Send Hand

TECHNICAL DEVELOPMENT REPORT NO. 388

EVALUATION OF THE TI-440 PICTURE TRANSFORMER EQUIPMENT AND NOTES ON TELEVISION-TYPE AIR TRAFFIC CONTROL DISPLAYS

FOR LIMITED DISTRIBUTION

by

William E. Miller
William G. Covell

Navigation Aids Evaluation Division

March 1959

1637

FEDERAL AVIATION AGENCY
TECHNICAL DEVELOPMENT CENTER
INDIANAPOLIS, INDIANA

FEDERAL AVIATION AGENCY

E. R. Quesada, Administrator

D. M. Stuart, Director, Technical Development Center

This is a technical information report and does not necessarily represent FAA policy in all respects.

EVALUATION OF THE TI-440 PICTURE TRANSFORMER EQUIPMENT AND NOTES ON TELEVISION-TYPE AIR TRAFFIC CONTROL DISPLAYS

SUMMARY

The Type TI-440 Picture Transformer equipment manufactured by Compagnie Generale De T.S F in France is a rho/theta-to-rectilinear scan-conversion equipment using a Type TMA 403X storage tube It is designed to convert radar plan position information into a composite television video and sync signal suitable for providing a display on television types of monitors. Tests indicate that the storage tube resolution, halftone writing, and storage characteristics permit this display to compare very favorably with that of a plan position indicator using a cathode-ray tube with a P-7 phosphor. The great advantage of the scan-conversion displays over conventional radar presentations is greater brightness Greater brightness is achieved because the information read from the storage tube can be displayed on low-persistence, bright-phosphor, cathode-ray tubes, and because the information is displayed at high rates.

The results of tests conducted during the evaluation reported herein indicate that scan-conversion equipment having similar performance characteristics should be procured for use at air traffic control facilities to provide improved displays Although the design of the TI-440 equipment does not meet some of the FAA equipment and display requirements, limited quantities of this equipment can be used at critical locations to obtain immediate improvements in displays Implementation of scan-conversion systems at other locations can be made as soon as systems meeting all the FAA requirements are procured

INTRODUCTION

The development of better radar displays for air traffic control has been a continuing project at the FAA Technical Development Center (TDC) In the fall of 1956, a survey was conducted to determine the state of the art in the radar display field. Several new possibilities were uncovered as a result of this survey A display system which appeared to offer the most promise with regard to quality of presentation and possibility of early employment was a scan-conversion equipment This equipment, referred to as Picture Transformer, Model TI-440, was built by Compagnie Generale De T S F., 79 Boulevard Haussman, Paris 8, France The French company is represented in the United States by Intercontinental Electronics Corp. (INTEC), Mineola, N Y.

The TI-440 unit used in the evaluation was brought to the United States by INTEC and demonstrated to engineers at this Center in February 1957 During the demonstrations, it was evident that the display provided by this equipment had several very desirable characteristics Accordingly, the equipment was purchased from INTEC for further evaluation

PURPOSE OF EQUIPMENT

The TI-440 Picture Transformer equipment accepts video, trigger, and azimuth information from a radar, and by use of a two-gun electronic readout storage tube and associated circuitry, converts it to a television-type composite video and sync signal. The composite output signal may be used to drive television-type monitors to provide a radar display for use in air traffic control. One advantage of such a display is its high brightness, for it can be viewed under much higher ambient light levels than a conventional plan position indicator (PPI). Scan-conversion systems[1] evaluated previously had less resolution, a poorer signal-to-noise characteristic, loss of gray scale, and in some cases, lack of adequate storage or persistence, when compared directly with a PPI using a cathode-ray tube (CRT) with a P-7 phosphor. These restrictions appear to have been overcome in the TI-440 equipment.

DESCRIPTION OF EQUIPMENT

General

All of the components of the TI-440 equipment, Fig. 1, are mounted in one cabinet approximately 5 feet high, 3 feet wide, and 2 feet deep A panel door on the left-hand side contains the operating controls. The principal chassis are mounted vertically on a swing-out frame which is available behind an access door The swing-out frame facilitates the maintenance of these chassis The low-voltage supplies are mounted at the bottom of the cabinet and the filament transformers are mounted on the back panel

The equipment was designed to operate from a 220-volt, 50-cps, single-phase, primary power source but operates satisfactorily with 60-cps power It operates with radar inputs as follows. video, approximately 2 volts peak-to-peak, positive polarity; trigger, minimum amplitude 10 volts peak-to-peak, positive polarity at pulse repetition frequencies (prf) from approximately 200 to 1,500 cps, synchro information, 1-speed and 10-speed (36-speed gearing is available).

The following controls are provided on the control panel:

1. Meter and switch to provide metering of all low-voltage power supplies, input line voltage, collector potential, antishading ring potential, and target potential.

2. Input radar video switch (selects either or both radar video inputs.

[1] William E. Miller, Marvin H Yost, and David S. Crippen, "Evaluation of the DuMont SRD-1 Bright Radar Display and Initial Study of Other Display Techniques," Technical Development Report No 288, October 1958

3. Radar range switch

4. Range mark switch

5. Writing-beam intensity.

6. Angle mark gain.

7. Centering for writing side of storage tube.

8. Sync generator AFC control and fast-erase switch

9 Storage control switch (has been replaced by potentiometer in later models).

10. Reading gun focus control

11 Reading gun beam intensity

12 Hour meter.

13. Fuses and main power ON-OFF switch.

Writing Circuits.

The writing circuits consist of a radar video mixer-amplifier, trigger amplifier, range-mark generator, servo amplifier, angle-mark generator, sweep generator, unblanking circuits, and protection circuits.

The radar video mixer-amplifier accepts two video inputs and range marks and amplifies them for application to the writing gun cathode.

The range-mark generator provides 5- and 25-nautical-mile (nm) markers with independent gain controls so that 25-nm marks may be written at a higher intensity than the 5-nm marks The output of the marker generator is connected to the radar video amplifier where it is mixed with the radar video

The sweep generator generates the sweep currents for the rotating sweep-deflection coil mounted around the writing end of the storage tube.

The servo amplifier accepts the selsyn voltages to provide correction to the two-phase motor that rotates the deflection yoke through a gear train. A microswitch that is actuated once during each rotation of the 10-speed selsyn provides a triggering potential from which the angle marks are derived. The angle mark trigger pulse also is used to derive a bias for the protection circuit which cuts off the writing beam during failure of either rotation or sweep voltage

Unblanking signals derived from the radar trigger amplifier are mixed with the angle mark video and impressed on the writing gun grid.

Normally, the higher speed selsyn in this equipment is a 36:1 unit, and it was with the higher speed system that the angle-mark generator was designed to work, thus providing 10° marks. With the 10-speed unit, the angle marks are too broad and occur every 36°. Therefore, they were not used during the evaluation.

Storage Tube.

The heart of the TI-440 equipment is the storage tube, Type TMA 403X See Fig 2. This tube is somewhat similar in principle of operation to the RCA Graphechon.[2] Its major sections are a writing gun, a reading gun, and a storage surface, or target assembly See Fig 3. The two guns are diametrically opposite each other with the target between them The writing beam is deflected magnetically and focused electrostatically Its cathode is operated at approximately 8,000 volts negative potential Since the target normally is operated at near ground potential, this provides a writing-gun accelerating potential of about 8 kilovolts (kv). The reading-gun beam is deflected and focused electrostatically and its cathode is operated at 1,200 volts negative potential

The target is a very thin metallic backplate which faces the writing gun. The surface toward the reading gun is an insulating material deposited on the backplate. The metal backplate potential normally is 40 volts positive, but in later models of the TI-440, the backplate is operated at ground potential

Also on the reading side of the target and insulated from it is a ring which, when slightly positive with respect to the target, helps prevents shading. In addition to the antishading element, there also is a collector which receives secondary electrons from the target insulator surface when it is bombarded by the reading beam. When used in the TI-440 equipment, the writing beam is deflected with a rotating PPI-type yoke and the reading beam is deflected in a rectilinear TV scan operating at 625 lines per frame at 30 frames per second.

In the absence of a writing signal, the reading beam, in scanning the insulator surface, operates in a mode which is above the first crossover point of the dielectric material which composes the insulator surface That is, more secondary electrons are leaving the surface to move to the collector than are arriving in the primary beam As the reading beam continues to scan the insulator, its surface potential tends to move toward that of the collector until a state of equilibrium exists. The secondary emission ratio approaches unity. When writing signals are applied, the thin metallic backplate, which is transparent to high-velocity electrons, permits the writing-beam electrons to reach the insulator and render it conductive during the time the beam is falling on it. As the writing beam moves on, the insulator regains its insulating properties, but its surface has assumed some portion of the backplate potential proportional to the writing-beam current. The surface charge resulting from the writing-beam bombardment is reflected in the secondary emission current on the reading side of the tube. The equilibrium is upset at the point of charge until

[2] Miller, Yost, and Crippen, op. cit

the reading beam has scanned sufficiently to bring it to a more positive potential. The storage characteristic is dependent upon writing-beam current, reading-beam current, and the difference of potential between the collector and the target backplate

The video output signal is a function of the secondary electron currents which appear across load resistors between the collector and ground, and the target and ground Since the signals are of opposite polarity at these two points, one is applied to the grid and the other is applied to the cathode of an early preamplifier stage in order to have them add in the plate circuit. This technique eliminates writing-beam crosstalk signals from the TV video signal since the crosstalk appears in phase at the two signal removal points.

The useful tube life has been found to be between 700 and 1,500 hours. So far, all tubes have had to be replaced because of an apparent loss of reading-gun cathode emission. This results in an extremely low reading-beam current, which causes a poor reading-side signal-to-noise characteristic and excessively long storage

Reading Circuit.

The reading side of the TI-440 equipment starts with the television sync generator which operates at either a 525- or 625-line standard. Experience with large display monitors indicates that the 625-line standard is the most satisfactory It has not been determined whether a greater number of lines per frame will provide a better quality picture. The sync generator provides the synchronizing pulses for reading sweep circuits, blanking circuits, video clamping circuits, and the composite sync waveform for use in synchronizing the monitor deflection circuits The composite sync waveform is of the French standard, which is somewhat different than the U. S. RETMA standard. In the French system, the vertical sync pulse is 20 microseconds wide, while in the U. S standard the width is approximately 190 microseconds The French standard does not require the use of equalizing pulses or serrations because of the narrow width of the vertical sync pulse. Since standard U S monitors are designed to operate with the much wider vertical sync pulses, some modification is required for proper synchronization and vertical interlace when the French sync waveform is used The French sync system does not lock in readily with RETMA sync generators.

