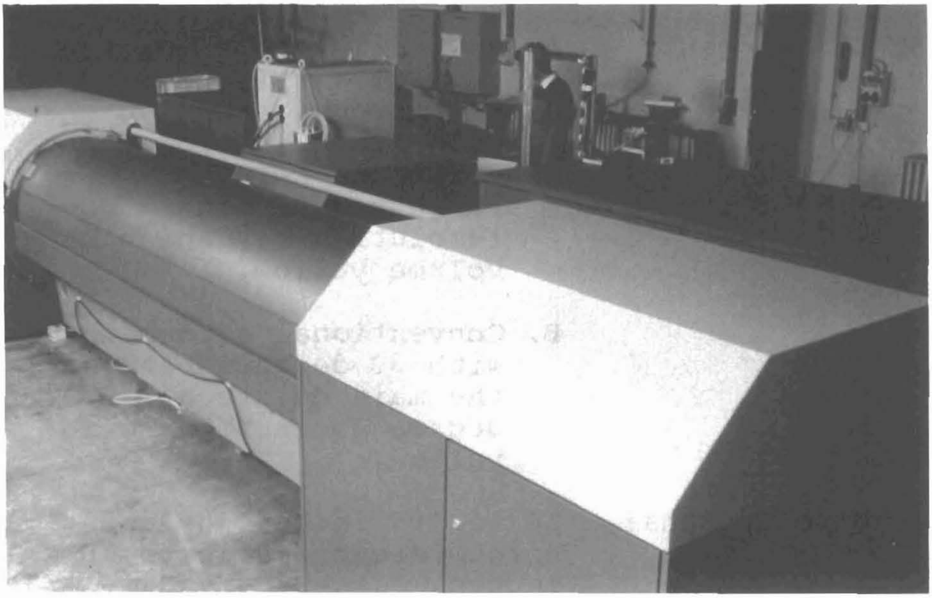


Picture 5 gives an impression of the cross section of high-volume cells.

The Construction of the EBG Machine

The following Picture 6 allows you an impression of our first demonstration and shows the main machine. It consists of a bed carrying a huge vacuum chamber where the prepared copper cylinder is put in. In this chamber, we have the motor drive system for the cylinder rotation and we have the crossfeed driving system to move the whole cylinder in crossfeed direction. This is different from the present day technology because the cylinder moves in both directions for rotation and crossfeed. The electron beam gun is fixed and does not move. After the cylinder has been put into the machine, the cover is closed, the vacuum pumps start to evacuate the whole machine and, after the rotation of the cylinder reached the final rotational speed, the engraving of the image or the ribbons into the copper can start. Electronic cabinets for controlling the machine for automatically controlling the cover and the starting and stopping procedures as well as cabinets for power supply, vacuum pumps and high tension supply complete the whole machine.

Picture 6



The laboratory model of the EBG machine shows the following dimensions:

Lengths:	24.0 feet.
Depth:	8.2 feet.
Height:	5.0 feet.

Prospective Specification of the EBG Machine

Engraving speeds:	The range over 100,000 up to 150,000 cells per second.
Screen:	125 to 225 lines per inch, for magazine printing, catalog printing and packaging printing.
Screen angles:	A. Comparable to the present day Helio-Klischograph technology, avoiding color shift by combining different screen rulings with high resolution key and high volume yellow. B. Conventional screen angles with 30 degrees between the main colors and 15 degree angle to the yellow.
Gravure lengths:	Up to 103 inches, cylinder circumference is up to 60 inches.
Cylinder speed:	For large diameter cylinders, slightly higher than rotational speed in new generation gravure printing machines in the range of 1000 revolutions per minute.
Cylinder loading:	Numerical controlled position bearing supports with self-setting collards for cylinder loading and de-loading.

Cylinder unbalance	According to specification for Albert-Frankenthal T6B cylinder family.
X-radiation:	Nonexistant for the operator because fully absorbed by the machine cover.

The Productivity of the EBG Process

Based on our present results, an improvement in overall productivity of a factor more than 2, especially for larger cylinder diameters, compared to the present-day Helio-Klischograph K202 with 8 engraving heads, can be expected. If we reduce the pure engraving time substantially, then the set-up time for changing cylinders is becoming relatively more and more important. That means cylinder handling and machine calibration of the EBG machine need an automation to minimize time consuming steps within the set-up phase. The final EBG machine will be prepared to be operated in an automatic mode using, for instance, the same cylinder transport system for sequential work flow of cylinders from plating, polishing to engraving and chroming without manually touching the cylinder's point. After some operator training time, and assuming good work preparation are expected, the complete set-up time will be reducible to 12 to 15 minutes per cylinder including vacuum, cylinder exchange and acceleration and automatic calibration for focusing and engraving depths.

