

**TEST AND EVALUATION OF ELECTRONIC
IMAGE GENERATION AND PROJECTION DEVICES
VOLUME I. EVALUATION TECHNIQUE**

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FOREWORD

The study under which this electronic evaluation method was developed was initiated by the Behavioral Sciences Laboratory of the Aerospace Medical Research Laboratories, Aerospace Medical Division, Wright-Patterson Air Force Base, Ohio. The research was conducted and the method developed by Systems Research Laboratories, Inc., (SRL) of Dayton, Ohio 45432, under Contract No. AF33(615)-1889. The evaluation method was developed by Mr. John H. Harshbarger, SRL Senior Engineer. Mr. Arthur T. Gill, Simulation Techniques Branch, Training Research Division, Behavioral Sciences Laboratory, was the contract monitor for the Aerospace Medical Research Laboratories. The work herein reported upon was performed in support of Project No. 6114, "Simulation Techniques for Aerospace Crew Training," Task No. 611405, "Visual Simulation." The research sponsored by this contract was initiated in July 1964, and completed in July 1965.

The research during which the present method was developed was conducted within the facilities of the Simulation Techniques Branch of the Behavioral Sciences Laboratory at Wright-Patterson Air Force Base, Ohio, using the basic equipment provided by the Air Force. Acknowledgement is made to Mr. C. F. McNulty, Chief of the Simulation Techniques Branch, and to Mr. J. D. Basinger, Branch Electrical Engineer, for the assistance, cooperation, and consultation throughout the progress of the program. The overall assistance and support of the program by Air Force personnel in general is gratefully made a matter of record.

This technical report has been reviewed and is approved.

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ABSTRACT

The report describes a method for evaluation of all types of displays in terms of resolution, brightness, and contrast ratio. The technique employs a television camera to replace human observation. This method thereby translates the characteristics of the display to measurable electronic waveforms. The waveforms are displayed on an oscilloscope where they may be analyzed directly and photographed, thus providing known standards of measurements in terms of electrical units rather than depending upon human judgment as a comparison standard. Direct evaluation may be applied to any display. The observer television camera furnishes data which are an expression of the display fidelity. Brightness is measured by a photometer. These terms are subsequently interrelated in an expression of the contrast ratio attainable at various resolution and brightness levels. The analytical evaluation, especially applicable to cathode ray tube (CRT) displays, obtains data through examination of the minute scanning spot as it traverses the image area. Analysis of the beam spot behavior enables one to predict the ultimate CRT capabilities without generating a complete display. Results of the analytical study are expressed so that they may be completely checked by application of the direct method to the full display. These methods of evaluation are adaptable to displays of every type as standard measurement technique.

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SECTION I

INTRODUCTION

Simulated astronautical flight training uses projected visual images which convey minute details to the observer. The image must be of high fidelity and be free of flaws; for this reason, research was undertaken to determine what specific problems are involved in generating a high quality, high brightness television display suitable for astronautical flight training applications.¹ Up to this time human observation has been used to evaluate display generation techniques. No standard procedures have been developed for such subjective evaluations. To be adequate, an evaluation procedure must be precise, complete and repeatable without undue complexity. It should be adaptable to all types of displays, whether projected or not. During the previous, above-mentioned research project, a television camera was employed as a standard observer to eliminate the human element from display evaluation. The data produced by this observer technique is expressed in oscilloscope waveforms which are measurable in scientific terms and in numerical units, and which are capable of undergoing subsequent analysis. This basic data is translated into the fundamental television terms: Such as resolution, brightness, contrast ratio, scanning spot size, scanning speed, scanning beam, and intensity.

An existing display may be evaluated directly. The direct evaluation is performed by arranging the "observer television camera" to view a small area of the display. The minute inspection thus performed by the observer camera will produce waveforms which are indicative of the information contained in the area under study. Data taken from the waveforms can then be reduced to an expression of resolution, that is, fidelity of detail that occurs in the area under inspection.

The ultimate capability of a cathode ray tube display may be determined through a detailed analysis of the scanning spot. Therefore, an analytical evaluation may be performed by a detailed

1. Harshbarger, John H., and Arthur T. Gill, Development of Techniques for Evaluation of Visual Simulation Equipment, AMRL-TDR-64-49 (AD 607680), Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, August, 1964, p.2.

study of the scanning spot under its expected conditions of scanning speed and beam intensity. In a television display this study is performed on a small number of television scanning lines, widely spaced, which are examined for detail of the scanning line cross section. The scanning spot profile obtained from the observer camera signals are then interpreted and related in terms of the ultimate resolution and contrast ratio that may be expected from this device.

The brightness of the display was measured by a photometer in either the direct or the analytical evaluation procedures. It is then possible to reduce the data to an expression of resolution and brightness. A unique relationship of the contrast ratio that may be expected for any brightness level is a unique product of this method of evaluation.

This technique has been used to completely evaluate television projection devices.² The evaluation was successful in every respect. The analytical evaluation was quite valuable in that the ultimate resolving capability of a cathode ray tube can be determined without requiring a system whose fidelity exceeds the expected tube performance limits.

2. Harshbarger, John H., Test and Evaluation of Electronic Image Generation and Projection Devices. Volume II. Evaluation of Television Systems, Aerospace Medical Research Laboratories, Wright-Patterson Air Force Base, Ohio, (in preparation).

SECTION II

THEORETICAL AND TECHNICAL CONSIDERATIONS

As stated in the previous section, the traditional technique for display evaluation has been human observation with the terms "good" and "bad" as the expressed measurement of display fidelity. This display technique meets none of the criteria set forth for a proper display evaluation technique. It is neither precise, nor complete, nor repeatable. Although the brightness of this display could be measured scientifically, resolution remained a matter of opinion. Therefore, an improved method had to be devised which would meet all of the requirements set forth above before meaningful research into display generation techniques could proceed.

A television camera may be defined as "a means for forming an image of a scene and translating the time and space variation of the light intensity which this image produces into electrical information."³ It was then deduced that a television camera could inspect the display, produce electrical waveforms that represent the content of this display, and thereby provide exact data which describes display content. Inasmuch as the television camera also provides repeatable data (that is, data taken from day to day from the same display will be consistent) the television camera was selected as a standard observer for display evaluation.

Monochrome displays contain two attributes of interest, resolution and brightness. Resolution designates that amount of detail which is perceptible to the viewer in any given image area. It appears as a pattern of contrast; a pattern of varying brightness levels. Brightness as it is usually measured describes the average intensity of light emanating from the display.

Contrast ratio describes the degree of intensity difference between dark and light areas in a given visual pattern. In the case of television, it is described in terms of the darkest level that may be obtained as related to the intensity in the brightest display areas as 100% contrast ratio. Less intense areas appear as shades of

3. Glasford, Glenn M., Fundamentals of Television Engineering, McGraw-Hill Book Co., 1955, Page 3.

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grey as compared to the bright, white portions of the display. A discussion of contrast ratio necessarily involves consideration of the grey scale that can be reproduced. Current systems generally are capable of ten-step grey scale rendition, implying that each step will represent a 10% contrast ratio change.

This rule holds true for large areas of pattern associated with a lower level of resolution. However, as finer patterns demand a higher resolution, dynamic range of reproduction is limited. Due to the basic nature of television systems, the signal level drops as black-to-white information develops a more closely spaced pattern. For instance, coarse patterns will command a 100% contrast ratio in the reproduced display. Fine detail which demands the limit of system resolution can only develop a "just noticeable difference" in pattern on the display screen, presumed to be 10% contrast ratio. Inasmuch as the full dynamic range, representing 100% contrast ratio, will permit reproduction of only ten grey steps, one must have at least a 10% contrast change to develop a noticeable pattern on the display surface. By extension of this analysis, one can expect the capability of seven grey steps at 70% contrast ratio capability, five steps at 50%, etc.

In both the direct and analytical evaluations described herein, resolution was related to contrast ratio that could be attained for that particular level of performance. The brightness range from widely spaced black-to-white patterns was used as a reference 100% contrast ratio. Then the range obtained for more closely spaced patterns was recorded and referred to the reference. The information obtained from such analysis is superior to a mere resolution figure; a complete appraisal of the contrast ratio obtained for each level of resolution permits complete description of display quality.

The equipment evaluated initially was a refractive television projector, which was originally designed to operate in the 525-line scanning mode. It incorporated a 7WP4 projection cathode ray tube. The equipment was updated to operate in a 1,029-line scanning mode and the projection tube was evaluated for its ability to operate in a higher resolution system. Therefore, the evaluating technique will be described as it was applied to this equipment. However, the technique is applicable to displays of all types.