Pulses from the sync generator are used to develop a blanking waveform which is applied to the control grid of the reading gun. Horizontal pulses are used to drive video clamping circuits. The equipment was modified slightly to provide a mixed blanking output. Horizontal and vertical sync pulses are used to derive the deflection voltages for the reading-side electrostatic deflection plates

The video signals from the collector and target elements of the storage tube are mixed in a video preamplifier. From the preamplifier, the signal is connected to a wide-band video amplifier where blanking and mixed sync signals are added. Two video outputs from this amplifier consist of composite sync and video signals.

TECHNICAL EVALUATION

The technical evaluation of the TI-440 equipment was concerned primarily with determination of storage tube characteristics. Tests of storage, resolution, and halftone writing characteristics were conducted. The ability of the TMA 403X tube to read signals in noise was compared with that of a P-7 phosphor-type tube. The linearity of reading- and writing-beam deflection systems was checked.

Storage.

As was pointed out previously, the storage characteristic of the TMA 403X tube in the TI-440 equipment is dependent upon writing-beam current, reading-beam current, and difference of potential between the target and the collector. Of these three parameters, reading-beam current and collector potential have the greatest effect on storage. It has been noted also that different tubes have somewhat different storage characteristics, apparently due to differences in the composition of the target dielectric. The manufacturer has stated that the differences were intentional and that different dielectrics can be used to provide almost any kind of storage characteristic that may be desired

The operator-adjustable storage control switch on the control panel permits selection of three steps of storage. This switch selects different values for the collector potential. A screwdriver adjustment of a potentiometer may be varied to change the range of storage adjustment by the three-position switch Storage times from a few seconds to several minutes may be attained.

For applications in radar and radar beacon presentations for air traffic control, a particular decay characteristic is desired. It is necessary that the brightness of the target on the presentation decay sufficiently within one antenna rotation period so that any new returns in the same area will not be obliterated by information stored previously The same decay characteristic is desirable for a beacon display so that identifying codes such as the double pulse or the "bloomer" blips may be distinguished.

It was possible to set the storage controls on the TI-440 so that such a characteristic was attained. Figure 4 depicts this characteristic. The curve was plotted from information obtained when beacon returns were being written with maximum readout amplitude, or brightness, on the monitor A Tektronix Type 524 oscilloscope, having television raster-line selector capability, was used for measuring the amplitude of the reading-side output signal. The amplitude was recorded every antenna rotation period of 4 seconds.

The same test was performed for antenna rotation periods of from 2 to 10 seconds. It was necessary to adjust the reading-beam current to a new value for each new antenna rotation period In making these tests, it became apparent that the setting of reading-beam current influenced the rate of decay for the first period, the interval during which maximum signal readout was obtained During subsequent periods, the decay was affected most by the settings of collector potential. Higher reading-beam currents produced quicker initial decay, while higher collector potentials produced longer decay times.

After operating with a low collector potential so that moving targets had relatively short trails, it was noted that trail information which had not been showing would appear if the collector potential was increased. This characteristic might be useful in a situation where it would not be practical to operate with long storage because of heavy air traffic However, if necessary, the controller could, by increasing the collector potential momentarily (pushing a button), bring up the old trail information to check past history on some aircraft The collector potential then could be reduced to return the display to normal

In another test of maximum and minimum storage, pulses from a Hewlett-Packard Model 212A pulse generator were synchronized with the radar trigger and connected to a video input. The amplitude was adjusted to produce full readout amplitude or maximum brightness. When the signals were written during one antenna rotation period under conditions for minimum storage, the trace was not visible after approximately 1 second Under maximum storage conditions, the trace was visible for 20 minutes.

Signal-to-noise ratio of the reading-side output signal and storage time were determined for various reading-beam current values. The results are shown in the curves of Fig. 5 Reading-beam current was measured by means of a microammeter in the cathode circuit of the reading gun. Signal-to-noise measurements were checked with an oscilloscope connected to the TV video output test point All tube parameters except the reading-beam current were held constant during these tests. From the curves, it is possible to determine reading-beam currents such that the readout signals will decay to 50 per cent amplitude during various antenna rotation periods

Tests to obtain information on the relationship of writing signal amplitude to storage time were made. The curves in Fig. 6 show the results.

Resolution.

The resolution test was performed using range-ring video from an AN/SPA-8A indicator that was setting alongside the TI-440 equipment. Range-ring video, at 1-mile range intervals, was connected to the radar video output of the TI-440. The sweep range of the TI-440 was adjusted until separation between rings was barely discernible in a horizontal strip through the center of the TV display The TV display was a French-made, studio-type monitor using a 14-inch rectangular Kinescope and having a video bandwidth of 8 Mc The TV line standard during this test was 525 lines interlaced 2 1 for a 30-cps frame rate The azimuth rotation rate was 26 rpm. Under these conditions, the average result of the observations of three observers was that the TI-440 equipment and the display device as a system were capable of resolving 600 lines horizontally Vertical resolution in wedges about 30° in width from the center up, and from the center down, was approximately 450 lines.

Halftone Writing Characteristics.

The halftone writing characteristics of the TI-440 were determined by using the output of two pulse generators and the 5- and 25-mile range markers. The range markers have independently variable gain controls, hence, their amplitudes may be set at different levels. The output of the pulse generators which were synchronized to the system, operating at the prf of 1,200 cps, were connected to the two video inputs. The amplitudes of all four writing pulses were adjusted until there were four different written levels of brightness of the viewed display. The width of all pulses at the 70 per cent amplitude point was approximately 0.5 microsecond. It was possible to discern four distinct steps of brightness plus the dark background See Fig. 7. The pulse amplitudes measured at the output to the storage tube writing-gun cathode were 10, 7, 5, and 3.5 volts.

Signal-to-Noise Characteristics.

Signal-to-noise characteristics of the TMA 403X storage tube in the TI-440 equipment were compared with those of an AN/SPA-8A indicator using a P-7 phosphor cathode-ray tube. The output of a pulse generator synchronized with the system trigger was mixed with the output of a gas tube-type noise generator. Oscilloscopic observations were made of the average peak noise and peak signals When the average peak-signal to average peak-noise ratio was 1 3·1, the display from the TI-440 was satisfactory. The signal could be seen during the first rotation of the sweep. However, when the ratio was reduced to 1 1, two sweep rotations, or antenna scans, were required before the signal was integrated into useful visibility. On the SPA-8A display, at this signal-to-noise ratio of 1:1, the signal was faintly visible during the first sweep rotation However, subsequent scans did not make it any more visible. Due to the integrating properties of the TMA 403X, the display of the signal after the third scan was quite good and better than that of the SPA-8A display.

Sweep Linearity.

To check the sweep linearity, video from a grating bar generator was superimposed on the TV video output of the TI-440 and displayed on a high-quality monitor. Inasmuch as the grating bar video was used, the linearity of the monitor was not considered. The writing sweep range of the TI-440 was adjusted to superimpose 5-mile range rings and grating generator bars. Linearity adjustments of both reading and writing sweeps were checked and optimum settings were made in an attempt to make the range rings tangent to their respective bars. Figure 8 shows the display after optimum settings were made. Areas of nonlinearity are quite obvious from the picture Maximum error appears on the right-hand side in the horizontal direction. This error is approximately 1 8 per cent of the picture height. Since the grating bar interval amounts to 4.55 per cent of the picture height, errors in other areas of the display may be determined by estimating their fraction of 4.55 per cent. Considering a centered radar display, the error of 1.8 per cent of the picture height could result in a maximum range error of 3.6 per cent.

DISPLAYS FOR USE WITH SCAN-CONVERTED PICTURE

After the radar information has been scan-converted to a TV form of video and sync, it may be displayed to the controller in a number of ways. Some of these methods have been tried or are in the process of evaluation at TDC. They are described in the following sections.

VG Display.

Before describing the TV displays under evaluation, it is appropriate to describe the VG display, Fig. 9, used at Air Route Traffic Control (ARTC) Centers employing radar, with which the TV displays were compared. This equipment is a World War II development which includes a 4-inch dark-trace tube and a Schmidt optical projection system and associated circuitry. The dark-trace tube, Type 4AP10, stores radar signals which are written on the face of the tube The storage period can be controlled to some extent. A projection lamp and the optics cause the dark traces on the face of the 4AP10 tube to be focused on the underside of a 24-inch-diameter, ground-glass screen The display, while the best available for radar plotting purposes in the past, has poor resolution, insufficient control of storage, short tube (4AP10) life, and it is not large or bright enough for present day ARTC Center functions. These deficiencies notwithstanding, the VG display does permit ATC operation under marginal ambient light conditions and has the advantage that limited amounts of data can be associated with the radar target data. This is accomplished by placing small transparent chips on the top surface of the ground-glass screen and by positioning them so that they are associated with their respective radar target. On these chips, controllers write the flight identity, and sometimes aircraft altitude, with a grease pencil.

Thirty-Inch DuMont Direct-View Display.

This unit, designed and manufactured by the Allen B. DuMont Laboratories, Inc., originally was a part of the CAA bright display equipment, Type SRD-1.[3] It incorporates a 30-inch, round television tube mounted with the face up in a large metal table The unit has self-contained power supplies, deflection circuitry, and video amplification. Of the direct-view TV displays, this was the largest. There are two important operational objections to it: (1) a large amount of parallax exists, particularly at the outer periphery of the CRT, between the flat plotting surface and the display phosphor of the tube; and (2) hand capacity distorts the display severely each time the operators move a marker chip. This latter objection undoubtedly can be overcome by better design. Figure 10 shows this display being used during a simulation test

Twenty-Two-Inch, Direct-View, Flat-Face Display.

This unit, shown in Fig. 11, was designed and constructed at TDC for demonstration and evaluation purposes. It does not have the parallax and hand-capacity effects found in the 30-inch display. A 22-inch,

[3] Miller, Yost, and Crippen, op. cit.

flat-face tube, manufactured by the Rauland Corp , is mounted face up in a wooden cabinet and is driven by a standard CONRAC 27-inch TV chassis, Type CG27-A.

The main advantage of this display is the reduction in parallax, as compared to that of the 30-inch display, and the smaller physical size of the cabinet, as compared to the VG, although the size of the plotting surface is almost equivalent to that of the VG plotting display. The unit weights only 200 pounds as compared with 1,000 pounds for the VG. A properly designed unit would have contrast, resolution, and brightness equivalent to other TV displays, however, the size is not as large as is desired for en route control use.