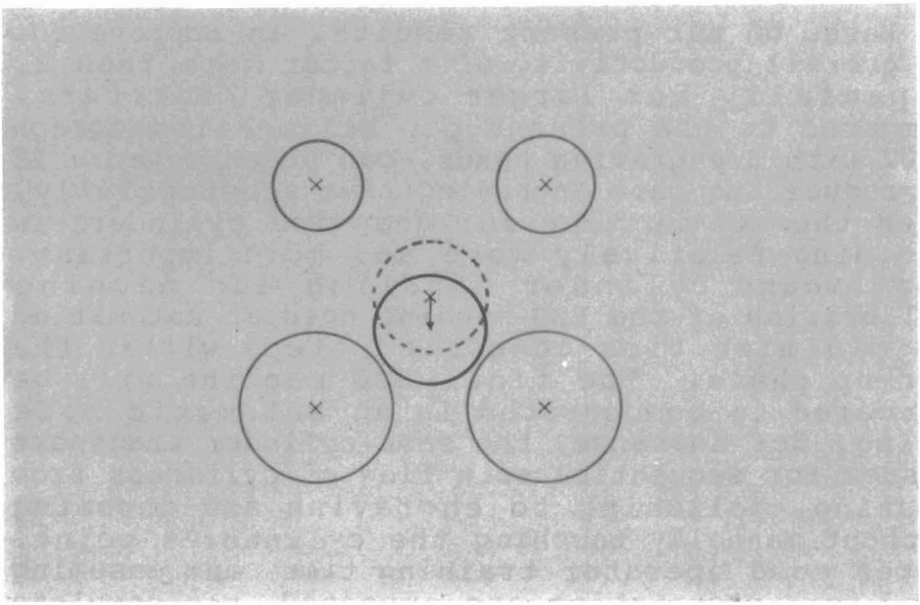
Quality Improvements with EBG

Beside higher productivity in conventional screen layouts, I feel EBG will be in the position to give some significant quality improvements to our future EBG customers:

- Increased cell volume and good ink transfer characteristic to paper.

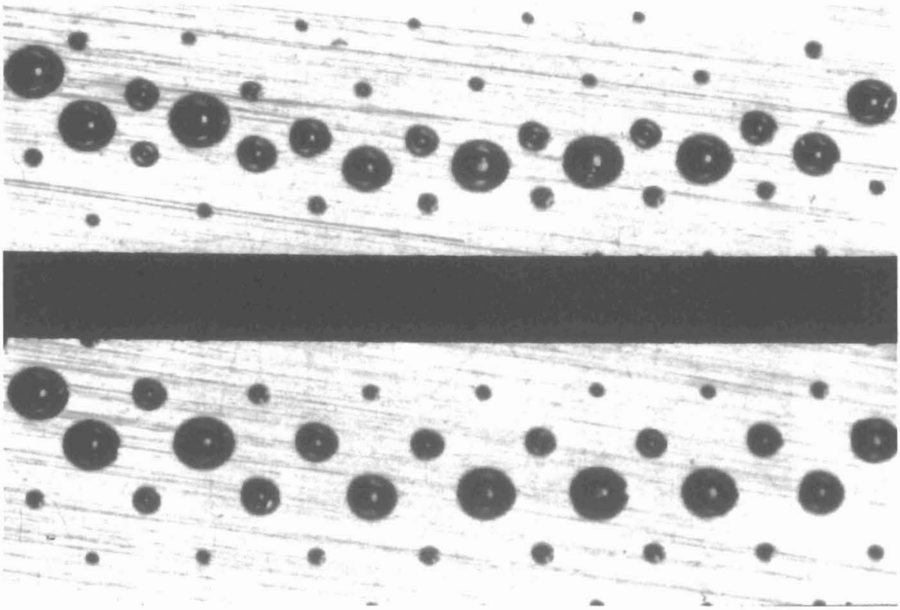
- An improvement in engraving of text and line work by shifting the position of the cell gravity center at the surrounding of characters, line work or even of contrast borders within the halftone picture to the contour itself by real time image processing.

