RB-49

PRINTING OF THREE-COLOR PHOSPHOR PATTERNS ON FLAT GLASS BY OFFSET LETTER PRESS

RADIO CORPORATION OF AMERICA
RCA LABORATORIES
INDUSTRY SERVICE LABORATORY

RB-49

1 OF 9 PAGES

MAY 3, 1956

RADIO CORPORATION OF AMERICA

RCA LABORATORIES

INDUSTRY SERVICE LABORATORY

RB-49

Printing of Three-Color Phosphor Patterns on Flat Glass by Offset Letterpress

Printing of Three-Color Phosphor Patterns on Flat Glass by Offset Letterpress*

This bulletin describes a method of printing three color phosphor patterns on flat glass plates by offset letterpress. The resulting plates are suitable for use in color television tubes. The problems encountered in developing this method are discussed along with their solutions.

Introduction

The principles of producing color pictures in television are similar to those used in conventional printing in that the entire spectrum is obtained with a limited number of color elements. In the conventional process, the entire range of colors is obtained by overprinting four color elements: yellow, red, blue, and black. In color television, the color elements are composed of red, green, and blue emitting phosphors which must be adjacent with no overlapping. In both processes, the patterns may be composed of either dot or line elements.

Printed phosphors screens must meet the following specifications. The elements must be in the proper location with no overlapping and they must be uniform and of adequate thickness. No contamination must be introduced from undesirable foreign matter or from other phosphors being printed. In addition, the ink ingredients have to be selected on the basis of meeting the burn-off temperature specifications of the screen.

This bulletin describes the development of an offset letterpress process for printing phosphor patterns on flat glass. The selection of the printing process, ink formulation problems, and the results obtained are covered in detail.

Adaptation of the Offset Letterpress Process

The prime consideration in selecting a printing process was the absolute necessity of preventing inter-contamination of the three phosphors during printing. This fact automatically eliminated gravure and lithographic printing and suggested a letterpress process. The second consideration was that the printing surface was flat glass; thereby, eliminating any direct or cylindrical letterpress process.

Two processes which offered good possibilities were the offset letterpress process and platen letterpress process. Preliminary tests with both types of equipment indicated that accurate registry for overprinting within the tolerance limits would be more readily obtained with the offset letterpress process.

A Vandercook No. 22-34 one color offset proof press was selected for the basic laboratory studies since only relatively minor mechanical changes were necessary to permit printing on flat glass. This press was originally designed as an offset lithographic press, in which both the litho plate and the paper lie on the flat press bed and the ink transfer between them is accomplished by means of the rolling action of an offset blanket cylinder. For printing of the phosphor patterns, the press was modified to operate with a dry offset process. The water distribution system and fountain were removed. A letterpress plate was substituted for the litho plate and glass was substituted for the paper. The press bed was undercut to accommodate the additional thicknesses of the plate and glass. A vacuum system was installed for holding the plate and glass in position.

Press Operation

The operation of the modified press shown in Fig. 1, is as follows. A movable carriage supporting the form rollers and the offset blanket cylinder travels back and forth over the press bed. The normal printing cycle starts with the carriage at rest at the near end of the press with the ink distribution system being power driven by the roller in the press bed. After the ink has been applied to the rollers and has distributed satisfactorily, the carriage moves to the opposite end of the press bed (position shown in Fig. 1) during which operation the two form rollers are positioned to ink the letterpress impression plate. On the return travel of the carriage the form rollers again ink the impression plate, after which the offset blanket cylinder picks up the impression from the plate and transfers it to the glass. The carriage then returns to the end of the press for a redistribution of the ink on the form rollers, after which the cycle can be repeated.

---

*This work was done under contract at the Institute of Research, Lehigh University, Bethlehem, Pa.

