FINAL ENGINEERING REPORT NO. BRD-88

AIR TRAFFIC CONTROL RADAR BEACON SYSTEM COMPONENT AND SYSTEM INVESTIGATIONS, EVALUATIONS, AND INSTALLATION

PREPARED FOR
FEDERAL AVIATION AGENCY
BUREAU OF RESEARCH AND DEVELOPMENT
UNDER
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CONTRACT NO FAA/BRD-88

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1.0 SCOPE

The contents of this manual comprises the final engineering report submitted by Stewart-Warner Electronics to the Federal Aviation Agency (FAA) Bureau of Research and Development under Federal Aviation Agency contrast number FAA/BRD-88 Stewart-Warner originally contracted with the Civil Aeronautics Administration (CAA) Technical Development Center under contract number C13ca-639 Amendment #2 to the contract, dated 18 March 1959, transferred the responsibility of administering this contract to the Federal Aviation Agency Bureau of Research and Development (BRD). This same amendment changed the contract number to FAA/BRD-88 in lieu of C13ca-639

Stewart-Warner, under the sponsorship of CAA, then later under FAA, contracted for engineering and related services for the evaluation and determination of equipment performance improvements of the Air Traffic Control Radar Beacon System.

Investigations and evaluations of system components were conducted in the laboratories of Stewart-Warner Electronics. Additional data was obtained from the two Chicago airfields, Midway and O'hare, which were being equipped with Air Traffic Control Radar Beacon Systems. Engineering assistance was provided during the beacon installation at these two sites.

Assignments were forwarded to Stewart-Warner Electronics in the form of tasks on various dates.

2 0 INTRODUCTION

This final engineering report is a compilation of the individual tasks that were assigned and accounted for in the monthly progress reports or in a task completion report

The tasks are divided into sections in this report and consist of the following:

(a) Video Standardizer For Air Traffic Control Radar Beacon System (Section 3 0). This task covered a study of video standardization, signal-to-noise ratios, effect of temperature change on the equalizer characteristics, signal attenuation with various lengths of cables, design and construction of a video standardizer unit, pulse shaping circuits, and study of Line Compensator trigger output.

(b) Safety Beacon Interrogator Antenna (Section 4.0). This task required tests be made of the waterproofing characteristics of the Safety Beacon Interrogator Antennas. The tests included the effects of ambient temperature changes and a wide variation of relative humidity on the antenna.

(c) Panoramic Photographs of O'Hare Field and Midway Airport (Section 5.0). This task requested panoramic photographs of these two fields for the purpose of evaluation of the sites for beacon antenna installations

(d) Life Test of Video Interconnection Equipment (Section 6 0). The object of this task was to determine the deterioration of electrical and mechanical functions of the Video Interconnection Equipment under conditions simulating two years of normal operation Recommendations were submitted for improvements to the unit that could increase its stability, reliability, and ease of maintenance.

(e) Electromagnetic Delay Line Study (Section 7.0). This task requested a survey be made to determine the sources, characteristics, size, and cost of delay lines best suited to delay radar video from four to 20 microseconds Five delay lines of different manufacture were obtained for this test and the results are submitted in this portion of the report.

(f) Scan Conversion Display Decoder Gating Study (Section 8.0). Under this task, a written study was made to determine if it was practical to use a co-ordinate conversion system to obtain the active beacon decoder gating function when scan-conversion display systems were used. The objective of this study was to determine the number of tubes required, the number of critical circuits which may require frequent adjustment, and the minimum size of gate required, as displayed on a 22-inch television monitor.

(g) Setrin Circuit for Side Lobe Suppression (Section 9 0). In the work being conducted under the ATC Common Safety Beacon program, a system of side-lobe suppression which is both practical and reliable is in high demand One system which has been presented, is that of Mr. M. Setrin of the Rome Air Development Center. This system involved the addition of a special suppression circuit to the transponder. A portion of the modification work conducted by Stewart-Warner under this contract, involved the installation of this circuit in twenty ANDB Type III transponders.

(h) Engineering Assistance (Section 10.0). This task required engineering assistance to the FAA installation and maintenance groups at Midway and O'Hare Field. Since test coders were not available at the sites at the beginning of this task, the beacon equipment was inspected, tested, and aligned at Stewart-Warner laboratories as far as possible to minimize field adjustments at the sites. As components of the equipment were installed, checks were made for proper installation and operation.

3.0 VIDEO STANDARDIZER FOR AIR TRAFFIC CONTROL RADAR BEACON SYSTEM

Task number one in assignment of 15 January 1958, requested a study to be initiated of the feasibility of using a video standardizer in the beacon system preceding the Video Interconnection Equipment (VIE) A video standardizer would reshape stretched and distorted video pulses and maintain a more constant input level to the VIE. At the same time an investigation of the effects of video standardization upon interleaved reply codes, insertion loss, and pulse jitter was requested.

3.1 FAA Video Standardization Study

The following items were studied regarding video standardization:

(a) Limits over which a specific decoder would reliably decode pulses including multiple replies, interleaving, and other heavy traffic conditions, which have been deteriorated due to cable or link transmission.

(b) Effects on pulse information such as deterioration of video pulses regarding rise time, decay time, pulse width, droop, pulse spacing, jitter, noise, attenuation, and bandwidth requirements by relaying beacon video via 10,000 feet of coaxial cable and/or up to 100 miles of microwave relay link.

(c) Methods of reconstituting or reshaping pulses considering rise and decay time, pulse widths, spacing, amplitude sensitivity, droop and jitter, and determine limits over which this was practical in a decoding scheme

(d) Design and construction of a video pulse reshaper to obtain experimental data for comparison with theoretical or calculated results This design could be the basis for a video standardizer to be included in the FAA beacon equipment.

(e) Location of standardizer in the beacon chain for various link configurations.

3.1.1 Signal-to-Noise Ratios of Component Parts of the Transmission Link

In the study to determine the feasibility of using a video standardizer in the beacon system preceding the Video Interconnection Equipment, a phase of the study was designed to analyze the signal-to-noise ratios of the component parts of the transmission link. The following is a report of Stewart-Warner's analysis of this phase.

Calculations of the Spot Noise represented as Figure F of that portion of the video transmission link consisting of the Video Line Driver 2.3 N57/AM-1, RG 13/U Cable, and Line Compensation Amplifier 2.3 N57/AM-2 were made. An extreme case involving 10,000 feet of RG 13/U cable was considered.

It was considered of interest to establish the contribution to the total Noise Figure of the various portions of the video transmission link referred to above, in order to determine the areas wherein some improvement in the signal-to-noise ratio might be realized It was particularly desired to determine the effect of the equalizer on the signal-to-noise ratio.

The calculations necessary to establish the Spot Noise Figure F, are shown in Figure 1. To a close approximation the Spot Noise Figure reduced to the following:

$$F \cong F_1 + \frac{(n_4 - 1)}{G_1 \; G_2 \; G_3 \; G_4} + \frac{n_5}{G_1 \; G_2 \; G_3 \; G_4 \; G_5}$$

The first term, F_1 was the Noise Figure of the first video amplifier in the line driver while the second and third terms represented the contributions of the cable and equalizer, respectively. When computed out to 5 mc., these terms never exceeded the value of 0.1. The Noise Figure was almost entirely determined by the Noise Figure of the first video amplifier

3.1.2 Noise Figure Of The First Video Amplifier Stage

The Noise Figure of this stage was given by the following relationship.

$$F = \left(1 + \frac{2Rn}{Rg}\right) + \left(\frac{n_1}{Rg} + \frac{Rn}{Rg_2}\right) Rs + \frac{Rn}{Rs}$$

Rs = source resistance

Rg = total resistance in the grid circuit

Rn = equivalent noise resistance of the tube

n_1 = noise ratio, unity of at uniform room temperature

Considering the Noise Figure with the grid circuit shunted by 74 ohms and a source impedance of 74 ohms, the result would be:

$$F = 1 + 1.1 + 77 \cong 79 = 38 \text{ db.}$$

This was a very high Noise Figure.

With the 74 ohm terminating resistance removed, the result would be:

$$F = \frac{(1,025)}{(74)} = 13.9 = 23 \text{ db}$$

The 74 ohm terminating resistor raised the Noise Figure by 15 db. This illustrated the importance of presenting the correct source impedance to the first video amplifier for minimum Noise Figure. The source resistance for minimum Noise Figure was given as follows:

$$Rs = \sqrt{\frac{Rn}{\frac{n_1}{Rg} + \frac{Rn}{Rg^2}}}$$

Using this relation it was found that if a 74 ohm resistance was shunted across the grid circuit of the first video amplifier, the reflected source impedance should be approximately 20,000 ohms. With a 20,000 ohm source impedance the Noise Figure of the first stage became:

$$F \cong 1.1$$

3.1.3 Effect Of First Stage Noise Figure On The Overall Signal-To-Noise Ratio

Little improvement could be realized in the overall signal-to-noise ratio, including the Beacon Interrogation Unit, by an improvement in the Noise Figure of that portion of the video link represented by the video line driver, transmission cable, and equalizer.

The thermal noise power from the Beacon Interrogator Unit 2.3 NSI over a bandwidth of 5 mc was approximately:

$$P = KTB = (1.4 \times 10^{-23})\ (300)\ (5 \times 10^{6}) = 21 \times 10^{-15} \text{ watts.}$$

With the existing design, under the extreme conditions previously described, the line driver, transmission cable, and equalizer link would contribute:

$$(21 \times 10^{-15})\ \ (79) = 1\ 6 \times 10^{-12} \text{ watts of thermal noise.}$$

According to Spec. 2.3NSI, Supplement 1, Paragraph A3, the Beacon Interrogator may have a signal output of 2 volts with a peak signal to noise of 4 to 1. This corresponds to a noise power level of $3\ 4 \times 10^{-3}$ watts. The maximum available noise power (FKTB) of the line driver, transmission cable, and equalizer would be about 90 db below the maximum noise power developed by the Beacon Interrogator Unit which is 2 volts peak video output. The signal to noise of the Beacon Interrogator source represents the determining factor.

3.1.4 The Results Of Equalizer Characteristics As A Function Of Temperature

Calculations on cable and equalizer insertion loss are plotted in Figures 2 and 3. The effect of temperature change on the equalizer characteristics was quite pronounced below 100 KC as an examination of Figure 2 will indicate. All of the energy in the video spectrum at the present time lies above this frequency. However, this may become important if video information is added at a later time having lower frequency components.

