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STUDIES OF DISPLAY SYMBOL LEGIBILITY

PART VII: Comparison of Displays at 945- and 525-Line Resolutions

MAY 1966

D. Shurtleff
D. Owen

Prepared for

DEPUTY FOR ENGINEERING AND TECHNOLOGY
DECISION SCIENCES LABORATORY
ELECTRONIC SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
L. G. Hanscom Field, Bedford, Massachusetts

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Project 7030

Prepared by

THE MITRE CORPORATION
Bedford, Massachusetts

Contract AF19(628)-5165

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FOREWORD

This report is one of a series describing symbol legibility for television display. Additional information on this topic may be found in the following reports: "Studies of Display Symbol Legibility: The Effects of Line Construction, Exposure Time, and Stroke Width," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-249, February 1963; "Studies of Display Symbol Legibility, II: The Effects of the Ratio of Width of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," by B. Botha and D. Shurtleff, The MITRE Corp., Bedford, Mass., ESD-TR-63-440, July, 1963; "Studies of Display Symbol Legibility, III: Line Scan Orientation Effects," by B. Botha, D. Shurtleff, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-138, May 1966; "Studies of Display Symbol Legibility, IV: The Effects of Brightness, Letter Spacing, Symbol Background Relation, and Surround Brightness on the Legibility of Capital Letters," by D. Shurtleff, B. Botha, and M. Young, The MITRE Corp., Bedford, Mass., ESD-TR-65-134, May 1966; "Studies of Display Symbol Legibility, V: The Effects of Television Transmission on the Legibility of Common Five-Letter Words," by G. Kosmider, The MITRE Corp., Bedford, Mass., ESD-TR-65-135, May 1966; and "Studies of Display Symbol Legibility, VI: Leroy and Courtney Symbols," by D. Shurtleff and D. Owen, The MITRE Corp., Bedford, Mass., ESD-TR-65-136, May 1966.

REVIEW AND APPROVAL

This Technical Report has been reviewed and is approved.

James D. Baker | Roy Morgan

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ABSTRACT

The legibility of Leroy alphanumerics was determined for 6, 8, 10, and 12 active scan lines per symbol height on a good quality 945-line television system. These results were compared with those of a similar study in which an inexpensive commercial 525-line television system was used. One group of subjects identified symbols displayed by the 945-line system while a second group identified symbols displayed by the 525-line system. The symbols were presented singly, and the speed and accuracy with which the subjects were able to identify them were recorded. The results showed that, even with good quality television, identification performance deteriorated for resolutions lower than 10 lines per symbol height. Performance for the two television systems was similar for 8, 10, and 12 lines per symbol height; but at 6 lines per symbol height, performance was better for the 945-line television than it was for the 525-line television system. As with previous experiments in this series, 10 lines per symbol height was the lowest resolution recommended for television displays.

CONTENTS

SECTION I

INTRODUCTION

LEGIBILITY, LINES, AND RESOLUTION

Previous studies [1, 2, 3, 4] have shown that, to produce satisfactory identification of symbols, the number of active scan lines required will be at least 10 lines per symbol height, viewed on an inexpensive commercial 525-line system (both speed and accuracy of identification decline for 8 and 6 lines per symbol height). Symbol identification was worse at 5 lines per symbol height than at 11 lines per symbol height, when simulated television scan lines were used. A question was raised about the applicability of these results to other television systems, and in particular, it was argued that the figure 10 lines per symbol height is probably a conservative estimate for live television displays. With better quality equipment, for example, a good 945-line television system, acceptable reading performance could be obtained with fewer lines per symbol height.

SIMULATED AND LINE DISPLAYS

Although the results for the simulated television showed some deterioration of performance at 5 lines per symbol height (with a scan line quality better than could be expected from any live television system) it was possible that with better quality live television the recommended number of scan lines per symbol height could be reduced to some value less than 10 lines (found for the inexpensive 525-line television) but greater than 5 lines per symbol height (found for the simulated television).

A General Precision 945-line television was available for research use. Using this system, it was possible to determine the smallest number of lines per symbol height required for good quality television and to compare symbol identification for expensive and inexpensive television systems. Speed and accuracy of identification of standard Leroy symbols were compared for the two television systems at 6, 8, 10 and 12 active scan lines per symbol height.

SECTION II

PROCEDURES AND APPARATUS

PREVIOUS 525-LINE STUDY

This study duplicates the procedures employed in an earlier study, which used a 525-line system,[3] * therefore, the description of procedure and apparatus given here is limited to the particulars that apply to the 945-line system (see Appendix I and II.)