SECTION III

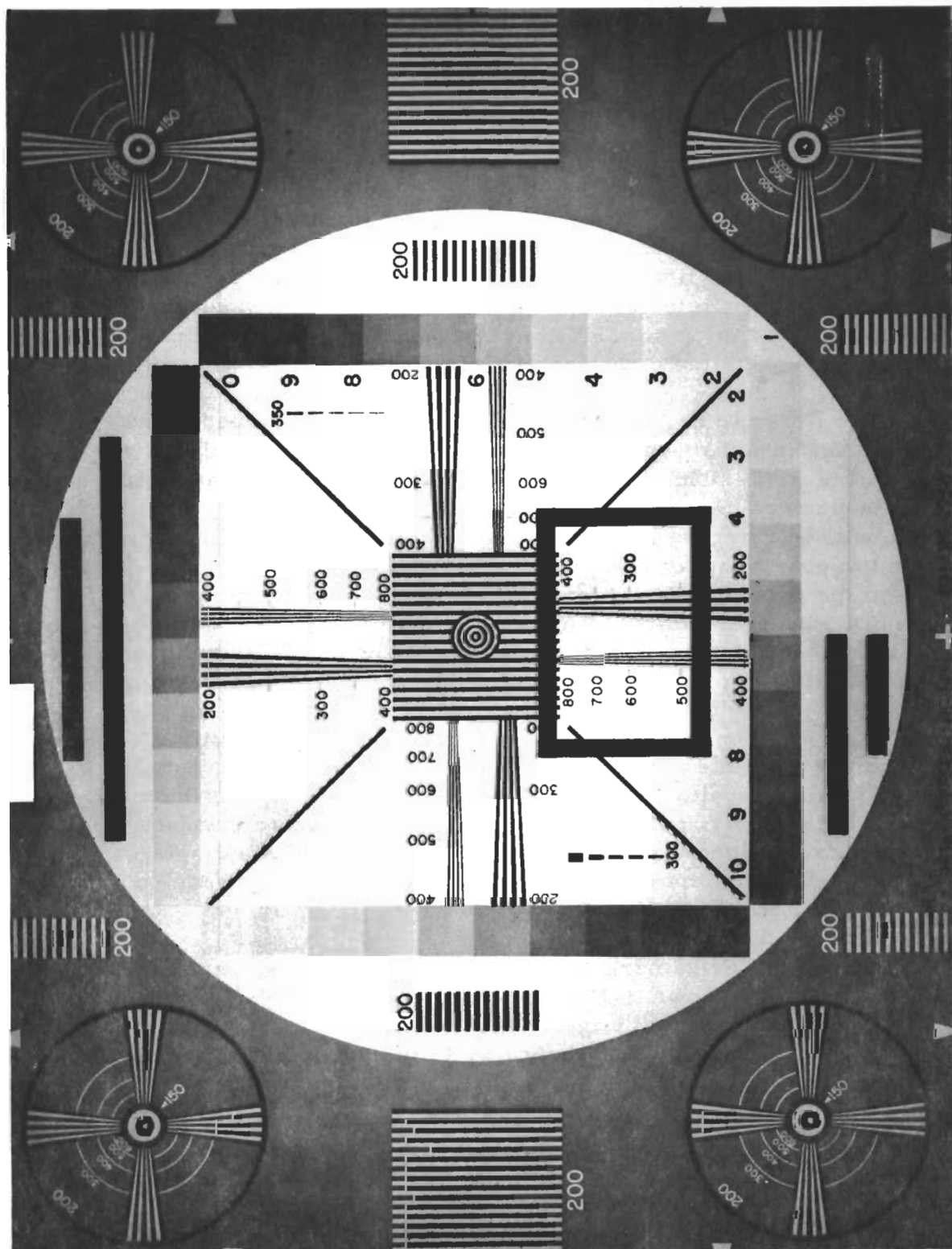
DIRECT EVALUATION

Direct evaluation may be applied to visual presentations of all types, such as computer-developed or televised CRT displays, photographic displays, or even live scenes. The only criteria is to arrange the observer television camera to view a small area of the display within the limitations set forth below. In the current research program a television projector was to be evaluated; the image of standard television RETMA test chart shown in Figure 1, was used throughout the direct analysis.

The image to be displayed in this case was developed from a RETMA test chart mounted in a uniformly illuminated holder, as shown in Figure 2. This test chart was viewed by a high-resolution television camera capable of 1200-line fidelity. Hereafter, this camera will be referred to as the pick-up camera to differentiate it from the observer camera. The high-resolution video signal was cabled to the projector, to a set-up monitor used to adjust the pick up camera, and to a reference monitor in the projection room. A line-finding oscilloscope was connected at the projector to monitor the waveform of the scanning line selected for study. The monitoring took place both into and out of the projector video drive amplifier (Figure 3), thus indicating the performance of the amplifier at any time. The intensity gate of the oscilloscope was connected to the reference monitor to indicate which particular line of the display was under study at the time (see Figure 4). The reference monitor also provided a ready visual comparison between display quality, as shown on the monitor, and display fidelity, as seen on the projector screen.

The observer camera viewed the image as presented on the display screen, as shown in Figure 5, and converted this information back into an electrical waveform. The waveform was displayed on a monitor in the observer camera system (Figure 6), and again an oscilloscope was used to analyze the information detected, as shown in photograph 3 of Figure 7.

The waveforms from the pick-up camera, from the projector amplifier, and from the observer camera system are grouped in Figure 7. Photographs 1 and 2 in the figure are of the production from