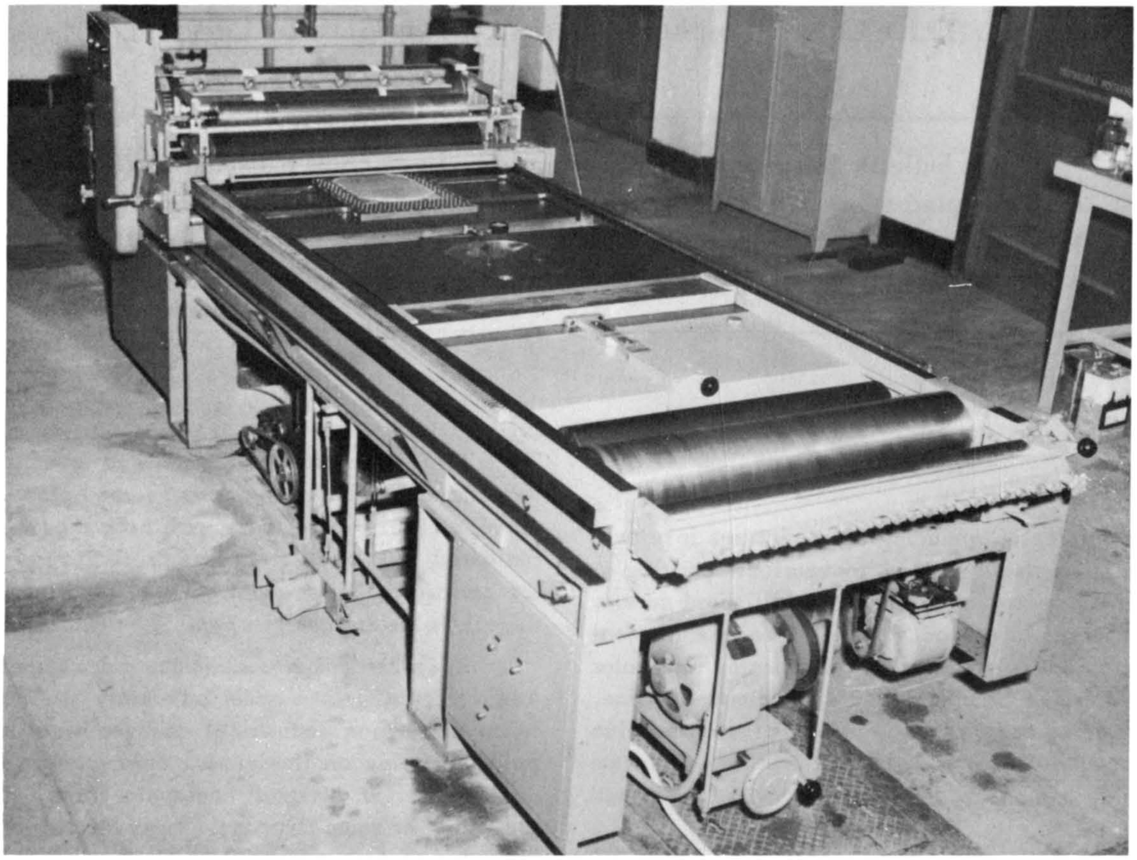


Fig. 1 – Vandercook 22-34 offset proof press, modified for printing on flat glass.

The Vandercook No. 22-34 press was designed with a set of wedge plates for adjusting the height of the printing surface. The glass was positioned on the wedge plates with a special jig and held down firmly with the vacuum system.

Impression Plates

A photomicrograph of the letterpress impression plate for a single color dot pattern is shown in Fig. 2. The distance between dot centers is 0.0237 inches. During the inking operation, ink is deposited on the raised circular surfaces. It is readily apparent how the inked pattern on a letterpress impression plate can be transferred to an offset blanket without interfering with other patterns already deposited on this blanket. A gravure or a lithographic impression plate does not possess this advantage.

The first impression plates were made from zinc by a conventional photoengraving process. Later developments showed, however, that a higher quality impression plate could be made from magnesium stock using the Dow Chemical Company Rapid Etch Process. Impression plate surfaces of zinc, nickel, chromium and magnesium showed no significant differences in ink receptivity.