3.1.5 Signal Attenuation With 10,000 Feet of Cable

For 10,000 feet of cable, the combined cable equalizer attenuation (for equalization to 5 mc.) under conditions of maximum temperature was 52.5 db. With the present video line driver this should produce a peak video signal to the order of 0.1 volt at the output of the equalizer As previously explained, the signal-to-noise ratio at the output of the equalizer will, for all practical purposes, be governed by the signal-to-noise ratio of the input signal to the first video amplifier located in the line driver unit.

In the following portions of this section, the study under this phase of the contract will cover a video standardizer which will reshape distorted pulses and maintain a constant signal level.

3.1.6 Design And Construction Of Video Standardizer

In the design and construction of the video standardizer, it was found that the calculated attenuation and phase characteristics of the video line driver, coaxial cable, and equalizer placed limitations on the circuits that could be used. A graph of the overall attenuation characteristics (see Figure 7) showed that the signal would be approximately 25 db. down at the output of the equalizer at 10 KC and 8 MC. Sufficient gain might be available in the video amplifier to provide the required output A plot of cable and equalizer characteristics (Figures 4, 5, and 6) showed that the phase response was unsatisfactory. The slope of the phase response curve was the time delay, and the slope should be fairly constant for distortionless transmission. Unequal time delays for various frequency components would cause a serious loss of signal detail. The equalizer gave amplitude compensation, and little phase correction. Examination of total phase shift characteristic (Figure 6) revealed that deviation from linearity was in excess of 40 radians. An arbitrary criterion[1] stated that if the variation from a linear phase characteristic was as much as one radian in a frequency range of $\frac{1}{3 \times \text{pulse length}}$, there would be a serious loss of signal detail. This criteria applied to the frequency bands that contained the major portion of the signal energy if we assumed a bandwidth of $f_s = \frac{2}{T_2 - T_1}$ needed for rise time requirements, then $f_s = 4.45$ mc bandwidth In this bandwidth, it was discerned that under conditions where the equalizer was matched to R_o of the line, the phase response criterion was not achieved. It was difficult to establish, however, what the required bandwidth would be The composite insertion loss (Figure 7) was far from flat, so that the bandwidth over which linearity was desired, could be narrower than 4.45 mc Phase response for all line lengths was flat from 1 mc up, with the amplifier peaked at 2 mc.

Further studies were made to determine how serious the equalizer problem could be under all coaxial line conditions. A Video Line Driver 2.3NS7/AM-1 and Line Compensating Amplifier 2 3NS7/AM-2 were obtained from O'Hare Field so that tests could be conducted using code train pulses. The results of these tests were applied to the design of the video standardizer.

The manufacturer's data for cross-talk isolation in a coaxial cable was as follows:

RG11/U	Single Shield	35-40 db shielding effectiveness
RG13/U	Double Shield	50 db shielding effectiveness
	Triple Shield	60 db shielding effectiveness

No standards exist to date on the methods of measurement or definition of terms, therefore the manufacturer used the term "shielding effectiveness" to describe the cross-talk isolation available in the cable.

3.1.7 Video Standardizer Unit

A video standardizer unit was constructed which sharpened the rise time of pulses to about 0.1 u sec but had the property of widening the input pulse about three percent. This did not meet the pulse width requirements, however, the method of amplifying and clipping did not introduce any additional jitter.

A blocking oscillator (B.O.) type of pulse shaper was built to determine if the minimum jitter requirements could be met and if a maximum jitter of 0.05 u sec was critical. The B.O. type pulse shaper permitted more precise shaping of pulse widths.

3.1.8 Characteristics Of 10,000 Feet Of Coaxial Cable

The use of 10,000 feet of RG11/U 75 ohm cable was obtained and tests were conducted of attenuation and phase shift characteristics. The time delay and introduced rise time using the cable and equipment was investigated. The time delay from the input of the line driver to the output of the line compensator was approximately 1.55 u sec per 1,020 feet, which was in close agreement with the time delay of polyethylene cable. $t = 0.0033 \sqrt{E} = 0.005$ u sec per meter. The introduced rise time T_{R_2}, where T total $= \sqrt{T_{R_1}^2 + T_{R_2}^2}$ was about 0.17 u sec for the 10,000 foot condition.

3.1.9 Pulse Shaping Circuits For Video Standardizer

The two methods of pulse shaping used in the tests are shown schematically in Figure 8. The first method of amplifying and clipping produced pulses with improved rise times and with no delay. However, the pulse widths are increased and this may be undesirable beyond certain limits. (Figure 9 shows some of the waveforms obtained when degraded pulses were fed into the shaping circuits.) The basic spacing between pulses was retained, in addition, the rise time was improved. Since the ten percent point of the original pulse was amplified and clipped to provide the improvement in rise time, the resulting pulse width was that of the ten percent level of the original pulse. Although tests with the present decoder indicated that the leading edge information was the most critical portion of the pulse, the additional widening of the pulse reduced the traffic capacity of the decoder.

The blocking oscillator pulse shaping circuit, although it produced a delay of approximately 0.3 u sec, generated pulses which indicated good rise and decay times with constant width. The width of the pulses was controlled by the shut-off line which was set to provide a given width. An amplifying and shaping network preceded the blocking oscillator to provide positive triggers of sufficient amplitude to trigger the blocking oscillator.

The input pulses to the reshapers were applied from an AN/GPM-17 coder through 10,000 feet of RG/11U coaxial cable to provide an essentially degraded pulse.

3.1.10 <u>Effects Of Code Pulse Spacing And Widths on Decoder-Modifier In VIE</u>

Tests were conducted on the decoder-modifier to determine the effects of code pulse spacings and widths. It was found that pulse spacing was much more critical than pulse width. The width can vary from 0.20 to 1 0 u sec, but the pulse spacing should be maintained to 2 9 ± 0 1 u sec for proper decoding If the spacing requirements are not achieved, incorrect replies could result In tests with intentionally distorted pulse code groups, the decoder operated well regardless of wave shape as long as the spacing was correct.

3.1.11 <u>Video Line Driver 2.3NS7/AM-1 Used In Study of Video Standardizer</u>

This unit consists of two channels of mixed video and trigger. They may be used separately or together, depending on whether one or two line operation is desired. In the studies, only the one line operation was considered, as this would include all operating problems.

No trouble was noted in the trigger circuits, so study was directed to the video portion.

Initially, an effort was made to determine overall line driver plus cable and line compensating amplifier response versus frequency. Figure 10 compares calculated gain of the first two stages only, with measured gain. Overall response of the line driver to a sine wave input, however, was quite poor. This resulted from the fact that the cathode follower combination V3 and V4 is biased in a considerably nonlinear region, to obtain pulse shaping effects (see Figure 11).

Since examination of the output waveform for a video pulse train input showed negligible deterioration, (less than .01 microsecond introduced rise time), study efforts were directed to the line compensating amplifier. Although further pulse shaping might be obtained at the line driver, gain would have to be sacrificed with the result that another stage might possibly have to be added, therefore, the line driver was considered acceptable as is.

3.1.12 Line Compensating Amplifier 2.3NS7/AM-2 Used In Study Of Video Standardizer

The line compensating amplifier was designed to accept the deteriorated pulse train from the output of the coaxial cable and restore it to its original shape. It will also separate and amplify the two triggers.

The pulse shape restoration was accomplished in this equipment by equalization of the cable characteristics and amplification, plus a pulse shaping cathode follower. Tests of the equipment with up to 10,200 feet of actual cable revealed excessive deterioration.

In the preceding studies, graphs indicated expected phase and attenuation characteristics of the equipment A more thorough study indicated that the phase delay was tolerable to the extent that it was present The equalizer contributed to phase correction at frequencies below 1 mc At higher frequencies, where most of the signal energy lies, phase correction was not as necessary, since the cable had fairly constant phase shift with frequency. For a constant group delay, the relation $T_g = \frac{X}{V_g} = \frac{db}{dw} x$ must be constant over a frequency range of $\frac{1}{3 \times \text{pulse length}}$. Stated in another manner, the phase shift should be linear with frequency to better than one radian over the desired frequency range, for distortionless transmission Within the accuracy of graphical analysis, this condition was achieved, and distortion was primarily due to amplitude attenuation which was not constant with frequency.

As a first test of amplitude equalization, attenuation characteristics for the 10,200 feet of RG11/U cable were checked (see Figure 12). This cable, which was the only type available, was supposed to duplicate the characteristics of RG13/U, except for shielding qualities. Results of this test were satisfactory, so an overall study of the line,plus line compensating amplifier was instigated.

3 1.13 Line and Line Compensating Amplifier Study

Reference photographs were taken of the line compensating amplifier equalizer output when fed by the test coder, line driver, and various lengths of cable. In all cases, the equalizer was adjusted for optimum pulse output The tabulated results are as follows:

Test Coder AN/GPM-17 Output: 0.08 u sec. rise time, 0.44 u sec pulse length

$$T_{intro} = \sqrt{T^2 \text{ total} - T_{in}^{\;2}}$$

Length of Line	Line Driver		Line Comp. Eqlzr Output		Total Intro Rise Time
	Rise Time	Pulse Length	Rise Time	Pulse Length	
1,000 ft.	0.09	0 45	0.11	0.45	0.076
2,000 ft.	0.095	0.44	0.12	0 41	0 09
4,000 ft.	0.10	0.44	0 14	0.37	0.11
6,000 ft.	0.10	0.43	0.15	0 36	0.13
8,000 ft.	0.10	0.43	0.17	0.38	0 15
9,000 ft	0.10	0 43	0.18	0.40	0.16
10,000 ft.	0.10	0.43	0.185	0.40	0 17

For line lengths over 3,000 feet, the desired introduced rise time of 0.14 u sec was not achieved since the equalizer was not able to make the frequency response of the line flat enough. As the length of line increased, proper equalization became more important. For the longer lengths of line, an equalizer should be designed to provide enough attenuation so that the response would be flat to 5 mc, however, the signal level would be too low, and another amplifier stage would be needed.