SELECTION OF SUBJECTS AND THEIR DUTIES

The four subjects employed, whose ages ranged from 23 to 43 years, were screened for normal vision with a Bausch and Lomb Ortho-Rater. The subjects started symbol exposure by actuating a hand-operated switch and verbally identified the symbol by speaking into a microphone, which terminated the symbol's exposure. The time required to identify the symbol, and the symbol named, was recorded.

CONTROL OF SYMBOL BRIGHTNESS

The symbols used were Leroy alphanumerics. They were projected one at a time onto a translucent screen, which was mounted on a modified Motion Analyzer. Brightness was adjusted to 20 and 2 foot-lamberts, for the symbol and the background. Symbol brightness was not as variable for this

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* Of particular relevance are the methods of procedure for the group viewing Leroy alphanumerics during the first part of the experiment, since the same procedure was used in the present study. The data obtained from that group are included in the present paper for comparisons of performance with the 945-line television. A description of the projection and recording equipment is given by Kosmider [5].

system (945-line) as it had been for the 525-line system. In the latter, brightness varied as much as 25 percent between measurements taken before and after an experimental session. The brightness, measured before and after a session in this study, varied by approximately five percent. In an attempt to maintain symbol appearance uniformity throughout the sessions, adjustments to the TV equipment were always made by the same individual, using one arbitrarily selected symbol as a standard.

PROCEDURE FOR TESTS

Each subject identified symbols for four values of resolution, viz., 6, 8, 10 and 12 active lines per symbol height. The camera-to-screen distance was varied to obtain the different values of symbol resolution, and the subject-to-monitor distance was varied to maintain the visual angle of subtense of symbol height at 11 minutes of arc for each value of resolution. The values of symbol resolution were assigned to subjects in the same way as in the study with 525-lines: each value of resolution preceded and followed each of the other values of resolution, and each value appeared in the first, second, third, and fourth position in the sequence. Each subject made five identifications of each of the 36 symbols (26 letters and 10 numerals) for each of four values of symbol resolution.

SECTION III

RESULTS

MEAN IDENTIFICATION TIMES

The mean identification times and the standard deviation of identification times with the 945- and 525-line television systems are shown in Table I. Mean average identification time was much the same for the two television systems for symbol resolutions of 8, 10, and 12 lines per symbol height. At 6 lines per symbol height, identification time was faster with the 945-line than with the 525-line system. These data are plotted in Figure 1, which shows the similarity between the two systems at 8, 10, and 12 lines, and their divergence at 6 lines.

Analysis of Variance

The mean identification times were converted to reciprocals and submitted to an analysis of variance appropriate for a mixed design. The results showed that symbol resolution was the only significant source of variance. There were no significant differences between television systems, and the interaction between systems and symbol resolution was not statistically significant.

MEAN ERROR PERCENTAGE

The mean error percentage and standard deviation of error percentage for all symbol resolutions are shown in Table II. Identification errors were less with the 945-line system than with the 525-line system at 6, 8, and 12 line values, but not at 10. At 6 lines per symbol height, half as many errors were made with the 945-line system as with the 525-line system. The

Table I

Identification Times and Deviations

Television System		Symbol Resolution (lines/symbol height)			
		6	8	10	12
945-line	M	0.79	0.66	0.50	0.47
	σ	0.12	0.09	0.09	0.05
525-line	M	1.08	0.70	0.54	0.49
	σ	0.29	0.16	0.04	0.04

differences between error percentages with the two television systems are evident in Figure 2.

Analysis of Variance

The error percentages were submitted to an analysis of variance appropriate for a mixed design.* The results are shown in Table III. First, it is noted that a significantly lower percentage of error occurred with the 945-line equipment than with the 525-line equipment; second, that symbol resolution significantly affected error percentages; and third, that the interaction between systems and symbol resolution was significant. The reason for this significant interaction is apparent from the plot of error percentages against resolution value shown in Figure 2. This figure shows that, for 6 lines per symbol height, fewer errors were made with the 945-line system than with the 525-line system, but both systems had similar error rates at 12, 10, and 8 lines.

*The results of this analysis should be viewed with some caution because of the truncated distribution of error scores for the higher values of resolution.