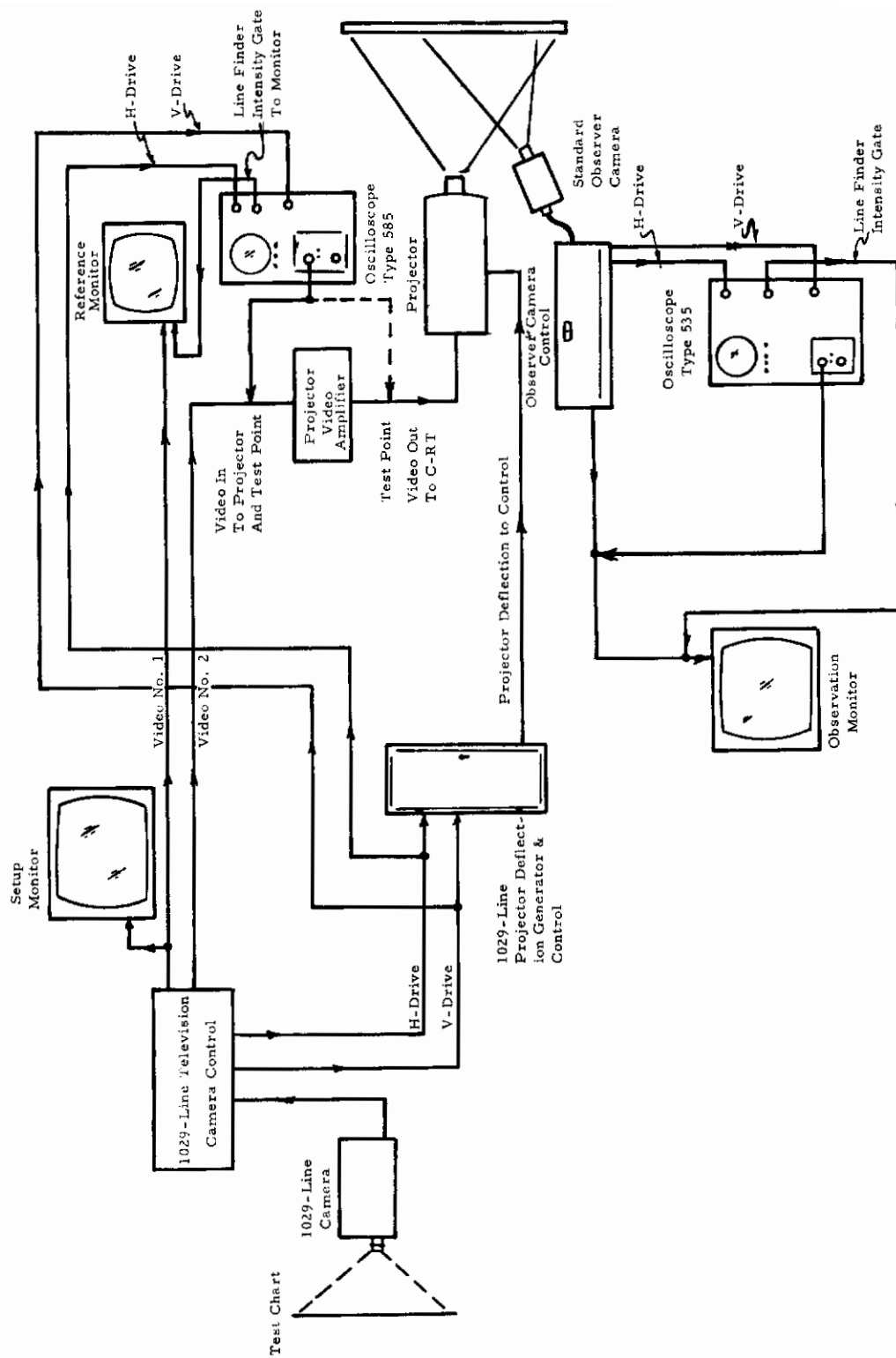
Test Chart Showing Area Under Analysis

FIGURE 1



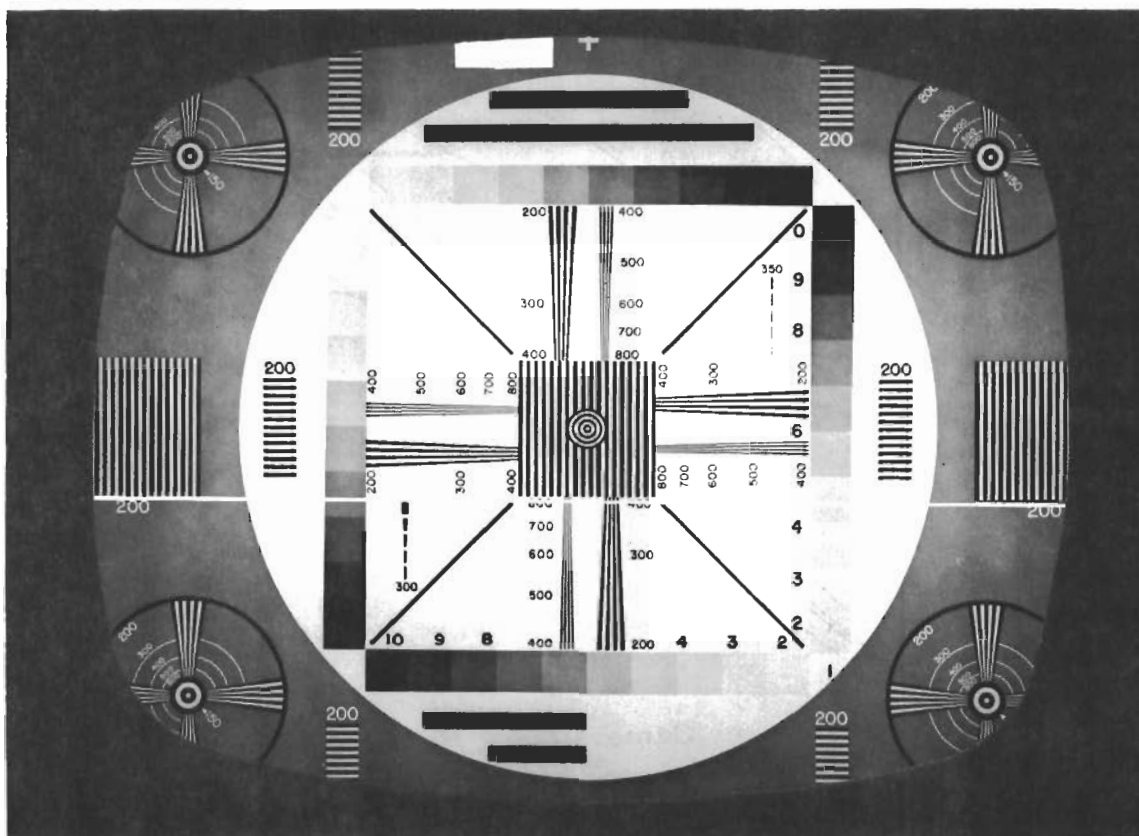
Camera Position to View Test Chart

FIGURE 2



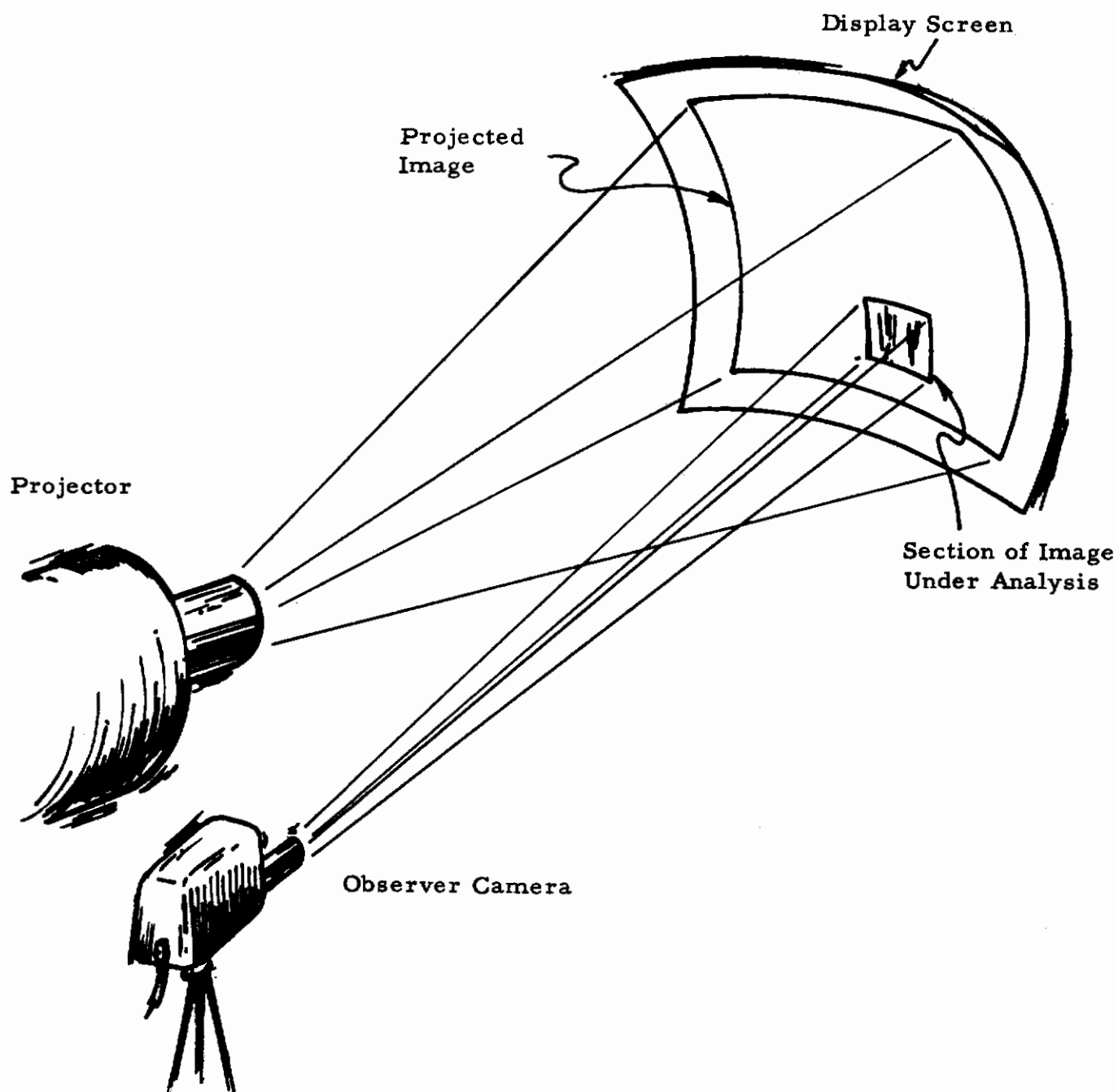
Equipment Interconnection Display Evaluation with Standard Observer