Picture 7



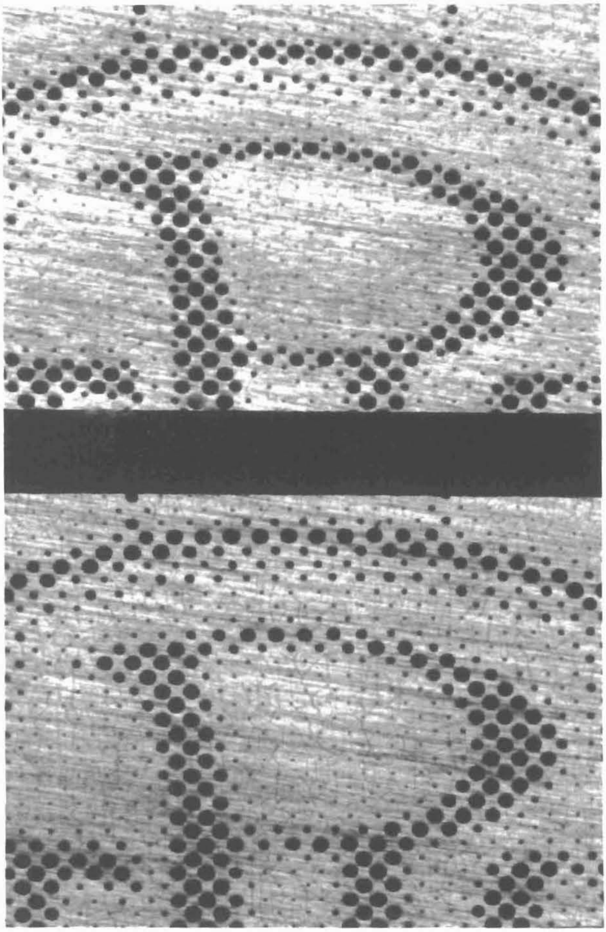
Picture 7. Using, beside unsharp masking, this additional EBG contour enhancement technique, improvements to the quality of line art and fine details will be achievable. This is possible because the electron beam may be deflected fast and with larger angles than any other engraving tool. As you know, the laser beam and the diamond stylus cannot be moved fast to the side in parallel to a fast engraving and circumferential direction. This is a technical possibility to be used only by the electron beam.

Picture 8



Picture 8 shows a small section of line work of a logo. Beneath, you see the normal appearance of a fixed position of the gravure cylinder regular screen raster point. But it is detectable that the gravity center of the cell can be shifted toward the contour of line work to improve quality of text and line art and to minimize any saw-tooth effect which is one of the problems of gravure until now.

Picture 9



Picture 9 shows a greater section of the same logo. In the lower part: normal position of the cells; in the upper part: with additional contour enhancement by shifting the cell position to the dots of the contour. This gives an improved sharpness of letters, as the audience may detect from larger distance.

Other additional improvements are:

- We have one engraving tool for all ribbons. Easy adaptation to different numbers of ribbons and good flexibility already in work preparation by adjusting ribbon numbers to compensate for paper work shrinkage according to dampening and drying.

- Checking of diameters of testing gravure cells by using electron beams in an operation mode similar to electron-microscopical technique, the cell shape may be quantatively visualized on the operator monitor.

Input to the EBG Machine

The EBG machine in the late 1980's probably will be fed preferably by image data out of a gravure data pool generated in image processing systems like Chromacom, and avoiding interim film steps.

However, for good economic reasons and for transition into the new technology, also the O/G process, the input of screened color separations and line material and, if necessary, also of continuous film material will be available.

A high-speed register pin controlled laser flat bed scanner is our CN 420. This is the input equipment to scan the input material into the gravure data pool which also collects information for all the pages in reference to be engraved later on. Controlled by comfortable file management software, the EBG engraving will fed real time out of this gravure data pool.

EBG and Existing Helio-Klischograph Technology

Let me say a few words about the relation of EBG to the existing Helio-Klischograph generation. Looking somewhat realistically into the future means that EBG initially will not replace today's well-accepted Helio-Klischograph technology of electromagnetic engraving with diamond styli. That rather will be phased in slowly. The EBG machine is more expensive than the Helio-Klischograph technology, the electron beam gun is remarkably more expensive than the present day engraving system, and this means we expect a good economic introduction of electron beam technology first at customers with larger cylinder production numbers per year. A great number of our customers with one or two Klischographs will further on use the electro-mechanical technology. I would like to stress Hell's clear intention here that we definitely will proceed to support further improvements of the existing Klischograph K 202. Among others with appropriate software developments for Helio Data Processing HDP II with adapting the existing generation of engraving machines to the gravure data pool interfaced to image processing systems like Chromacom.

Time Schedule for Pilot Installations and the First Series

In the present stage, we have shown a laboratory prototype model. It takes us about one year to finish equipment which could be used at a pilot installation under production conditions at a first EBG customer. I estimate that we need another year to have the feedback of the information to make the final changes in the introduction of the machine to full high efficiency use in a printing plant. That means that the first equipment to be put out of our factory as series models may be expected in 1988.