Another approach was to peak the outputs of V_1 and V_2 at the high frequency end This was tried with some success, as illustrated by Figures 13 and 14. Line lengths of less than 6,000 feet were not plotted, as equalization became less important for the shorter line lengths. In each case, the equalizer was first adjusted for optimum video pulse output. Changes in overall level were due to different settings of the equalizer adjustments Peaking of V_1 and V_2 resulted in a rise time for the 10,000 foot cable to 0.13 u sec Therefore

$T_{intro} = \sqrt{0.13^2 - 0.08^2} = 0.11$ u sec, a considerable improvement over 0.17 u sec.

To obtain further improvement in pulse shape, several approaches were open. These included increase of bandwidth of stages V_1 and V_2, equalization over greater bandwidth, and further pulse shaping by cathode follower V_3. All these would entail considerable circuit re-design and re-building. Peaking the stages V_1 and V_2 was considered the best approach, which was accomplished by replacing inductors L6 and L7 with 100 uh adjustable slug types, applying a 4 MC sine wave input, then adjusting L6 and L7 for maximum output from V_1 and V_2

3.1.14 Continuation Of FAA Video Standardization Study

During a visit to TDC on 19 December 1958, the video standardization study was discussed. The merits of a passive pulse reshaping circuit were discussed and the desirability of concentrating our efforts on this type of circuit studied. The pulse jitter and duty cycle considerations seem to rule out regenerative type pulse reshapers and point toward the passive types. As suggested by TDC, "tailbiting" or pulse width control through the use of a delay line should provide satisfactory results. During the month of January 1959, a circuit was designed and built using this principle to provide an amplifier-clipper pulse reshaper with pulse width control.

The video amplifier peaking coils proposed for the modification of the line compensator were of the adjustable type. This would provide, in addition to an increase of the amplifier bandwidth, a method of peaking the circuit to meet the requirements of each particular installation.

Tests conducted to determine the effects of pulse shapes and widths on proper decoding and reported earlier, indicated that pulse spacing was a critical factor. This assumes that the deterioration of pulse shape is the same for all pulses in a pulse group. In practice, this would appear to be the case in the decoder-modifier, line driver, line compensating amplifier, and cable combination.

The pulse reshaping circuit was modified to provide pulse width control An amplifier, delay, and non-additive mixer was added to the original reshaping circuit. This meant that approximately six tubes were required to utilize this method of reshaping.

3.1.15 Conclusion

Further work is required to improve the circuit The results of this work to date,indicated that although pulse jitter problems are minimized, the total improvement in rise time can be no better than about 0.1 u sec. This improvement in rise time is at the expense of dead time between pulses. The limitation of the rise time improvement is due to the limited total amplification available from the compensated amplifier, and the permissible clipping level.

This type of pulse reshaper should be located at the input to the decoder-modifier in a coaxial line system

3.1.16 Study On Use of Microwave Relay Links For Relaying Beacon Video

Stewart-Warner began investigations of the effects on beacon video using microwave relay links. The problems of phase shift, introduced rise time, bandwidth requirements, and other considerations were studied Manufacturers data was used to study existing microwave link equipment and enabled Stewart-Warner to determine capabilities of the equipment in transmitting pulse information. This assisted Stewart-Warner in formulating requirements of microwave link equipment for transmitting beacon information. Pulse reshaping requirements and the location of such reshaping circuitry were determined during the course of this study

Information of a very general nature was obtained on existing microwave link equipment suitable for relaying beacon video. Present frequency allocations dictate transmitter-receiver frequencies of from 7125-8400 MC. The video response for two microwave systems is tabulated below, using readily available data furnished by Motorola, Inc.

Link Type	3 db Bandwidth	Introduced Rise Time	Differential Phase
MRR	30 cps - 5 MC	0.06 u sec	3%
AN/TRQ-10	20 cps - 7.5 MC	0 04 u sec	3%

	Harmonic Distortion	
	2 nd	3 rd
MRR	4%	2.5%
AN/TRQ-10	2.5%	1.5%

The introduced rise time for more than one link increases as the square root of the number of identical links in a system. The differential phase increases in the following manner:

Number of Links	Differential Phase
2^n	3% (n + 1)

where n = 0, 1, 2, 3 ----

The problems of increased pulse jitter would be minimized if frequency modulated transmission of the video signals was employed Jitter may arise from multiplexing operations if blocking oscillators are used to provide the multiplexing pulses. No actual figures for pulse jitter introduced under multiplexing were available

In a microwave system, however, the ideal location of any reshaping circuitry is in the microwave relay line video amplifier.

3.2 Line Compensator Trigger Output Study

Before the decoding delay lines (Z-201) in the Line Compensating Amplifiers were re-tapped to give better mode decoding spacing, it was noticed that the "trig out" was sometimes lost when the video input to the Video Line Driver and the video output of the Line Compensating Amplifier were not set to their proper values of 1.8 volts and 2.0 volts respectively. When 1.8 volts of video was fed into the Video Line Driver, the "trig out" of the Line Compensating Amplifier was lost when the "video out" of the Line Compensating Amplifier was set below 1 8 volts. The loss of the "trig out" was further impaired by de-tuning the compensating network.

After the decoding delay lines were re-tapped, the units were peaked up to give optimum performance and a study of the inputs and outputs with mode spacing variations was made. A modification was made to the trigger circuitry to improve the reliability of the Line Compensating Amplifier to help insure operation under all mode tolerances, unit variations, compensator settings and tube ageing. The procedures and results of this study are as follows:

Readings were taken with Video Line Driver and Line Compensating Amplifier numbers 10, using 1,000 feet of interconnecting RG11/U cable.

The "video in" at the Video Line Driver was set for 1.8 volts as specified in the instruction book Video Remoting Equipment Type 2.3NS7 The mode spacing for the common mode was then varied in steps of 0.2 u sec. in both the positive and negative direction. The video gain control on the line compensator was adjusted to the point where the trigger output from the line compensator just disappeared. At this point for various mode spacing the amplitude of the "video out" was measured and recorded. Spot checks were made using 10,000 feet of interconnecting cable and with 10,000 feet of cable, triggering levels decreased by about 0.1 volt.

Points were also recorded for 1.3 and 2.3 volts of video into the Video Line Driver to cover the tolerance of 1.8 + 0.5 volts as specified in the aforementioned instruction book.

The circuitry of V-206 was changed to improve the operating range of the video output. Data was again recorded.

The results of the above mentioned checks are tabulated in Table I and Table II and are graphically represented in Figure 15.

Spot checks were made on the alternate modes (3 and 5 u sec) and as with the 10,000 feet of cable, the results showed about a 0.1 volt decrease in triggering level (curves in Figure 14 lowered about 0.1 volt). A composite picture of the mode tolerance is shown in Figure 16.

Table 1. 1.8 Volts Video Into Line Driver

	1,000 ft. of cable		10,000 ft. of cable	
Common Mode Spacing u sec.	Video Out at Trig. Lost Point Volts		Video Out at Trig Lost Point Volts	
	Before Mod.	After Mod.	Before Mod.	After Mod.
7.0	7.8	7.1		
7.2	7.6	5.8		
7.4	3.3	2.65	3.5	3.0
7.6	1.60	1.18		
7.8	1.40	0.95		
8.0	1.32	0.92	1.20	0.83
8.2	1.32	0.91		
8.4	1.41	0.99		
8.6	1.68	1.13	1.65	1.10
8.8	3.40	1.70	3.50	3.50
9.0	7.80	6.60		

Table II. Using 1,000 Feet Of Cable

Video Into Line Driver Volts	Video Out at Trig. Lost Point Volts	Video Out at Trig. Lost Point Volts
	Before Mod	After Mod.
1 3	0.9	0.6
1.8	1.3	0.9
2.3	1.7	1.1

The modification to V-206 consisted of grounding the cathode, which put the tube at zero bias, and increasing the plate resistor R-223 from 10 K to 27 K. The overall effect increased the gain of the tube by about 15%.

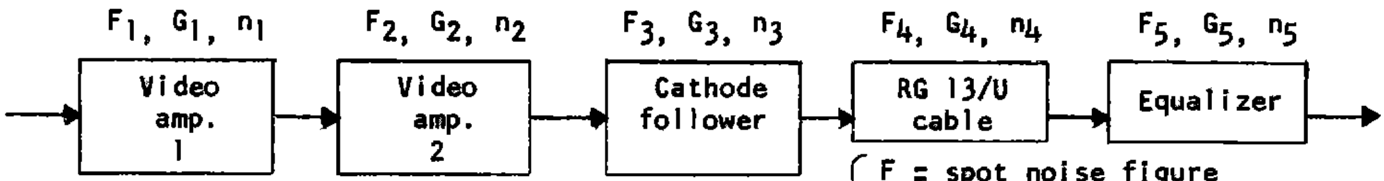
The circuitry change had the following effects:

	NORMAL	MODIFIED
Plate Voltage	159 v	75 v
Plate Resistor Voltage	91 v	175 v
Plate Current $I = \frac{E}{R}$	9.1 ma.	6.5 ma.
Plate Resistor Disipation	0.83 watts	1.13 watts

The plate current was reduced from 9.1 ma to 6 5 ma. A negative signal is applied to the grid which cuts down on the plate current so that the maximum disipation of the resistor will be its steady state value of 1.13 watts

The modification does not affect the trigger separator operation of V-207 to any significant amount. Before the modification, video signals would just start getting through to the cathode of V-207 when the video output was set at 4 8 volts; with the modification the same effect is noticed when the video output is set at 4.0 volts. This video, even if present, and the video output ever be set that far above 2 volts, would never reach an amplitude high enough to cause a decoded signal out even when properly spaced.

It can be seen from the preceding investigation that if loss of the "trig out" from the Line Compensating Amplifier is, or ever does become a problem, a circuitry change at V-206 would be a possible solution.



$$(F-1) = F_1 + \frac{F_{2-1}}{G_1} + \frac{F_{3-1}}{G_1 G_2} + \frac{F_{4-1}}{G_1 G_2 G_3} + \frac{F_{5-1}}{G_1 G_2 G_3 G_4}$$

F = spot noise figure
G = available gain
n = noise ratio (at room temp)

$F_1 \times F_2$ are given by:

$$F = 1 + \frac{Rs}{R_1} + Req\ Rs\left(\frac{1}{Rs} + \frac{1}{R_1}\right)^2 + Req\ RS\ (WC_1)^2$$

R_s = Source res.
Req = eqiv noise resistance of tube
R_1 = grid resist.