FIGURE 3



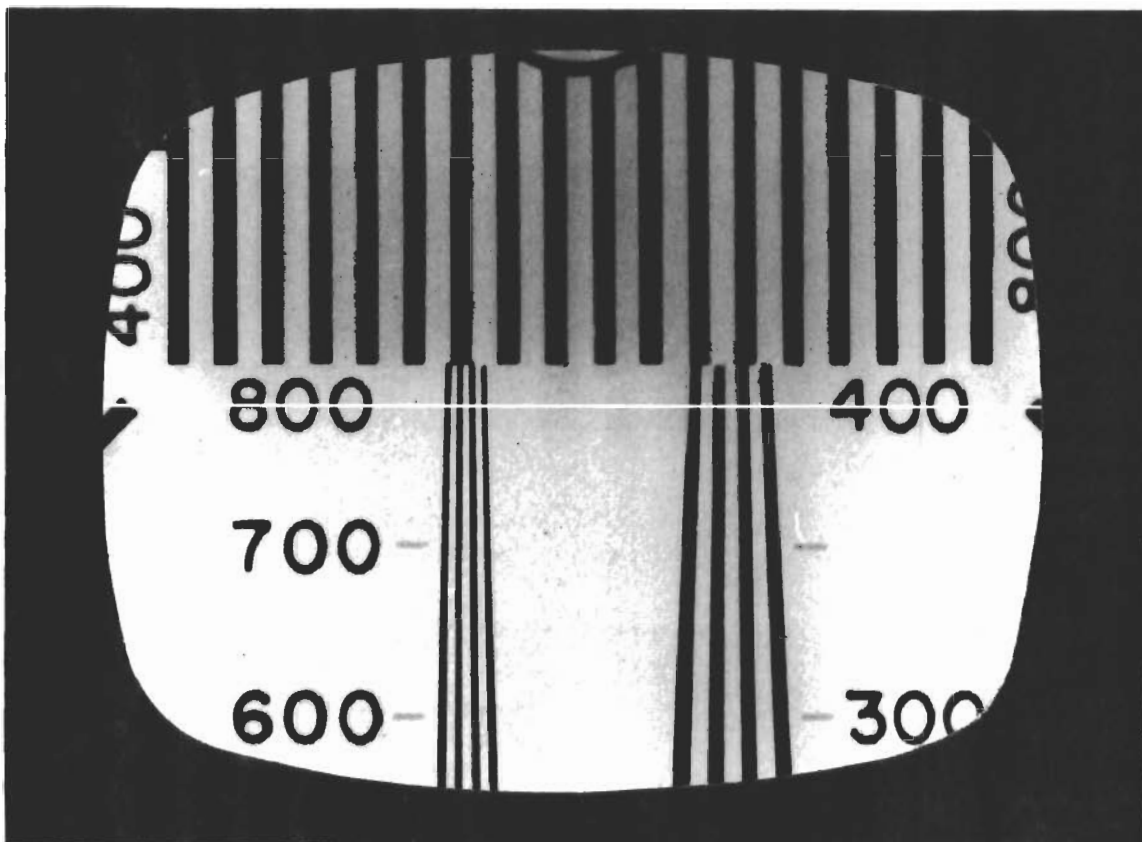
Picture of 1029-line Monitor Display

FIGURE 4



Standard Observer Viewing Arrangement

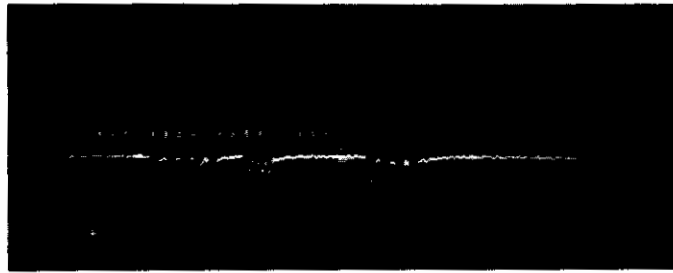
FIGURE 5



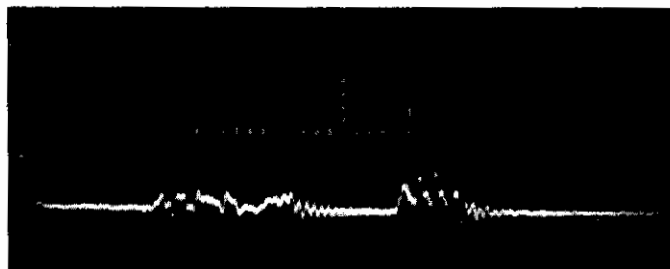
Picture of 525-line Monitor Display with
Line Finder @ 800 & 400-line Point of Projected Display

FIGURE 6

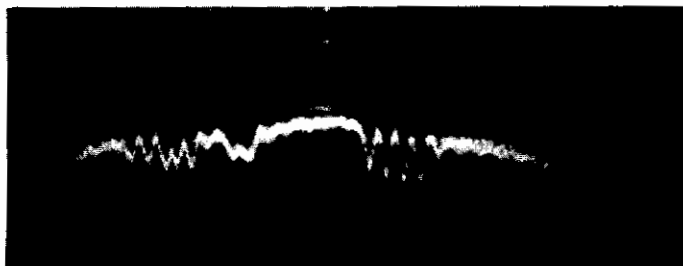
Contrails



1. Waveform at 700 lines and 350 lines resolution as fed into the projector amplifier



2. The same information waveform observed coming from the projector amplifier



3. The same information as detected by the Standard Observer Camera

Waveforms of Test Signals - 1029-line television

FIGURE 7

the pick-up system. They show a well-modulated signal developed by the pick-up camera and as presented to the projection cathode ray tube. Photograph 3 shows the waveform developed in the observer camera from the same information.

A series of tests were performed to check the adequacy of the observer camera system. Waveforms were recorded while the camera was viewing a test chart to insure that the system was not limiting the signal as detected. These data indicate full response of the observer camera system to 300 lines, with a gradual roll-off beyond this point. Half response is indicated at approximately 500 lines, with one-quarter response at 800 lines, as shown in Figure 8. The camera was placed to space the 800-line position of the resolution wedge in $1/21$ of the detected image width as shown in Figures 1 and 6. This is an effective resolution requirement of:

$$\begin{aligned}\text{Effective } n &= 21 \times \text{number of elements per wedge} \\ &= 21 \times (4 \text{ black} + 3 \text{ white}) \\ &= 21 \times 7 \\ &= 147 \text{ lines per horizontal scan of the observer camera.}\end{aligned}$$

Since this indicates an 800-line capacity available to display information containing less than 150-line content, the observer camera system is considered adequate.

Further comparison was achieved by projecting a standard test chart directly onto the screen by optical methods and detecting this "perfect" display in the same manner. The results, shown in Figure 9, indicate that the observer camera system is capable of detecting 800-line information and producing a waveform which completely describes the display. The amplitude at 800 lines is the same as that at 200 lines; thus full modulation is obtained at the highest information rate to be encountered. This proves that the detector system is adequate.

The waveforms to be used in the analysis are the video signal generated at the pick-up camera, the video signal being delivered to the projector CRT, and the video signal generated at the observer camera. Oscilloscopes were connected into the circuitry at these three places to display and measure these waveforms. When the set-up was completed, it was possible to compare directly the waveforms at reference image pick-up, at the projection device, and at the observer system which viewed the projected image. If the display is to be

PERFORMANCE TEST OF THE
STANDARD OBSERVER TELEVISION SYSTEM
(525 LINE MODE OF OPERATION)



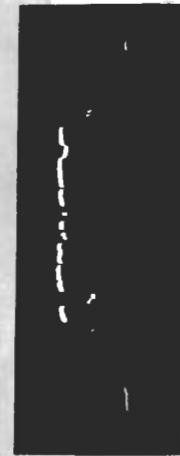
400 & 200 LINE RESOLUTION
(EXPANDED WAVEFORM)



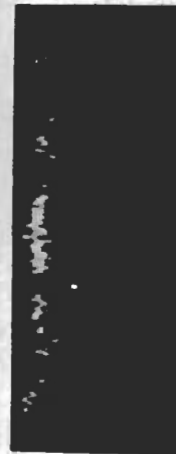
BOTTOM GRAY SCALE
UNEXPANDED COMPLETE LINE



600 & 300 LINE RESOLUTION
(EXPANDED WAVEFORM)



600 & 300 LINE RESOLUTION
UNEXPANDED COMPLETE LINE



800 & 400 LINE RESOLUTION
(EXPANDED WAVEFORM)

Performance Test of the Standard Observer System

FIGURE 8

considered acceptable, the three sets of waveforms should be alike; the measurement of the waveforms should agree within a small degree of acceptable variation.

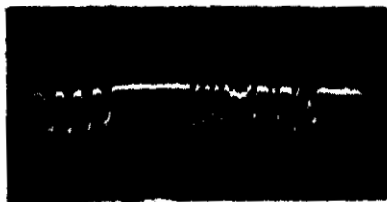
The waveforms shown in Figure 9 show that there was noise in the observer camera pick-up. This is to be expected, for the vidicon camera was viewing displays of very low light level. The noise was minimized during the actual tests by placing a 5000-micromicrofarad shunt filter capacitor at the observer camera system output, thereby removing the larger portion of this interference. Later observations verified the calculation which indicated that a capacitance of this value would not degrade the low resolution (and, therefore, relatively low frequency) data from the display.

Ability of a device to produce various shades of grey is evaluated by a grey scale. The standard RETMA test chart, Figure 1, presents four grey scales of ten steps in shading between black and full white. In the direct evaluation, each step of the grey scale presented through the display device under evaluation is measured with a photometer. Of course, a non-directive display screen must be used in projection display tests; the directivity of the semi-specular screen used for resolution tests was found to influence grey scale values, recorded from a central measuring point, so tests of grey scale rendition were conducted from a flat beaded screen.