Overhead Projection Display.

Direct-view CRT's have certain physical limitations that introduce parallax and limit their maximum size. Larger displays can be obtained by the use of projection systems. To show the possibilities of TV projection systems, overhead projection displays were constructed. Figure 12 shows a display obtained by overhead projection. The overhead system was obtained by modifying a commercial system, Type PB611-B, manufactured by General Precision Laboratories. The unit uses a 5-inch CRT, Type 5AZP4, operating at an anode potential of 40,000 volts. It uses a Schmidt optical system similar to the VG. The principal purpose of the TDC modification was to improve display linearity and video quality

While the projection systems eliminate parallax and do not impose restrictions on display size, there are certain disadvantages inherent in existing projection equipment. The brightness of the projected display is not adequate if display sizes between 40 and 50 inches are required, which makes it necessary to operate with low ambient lighting. Also, the display resolution is poor due to limitations in CRT resolution and in the lens system.

Superimposed Panoramic Radar Display (SPANRAD).

In the foregoing sections, the characteristics of VG, direct-view TV, and TV projection displays were discussed briefly. For some time, TDC has tried to reduce the number and magnitude of the compromises of the various display characteristics dictated by existing techniques One of these approaches has resulted in a display referred to as SPANRAD, shown in Figs. 13 and 14. One element of a SPANRAD system is a plotting surface which may be as large as desired. Opaque markers positioned manually on the plotting surface are picked up by a TV camera mounted overhead. A second element is a direct-view TV monitor on which is displayed the radar picture from the TI-440 or other scan-conversion equipment, as well as the output of the TV camera The advantages of the SPANRAD system are that resolution and brightness qualities of bright-phosphor cathode-ray tubes are retained, and the flight markers are positioned with reference to radar targets viewed on the TV monitor The TV camera will not resolve small written data carried on the markers, but larger numbers or symbols on the markers can be used to identify the markers on the TV monitor. This results in a display that has a limited amount of alpha-numeric or symbolic information associated directly with the radar return.

TV Displays in Tower Cabs.

TV monitors have been installed in the cab of the Indianapolis Airport control tower on an in-service evaluation basis. These are 17- and 21-inch CONRAC monitors with no refinements or modifications. Originally, they were driven from a remotely located TI-440 scan-conversion equipment. Recently, new TI-440 units have been installed in the tower equipment room. The monitors are used to assist the tower in sequencing VFR and mixed VFR/IFR traffic in the airport pattern and for VFR advisory service. For these purposes, the TI-440 is connected to the airport surveillance radar, Type ASR-2. A view of a TV monitor in the Indianapolis tower is shown in Fig. 15. A close-up view of a scan-converted display of the ASR-2 radar is shown in Fig. 16. In-service tests of displays at the Indianapolis Airport control tower are described in another report.[4]

CONCLUSIONS

The results of tests of the TI-440 equipment and its storage tube indicate that the resolution, halftone writing, and storage characteristics are such that very useful radar displays can be obtained. Displays of scan-converted radar information from the TI-440 equipment compare favorably with plan position indicators using a cathode-ray tube with a P-7 phosphor. In addition, scan-converted displays derived from storage tubes have the advantage of much greater brightness The TV-type reading scan, together with storage, permits continuous renewal of information on bright-phosphor tubes which may be viewed under high ambient light conditions.

The TI-440 equipment in its present form is not considered suitable for implementation on a large scale. However, it can be used for in-service testing and at critical locations having specific display problems Drawbacks in the present design are:

1. The television sync system, being of the French standard, is not compatible with the United States' RTMA system.

2. Reading-side deflection voltages are not sufficiently linear.

3. The rotating coil used for deflection of the writing beam does not permit off-centered operation of the writing beam.

[4] Loren S. Foot, Arnold W. Grimes, Fred S. McKnight, William G. Covell, and Fred H Ottersberg, "Initial Evaluation of Two Bright Radar Displays in the Indianapolis Tower," Technical Development Report No 339, February 1958.

RECOMMENDATIONS

Because of the favorable results of the tests on the TI-440 equipment, it is recommended that.

1. Consideration be given to further in-service evaluation of the TI-440 equipment.

2. Scan-conversion techniques, as a means of providing air traffic control displays, be exploited to the limits of the state of the art.

3. In order to implement the above recommendations, specifications for scan-conversion equipment designed to meet the display requirements of control towers and en route control centers be prepared and submitted to the industry. Consideration should be given to installing such equipment in those towers and centers where the need exists.

4. Techniques for displaying the scan-converted radar information to the best advantage for the controller be investigated further.

