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CONTENTS

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RCA REVIEW

AN ELECTRON TUBE FOR HIGH-SPEED TELEPRINTING*

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Summary—*A new type of image-selection and display tube is being developed to reproduce letters and numbers in luminous form, which may then be recorded photographically. Selection from the compound beam produced by photoemission is accomplished by magnetic deflection from coded input control. A second deflection system positions the characters into any desired format on a fluorescent screen. A major field of application is in business machines where high-speed operation is required. Speeds of several thousand letters per second are achieved with a format of 4000 well-formed characters on a 5-inch screen. Precision electronic control is required for the deflection and focusing currents.*

INTRODUCTION

WITHIN the past few years the development of electronic applications in various fields has created a need for high-speed printing devices which operate directly from data in coded form. Since the speeds required begin to tax the upper limits of electromechanical devices, it appears natural to turn to electronics for a new method.

This paper introduces a new electron-image tube for selecting and displaying characters in a luminous form, which may then be photographically recorded. The operation of this tube simulates typesetting in the steps of selecting letters one-by-one from a "font" and placing them in a line or format. The "font" consists of a chart of characters on a lantern slide which is projected onto a photoemissive cathode. Selections are made from the resulting electron-image stream and directed to the desired position on a phosphor screen. The resulting luminous images may then be projected onto a photographic film as a means of recording or of making a master for printing.

The input control may come from any of the usual sources but preferably in a sequential pulse code. Perforated paper tape or magnetic tape are typical examples. The control can also come directly from a keyboard or from electrical storage. Similar signals received via wire or radio could also be used.

* Decimal Classification: R138.31.

THE IMAGE SELECTION AND DISPLAY TUBE

This new tube is fundamentally an electron-image device and consequently differs in several respects from the more common forms of beam-type cathode-ray tubes such as those used in oscilloscopes and television sets. The essential parts of the tube with its associated magnetic coils are shown in Figure 1. The photoelectrons liberated from the cathode when a letter chart is projected on it are accelerated by a potential of about 100 volts applied to the conductive wall coating. The resulting electron stream is focussed at essentially unity magnification upon the plane of a selecting aperture by a uniform axial magnetic field of about 100 gausses from the first focus coil. The aperture size is made such that one letter only from the array can pass through it at a time. In present models the aperture is round with a diameter of 0.04 inch. A set of magnetic deflection coils located inside the first focus coil deflects the entire electron-image stream for letter-by-letter selection.

The single-letter portion of the electron stream emerging from the aperture enters the positioning and reproducing end of the tube. Here it passes axially through a polished metal cylinder, the potential of which is maintained a few volts negative with respect to the aperture in order to suppress secondary emission. Next it enters the high-potential region where the wall coating is operated at 20 to 30 kilovolts. The letter is finally reproduced on a 5-inch-diameter aluminized phosphor screen. Focusing and positioning on the screen are accomplished by means of a second focus coil and a second set of deflection coils, also shown in Figure 1. The reproduced letters may be displayed in lines and columns as desired. The high-voltage limitation of the tube is set by field emission between the polished electrode and the wall coating. The image definition and brightness are both best at the maximum usable voltage. Present models of the tube are 25 inches long from photocathode to phosphor screen.

Adjustment of the second-focus-coil current and position may be used to vary the size of the letters on the screen from 1.5 to 12 times that at the selecting aperture. When properly adjusted the tube shows no interaction between the letter-selecting and letter-positioning operations. The reproduction and alignment of the letters is good from any location on the photocathode chart to any position of the image on the phosphor screen. It is essential that there be accurate alignment of the coils with respect to the tube and that the plane of the photocathode and of the selecting aperture be simultaneously in focus upon the screen. Optimum performance is obtained by a series of small trial adjustments of electrode potentials and focus-coil currents.