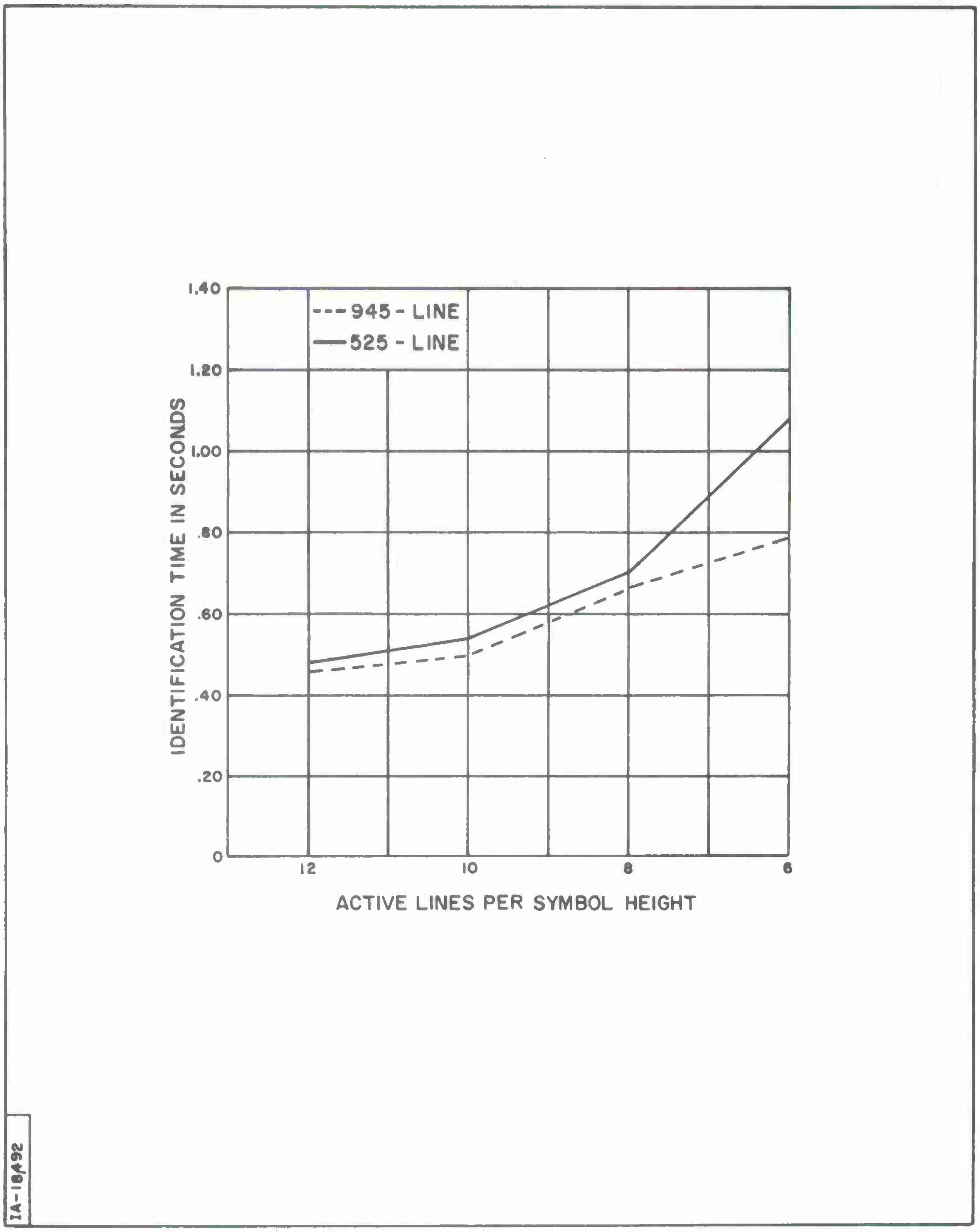

Figure 1. Average Symbol Identification Times.