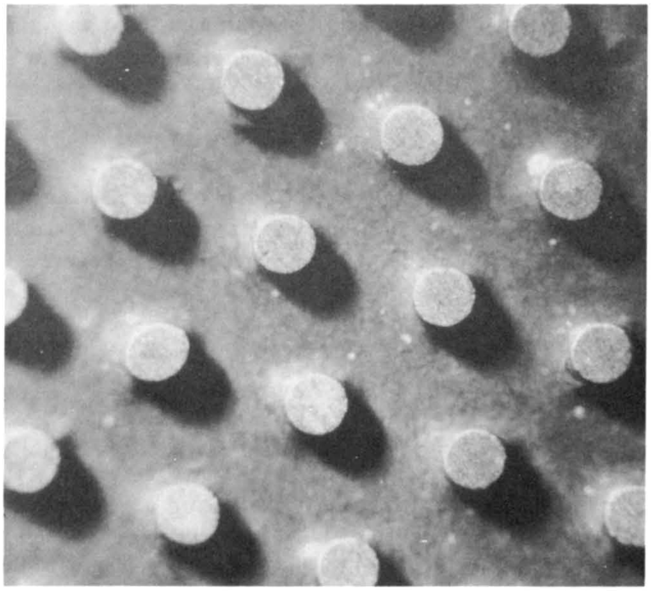


Fig. 2 – Letterpress impression plate with single dot pattern.

The size of each individual element on the impression plate had to be carefully controlled during the engraving. The elements had to be uniform and of a size which was selected to allow for pattern enlargement in the ink transfer steps.

One of the critical factors in securing satisfactory press operation was the adjustment of the surface of the impression plate to the proper height to give a full uniformly inked impression on the offset blanket. This adjustment was accomplished by inserting sheets of paper under the base plate and by applying makeready tissue directly under the impression plate.

Composition of the Distribution Rollers and Offset Blanket

The suitability of the form roller and offset blanket composition for distributing and transferring, respectively, the particular phosphor ink formulations in use proved to be a very important factor in securing satisfactory prints on the glass. The original vulcanized oil form rollers and and many rubber blanket materials were found to absorb the solvent from the ink to such an extent that ink distribution and transfer were seriously impaired. Non-absorbing blanket materials such as polyethylene, teflon and Kel-F plastic did not possess adequate mechanical strength or else had uneven surface contours. Special types of synthetic rubber form rollers and blankets were finally found which exhibited very low solvent absorption.

Procedures in Formulating Inks

In the initial considerations of the problems of printing phosphor patterns on glass, there was much conjecture about whether registry could be obtained to meet the geometric precision required for satisfactory tube operation. As work progressed, however, it become evident that the ink formulation would constitute the major problem because the restrictions imposed by tube operation eliminated most of the ink ingredients normally used in commercial printing.

Selection of Ink Ingredients

A printing ink consists of a pigment, in this case the phosphor, and a vehicle which holds the pigment in dispersion and transports it from the press distribution system through the various transfer steps to the final print. The vehicle may vary from a single component fluid to a complex mixture of resins and solvents.

The choice of the phosphors was dictated entirely by their light output and electron excitation characteristics. Because of the "burning-off" process which the printed phosphor screens undergo, the first property to be considered in the selection of a vehicle system was its burn-off temperature. Another essential property was its press stability, i.e., it must not be absorbed by the distribution rollers and blanket or evaporate into the atmosphere.

The 425 degree C burn-off temperature imposed by the phosphors eliminated the use of practically all common printing ink vehicles, such as litho varnishes and steam-set resins. Very few binder materials passed the burn-off test and several of these could not be used because they were not sufficiently soluble in solvents having adequate press stability. After the burn-off, solubility, and press stability characteristics had been determined, only three classes of binder materials remained as possible ingredients for the phosphor inks: methacrylic resins, soluble starches, and ethyl celluloses. None of these were recognized as previously used ink vehicle ingredients for presswork requiring a distribution system.