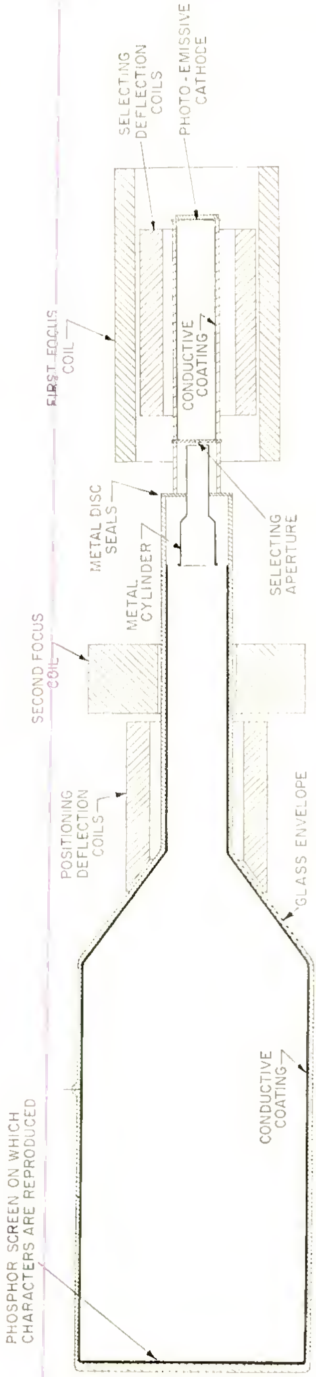

Fig. 1—Sectional view of image selection and display tube with focus and deflection coils.

System Operation

Before discussing performance characteristics and other features of the image selection and display tube, information will be given in connection with an experimental operating system as depicted in Figure 2. In this setup of equipment, which has been extensively used to evaluate the tube performance, standard 5-unit perforated teleprinter tape serves as a source of coded input information. A motor-driven loop of this tape with a repeated test combination of characters is convenient since the observed result appears to be continuously

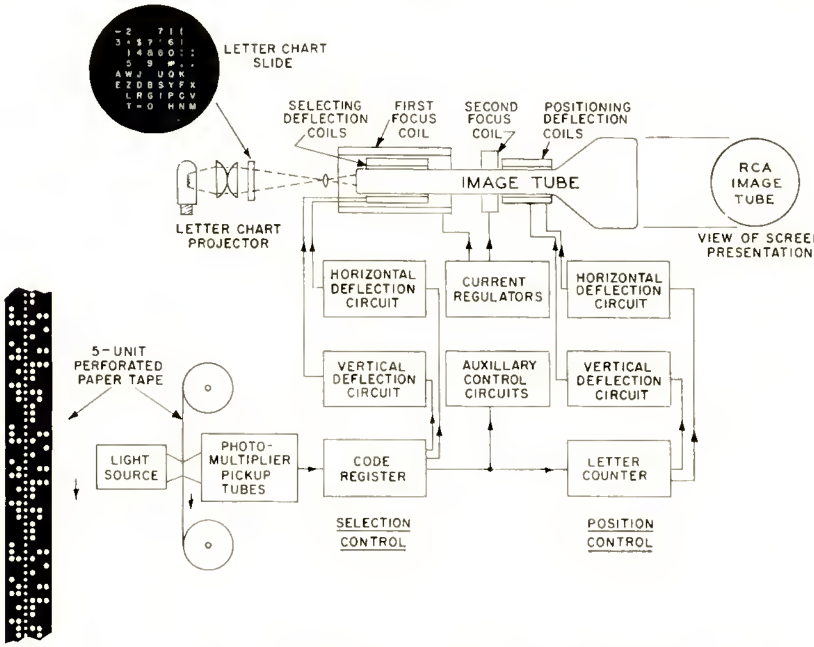

Fig. 2—Experimental operating system for testing image selection and display tubes.

displayed on the screen. To obtain high-speed reading of the perforated tape, the usual mechanical sensing is replaced by a light-beam method. The lateral rows of tape code holes are flooded with light and their images are projected onto a series of secondary-emission photomultiplier tubes. Each code combination then exictes a different combination of phototubes according to the letter to be selected. A set of locking-type multivibrators, actuated by the phototube outputs, acts as a code register to hold each selection until the next one arrives.

The letter chart to be used is projected steadily on the photocathode to produce the compound electron stream from which selections are made. Since this image-type stream is subjected to twist or rotation as it passes through the focus-coil fields, the letter-chart slide in the projector must be rotated to produce proper character orientation on the screen. The selecting deflection yoke must also be appropriately positioned to make its deflection axes orthogonal to the chart.

Two letter-chart slides mounted in ring gears are depicted in Figure 3. The left-hand one comprises a set of conventional block-type letters, numerals and punctuation marks while the right-hand one consists of upper and lower case letters of Bodoni type face.