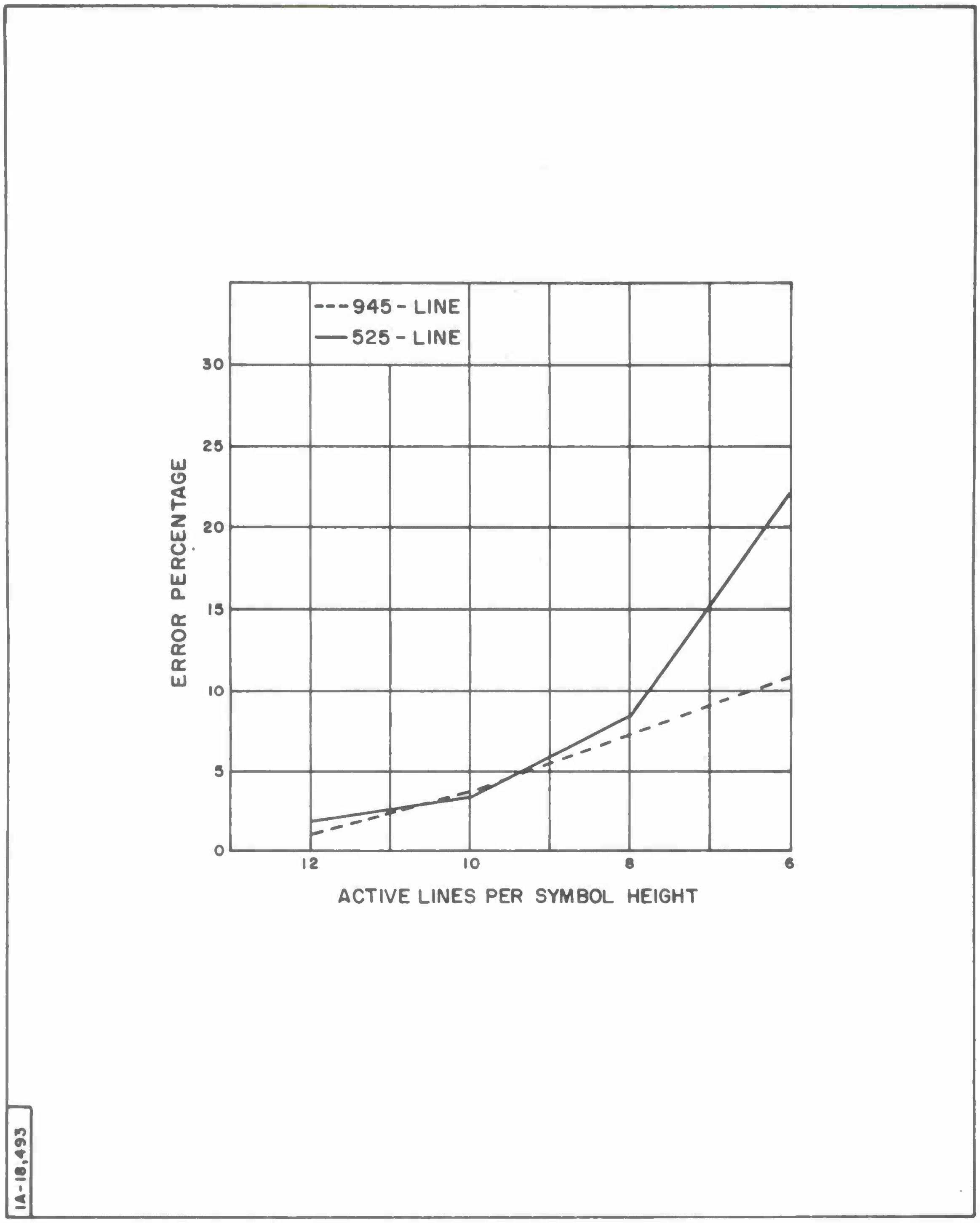

Figure 2. Average Error Percentage.

Table II

Error Percentage and Deviations

Television System		Symbol Resolution (lines/symbol height)			
		6	8	10	12
945-line	M	11.0	7.2	3.6	1.0
	σ	3.4	4.6	2.2	0.4
525-line	M	22.5	8.6	3.5	2.8
	σ	0.6	3.1	2.0	0.8

Table III

Variance of Error Percentages Analysis

Source of Variation	Sum of Squares	df	Mean Squares	F	P
Between Systems	104.80	1	104.80	29.0	0.01
Between Subjects	21.68	6	3.61		
Total Between	126.48	7	18.07		
Symbol Resolution	1066.25	3	355.42	55.90	0.001
Symbol Resolution x System	168.26	3	56.09	8.82	0.001
Symbol Resolution x Subjects	114.45	18	6.35		
Total Within	1348.96	24			
Total Sum of Squares	1475.44	31			

SECTION IV

DISCUSSION OF RESULTS

SMALLEST REQUIRED SYMBOL RESOLUTION

These data indicate that the smallest value of symbol resolution required, for both the 525-line and 945-line television systems, is 10 active lines per symbol height.

ADVANTAGES OF 945-LINE SYSTEM

Symbol identification for resolutions of 8 and 6 lines per symbol height was better with the 945-line than with the 525-line system; but, with both systems, performance was not as good as that for 10 lines per symbol height. Although reading performance at 6 lines per symbol height was better for the 945-line television system than for the 525-line system, the particular factors involved are not known. The groups of subjects viewing the two systems had similar speed and accuracy scores for solid-stroke Leroy alphanumerics; therefore, the differences noted in performance with the television systems were not due to initial differences between the abilities of the two groups to identify symbols.