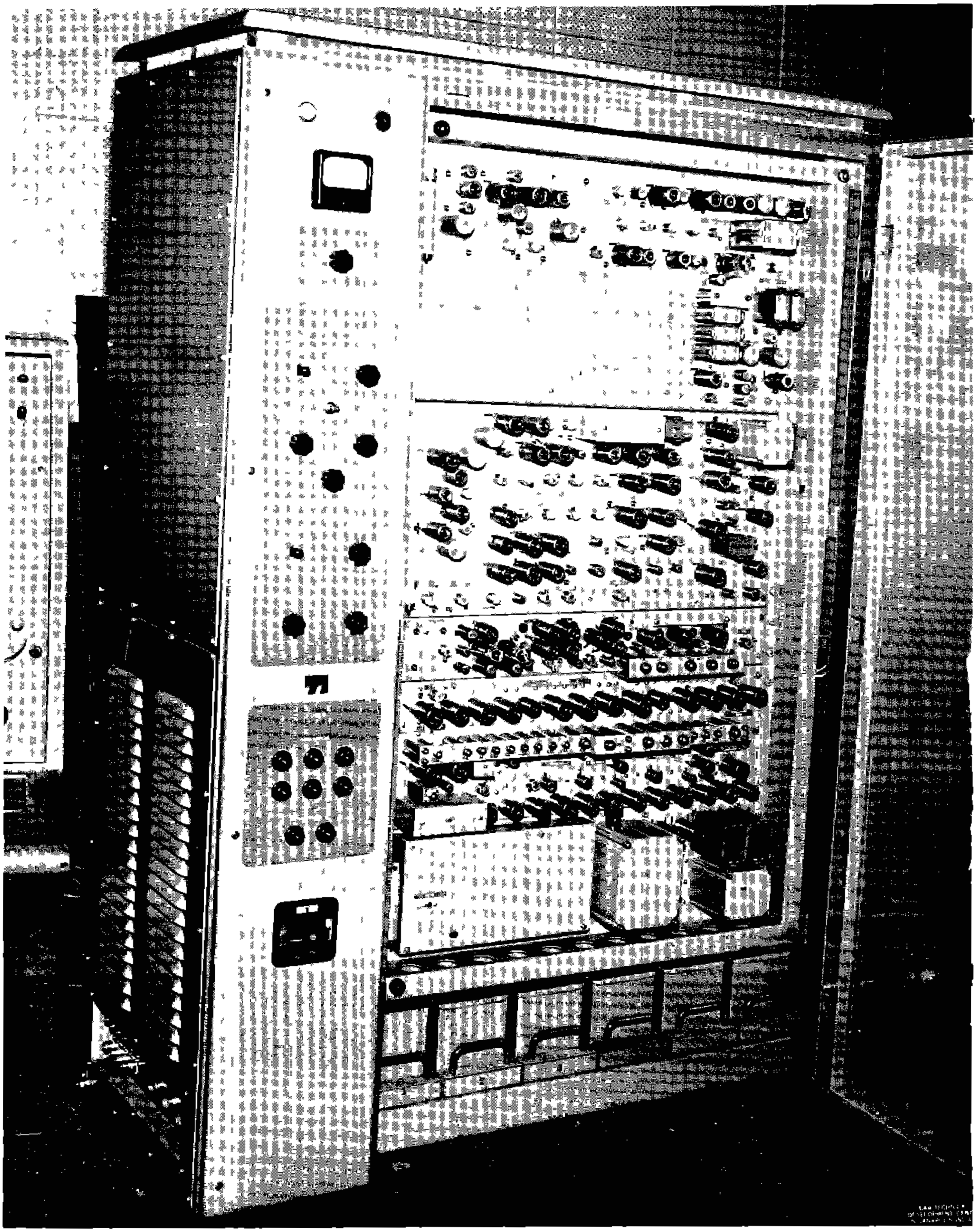

FIG. 1 TI-440 SCAN-CONVERSION EQUIPMENT

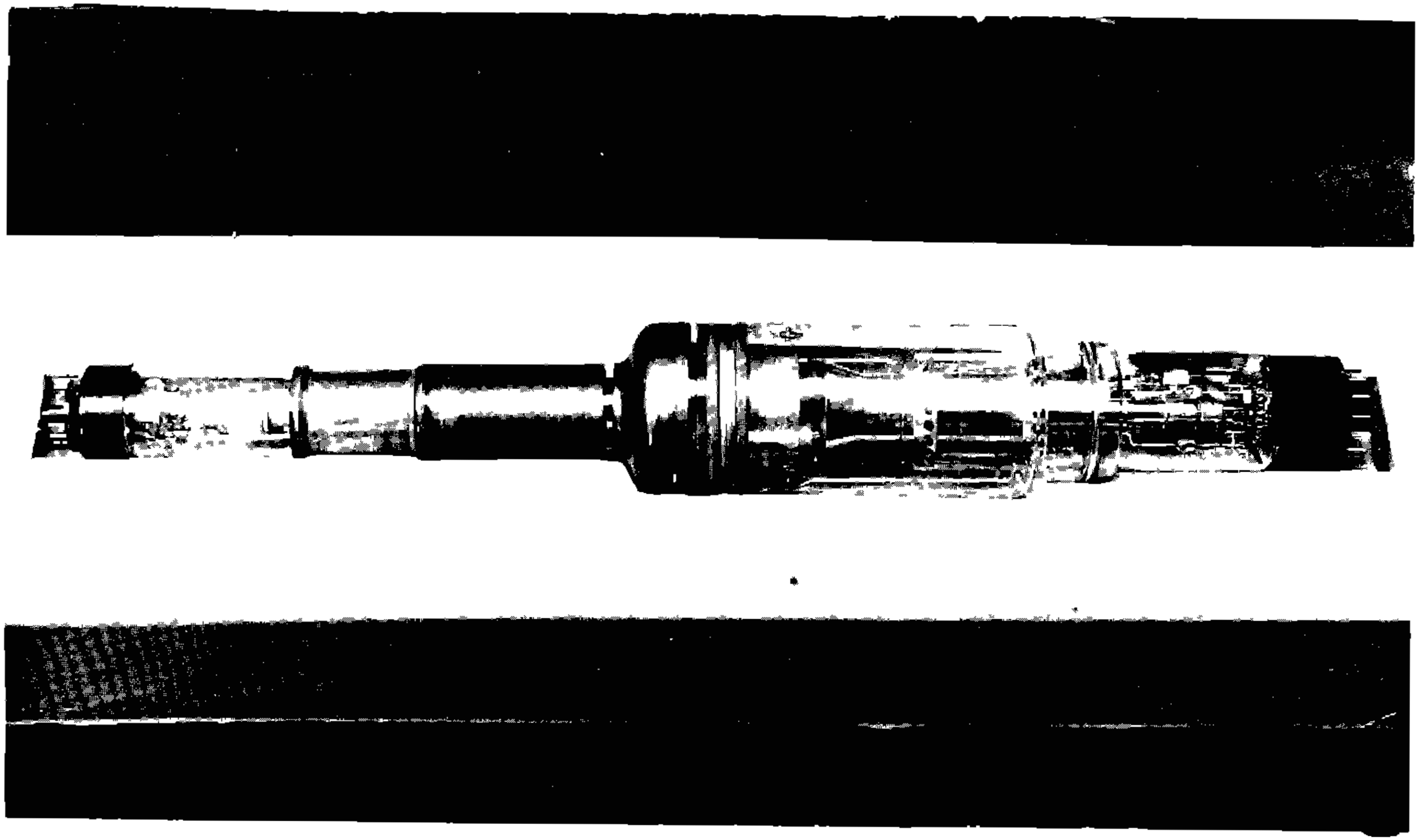

FIG 2 TMA-403X STORAGE TUBE

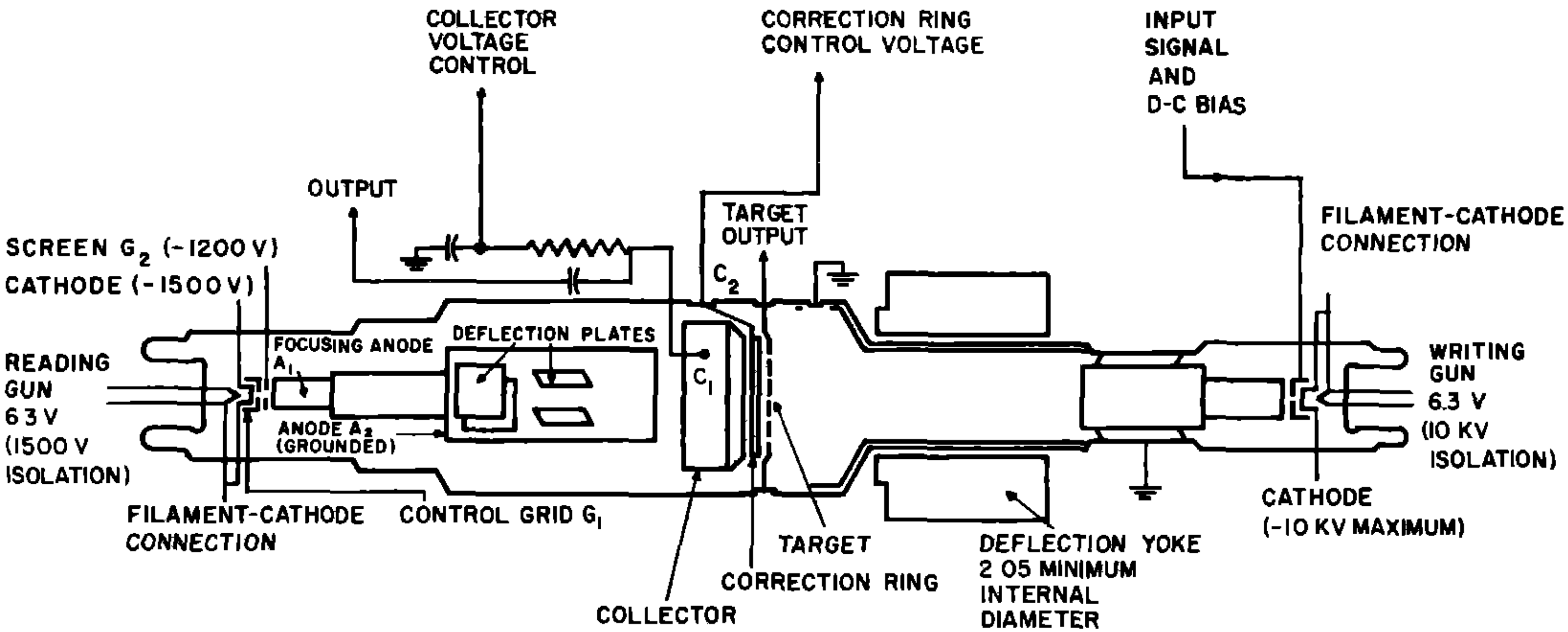

FIG. 3 TMA-403X STORAGE TUBE

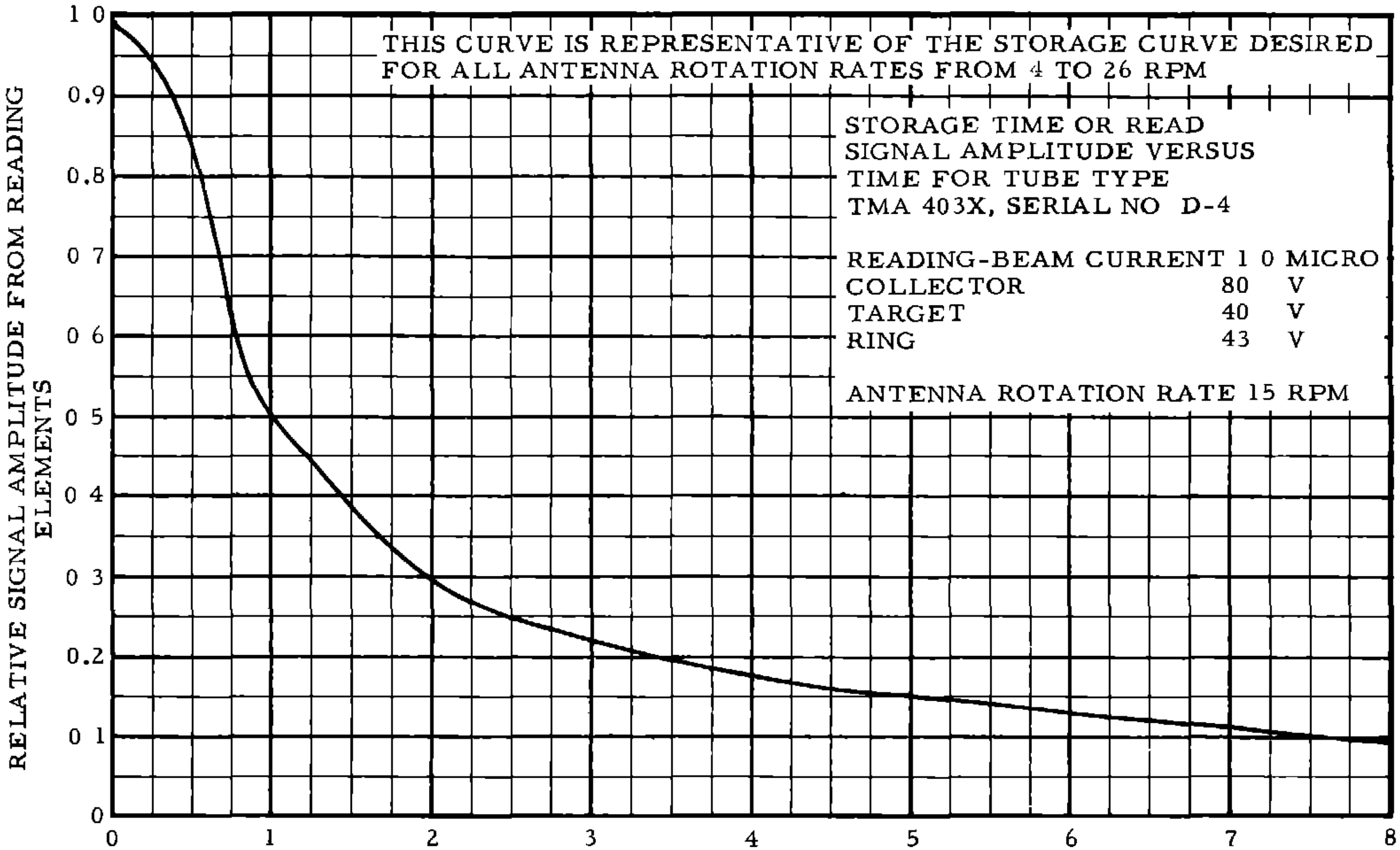

FIG 4 TIME IN ANTENNA ROTATION PERIODS