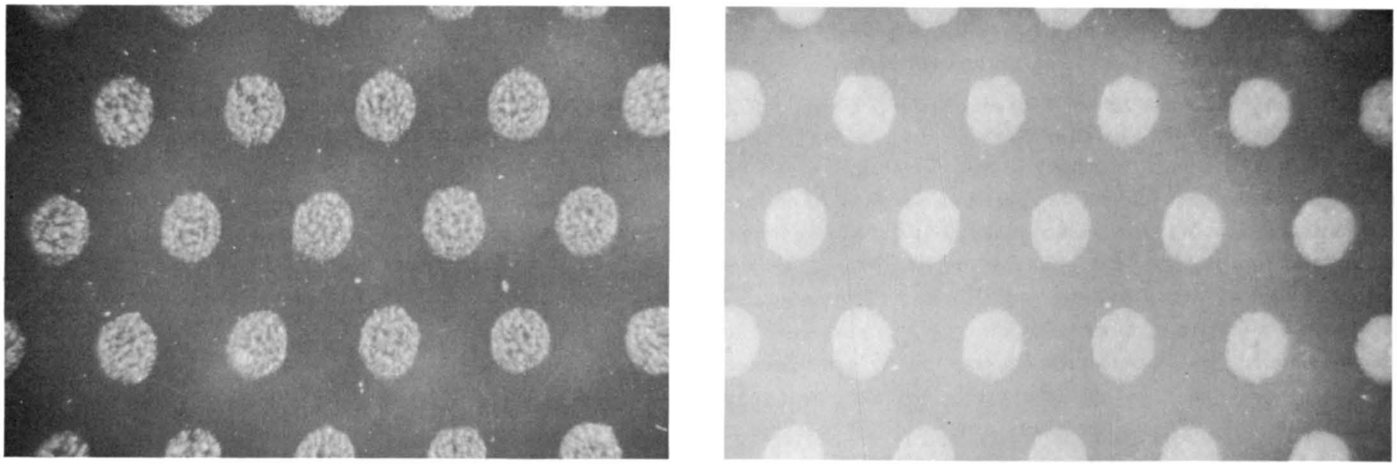
Dispersion of the Phosphor Inks

In the printing industry it is a generally accepted fact that the presence of oversize particles and agglomerates in inks is detrimental to distribution properties and the formation of uniformly smooth printed patterns. The phosphors which are produced commercially for use in color television tubes have relatively large particle sizes. For example, an analysis made with a Fisher Subsieve Particle Size Analyzer showed that the green phosphor had an average particle size of four microns. On the other hand, most common printing ink pigments have particle sizes of about 0.5 micron, with a few as low as 0.01 or 0.001 micron. In addition, the phosphors had a marked tendency to form agglomerates which could not be broken easily with grinding or milling without introducing excessive strains into the crystal.

This large particle size necessitated particularly good dispersion into the vehicle to obtain usable press performance. At the same time care had to be taken not to reduce light output efficiency due to contamination or excessive physical working. The dispersion technique selected initially was hand mulling with a glass muller on a ground glass plate. Commercial roll mills and ball mills were not considered at first because it was believed that the steel parts worn off by abrasion would poison the phosphor. Later, however, electron tube tests showed that the phosphor light output efficiency was not seriously reduced except under severe milling conditions. The iron contamination which was introduced in milling was minimized by the use of hardened steel knife blades. Roll milling not only dispersed large quantities of ink thoroughly, quickly, and reproducibly, but also improved ink distribution on the press rolls and the formation of better phosphor patterns on the glass. Some effects of mill size and milling pressures are illustrated in Fig. 3.