The arrangement of the characters in the make-up of the chart follows in this case from the standard teletype code and the use of binary stepped increments of horizontal and vertical deflection cur-

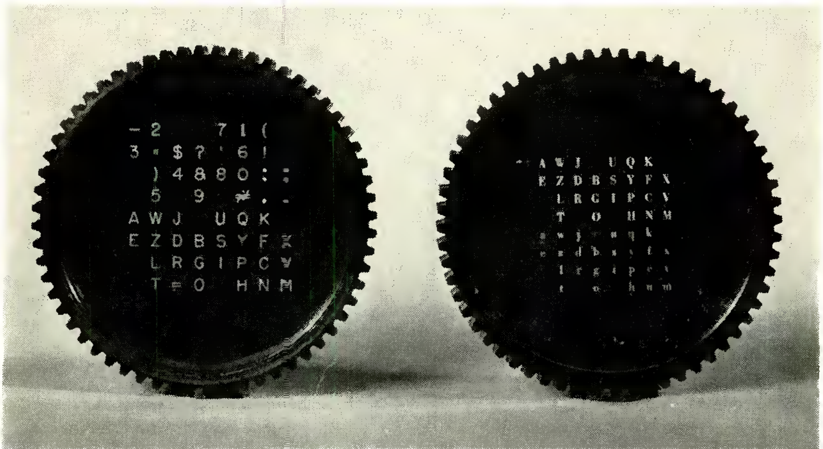

Fig. 3—Photograph of letter-chart slides mounted in ring gears for rotational adjustment.

rents. Each code hole is translated into a vertical or horizontal component of deflection current having a value of 1, 2, or 4 units. The general details of one of the deflection circuits are shown in Figure 4 in order to illustrate how this binary decoding scheme functions.

Deflection- or yoke-coil currents ranging from positive to negative values are supplied in a differential manner from a pair of tandem-connected triode tubes V1 and V2. With no input from the code register, the centering control is set to give a value of deflection current corresponding to zero or no letter selection (lower left-hand corner of chart). In this condition, as well as for all other selected steps, the yoke current is accurately stabilized by the feedback action of the circuit. Any stray variation in this current causes a change in the sensing potential across resistor R1. This changes the feedback amplifier input which drives the grids of supply tubes V1 and V2 to bring the current back to the proper value.

A second and opposing component of the feedback amplifier input comes from a second sensing resistor R2 which is many times larger than R1. The passage of small control currents through R2 results in the production of relatively large currents in the yoke coil since the algebraic sum of sensing potentials must remain constant. The circuit may be regarded as self-balancing since it tends to hold the amplifier input potential at a constant value.

A series of switch tubes V3, V4, and V5 are arranged to draw binary-weighted control currents through resistors 4R, 2R and R, respectively. These resistors are large compared to the tube-plate impedances so that precise steps of current are drawn through R2. As one or more of these switch tubes are turned on by a combination

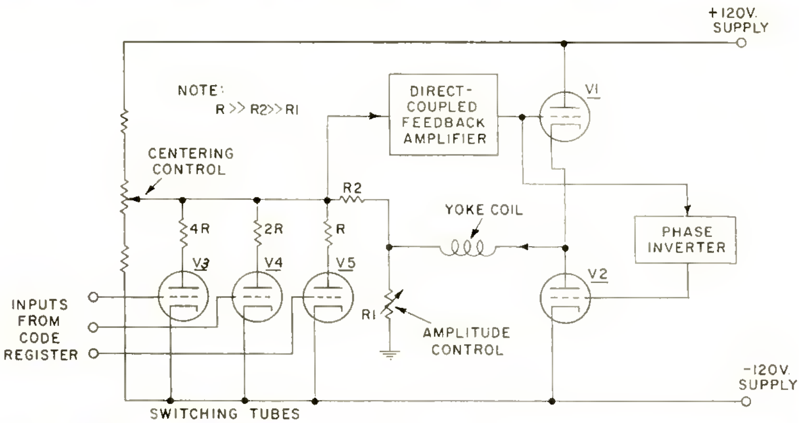

Fig. 4—Precision deflection circuit for producing binary controlled steps of current.

in the code register, the potential across R2 changes to a different value. This causes the feedback loop to stabilize on a different value of yoke current corresponding to the demand. With this triple binary arrangement, eight steps of current can be produced for the eight lines or columns on the chart.

If the selecting deflection current steps are accurately adjusted, each selected letter image in the cross section of the electron stream will pass precisely through the center of the aperture and good character alignment on the screen will be obtained.

Certain other circuit functions pertinent to the operation of the selecting end of the image tube are indicated by a block in Figure 2 designated Auxiliary Control Circuits. One of these is a blanking device which momentarily stops electrons from reaching the screen during the interval of transfer from one letter to the next. Another circuit portion operates as a special code detector and vertical-deflection-shift means so that selections may be made from the figures (FIGS) section of the chart as well as from the letters (LTRS) section. This utilization of two code combinations for the FIGS–LTRS shift operation allows an increase from the 32 five-unit code combinations to 60 character selections. This is needed for the alphabet plus numerals plus punctuation marks and other symbols.