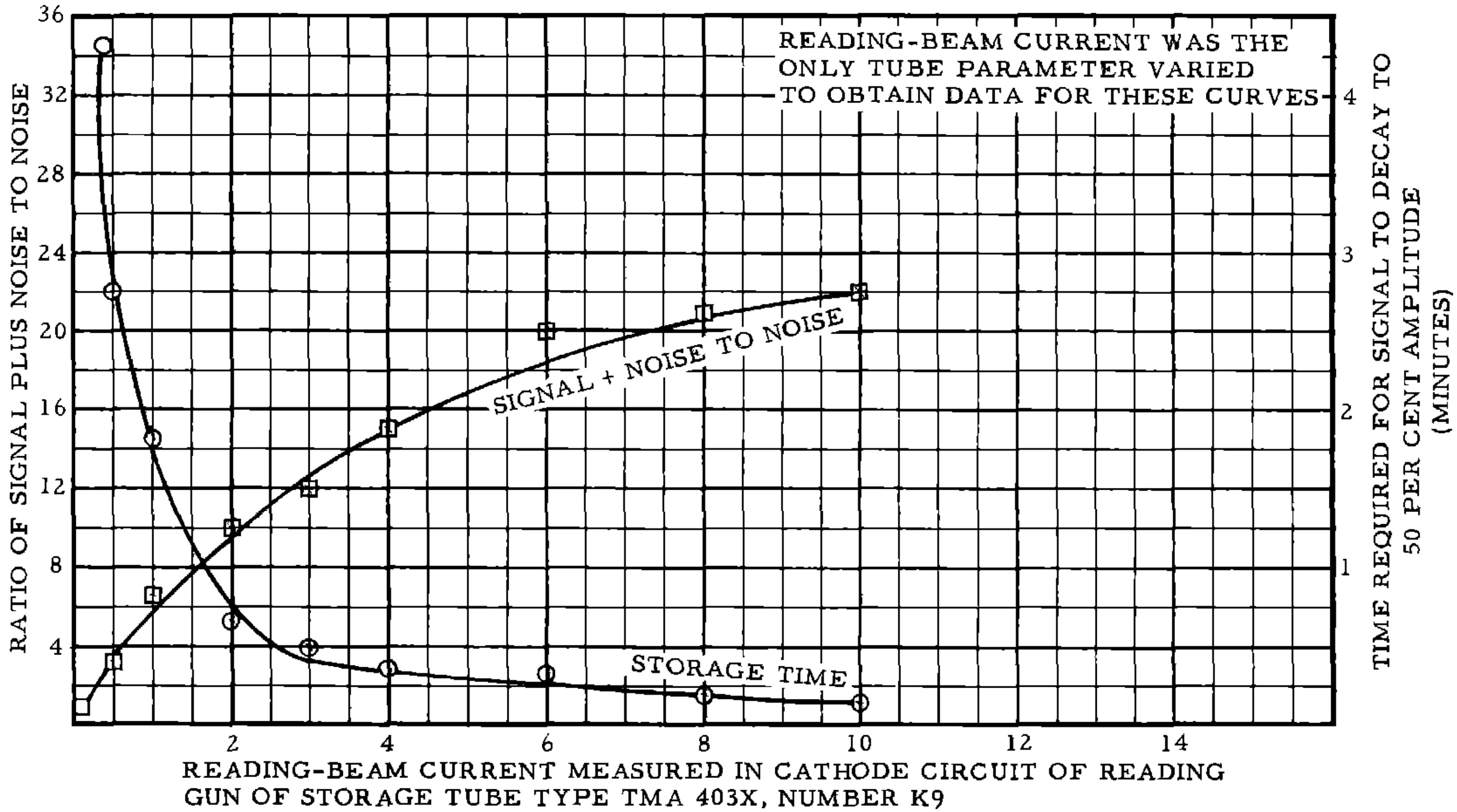

FIG. 5 SIGNAL NOISE NOISE AND STORAGE TIME FOR VARIOUS
READING-BEAM CURRENT VALUES

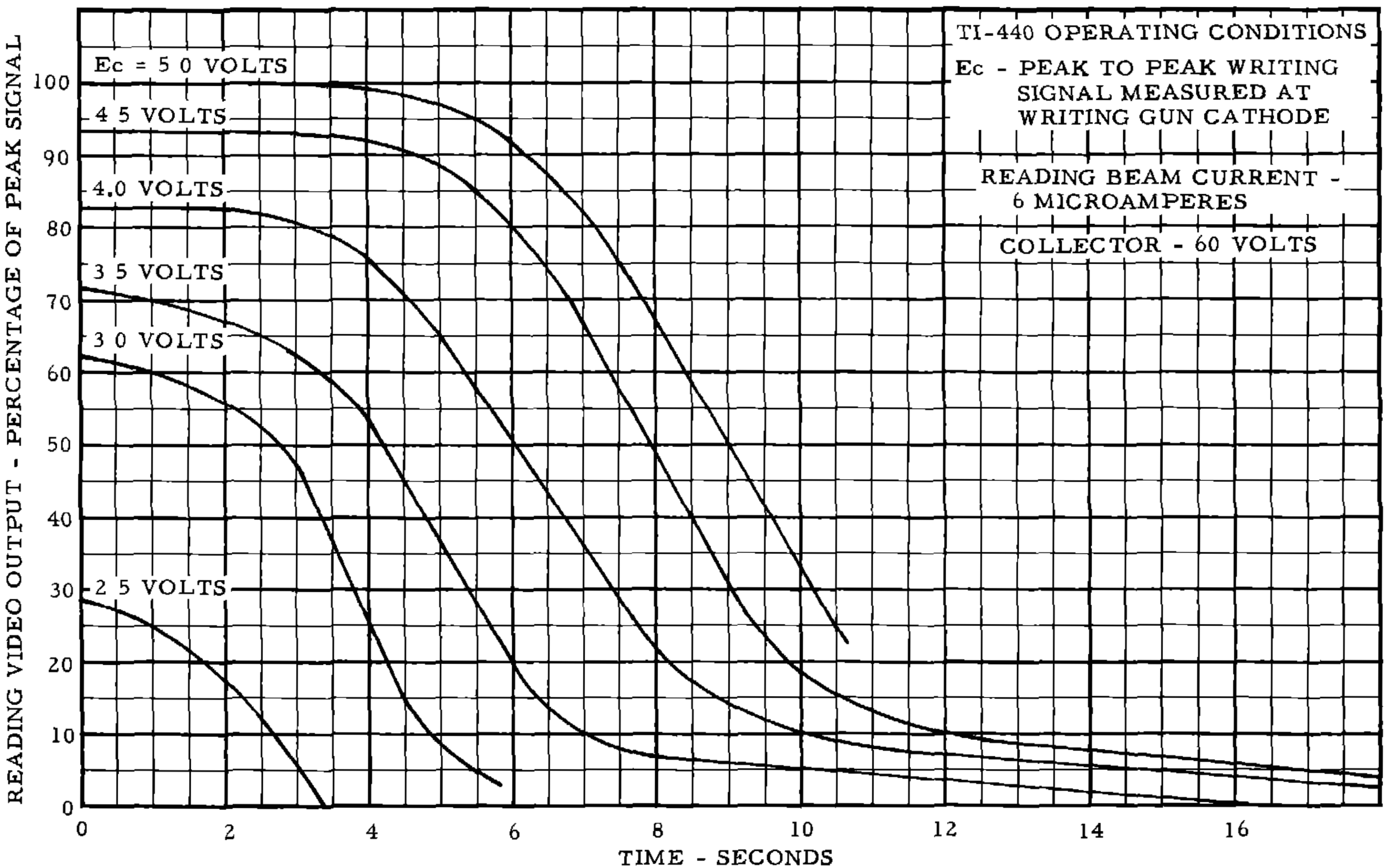

FIG 6 STORAGE TIME VERSUS WRITING AMPLITUDE FOR STORAGE TUBE TYPE TMA 403X

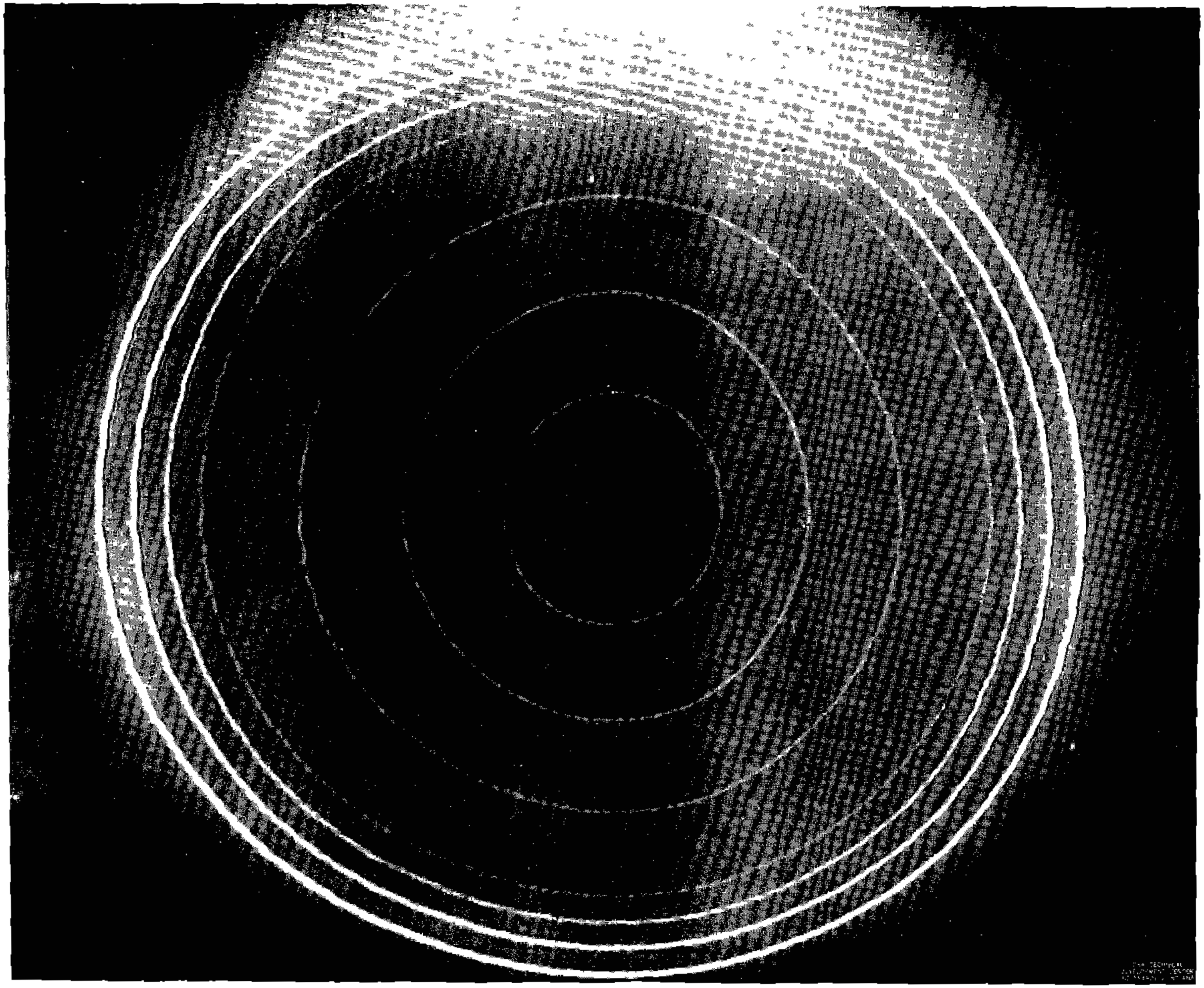