$G_1 + G_2$ are given by:

$$G = gm^2\ Gs\ 2p / |Ys|^2$$

$$G_3 = gm^2\ Gs \Big/ \frac{u+1}{rp} + |Y|^2 \ ; \qquad F_3 = 1 + \frac{G_1}{G_3} + \frac{Req\ gm\ |Y_3|^2}{|qm|^2\ Gs}$$

$$G_4 = {}^{-2\alpha} \quad \text{where } \alpha = \sqrt{\frac{wc}{2}\left[\sqrt{r^2 + L^2 w^2} \quad -WL\right]}\ \ell$$

$g \cong o$

$|r = .716|$ 100 to 100 KC

$|r = 3.3 \times 10^{-3} \sqrt{f}|$ 100 KC to 10 mc.

$m_4, m_5 = 1.1$
$(T = 50^\circ C$

$$G_5 = \left[\frac{\left|1 + 1c + 1)\ \frac{21}{2Ru}\right|}{\left|1 + 1c-1)\ \frac{21}{2}R_u\right|}\right]^2 = \text{available gain of equalizer}$$

$$(F-1) \cong F1 + \frac{n_4}{G_1 G_2 G_3 G_4} - \frac{1}{G_1 G_2 G_3} + \frac{n_5}{G_1 G_2 G_3 G_4 G_5} - \frac{1}{G_1 G_2 G_3 G_4}$$

Now $G_4 = G_5$ is determined by the cable loss and the range over which equalization is to be accomplished. In this case $G_4 \cdot G_5 = 8 \times 10^{-4}$ over 5 Mc.

Also $G_1 \cdot G_2\ G_3 = 9.2 \times 10^3$ (to 5 Mc)

The term $1/G_1 G_2 G_3$ is negligible therefore:

$$(F-1) \cong F_1 + \frac{n_4 - 1}{G_1 G_2 G_3 G_4} + \frac{n_5}{G_1 G_2 G_3 G_4 G_5} \cong F_1$$

Figure 1. Spot Noise Figure F, Calculations

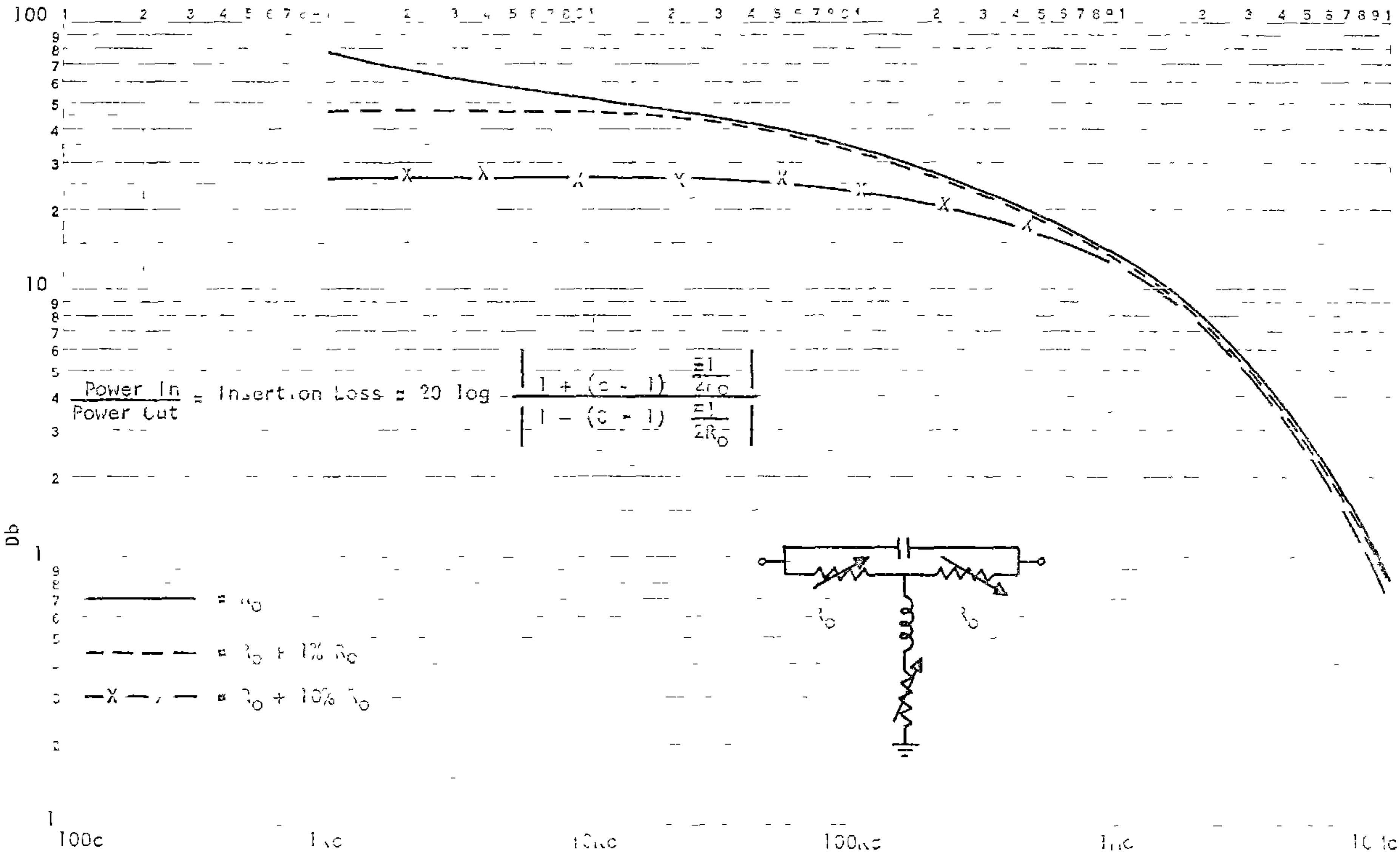


Figure [illegible] Predicted Attenuation of Equalizer Network for 10,000 Feet of Cable with Variations in Temperature