Waveforms of information detected
by Observer Camera viewing test
chart resolution wedge at:



200 & 400 lines



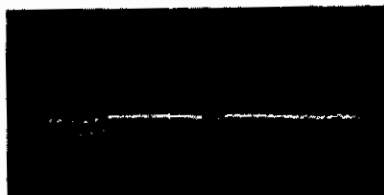
250 & 500 lines



300 & 600 lines



350 & 700 lines



400 & 800 lines

Detected Information from Test Chart
(Optical Projection)

FIGURE 9

SECTION IV

ANALYTICAL EVALUATION

Those displays which are composed of incremental areas may be analyzed by a thorough study of the fundamental increment itself. A CRT display is typical of such images, in that it is generated or "painted" by a small scanning spot traversing the display area. This incremental scanning spot ultimately limits the overall display fidelity. Therefore, a complete description of the increment which generates the display will permit the prediction of its overall quality and maximum fidelity. However, it was found that the prediction depends on analyzing the spot under typical conditions of operation only. The spot must be moving at a rate representative of actual conditions, and the spot intensity (brightness) must be at the level to be used in the overall display generation.

Basic spot size may be properly analyzed by using a scanning line containing known information; in this case, all-white information was selected. When the CRT beam is deflected horizontally, there is negligible vertical deflection in the time it takes to develop one scanning line. The width of the scanning line is a true indication of the size of the basic spot generating that line. Furthermore, the spot is presented for study in a dynamic condition such as that which occurs during normal operation of the CRT. This is the premise under which the ultimate resolving capacity of the CRT may be determined.

Several problems must be overcome to render this technique practical. The normal television raster does not space the scanning lines so that they are widely separated. Vertical deflection of the raster must be increased to further separate the lines. The increase in vertical deflection size will cause overscanning of the CRT, a practice forbidden for many projection CRT devices. It was decided that these difficulties could be eliminated by activating the CRT display for only one to six lines during a television field. At the same time, the alternate field of the interlaced frame would be completely suppressed. This prevented the appearance of scanning lines between the previously gated pattern of lines, and provided greater separation of the few lines selected for display.

The development of a display containing few scanning lines required a brief secondary investigation. The previous research with

the 7WP4 CRT had employed a field gating technique in which only one field had been displayed. The vertical size had been increased, the CRT operated in an overscanned condition. The tube in use at that time had been considered expendable. However, for the research being reported, new tubes were under study and these were not to be abused.

The first experimental approach to develop only a few lines was to feed a simple gating waveform into the amplifier without sync or blanking. The amplifier clamp was disconnected. However, tests confirmed that the amplifier low frequency response was unable to process a gate six lines in duration without severe differentiation. The first line of the resultant display was at extreme brilliance, with five remaining lines gradually decaying to grey. It was apparent that the test signal must contain either sync or blanking at the normal horizontal rate to permit clamp operation, thus avoiding the signal differentiation encountered.

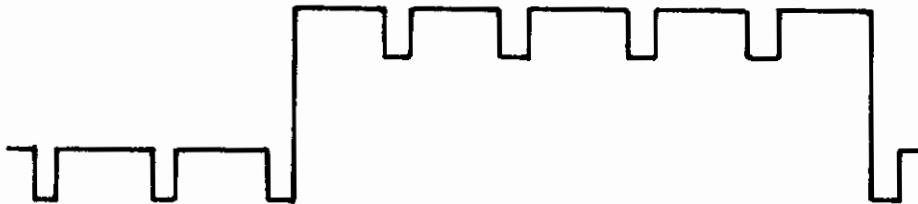
The second approach investigated was the simple intensity gating of an input sync and blanking waveform. This did provide intensification of the signal over a few lines, but the level of the blanking waveform was also elevated. Connecting the amplifier clamp was very effective in applying a correction to this situation. It pulled the blanking down to the proper level, but a tilt was introduced in the first few lines of the display as the clamping correction took place (see Figure 10). When the clamp was disabled to improve this situation, signal differentiation recurred. It was obvious that a complete video signal must be synthesized to permit proper test signal generation. The connection of the equipment as shown in Figure 11 accomplished this objective. The signals into the CRT produced by the arrangement shown in Figure 11 are presented in Figure 12.

The operational procedures are outlined as follows:

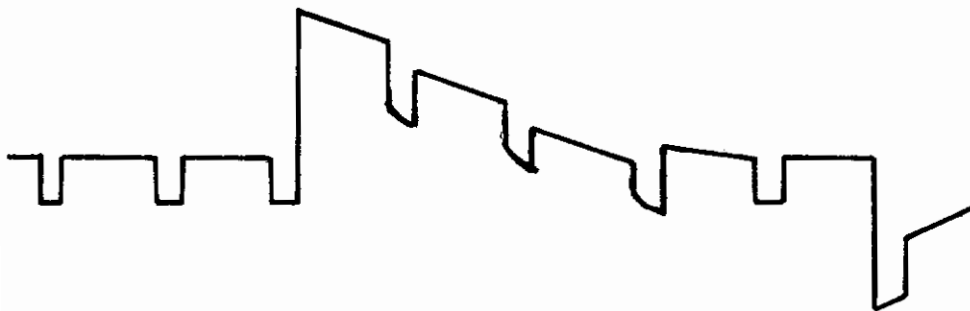
1. The oscilloscope is connected in the conventional manner for television line-finding operations. The vertical drive is connected into the oscilloscope delaying sweep, and the horizontal drive is connected to the oscilloscope main sweep delayed. The delay time control is then adjusted to select the particular t.v. scanning lines which are to be displayed on the oscilloscope. The delaying sweep interval must be greater than one field period to prevent retriggering of the oscilloscope on the second field of the interlaced frame. Thus, a wider separation of the lines for study is accomplished because only the lines of one field are displayed.



(a) Basic Blanking Signal on Video Line
with Camera Beam Turned "off".



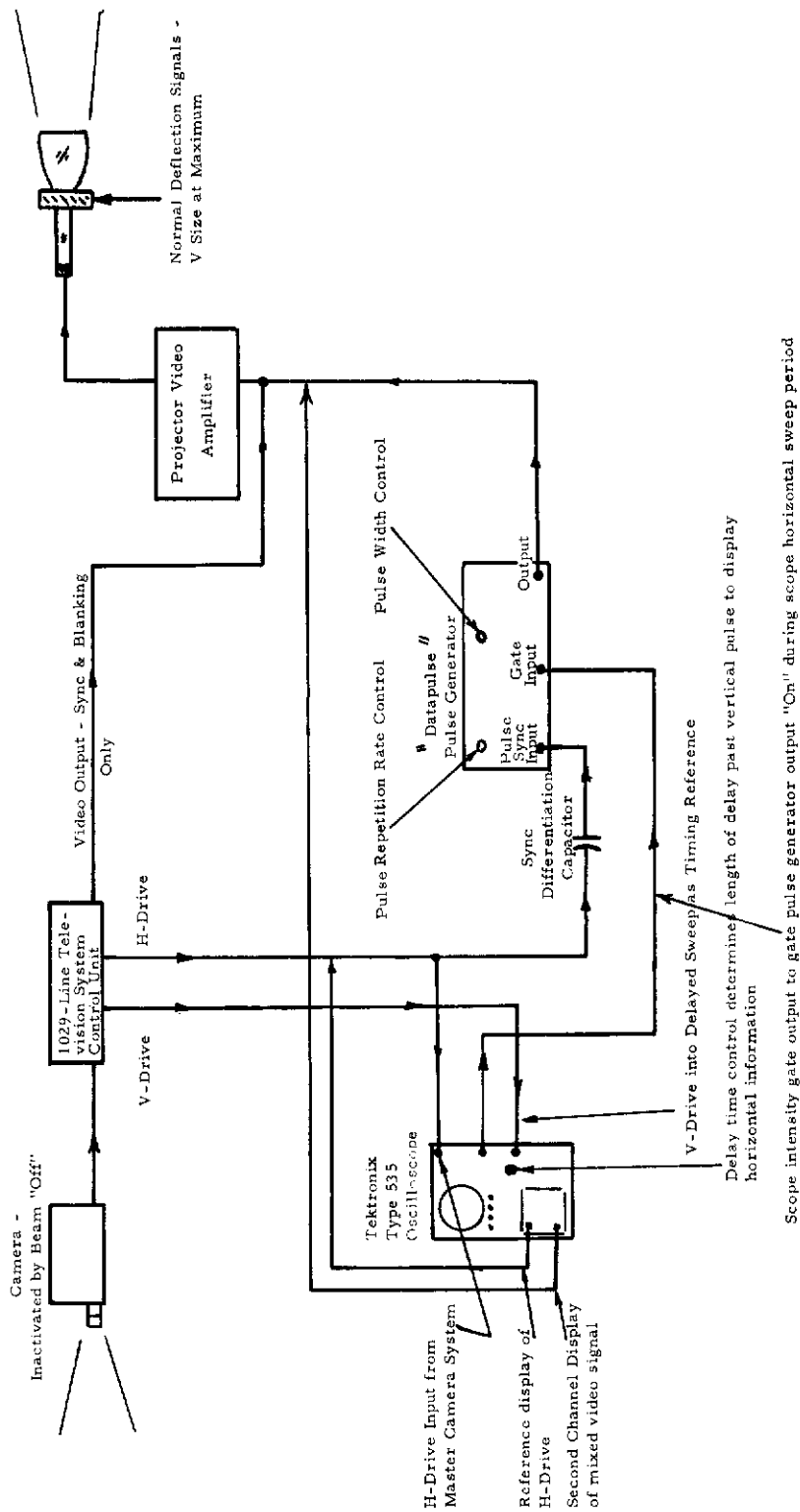
(b) Basic Waveform with Intensity
Gate Superimposed.