FIG. 7 HALFTONE CHARACTERISTICS OF TMA-403X STORAGE TUBE

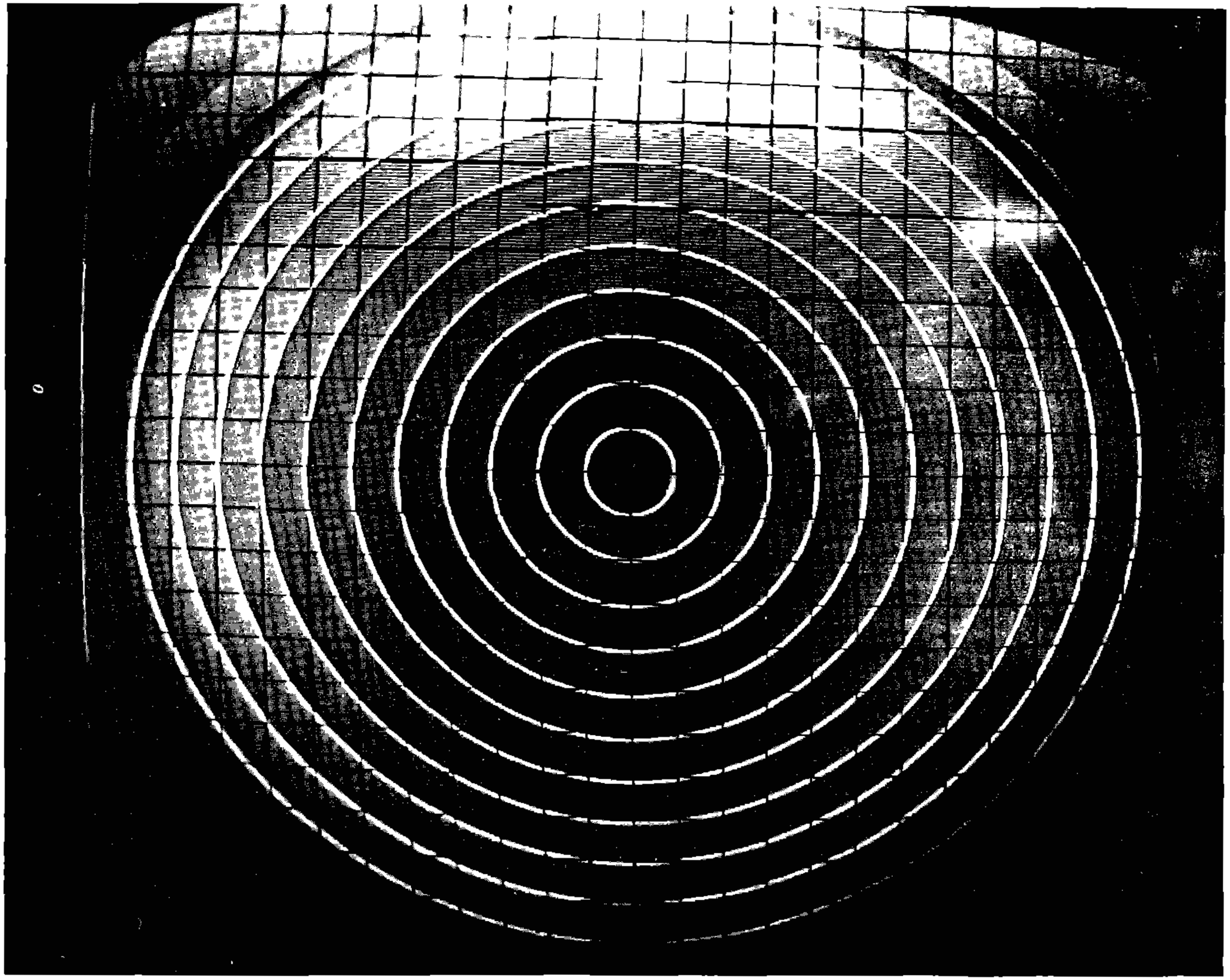

FIG. 8 RANGE RINGS FROM TI-440 SUPERIMPOSED ON GRATING GENERATOR VIDEO

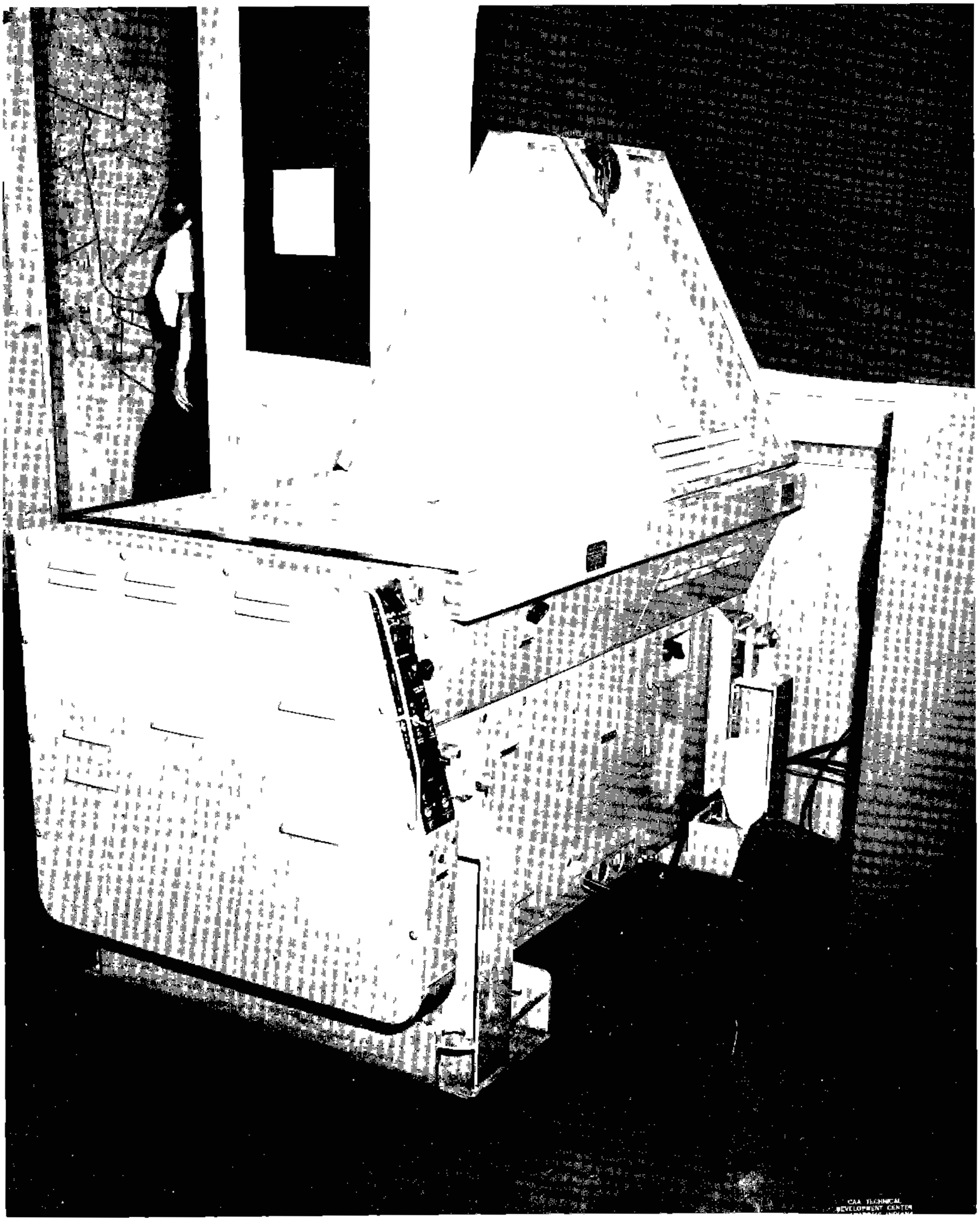

FIG. 9 STANDARD VG DISPLAY WITH ASSOCIATED FLIGHT PROGRESS BOARD
NOTE SMALL TRANSPARENT CHIPS ON PLOTTING SURFACE