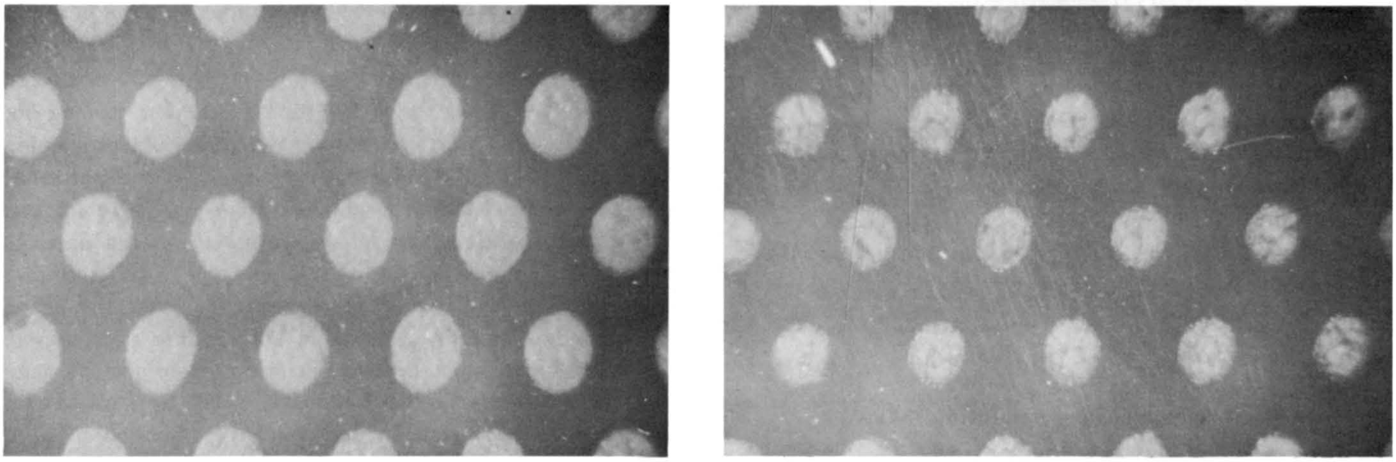
Characterization of the Inks

In order to reproduce and control the properties of the ink dispersion, the following tests were performed.



4 x 8 Mill, 1000 psi

6 x 14 Mill, 200 psi



6 x 14 Mill, 600 psi

6 x 14 Mill, 800 psi

Fig. 3 – Effect of mill size and mill pressure on quality of printed pattern.

(1) The degree of dispersion of the phosphor into the vehicle was evaluated by determining the fineness-of-grind on an NPIRI Production Grindometer.[1] This measurement permitted an investigation of correlations between milling conditions and light output efficiency and led to the establishment of fineness-of-grind limits. (2) The RCA Vibrating Plate Viscometer[2], was selected for measuring relative viscosities because it was capable of handling small samples and producing a rapid evaluation. (3) Length, defined as the ability of an ink to be drawn out into a thread, was determined by qualitative observation.

Printing of Single-Color Phosphor Patterns

The merits of each ink formulation were evaluated by printing single patterns with the green phosphor. Many of the ink formulations failed immediately due to their inability to distribute the large particle sized phosphors on the press roller system. Because the high specific gravity of the phosphors also hampered adequate transfer through the printing process, a great deal of work was done in determining the optimum printing conditions for effecting good transfer and improving the deposit of phosphor on the glass.

Press Operating Techniques Affecting Printing Performance

Although the controlling factor in the production of phosphor patterns on glass was the ink formulation and its relation to various press parts, the techniques in operating the press were also important: the amount of ink on the press, the number of ink transfers, and the various pressures involved.

It should be mentioned first that the most significant improvement in transfer of the phosphor ink from the blanket to the glass plate was produced by coating the glass with a resin ingredient of the ink. Techniques for spraying the film and for roller coating the glass directly on the press were developed. The coating increased the "ink receptivity" of the glass and, therefore, permitted heavier deposits of the phosphor ink as shown in Fig. 4.