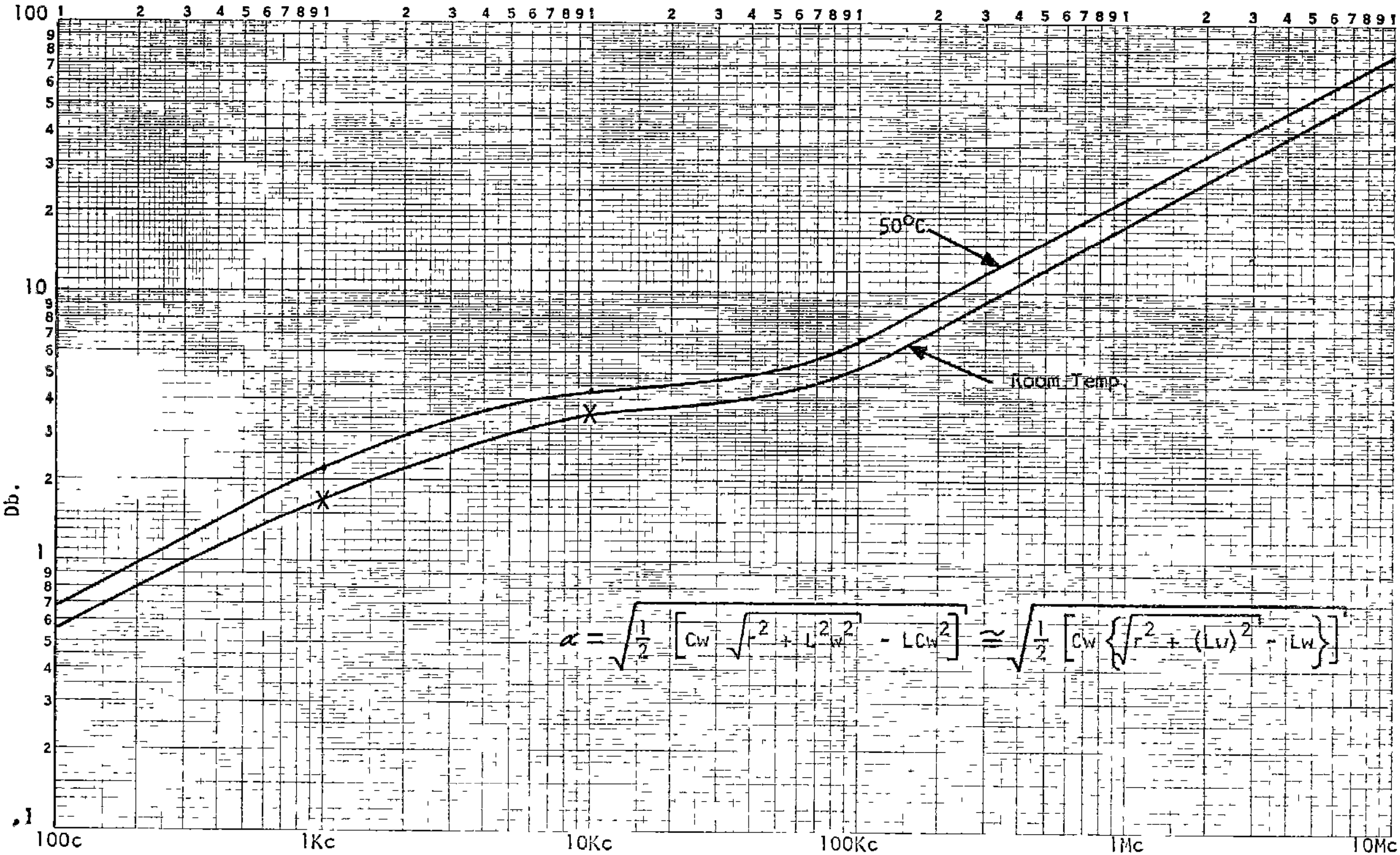


Figure 3 Predicted Insertion Loss For 10,000 Feet of RG-13/U Cable

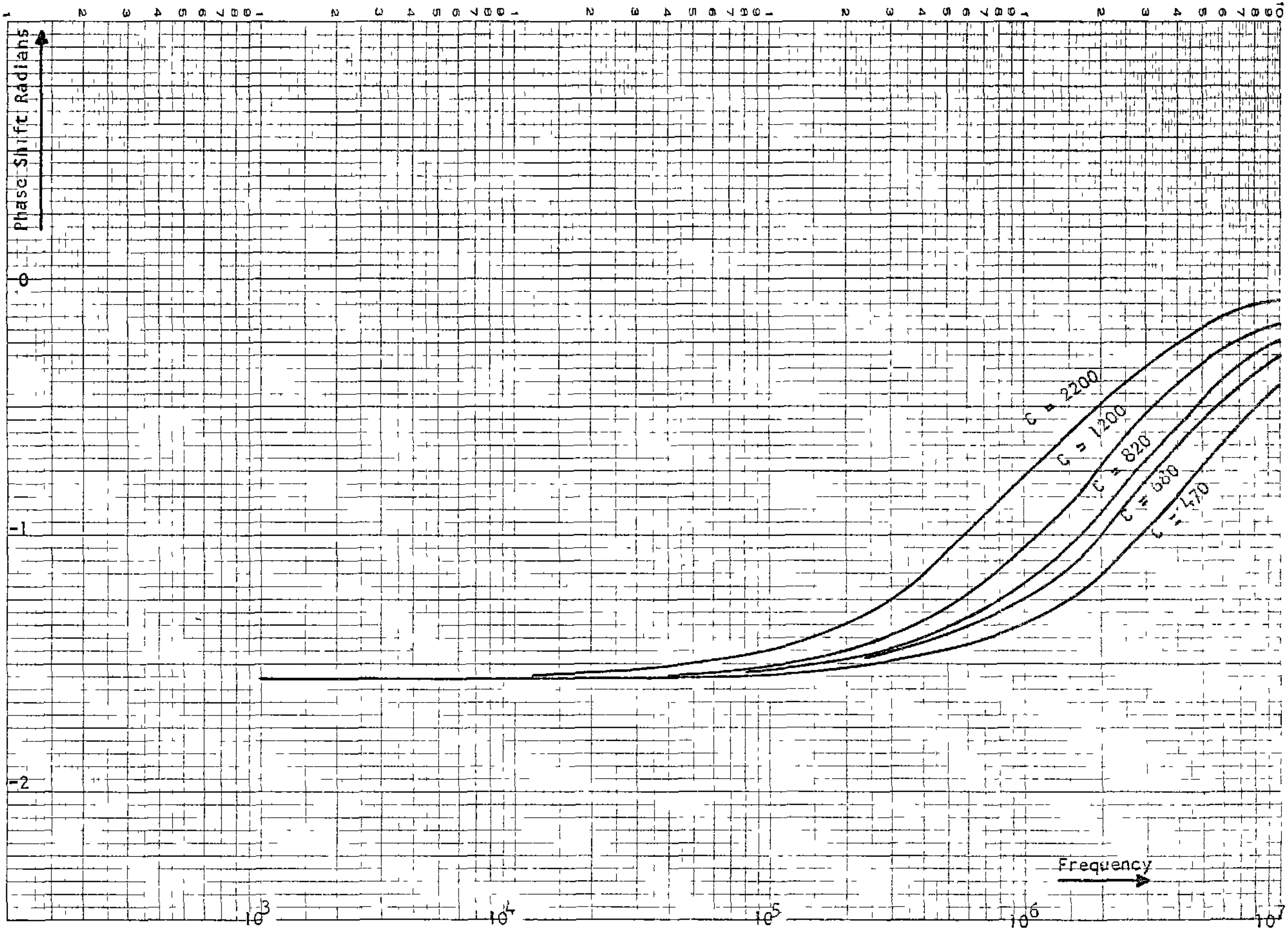


Figure 4 Calculated Phase Shift Characteristic, Equalizer Only

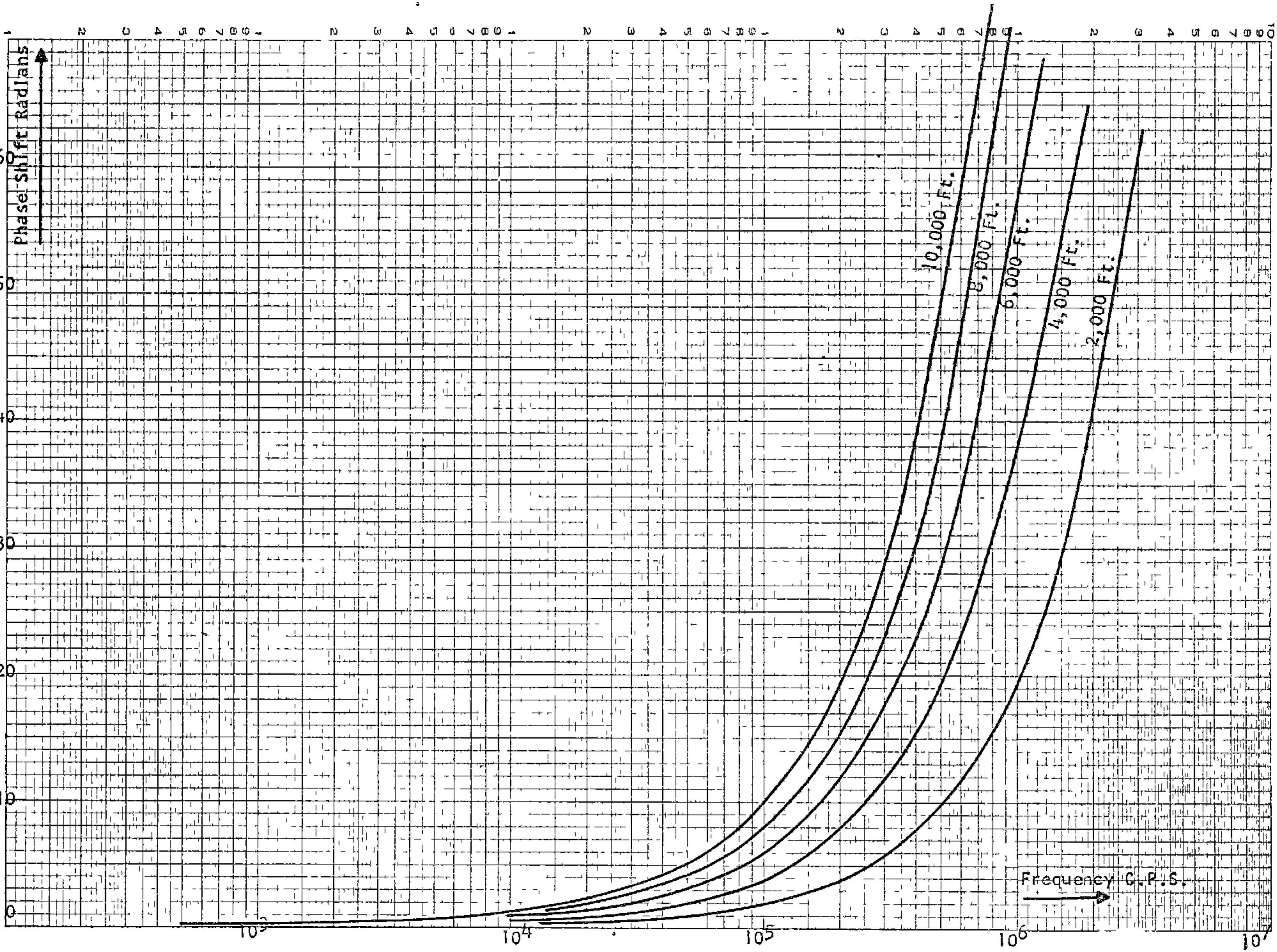


Figure 5. Actual Phase Shift Characteristic, RG-13/U Cable Only

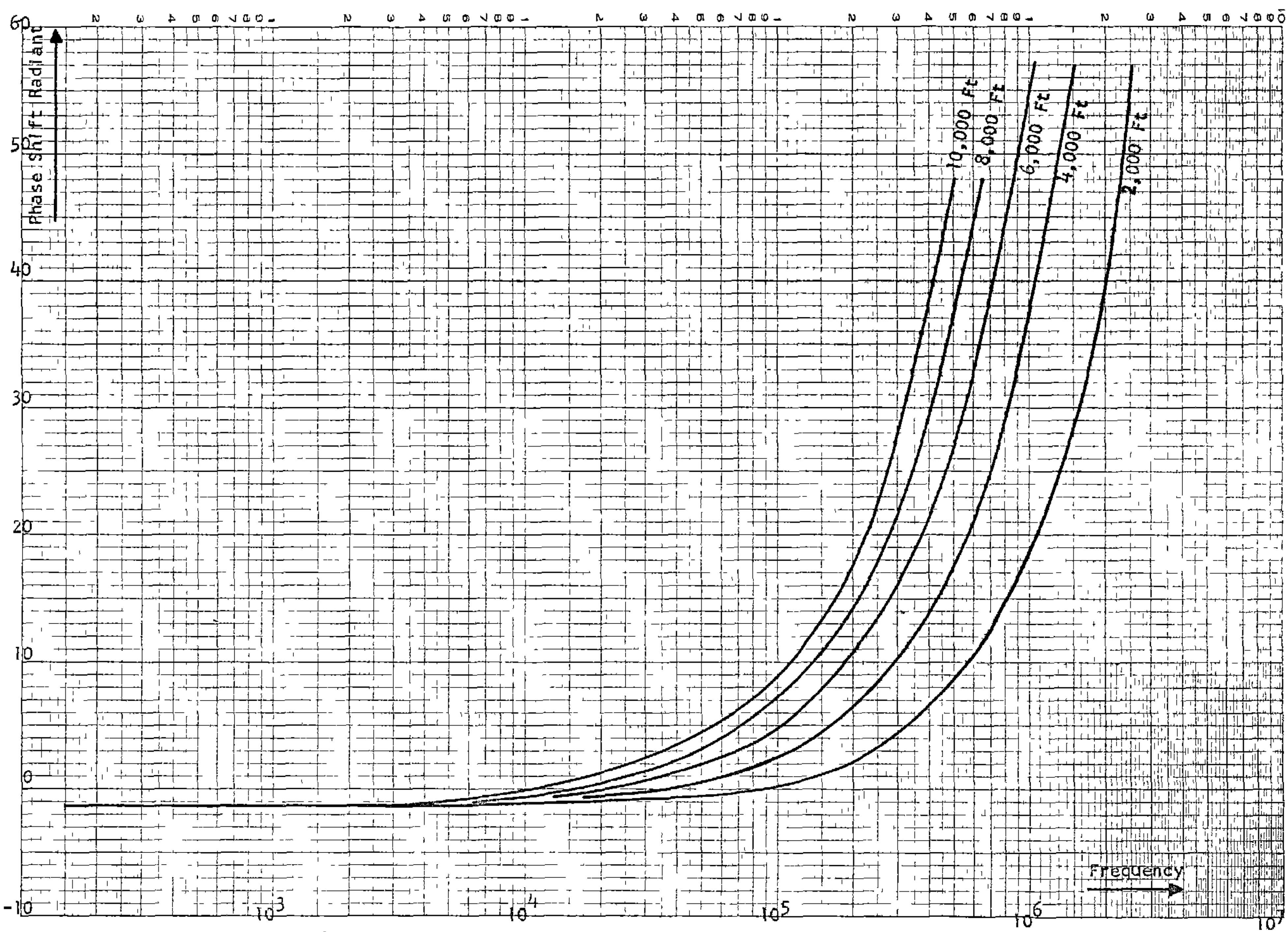


Figure 6 Calculated Total Phase Shift Characteristic, Equalizer Plus Cable

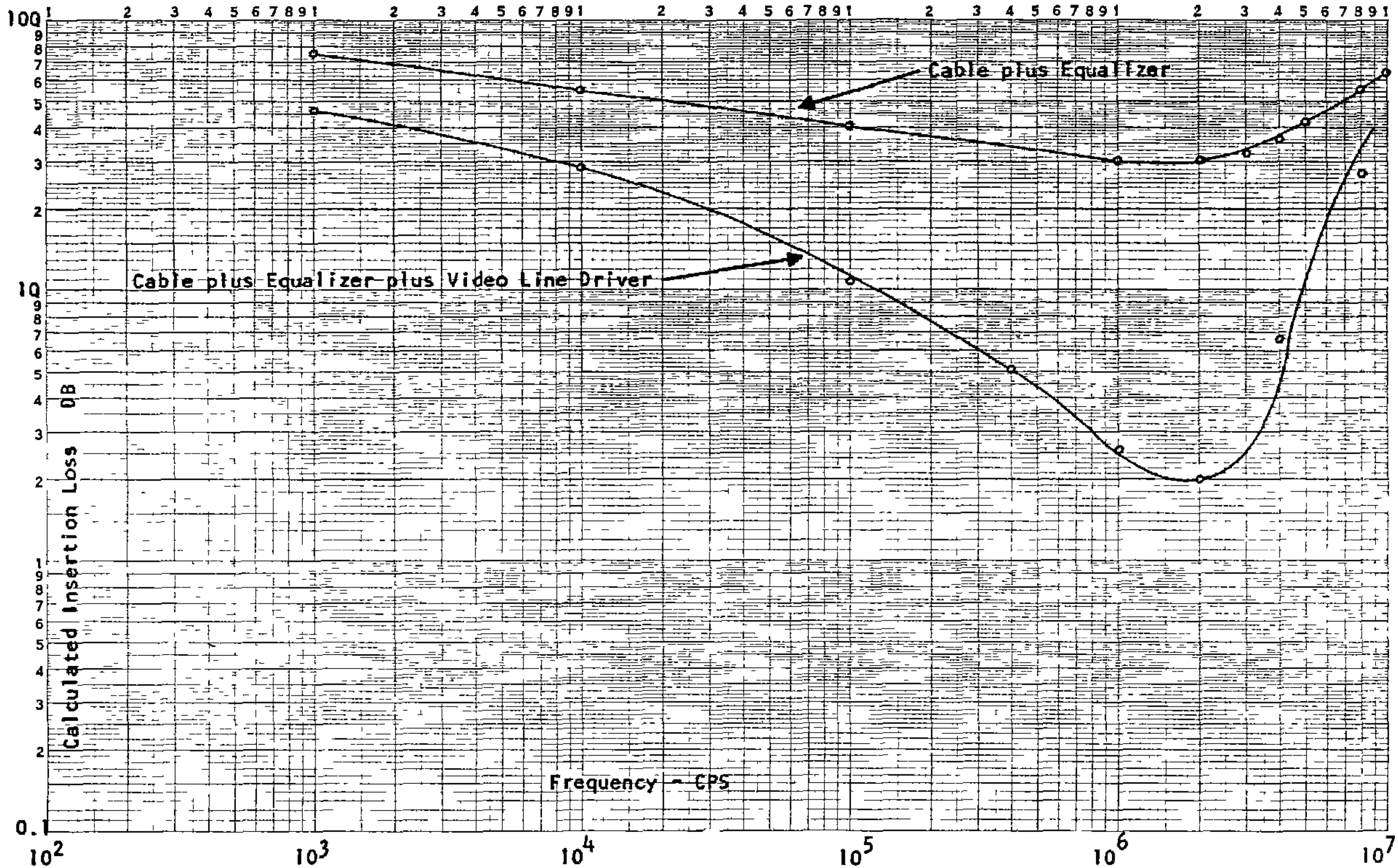
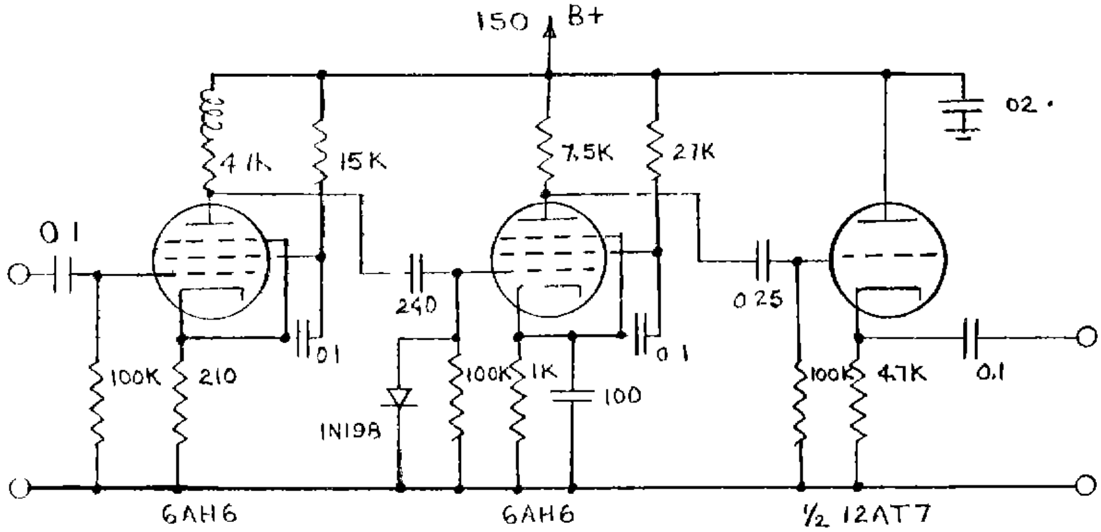
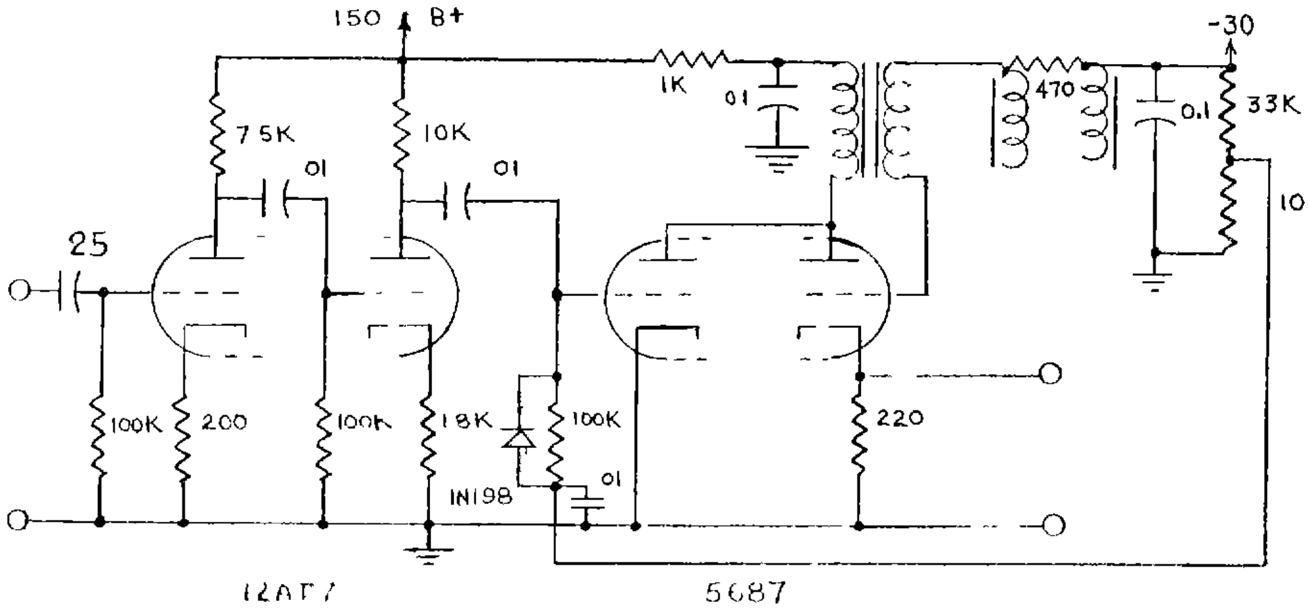


Figure 7 Calculated Overall Attenuation Characteristics, Cable, Equalizer, and Video Line Driver



PULSE SHAPER - AMPLIFIER CLIPPER

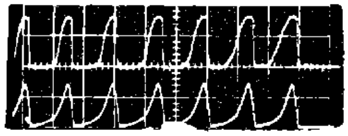


PULSE SHAPER - BLOCKING OSCILLATOR

Figure 8 Pulse Shaper Circuit, Schematics

Output from Amplifier-Clipper Pulse Reshaper

Input to pulse reshaper from 10,000' coaxial cable



SWEEP 2us/cm
1v/cm

5v/cm

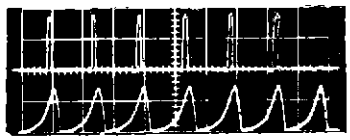
Same as above

SWEEP 5us/cm
1v/cm

5v/cm

Output from Blocking Oscillator Pulse Reshaper

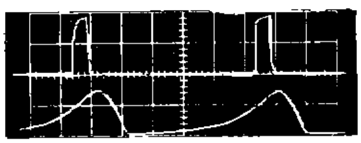
Input to pulse reshaper from 10,000' coaxial cable