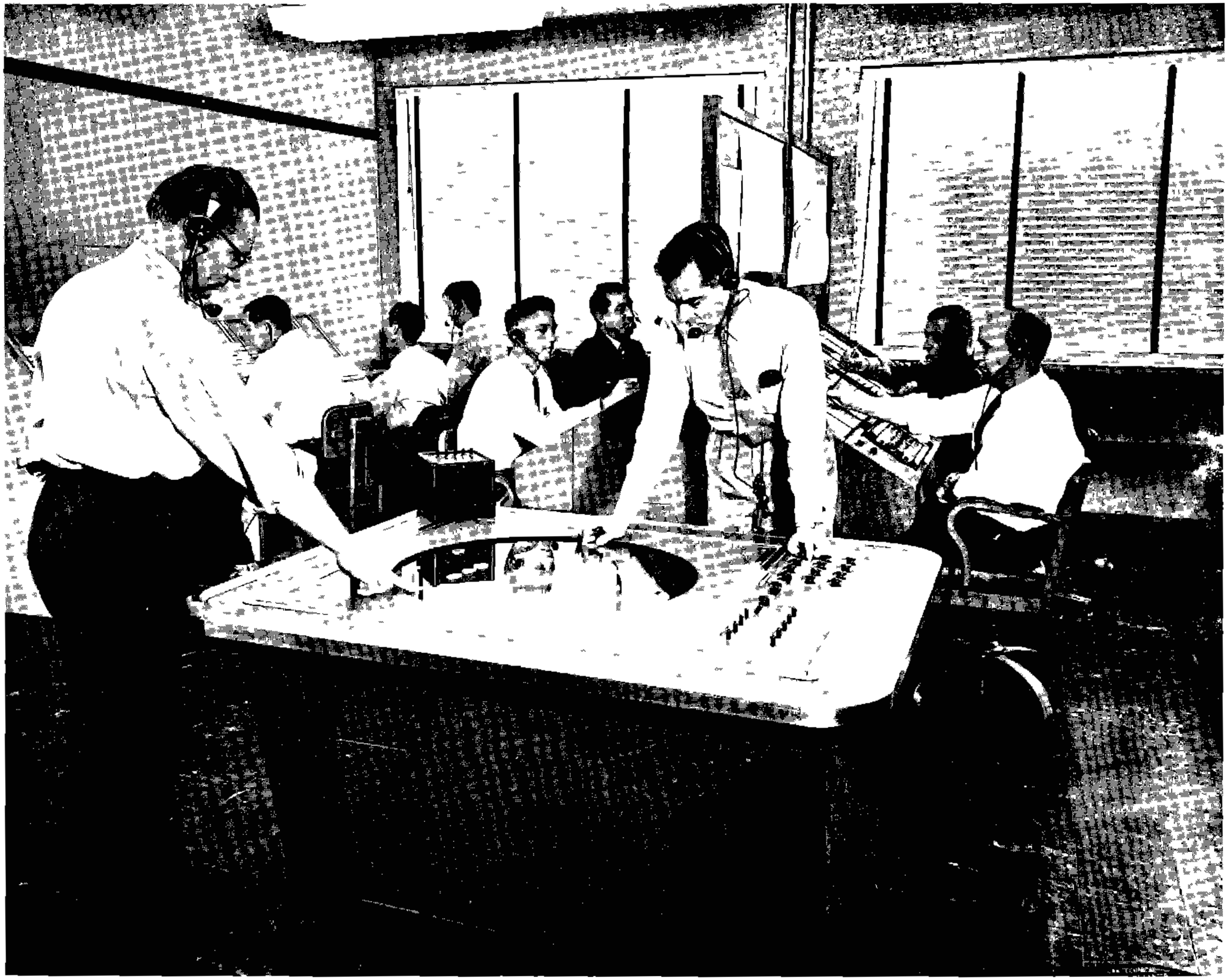

FIG 10 30-INCH DUMONT DIRECT-VIEW DISPLAY

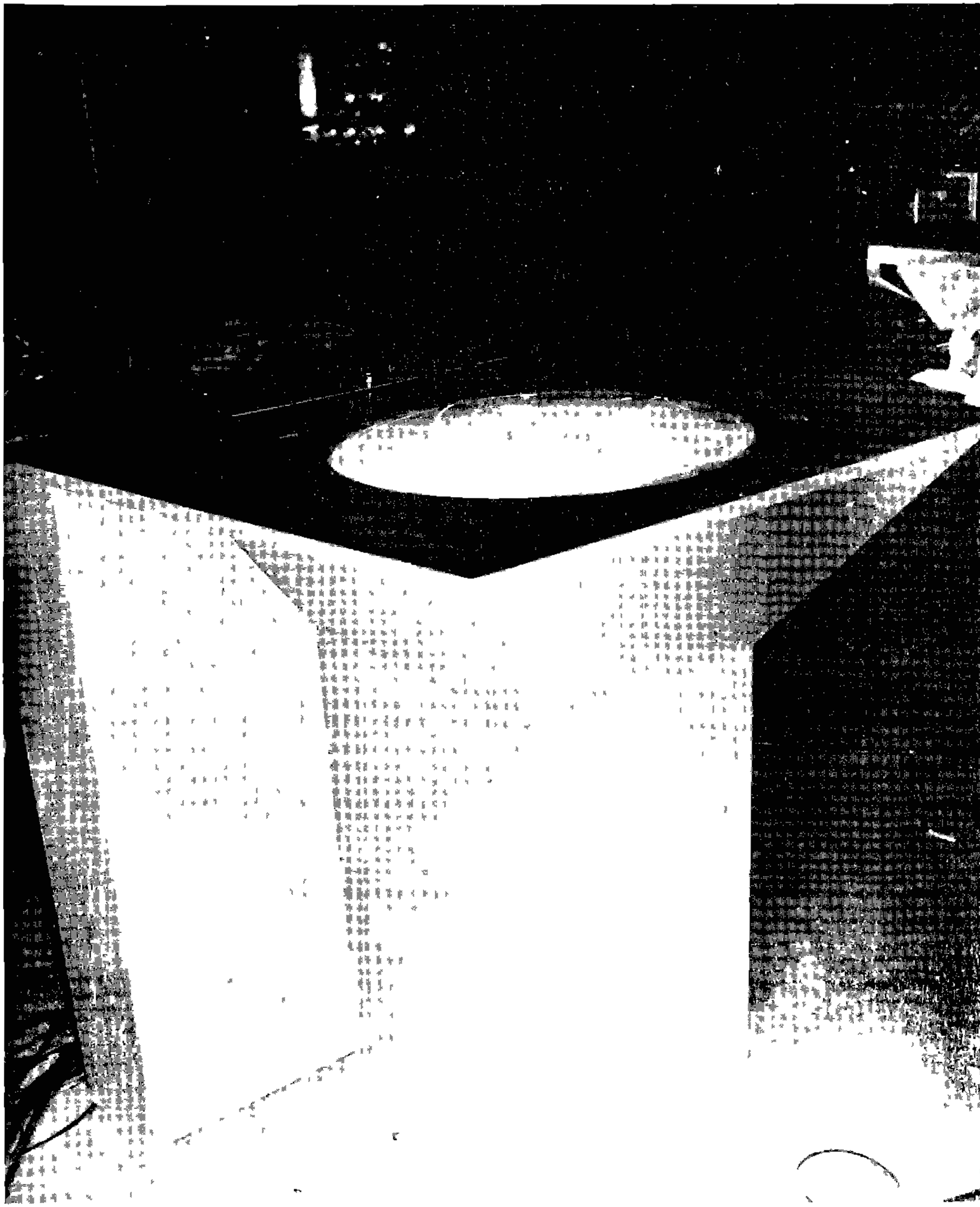

FIG 11 22-INCH FLAT-FACE DISPLAY

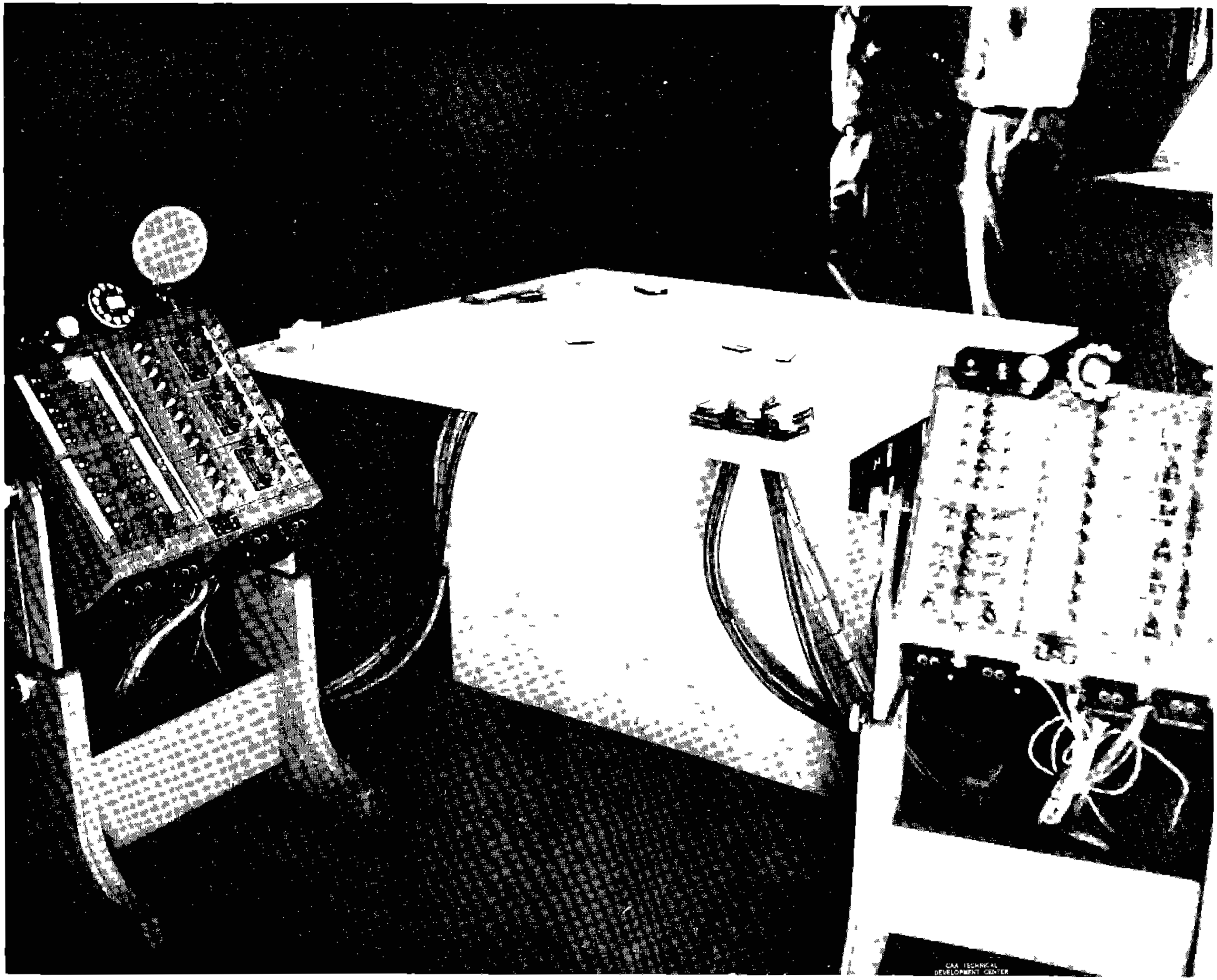

FIG. 12 DISPLAY PROJECTED FROM OVERHEAD

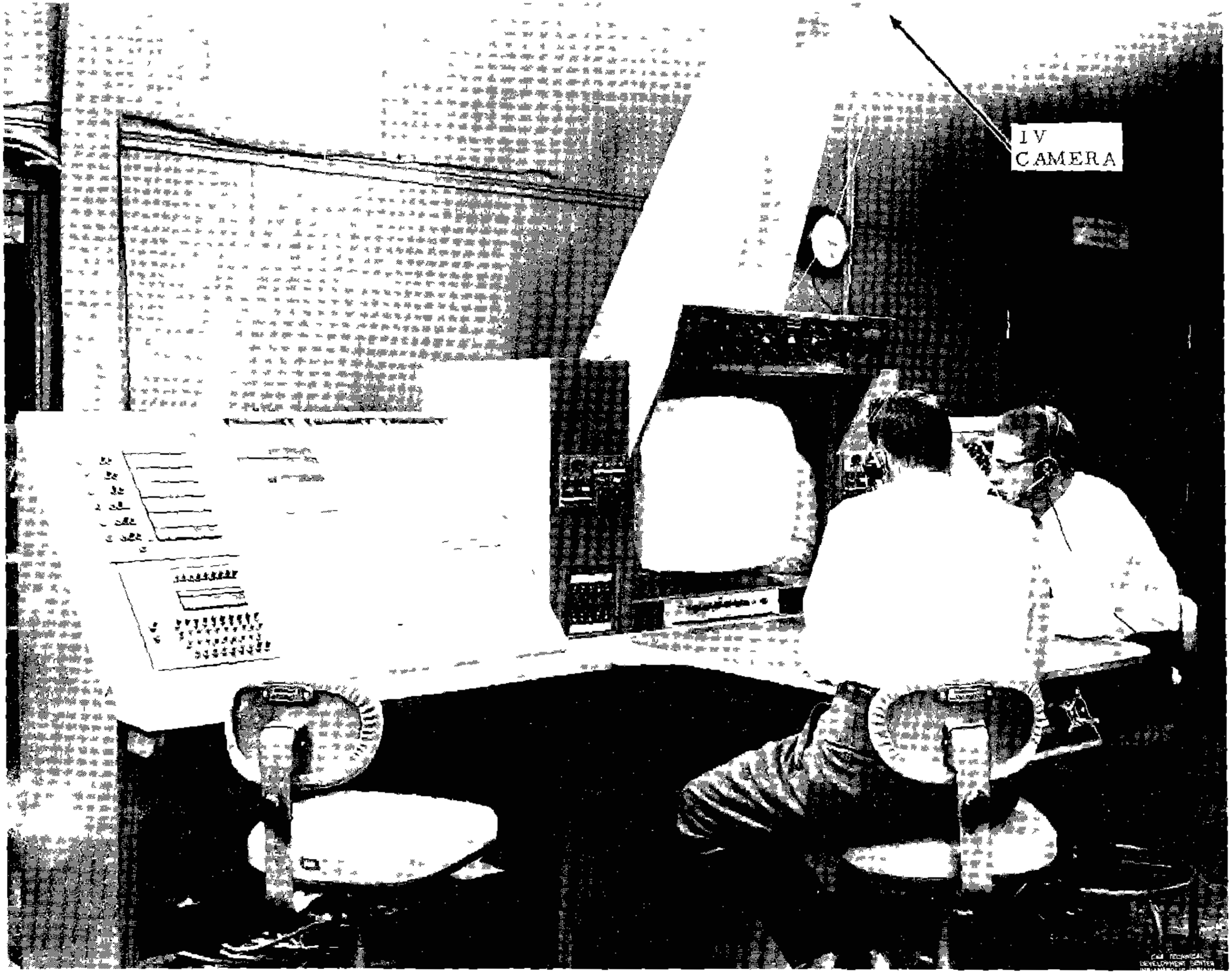