(c) Signal After Clamp Corrective
Action

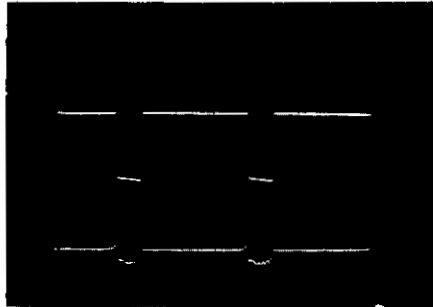
Test Waveform with Intensity Gate Superimposed

FIGURE 10



Equipment Interconnection to Display Individual Scanning Lines

FIGURE 11



(a) H Drive Reference Signal and Video Input to Projection Amplifier Without Gating Pulse (completely dark screen).



(b) H Drive Reference Signal and Video Input to Projection Amplifier with gating pulses mixed into video (with three scanning lines displayed).

Typical Test Signals for Presentation
of 1, 3 or 6 Scanning Lines

FIGURE 12

2. The output intensity gate from the main sweep of the oscilloscope is directed to the gate input of a Datapulse generator. This controls the time during which the Datapulse output will be present. This connection insures an output only for that length of time in which the few lines of the field selected by the oscilloscope can be displayed.

3. The horizontal drive signal is differentiated by a small capacitor in the line. The resulting positive spike is used as sync for the Datapulse unit, forcing the generator into synchronism with the image pick-up television system.

4. The Datapulse output is shown on the oscilloscope with a horizontal drive waveform as reference. The pulse length from the Datapulse is adjusted to be exactly equal to the period between horizontal drive pulses, thus generating a synthetic white video signal for the few lines selected, as shown in Figures 12(a) and 12(b). The basic level of the horizontal drive, blanking, and setup in the video channel will not be upset under these conditions, as they were when the simple gate mixing of the video was accomplished.

5. The camera system used to develop test images will control all operations through the horizontal and vertical drive signals. The video output from the system is connected to the projector video amplifier to supply blanking and setup as used in normal operations. The camera beam control is turned "Off" position to remove all video signals from this output.

6. The Datapulse gated output is also connected to the projector video amplifier; the input acts as a mixing point for the synthetic video and sync, developing the final test signal as shown in Figure 12.

7. The signal level is adjusted at the projector video amplifier input to project only the few lines selected for display and study. If a white background should appear at higher intensity levels, the amplifier output bias may be adjusted to remove this effect.

8. Beam current will be minute for displays of 1, 3, and 6 lines in a 1029-line system. The normal beam current monitoring instrumentation at the projector will show no indication whatsoever under these test conditions. Therefore, a microammeter was connected in the CRT cathode leads to measure current directly.

The procedure described will present a display of a few scanning lines, down to a single stripe. It provided a very graphic

insight for CRT analysis. This technique also proved far superior for the field gating method employed in the previous 7WP4 CRT studies made in the 525-line operation.⁴

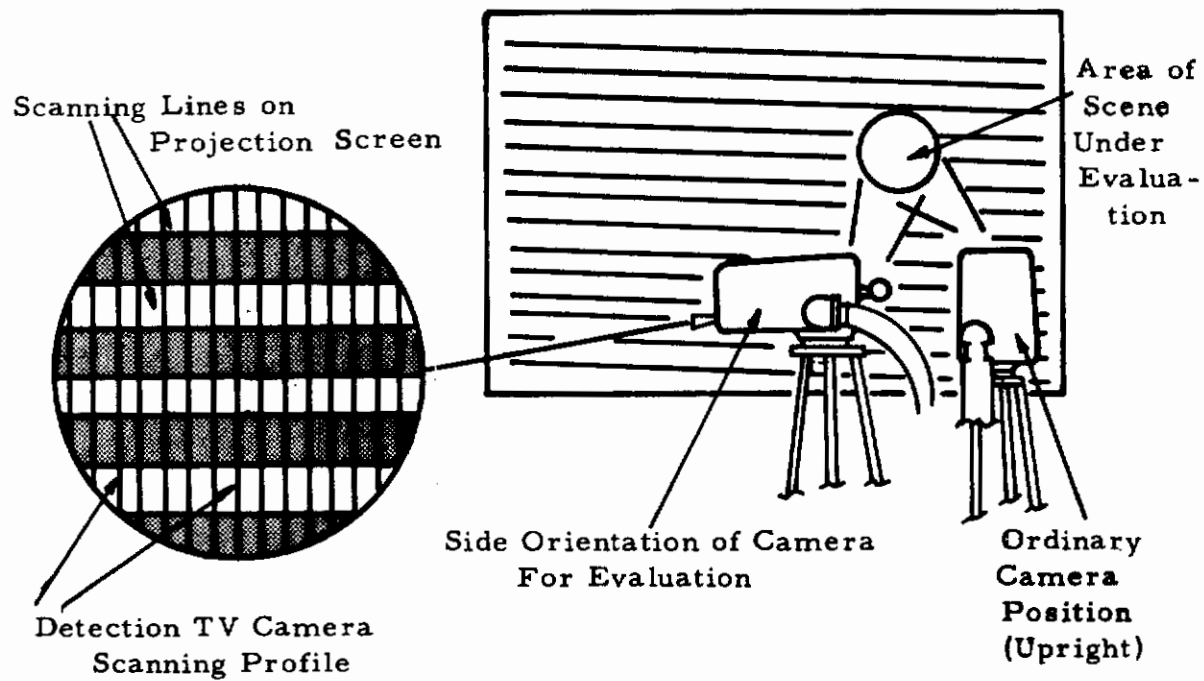
At one time during the previous studies made in the 525-line mode of operation, the observer camera had been turned 90° to view the display (Figure 13). The transverse scanning of the display had been successful at that time, and it was adopted now. This refinement of technique permitted the thorough analysis of the few lines under study, and the development of waveforms which completely described the lines displayed as seen in Figure 14. In these tests, line spacing initially was set wide to insure the presence of unexcited black lines separating the white lines, giving a true 100% contrast ratio. The profile of a scanning line thus developed was plotted, based upon actual measurements taken from photographs of the detector camera waveforms.

Analysis is based upon the data obtained from this plot of the intensity profile, as set forth completely in Part II of this report.⁵ The procedure described therein permits a complete prediction of device capabilities. The degree of reduction in contrast ratio for various levels of resolution may be studied by varying the spacing on the 3- and 6-line groupings and comparing the relative peak-to-peak amplitude. Variations resulting from increased data density are quite graphically displayed.

The analysis of the data collected by the observer camera confirmed the belief that the information which was contained in one line of the display was sufficient to describe the information contained in the whole area from which the line was taken. The data was plotted to produce curves describing the operation of the CRT in the 1029-line scanning mode under varying conditions. It was determined that spot size was smaller in the 1029-line mode than in the 525-line mode, and that resolution determined in one mode could not be used to predict resolution in any other mode.

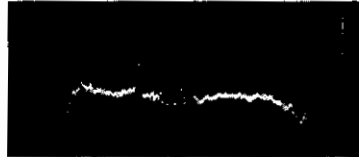
4. Harshbarger and Gill, op. cit., p. 49.

5. Harshbarger, op. cit., p. 57.

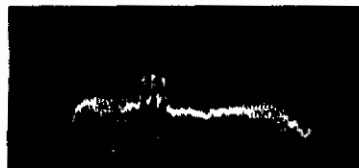


Camera Positioning

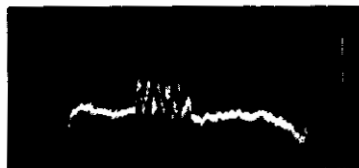
FIGURE 13



1 line



3 lines



6 lines

Detected Waveforms for Individual
Scanning Line Analysis

FIGURE 14

While the above studies were being made to determine resolution, brightness was also being studied. A photometer was set to view the faceplate of the CRT by viewing back through the projector lens. This measurement of the brightness of the few lines being displayed was doubly compensating. The measurement was made through the projector lens, thereby compensating for the light attenuation of the lens as well as loss of light in the tube itself. This set of studies provided more corroboration that the brightness of any significant area under scrutiny will be dependent upon the intensity of the beam current and the amount of time the beam impinges on the specific area of phosphor under study. As mentioned above, it was found that the beam spot size will vary as the scanning speed is varied; the faster the scan the smaller the spot.