SWEEP 2us/cm
10v/cm

5v/cm

Same as above



SWEEP 5us/cm
10v/cm

5v/cm

Pulses into 10,000' coaxial cable from GPM-17 Test Coder

Output from Blocking Oscillator

1v/cm

SWEEP 2us/cm
10v/cm

TIME ←

Figure 9. Pulse Reshaper Waveforms

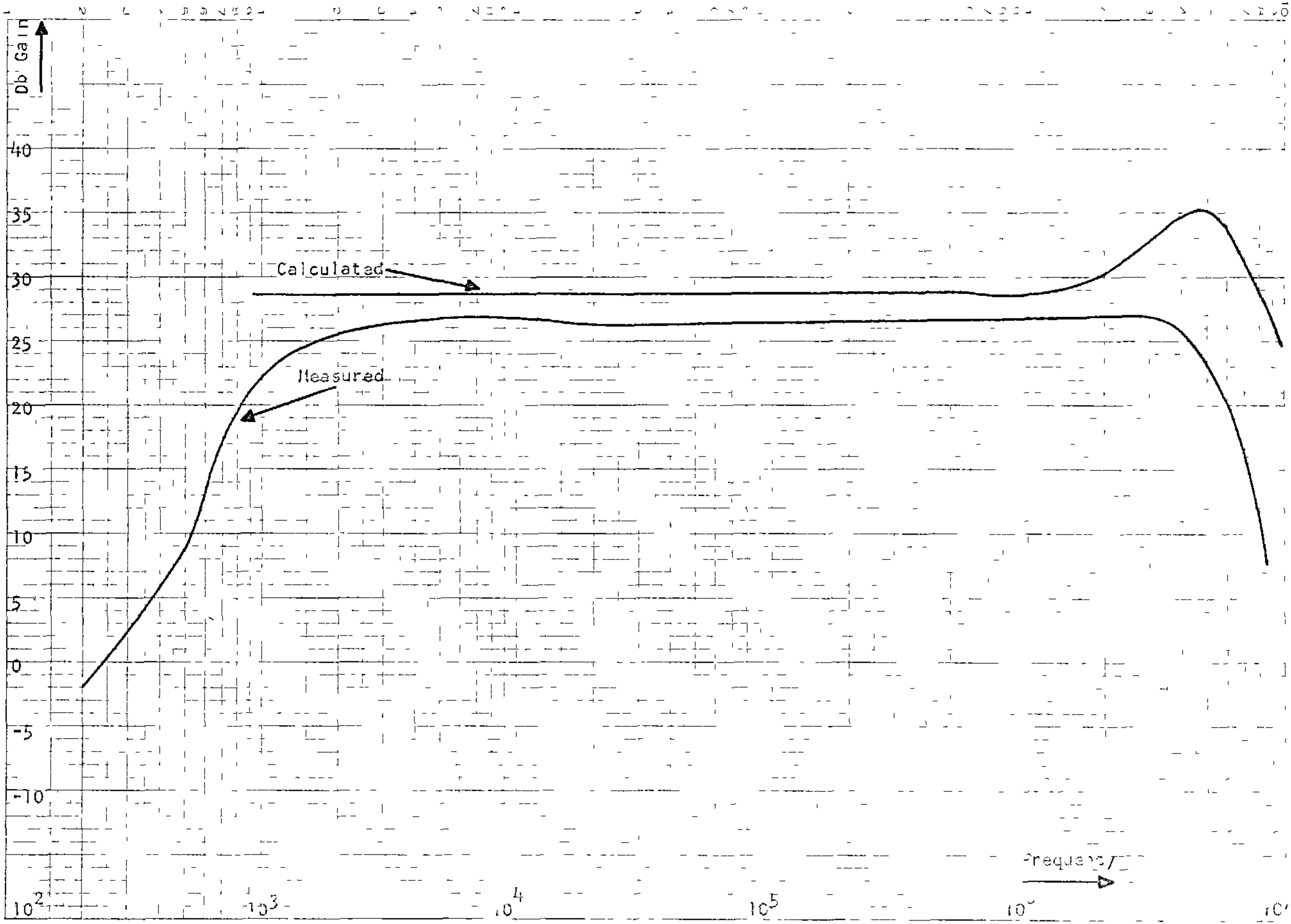


Figure 10 Calculated Versus Measured Gain, Line Driver Plus First Two Video Stages

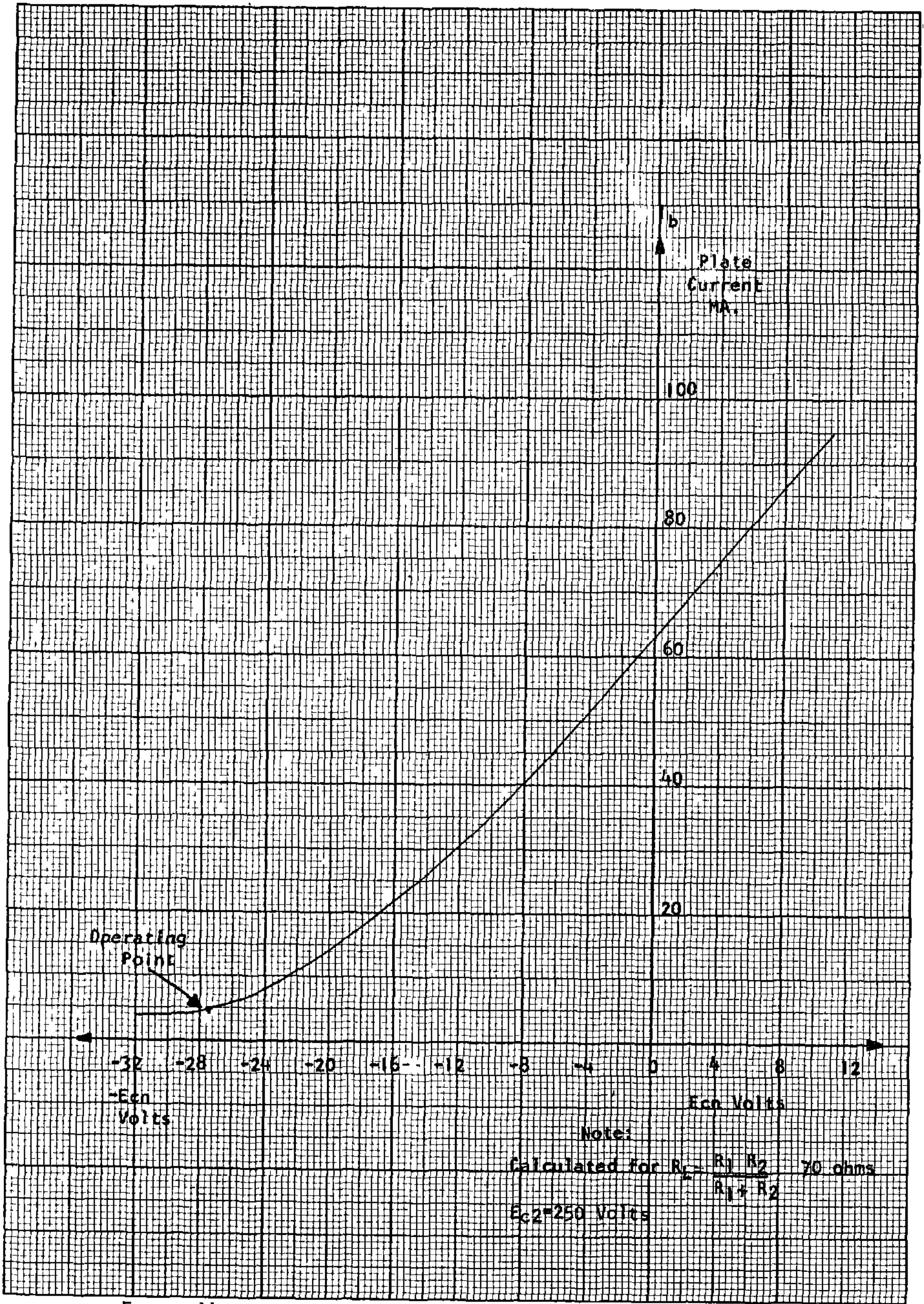


Figure 11 Line Driver Cathode Follower Combination V3, and V4, Dynamic Characteristics