In the experimental test setup, the positioning of selected characters is controlled by a letter counter. With no positioning deflection current, all letters would be reproduced in a common position at the center of the phosphor screen. The letter counter receives one pulse for each letter selected and controls the horizontal and vertical positioning deflection circuits to put these letters uniformly across the screen in one or more rows. Since the counter is a binary-chain device, it allows use of a binary-step deflection system similar to that just described except that more steps are used.

Performance and Applications

The required quality of reproduced characters for a typical machine printing application is comparable to that of teletype printing. This level of quality lies somewhere above that required for accurate readability. In other words, each reproduced character should have not only sufficient sharpness to be unmistakably identified but must also be easy to read. It has been observed with block-type characters that a limiting condition has been reached in accurate identification when a letter B can just be distinguished from a figure 8. A practical printing system for the above type of application must do much better than this.

The original goal picked for the image tube was to produce 48 lines of 80 characters each on its screen. This represents a square raster since the final output printed copy was to have 10 characters per inch horizontally and 6 lines per inch vertically. On a round phosphor screen the equivalent number of letters across the diameter (corresponds to a diagonal of the square) is $80\sqrt{2} = 113$. For a nominal 5-inch tube having a 4.25-inch useful screen diameter, a requirement of 26.6 letters per inch is indicated.

It is pertinent to try to evaluate this requirement in terms of the television and facsimile terminology for definition. In this case definition is expressed as the maximum number of alternate black plus white lines that may be resolved across the full raster or line length. Various experimenters have observed that the so-called matrix type of printing requires a grid of at least 5 points by 7 points to produce letters and figures that can be accurately read. Translating this directly into lines of resolution or definition and allowing 20 per cent for the space between characters gives 500 lines for the 80-letter line. Since this is the minimum requirement for accurate readability, the number should probably be doubled. Thus in common parlance, something in the order of at least 1000-line definition is required.

In addition to the requirement for definition there are the matters of speed and format composition. Operation at several thousand characters per second appears to be a practical speed and can readily be attained with an electronic device. In many applications there is a need to control the composition of output characters to fit into spaces on a prearranged form. The new tube offers wide flexibility in this matter since it is not only possible but entirely practical to include positioning information in the input code. For example in producing a financial statement, groups of words and figures must be placed in various positions on the form. A portion of the input coded data may be directed to control the positioning deflection circuit so as to accomplish this result. The tube and the system have been developed to meet these requirements of definition and format composition.

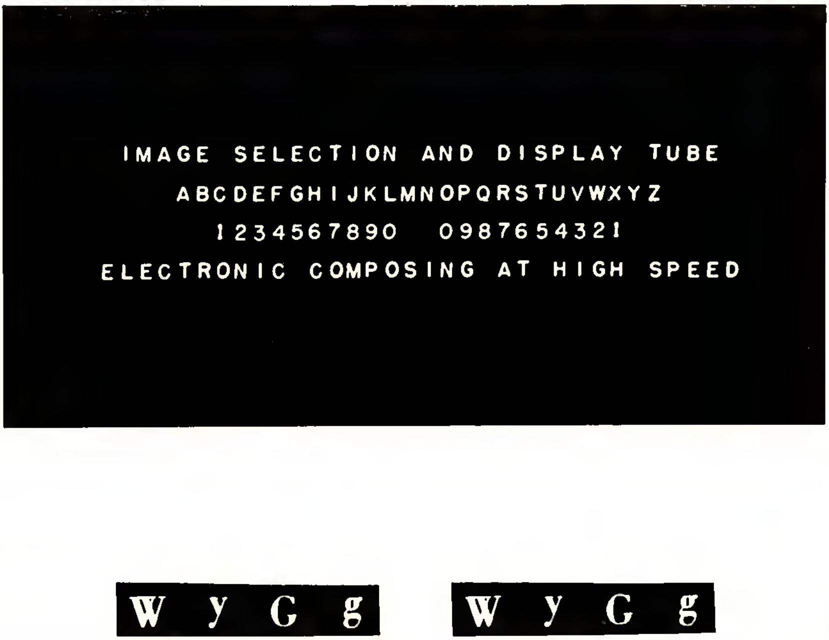

Fig. 5—(Upper) Photograph of image tube screen operating at 1100 letters per second spaced 12.5 per inch on the screen.
(Lower) Screen photographs of reproduced Bodoni type-face letters.

Figures 5 and 6 are photographic reproductions from the 5-inch screen of an experimental tube. The upper part of Figure 5 shows typical operation at 1100 letters per second of suitable size to give 12.5 characters per inch on the tube screen. Figure 6 is a raster of 48 lines of 80 characters each. Readable letters have been observed on a 5-inch screen with more than 35 per inch. Good reproduction with no defocusing occurs over the entire screen.