Analysis of the data collected from the use of the study technique for the few lines of the CRT raster displayed confirmed the belief that the information in an area may be evaluated by the measurement of the scanning line which traverses this area. The curves describing the operation of the CRT in the 1029-line mode were used to derive other curves relating resolution and brightness. From these curves predictions could be made concerning the operation of the CRT in the 1029-line mode. The entire analysis substantiated the proposition that the incremental beam must be in operation under realistic conditions in order to produce data for a meaningful analytical evaluation of the operation.

SECTION V

CONCLUSIONS

Prior to the time of this investigation and development, display evaluation was dependent upon the observer's opinion. There was no real standard of comparison by which displays of all types could be evaluated, or even compared. The situation existed because there was no technique described for the precise delineation of a display. When a need for accuracy in evaluations did occur opinion could no longer be the criteria for evaluation.

Human observation has been replaced as the method of evaluation by the measurement of displays in terms of known standards. The use of a television camera as the "standard observer" reduced the study of displays to the analysis of electronic waveforms, which are measured in common electrical units. The waveforms are, in reality, the electrical description of the information contained within the display. Therefore, the observer camera is capable of measuring the fidelity with which the information contained within the display can be interpreted to the viewer. The photometer measures the amount of light available from the display. When these two factors concerning the display are related, a complete analysis of the display is accomplished.

The direct evaluation method outlined herein applies the basic premises above to the study of displays of any type. The analytical evaluation is especially applicable to the study of display that are the composite of minute elements, such as a television display that is a composite image developed by scanning of the beam spot.

It is concluded that the method described in this report is a precise, complete, and repeatable technique for the evaluation of displays.

Contrails

SECTION VI

TECHNICAL RECOMMENDATIONS

USE OF METHOD

The advantages of using the evaluation method described herein are evident in that the element of human visual interpretation has been eliminated. The resulting evaluation has been removed from the "opinion" status to one measured in terms of known electrical units. The observer television camera is constant, and objective. It is not subject to the physiological and psychological factors which influence the human eye. Therefore it is adaptable to reducing a wide variety of subjects to a common standard. There are many potential applications for this method, which implies that it be recommended as a standard. This is the only method now known to provide a common denominator for comparing and evaluating all types of displays.

COLOR

The presently described studies have been limited to the evaluation of monochromatic displays in black and white. The possibility of expansion into color displays is readily recognizable; the problem will be the assignment of relative values to the primary colors of the color television observer camera, and the integration of these values in the production of varying hues and shades of the primary colors.

In reality, the color television scanning spot is not singular but plural. For instance, in color CRTs, one beam scans the display screen, but it is divided into three in the effort to develop color. It is still but one scanning spot which has been electrically divided into its component parts of the spectrum of color. Not one, but three, elements are under study. The varying relationships between these three spots will determine the hue or shade of color, but the detailed information in the display remains visible regardless of coloring. The study of the spot will determine the fidelity of information conveyed at a specific moment of time.

It is recommended that the evaluation of color displays be investigated using the direct and analytical methods of evaluation.

EVALUATION OF TELEVISION DEVICES

At the time the 7WP4 CRT was under evaluation, it was discovered that information pertinent to its operation in the 1029-line scanning mode was not available from the manufacturer. This fact triggered the development of the analytical evaluation method; the method is particularly applicable to the evaluation of television display devices. It is recommended that the method be adopted by the television industry to determine realistic specifications for cathode ray tubes in particular, and other television apparatus in general. It is specifically recommended that the method be utilized to determine the acceptable amount of contrast ratio which defines the limit on the resolving capacity of cathode ray tubes.

QUALITY CONTROL IN THE PRODUCTION OF CRT DEVICES

At one time in the progress of cathode ray tube evaluation, it was discovered that a wide divergence existed in the performance of two new tubes. Eventually, other new tubes were introduced into the testing. Only the one tube was at wide variance with the others. No specific reason could be established for the variance, other than that the tube itself did not conform to the general specification for such tubes. The method developed under this program is recommended to tube manufacturers for determining the limits of specifications and the realistic limitations which must be imposed on manufacturing techniques to provide adequate quality control safeguards. It is believed that a variation of the analytical method could be devised to serve as a tool to prove that the control standards were being met.

VIDEO DRIVE AMPLIFICATION

The complete evaluation of the display using the direct method of evaluation was severely limited by the fact that the amplifier in the projection circuit was incapable of passing information at a level beyond the 800-line resolution mark. The bandwidth of the amplifier must be matched to the expected performance in such a manner that information is not limited before introduction to the display device. It is recommended that increased video amplifier bandwidths of 30 megacycles to 50 megacycles, or even to 100 megacycles, be investigated.

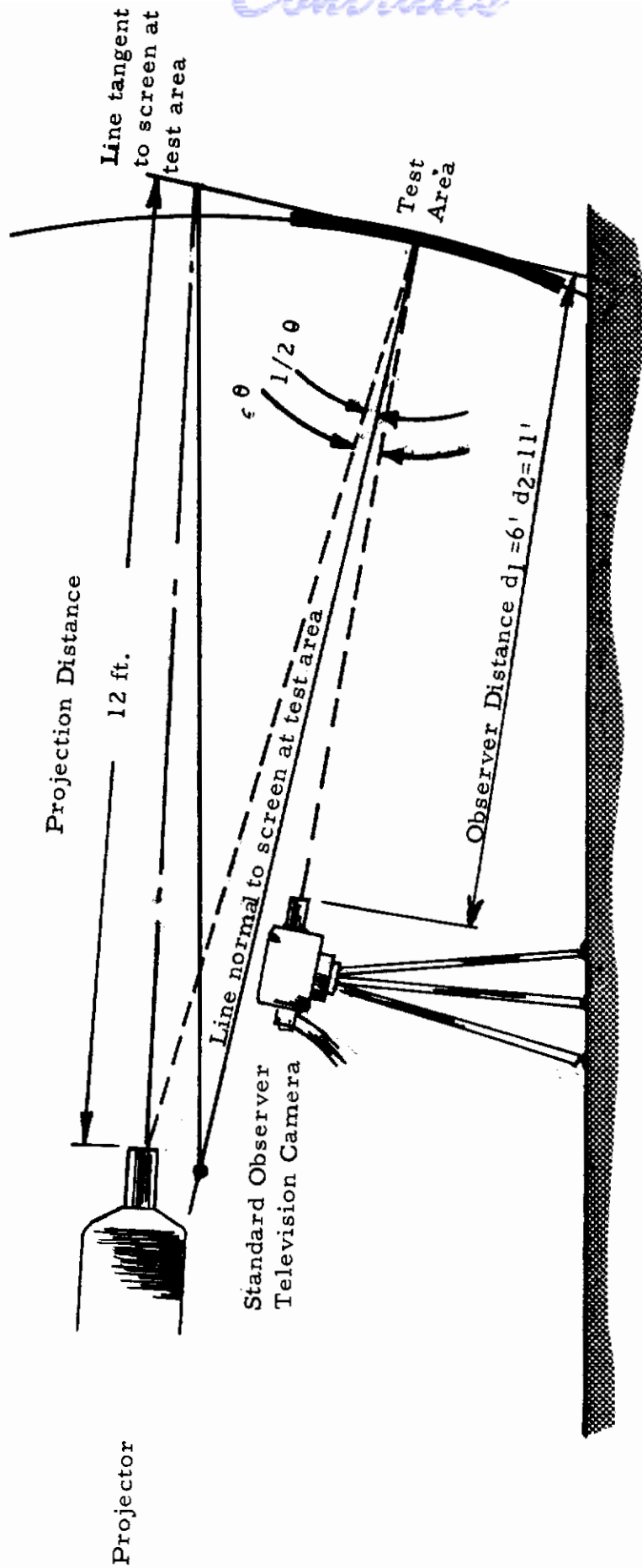
OBSERVER CAMERA LENS SELECTION

Optical efficiency of the observer camera must be maintained at all times to obtain valid data. In order to permit the camera to function properly during evaluation studies, the camera lens must be carefully selected on two counts: sharp focus over a relatively small area of a much larger display, and light attenuation. Only a small segment of the display is examined at any one time to prevent limiting of the data in the detector camera system. For instance, if the observer camera system has the capability of producing an 800-line resolution image, the data for evaluation should be well below that limit to insure full reproduction fidelity. In this series of tests, it was assumed that if the data remained at or below 10% of the detector system capability; that is, 80 lines or less in an 800-line observer system, that the data would be reproduced faithfully. This was verified throughout the tests.