The maximum quantity of each ink which could be carried on the distribution system was limited by the occurrence of ink flow over the edges of the raised elements of the plate. The two distribution rolls were found to deposit as much ink on the plate in one complete cycle (forward and back) as was possible with additional cycles. On the other hand, transfer equilibrium was approached when the blanket was inked twice by the impression plate and when the glass was printed six times by the blanket. The large number of press cycles required to deposit sufficient phosphor on the glass slowed down the process considerably.

The rheological properties of each ink determined the pressure between the plate and the blanket and between the blanket and the glass. Insufficient pressure resulted in non-uniform patterns; while, excessive pressure produced a non-uniform contour. The pressure between the blanket and glass, called impression pressure, was readily altered because of the adjustable wedge nature of the press bed. The blanket-plate clearance, on the other hand, was adjusted by changing the height of the impression plate with makeready.

In an effort to increase the phosphor ink transfer throughout the printing process, the use of thermal gradients in the ink path was investigated: application of heat to the distributing system and to the blanket, and the use of cold glass. This effort proved ineffective in increasing ink transfer, but the heated rollers improved the distribution of some high viscosity inks.

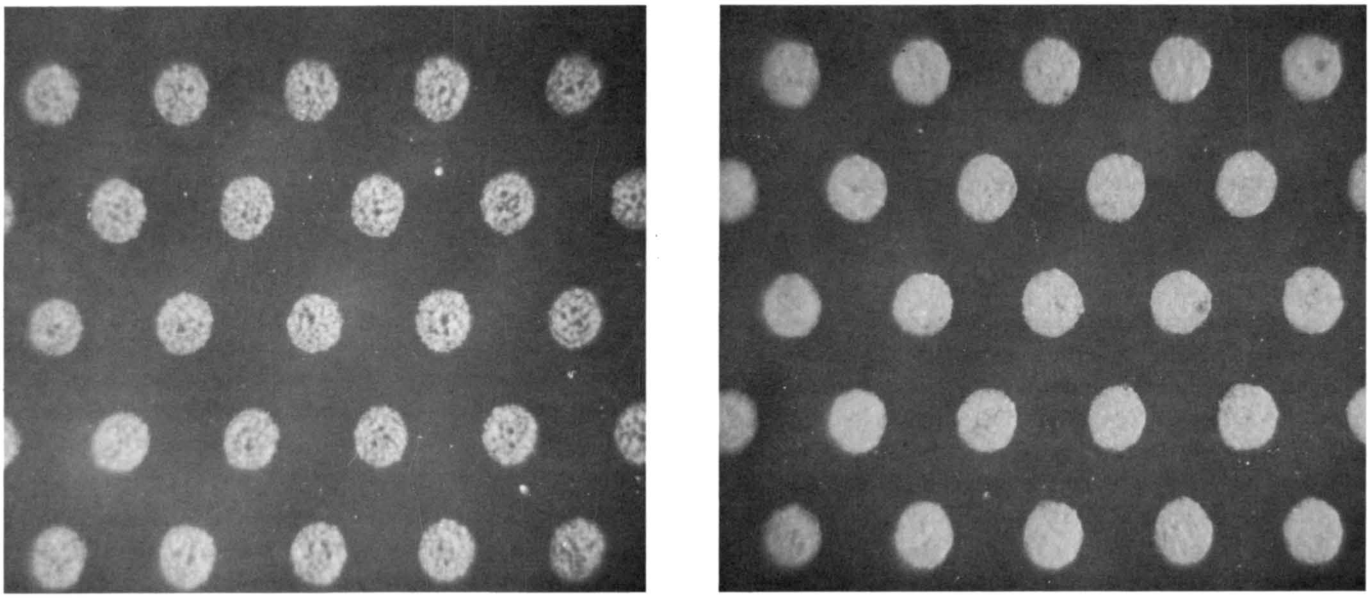
Methods for Evaluating Printed Phosphor Patterns

The printed phosphor plates were first examined visually with the unaided eye for general characteristics such as uniformity of deposit over the entire plate. A hand microscope and a stereoptic microscope with a magnification in the range of twenty to fifty times were then used for a closeup study of the patterns.