The present model of the image tube is the result of a series of several experimental tubes. The long spacing from positioning deflec-

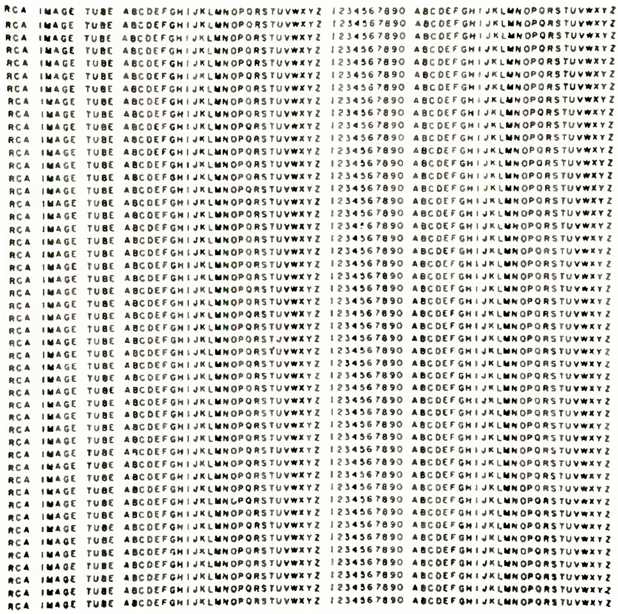

Fig. 6—Photograph of image-tube screen with an 80-letter loop of input tape repeated 48 times to fill the raster. Negative reproduction.

tion yoke to screen permits a low value of deflection angle, which not only lowers the deflection power requirements but decreases the distortion difficulties. Cathode-ray tubes usually experience a certain amount of defocusing at wide deflection angles but this has not been observed in any of the models. However, distortion in the form of letter twist or rotation has been observed in some cases at maximum deflection. This can be corrected readily by circuit means.

Power supplies for the system must have good regulation since variations in applied currents and voltages can affect both focusing and letter alignment. It has been found desirable to use regulators on the focus-coil currents to compensate for temperature changes. As indicated previously, the deflection circuits require considerable precision and stability.

This discussion would not be complete without some reference to light levels and letter sizes in the system. The present practice is to project the letters onto the photocathode with the over-all chart size reduced to 0.25 by 0.25 inch. This results in individual letter heights of 0.018 inch. The initial end of the tube operates with a slight magnification (about 1.0 to 1.2) so that the letters are readily selected by the 0.04-inch round aperture. Without the aid of the second focus coil there is a magnification up to about 0.25 inch at the screen. For 26.6 letters per inch the focus coil current is increased sufficiently to reduce the letter height to 0.035 inch.

A high level of screen brightness is required for photographic recording at the speeds previously indicated. In one case ample light was available from the screen to expose 35-mm film at 2,000 characters per second. With high sensitivity film, speeds of 10,000 letters per second seem to be within reach before serious screen browning occurs. With photocathode sensitivities of 10 microamperes per lumen or better, these levels of output can be obtained with an input light value of thirty thousand foot-candles. This is provided by a slightly modified standard slide projector with a 300-watt lamp and a short-focal-length lens.

Although the immediate application of this new tube is in the field of high-speed record or message printing, there is a definite possibility of future use in the general printing of such material as books and magazines. A considerable amount of development work by the graphic arts industry has been done in the photographic reproduction of characters for typesetting by optical means. Although the image tube offers a means of more rapid selection than conventional methods and a readily controlled presentation of optical letter images in a given format, the high standard of quality now required in the printing industry is difficult to attain. This offers a challenge for future development.

In this connection some letter chart slides were made up with three commonly used type faces (one of these was mentioned before and is shown in Figure 3). The letters in the lower part of Figure 5 are the result of this type of reproduction. It is apparent that the effects of limiting resolution on the phosphor screen can be overcome by producing the characters in large size and optically reducing them.

Conclusions

The continued development of the image selection and display tube should produce a practical design which will fill the need for a high-speed printer to operate directly from coded input information. Improvements in screen quality and size give promise of attaining at least 150 well-formed characters across the screen. This is more than ample for most printing where type lines seldom exceed 70 letters in length.

The outstanding features of this new electronic device are presented again in conclusion. As with all electronic devices, high speed of operation is inherent. Handling several thousand characters per second is practical in this case. Of particular interest is the feature that allows rapid change of letter style. The letter chart can be readily and quickly replaced by any one of a series kept in stock. For business machine printing, the matter of format or positioning control is important. The new device is extremely flexible in this respect and permits the composition of material to fit standardized forms. The feature of offering a visual display of information has merit for some applications.

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