DISPLAY AREA ON MONITOR

These data do not mean that the smallest value of symbol resolution required for both television systems will necessarily be the same for symbols displayed on all parts of the monitor's screen. The present data were collected for symbols displayed only at the center of the screen, and it is to be expected that a resolution greater than 10 lines will be needed when symbols are displayed on peripheral areas of the screen.[6] It is possible that the amount by which symbol resolution needs to be increased at the periphery will be less for 945-line than for 525-line television systems, because of the improved design of the deflection system in the 945-line equipment.[7]

EFFECTS OF BRIGHTNESS CONTROL

It was noted earlier in the procedure section that the brightness measures with the 945-line system were more stable than they were with the 525-line system. It is possible that in some instances the symbols on the 525-line set were dimmer than the symbols on the 945-line set, and this difference may account, in part, for the poorer performance with the 525-line system. At the same time, symbol brightness is only one factor among many which may have affected performance (see Tables I and II). The importance of these differences in determining reading performance in this study is not known.

CONCLUSION

The difficulties involved in generalizing about the results of studies like the present one have been discussed in a previous report.[3] The one conclusion, drawn from the data of other studies in this series,[1, 2, 3, 4, 5] that is supported by the data of this study, is that symbol resolutions of less than 10 lines per symbol height are associated with a deterioration of reading performance.

APPENDIX I

TV CAMERAS

CHARACTERISTICS OF TV CAMERAS COMPARED

Some selected characteristics of the TC-100 television camera (525-line) and the General Precision Camera P/N 5358-6 (945-line) are taken from the manufacturers' handbooks. [8, 9] A complete listing of specifications for the two cameras and control circuits may be found in the handbooks.

Specifications	525-Line	945-Line
Input Power	50/60 cycles, 95-125 vac., 0.5 amp., 45 watts.	115 vac., 50-60 cps., control voltage.
Scanning	Horizontal frequency, 15,750 cps.; crystal controlled; vertical frequency, 60 cps.	Horizontal frequency, 28,350 cps.; vertical frequency, 60 cps.
Frame Rate	30 cps.; 2:1 interlace	30 cps.; 2:1 interlace
Resolution (3x4 aspect ratio)	Horizontal, 400 lines; vertical, 300 lines, apparent.	1000 lines (center) @ 675, 875 and 945-lines/frame, vertical 600 lines.
Bandwidth	Nominal, 5 Mc.	17 Mc. $\pm$ 1.0 db.
Output	Composite video, 1.5 v. into 75 ohm line; RF:100 mv.; channels 2-6 into 75 ohm line.	Video, 1.0 v.; non-composite, 1.4 v.; composite impedance, 75 ohms, 2 outputs.
Operating Control	Beam, target, electrical and optical focusing, aperture control.	Beam target, pedestal, gain electrical and optical, focusing, aperture control.

APPENDIX II

VIDEO MONITORS

CHARACTERISTICS OF MONITORS COMPARED

Some selected characteristics of the Miratel 14 inch video monitor (525-line) and the Conrac 21 inch video monitor (945-line) are taken from the manufacturers handbooks.[10, 11] A complete listing of specifications for the two monitors and control circuits may be found in the handbooks.

Specification	525-Line	945-Line
Signal Input	from 0.25 to 1.0 v. peak-to-peak with sync. negative.	from 0.50 to 2.0 v. peak-to-peak with sync. negative.
Power Inputs	115 vac., 60 cycles, 300 watts.	117 vac., 50/60 cycles, 180 watts.
Video Bandwidth	video response beyond 10 mc.	flat to 20 mc. $\pm$ 1 db.

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(2) B. Botha, and D. Shurtleff, "Studies of Display Symbol Legibility II: The Effects of the Ratio of Widths of Inactive to Active Elements Within a TV Scan Line and the Scan Pattern Used in Symbol Construction," The MITRE Corporation, Bedford, Mass., ESD-TDR-63-440, July 1963.

(3) D. Shurtleff, and D. Owen, "Studies of Display Symbol Legibility VI: Leroy and Courtney Symbols." The MITRE Corporation, Bedford, Mass., ESD-TR-65-136, February 1965.

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(10) Miratel Electronics, Inc., Miratel "L" Series Television Monitor Technical Data and Specifications, St. Paul 12, Minn.

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13. ABSTRACT

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14. KEY WORDS	LINK A ROLE	LINK A WT	LINK B ROLE	LINK B WT	LINK C ROLE	LINK C WT
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