The use of photomicrographic equipment provided permanent and informative records of printing results. Transmitted light photographs aided in evaluating the patterns for size, coverage, shape, and definition. Reflected light photographs afforded excellent means of determining the uniformity of the deposit over the individual elements.

Evaluation by these visual means was sometimes misleading due to the various packing densities of the deposited phosphor. Actual deposit was determined by quantitative analysis: scraping off a definite area, burning and weighing. These results were then reported as milligrams deposit per square centimeter of pattern area.

Visual examination and the analysis of the phosphor deposit served only as a means of control in the printing process and as a means of eliminating prints which were definitely unsatisfactory because of poor pattern fidelity or obviously inadequate phosphor coverage. These methods could not detect the presence of contaminants which might have been introduced during the handling and printing process. The only complete and significant evaluation of the prints was obtained by checking the plates for registry and light output performance in actual television tubes.



Non-coated glass

Coated glass

Fig. 4 – Effect of glass coating on quality of printed patterns.

Printing Results with Three Types of Ink Formulations

The major emphasis was placed on the search for an ink formulation with the proper printing characteristics for producing acceptable phosphor patterns. General experience within the printing ink field suggested that the use of oil solvents would give ink formulations possessing good printing qualities with relative freedom from volatility and absorption effects. Initially, however, none of the binders which had burn-off temperatures approaching the requirements of the phosphors were sufficiently soluble in oil to permit development of an oil based formulation. Two systems with glycol soluble binders, ethyl cellulose and oxidized starch, were extensively investigated before a suitable oil soluble resin became available. As expected, this resin, a methacrylate, was extremely effective in producing ink formulations of satisfactory printing properties.

The relative merits of the three ink systems that were developed will be described in chronological order. Each succeeding ink system gave an increase in the amount of phosphor deposit and an improvement in printing performance.

The first ink system showing promise contained *ethyl cellulose* as the binder with *hexylene glycol* as the solvent. The best formulation of this type resulted when a low molecular weight ethyl cellulose was used and when high molecular weight polybutene was included in the dispersion. These inks were generally unsatisfactory. The phosphor deposit was low, seldom exceeding 0.7 mg./sq. cm., even on ethyl cellulose coated plates. The inks also had extremely poor press stability due to the high degree of absorption of the hexylene glycol by the vulcanized oil form rollers and the synthetic rubber blanket. The effects of the relatively high volatility combined with the hygroscopic nature of the hexylene glycol resulted in a rapid and pronounced change in the properties of the ink on the press. A Teflon blanket eliminated the absorption of the solvent into the blanket but created other problems in the transfer process due to its surface irregularities.

The second system embraced the use of a *glycol-soluble starch* as the binder material. The best formulation resulted from mixing three separate inks: phosphor dispersed in starch-diethylene glycol, phosphor dispersed in starch-dipropylene glycol, and phosphor dispersed in Triol. In addition, each of the three inks required a specific wetting agent. The starch-glycol inks produced phosphor deposit values in the range of 1.2 to 1.5 mg./sq. cm., on starch coated plates, but they possessed relatively poor press stability characteristics and introduced copper as a contaminant which seriously affected the emission of the blue phosphor. Besides appreciable absorption into the synthetic rubber form rollers and blanket, the glycols also absorbed moisture from the atmosphere, necessitating close control of the relative humidity.

The third ink system contained as the vehicle a special *methacrylic resin polymerized in an ester*. In order to obtain satisfactory distribution properties, it was necessary to include a specific wetting agent and mineral oil as a diluent for the dispersion. Representative phosphor deposits on tacky methacrylate coated glass reached approximately 2 mg./cm^2, with some values as high as 2.5 mg./cm^2. Electron tube tests showed that these deposits produced adequate light output efficiencies and that no contaminants to cause color shifts in the phosphors were present.