Lens aperture controls the efficiency of light transmission through the lens. Initial tests revealed that a 25 mm f/2.5 lens mounted on the observer camera placed twelve feet from the display screen was not adequate. This produced too large a viewing angle and introduced excessive light attenuation. Then, if the camera were moved closer to the screen to permit viewing of a sufficiently small area of the display, the camera shadow obscured the data to be viewed. Further experimentation with a 50 mm f/1.5 lens produced acceptable displays, but the camera had to be moved to a more remote location, again to prevent shadowing. The final lens selected was a 50 mm f/0.95 which proved even better in that signal-to-noise ratio was considerably improved. It is recommended that the observer camera lens be selected with great care.

DISPLAY SCREENS AND SURFACES

Light level is, of course, the limiting factor in the utilization of the television camera as the "standard observer" in evaluation studies. The arrangement of camera and screen in this study is shown in Figure 15. It will be noted that the screen depicted in the figure is not the conventional flat beaded screen. Projected displays exhibit a limited amount of brightness at best; the vidicon camera systems which were available required a moderate level of light input to develop a usable signal with acceptable signal-to-noise ratio.



Detailed Layout of Standard Observer Viewing Arrangement

FIGURE 15

it was soon obvious that the conventional screen was not adequate to provide a detectable image for the camera being utilized. However, it was obvious that a more efficient screen could provide an image which could be detected.

The Simulation Techniques Branch furnished a special high-gain semi-specular spheroidal screen which is very directive. Light is reflected from this screen over a very narrow included angle; in essence concentrating the reflected image at the focal point of the display surface. When the camera was located at this optimum point of observation, a suitable video signal was obtained. This advance in screen technology permits the use of the conventional vidicon camera as the standard observer in the evaluation method as applied to television projected displays.

The normal flat beaded screen is adequate when sufficient light is used to produce the image, such as that provided by slide projectors. In most cases where the projection medium is optical, sufficient light is developed for projection so that light pick-up by the observer camera is no problem. However, if the surface on which the image is to be developed is dull or rough in texture, it is possible that the lens might delineate details of screen texture too sharply and thereby present false information for consideration by the observer camera. This possibility can be checked by the observer camera before the display evaluation is to be started.

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APPENDIX

EQUIPMENT

The laboratory work necessary for the development of the evaluation method was performed in the facilities of the Simulation Techniques Branch of the Behavioral Sciences Laboratory, Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio. In addition, the equipment in use during the work was furnished by that branch. The equipment was not designed specifically for this study; it came from many sources. For instance, the television projector had been removed from an F-151 Gunnery Simulation Trainer and modified extensively; the high-gain screen was one which was in the possession of the Aerospace Medical Research Laboratory. A list of the equipment is given below, with pertinent comments on changes which were necessary. The equipment is grouped into three main systems: the evaluation group, the image projection group, and the image generation group (see Figures 3 and 11).

THE EVALUATION GROUP

This group includes all the equipment in the observer camera system; including the camera and its lens, the camera control, an observation monitor, an oscilloscope, the beam current meter, a photometer and the recording photographic camera.

1. The Observer Camera

The observer camera was the General Precision Laboratories Precision 800 camera. It operates with a raster of 525 scanning lines. It is capable of 800-line resolution. The camera was equipped with a Carl Meyer Speed Lens, $f/0.95$, 50 mm, capable of focusing at any point from 2 feet to infinity.

2. The Observer Camera Control

This also was a product of the General Precision Laboratories: Camera Control Unit Serial No. 200. This was the normal control unit furnished with the above camera.

3. The Observation Monitor

This was a standard General Electric Television Monitor, Model 4TH26A2, Revision 4. It was used to display the signals produced by the observer camera for ready reference and for comparison with the waveforms at the oscilloscope.

4. Oscilloscope

The oscilloscope used in the evaluating group was the Tektronix Model 535, Serial No. 5887. Waveforms of signals produced by the observer camera were displayed on this instrument. This oscilloscope furnished the data on which the evaluations were based.

5. The Photometer

This piece of equipment includes the Photo Research Spectra Brightness Spot Meter, Serial No. 1394, and the Photo Research Spectra Power Supply, same serial number. It was used to measure the amount of light developed by the image being projected. All data concerning brightness were furnished by this instrument.

6. The Beam Current Meter

The meter was a highly sensitive microammeter, the Sensitive Research Polyranger, Model USP, Serial No. 942492. Since the beam current in the development of a single line of a raster, or a group of the same lines, was so small that the normal instrumentation of the equipment could not measure it, it was found necessary to supplement the normal instrumentation with this meter. It was connected into the CRT cathode line at the projector to provide measurement for the exceedingly small current involved. All evaluation data on beam current were taken from this meter.

7. The Recording Camera

All data taken during the course of this work were recorded photographically with the Polaroid Camera, Dumont Type 297, Serial No. 349, attached to the oscilloscope. The Polaroid camera was used to provide prompt assurance that the subject matter had been properly and adequately recorded.

THE IMAGE PROJECTION GROUP

This is the group which contains the specific equipment to be evaluated, in the case of evaluation of equipment; or the lighting facilities which will be necessary in the case of evaluation of a static display such as a chart, graph, map, painting, tapestry, mural, mosaic, or the like. In the case of the reported study, this group was composed of the projection device and its lens, the deflection generator and control, the video amplifier, and the auxiliary equipment of each of these pieces of equipment.

1. The Projector

The projector had been taken from a fixed Aerial Gunnery Trainer, Type F-151, Serial No. AF-55-151-7, manufactured by Rheem Manufacturing Co. It was equipped with a General Scientific Corp., Model SOLMAR, 8-inch f/2 lens, Serial No. 102. The projector was designed to operate with the 7WP4 Cathode Ray Tube. It was first designed for operation in the 525-line scanning mode, and then revised to operate in the 1029-line scanning mode. The devices being evaluated were the 7WP4 CRTs.

2. The 1029-line Deflection Generator and Control

This special circuitry was designed by Systems Research Laboratories, Dayton, Ohio to provide high resolution operation of the projector. The modifications are shown more specifically in the schematic diagrams of the horizontal and vertical sweep circuits contained in the companion report.⁶

3. The Projector Video Amplifier

This was another of the pieces of equipment supplementing the Rheem F-151 Gunnery Trainer, the Dage Amplifier, Model TV-2-63-036, Serial No. 101. Bandwidth of this amplifier was 20 megacycles, although of a characteristic that was found to be deficient for certain purposes of this study.

6. Harshbarger, op. cit., p. 33.

4. The Setup Monitor

This monitor served to provide a visual check of the image being provided to the projection equipment for display. The monitor provided the means whereby the pick-up camera was maintained in focus and adjustment.

5. The Projection Comparison Monitor

Another 1029-line Conrac Monitor, Model CQC-17, Serial No. 51758, provided a visual comparison image for the display as projected onto the screen. The monitor was connected in such a manner that the image being displayed thereon was the one which was taken from the circuitry just before the projector amplifier input, and was a direct comparison with the image being displayed on the screen as produced by the CRT under evaluation. This monitor was placed in the projection room beside the projector.

6. The Oscilloscope

The Tektronix Oscilloscope, Model 585, Serial No. 4357, was the data collection device utilized in the image generation group. The waveforms generated by the pick-up television camera were displayed on this oscilloscope for recording photographically. In addition, this oscilloscope could be connected to the output from the projector amplifier for the display of the waveforms being delivered to the CRT for display, thus providing exact data of the input signal to the CRT. This also means that the input and the output of the amplifier could be directly compared for a check on the operation of the amplifier at all times.

7. The Datapulse Generator

This piece of equipment, the DATAPULSE Generator, Model 104, Serial No. 104-039, was used to develop the proper signal for generation of the single-line and small-group-of-lines used during the analytical study of the operation of the CRT.

8. The Recording Camera

This is the same piece of equipment described under the image evaluation group. It was also used here to record the data which were taken from the Type 585 Oscilloscope of this group.

9. The Screen

The screen originally used in the early portion of the study of projection techniques was a flat beaded screen, the type normally used in the projection of film, slides, or television projections. However, the amount of light reflected and radiated from such a screen was insufficient for the use of the television observer camera. A spheroidal section, high-gain screen, built by Goodyear Aerospace Semi-Specular Projection Screen for the Air Force (Contract No. AF33(615)-211) was in the possession of the Simulation Techniques Branch at the time. This was put to use most profitably. The gain in light intensity is most noticeable and the observer camera had no trouble in picking up the image displayed for evaluation. The projector and the observer camera must be precisely placed because of the narrow limits of reflection from this screen.

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