FIG. 13 SPANRAD DISPLAY UNIT

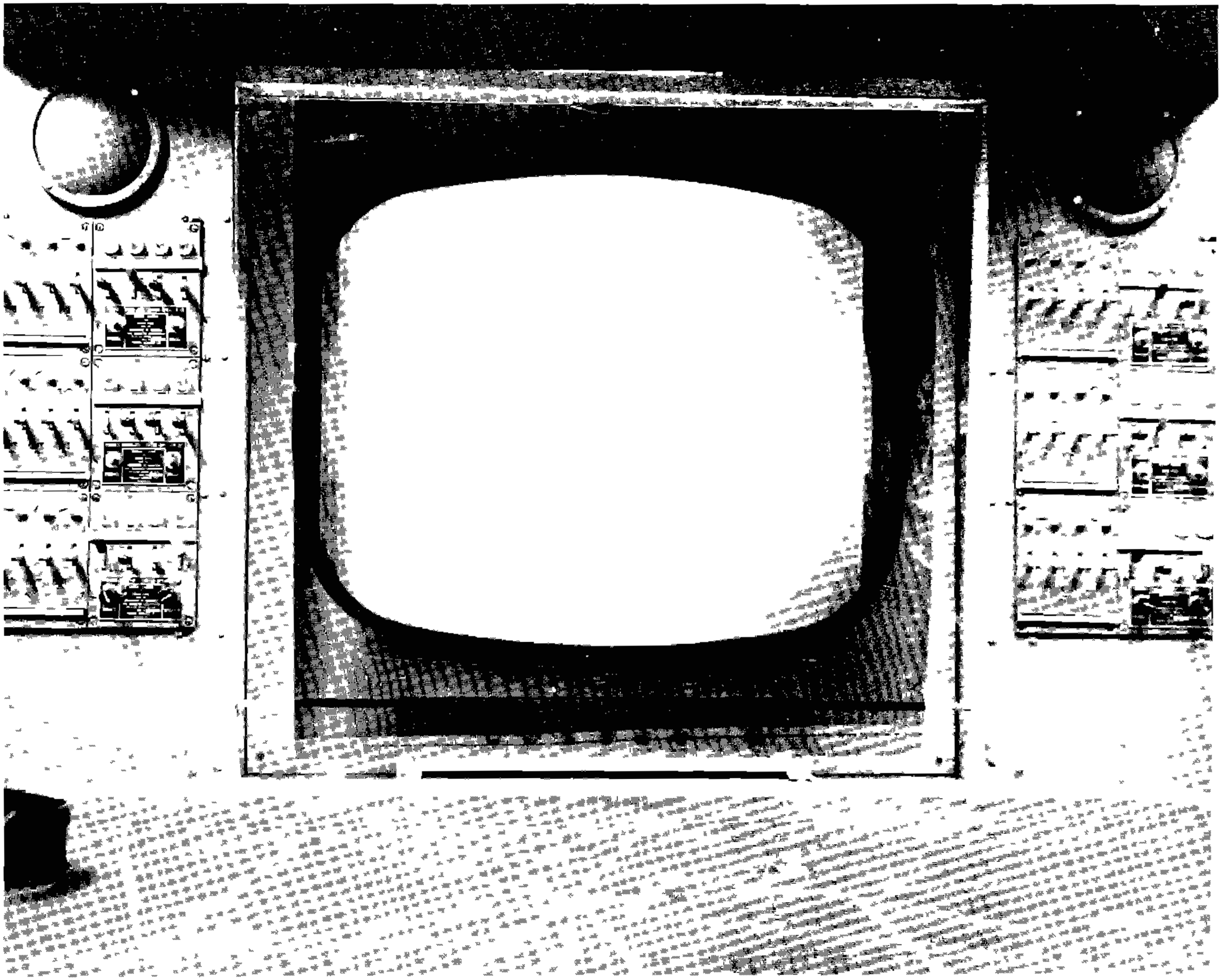

FIG. 14 CLOSEUP OF 27-INCH MONITOR IN SPANRAD DISPLAY SYSTEM

FIG. 15 CONTROL TOWER DISPLAY OF SCAN-CONVERTED RADAR

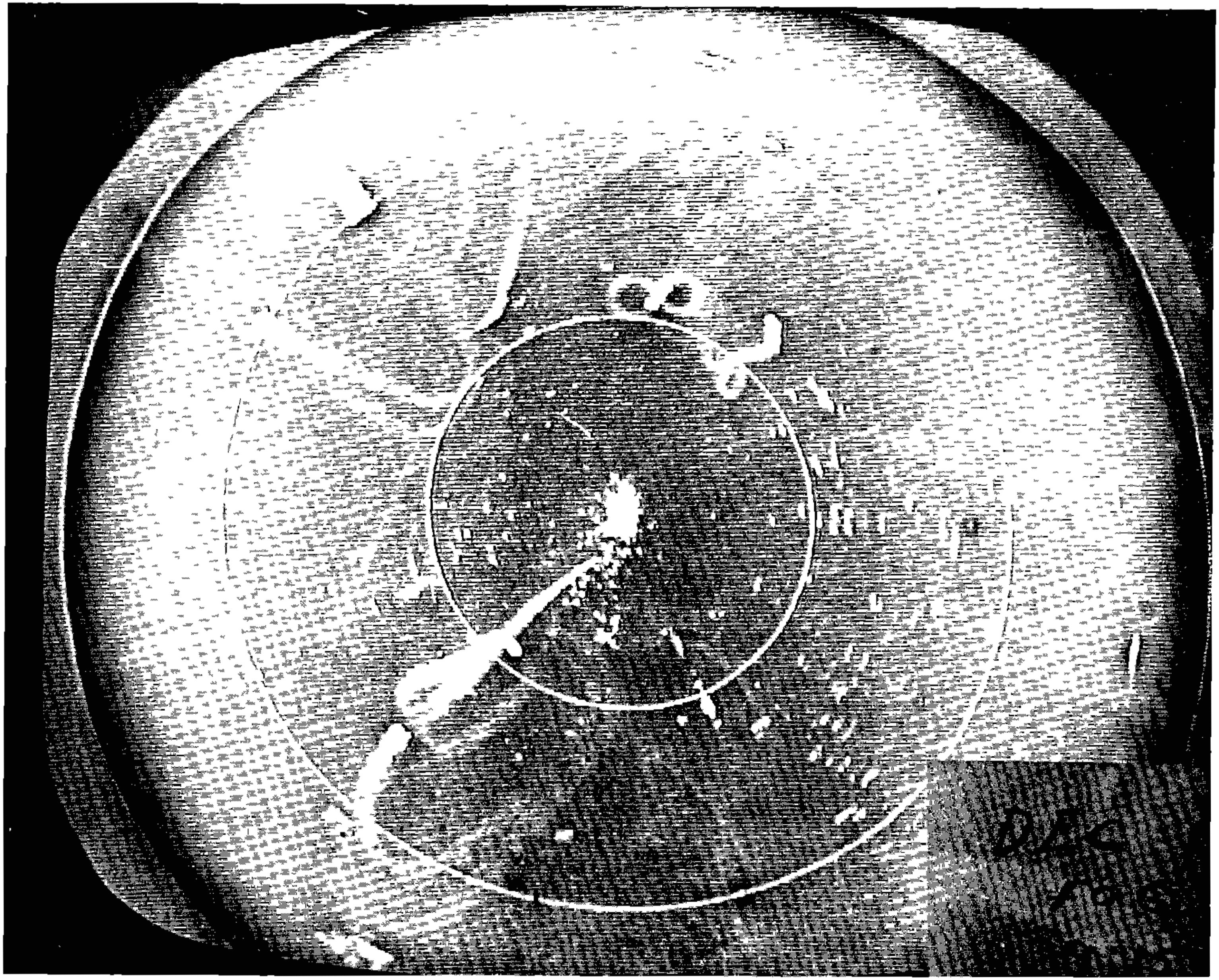

FIG. 16 SCAN-CONVERTED DISPLAY OF ASR-2 RADAR INFORMATION