The methacrylate inks had low volatility, were impervious to atmospheric conditions, and exhibited little tendency to be absorbed by the form rollers and blanket materials. The inclusion of mineral oil for obtaining good distribution properties created a problem in that the fluidity of the resulting inks required close control of impression pressure to prevent excessive pattern enlargement. The good distribution, press stability, and transfer characteristics of these inks made it evident for the first time that production of satisfactory three-color phosphor screens was actually possible with the offset letterpress process.

Printing of Three-Color Phosphor Patterns

When an ink formulation showed sufficient promise of producing satisfactory patterns with the green phosphor, the inks were reformulated with the red and blue phosphors for printing all three patterns. It was usually found that a formulation could tolerate about 5 percent more red and blue phosphor.

Printing Three Patterns on the Single Color Press

The Vandercook No. 22-34 Offset Proof Press could print only one color pattern at a time, and therefore a special technique had to be developed for printing three patterns.

After the first color pattern was laid down, the glass plate was removed from the press and dried in an oven so that the phosphor pattern would not be picked up by the offset blanket when subsequent patterns were printed.

For printing the second color, the press parts had to be completely cleaned of all traces of the first color ink to prevent intercontamination of the phosphors. A special three-pronged jig was used for repositioning the glass in the same location on the press bed. Registration of the second color was accomplished by moving the im-

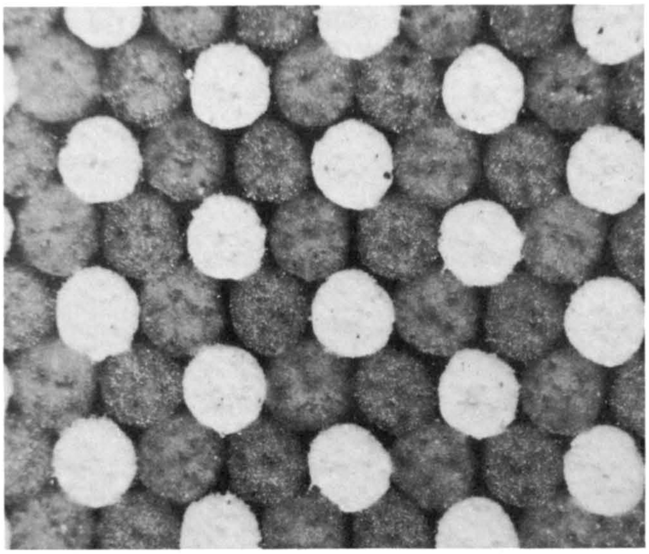


Fig. 5 – Three color print from the one color press.

pression plate the proper distance using dial indicators graduated to divisions of 0.5 thousandths of an inch. After the second color was laid down, the glass plate with the two patterns was again removed and dried, and the same procedure followed for printing the third color.

The three color patterns produced in this manner were then checked in an actual tube for registry, light output efficiency, uniformity, contamination, and inter-contamination. Typical patterns printed on the press are shown in Fig. 5. The best three color patterns were produced with the methacrylate-based inks.

Experiments on a Multi-Color Press

The success achieved in printing with the methacrylate inks on the one color press warranted extending the experiments to include printing the three patterns simultaneously on a multi-color press.

A Vandercook four-color offset proof press was modified and installed by the RCA Tube Department at Lancaster, utilizing the same principles of operation as described for the one-color press. Three separate impression plates for each of the colors were located on the press bed in proper registry. The offset blanket picked up the impression from each plate in sequence and then deposited the three patterns simultaneously on the coated flat glass.

Douglas L. Collins

Douglas L. Collins

Wm. C. Walker

William C. Walker

Jacqueline Fetsko

Jacqueline Fetsko

James V. D Eppes

James V. D. Eppes

Carolyn E. Moore

Carolyn E. Moore

Albert C. Zettlemoyer

Albert C. Zettlemoyer

References

[1] Walker, W. C., and Zettlemoyer, A. C., *Am. Ink Maker* 27 (9) 67 (1949).

[2] Woodward, J. C., *J. Coll. Sci.*, 6 (5) 481 (1953).