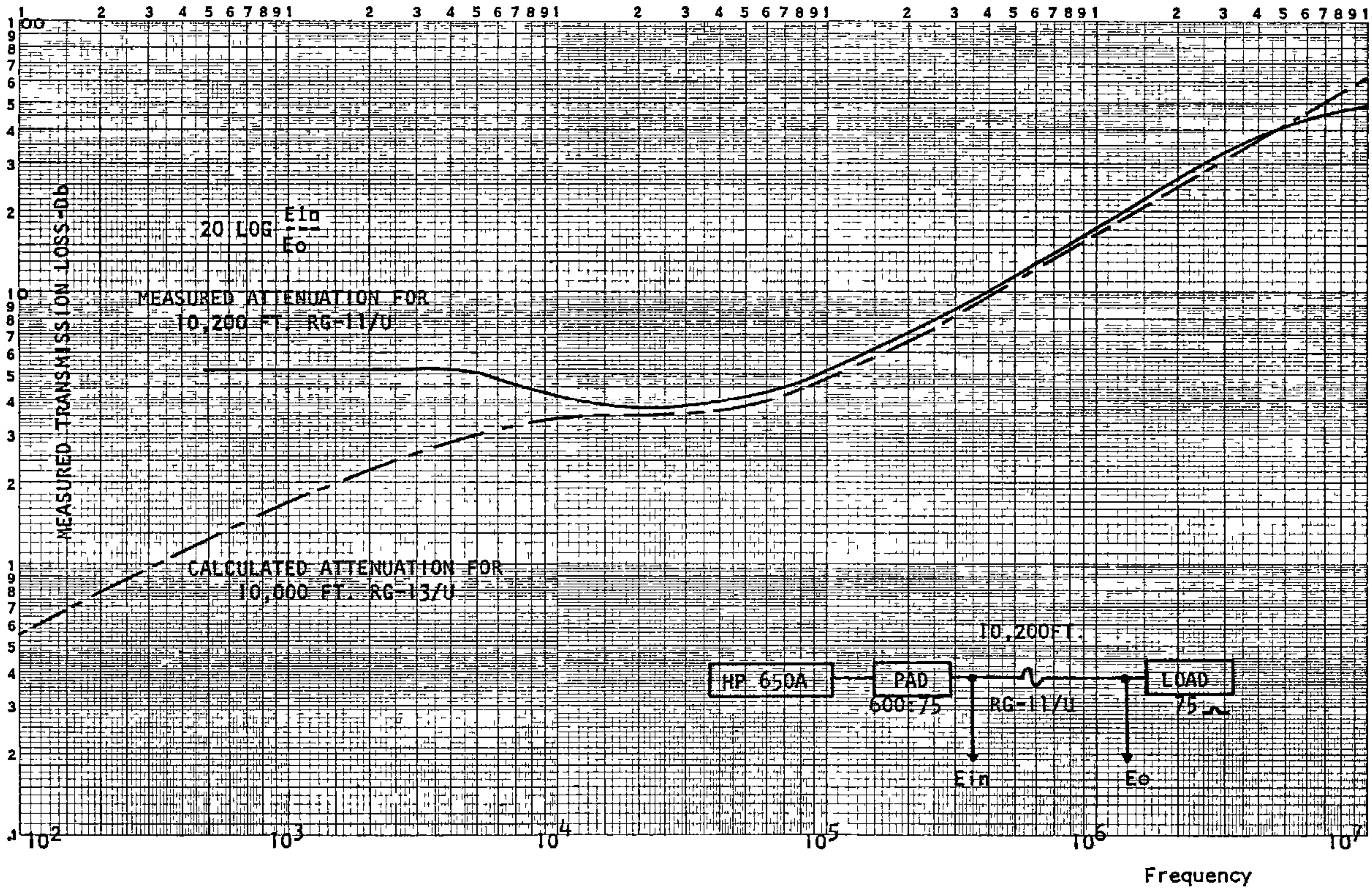


Figure 12. Attenuation Characteristics For 10,200 Feet of RG11/U Cable

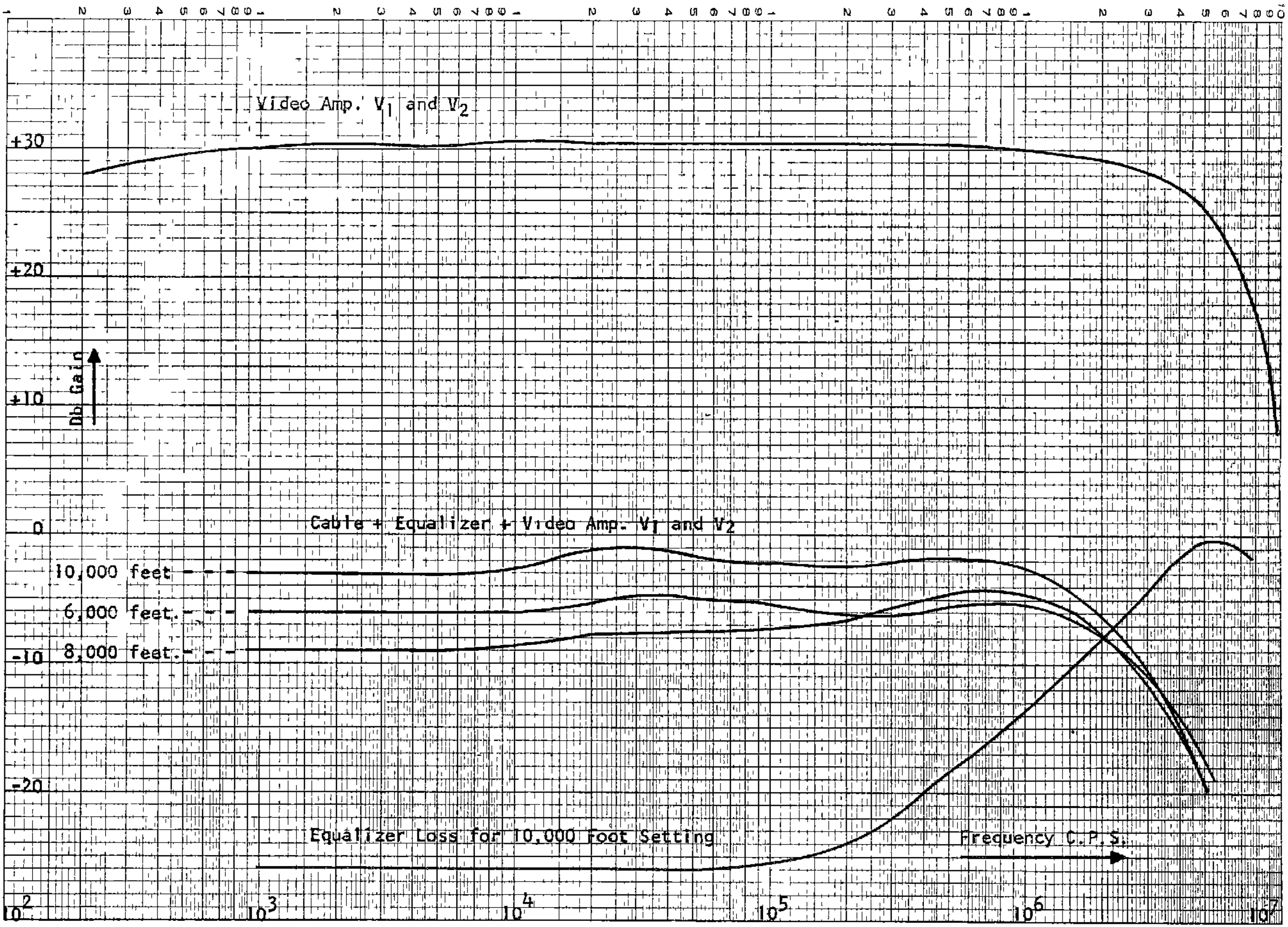


Figure 13. Attenuation Characteristics For Unmodified Line Compensator

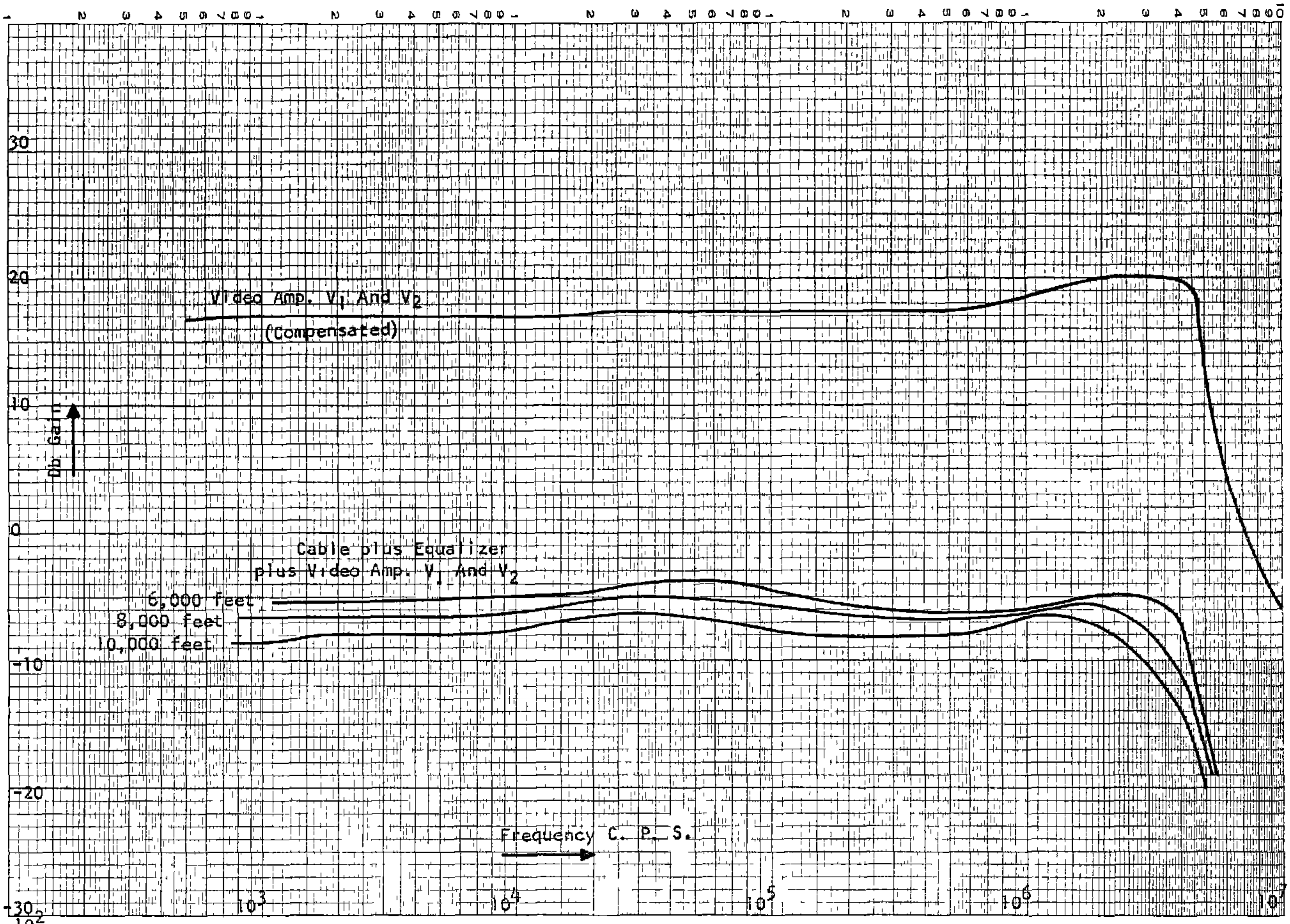


Figure 14 Attenuation Characteristics For Modified Line Compensator

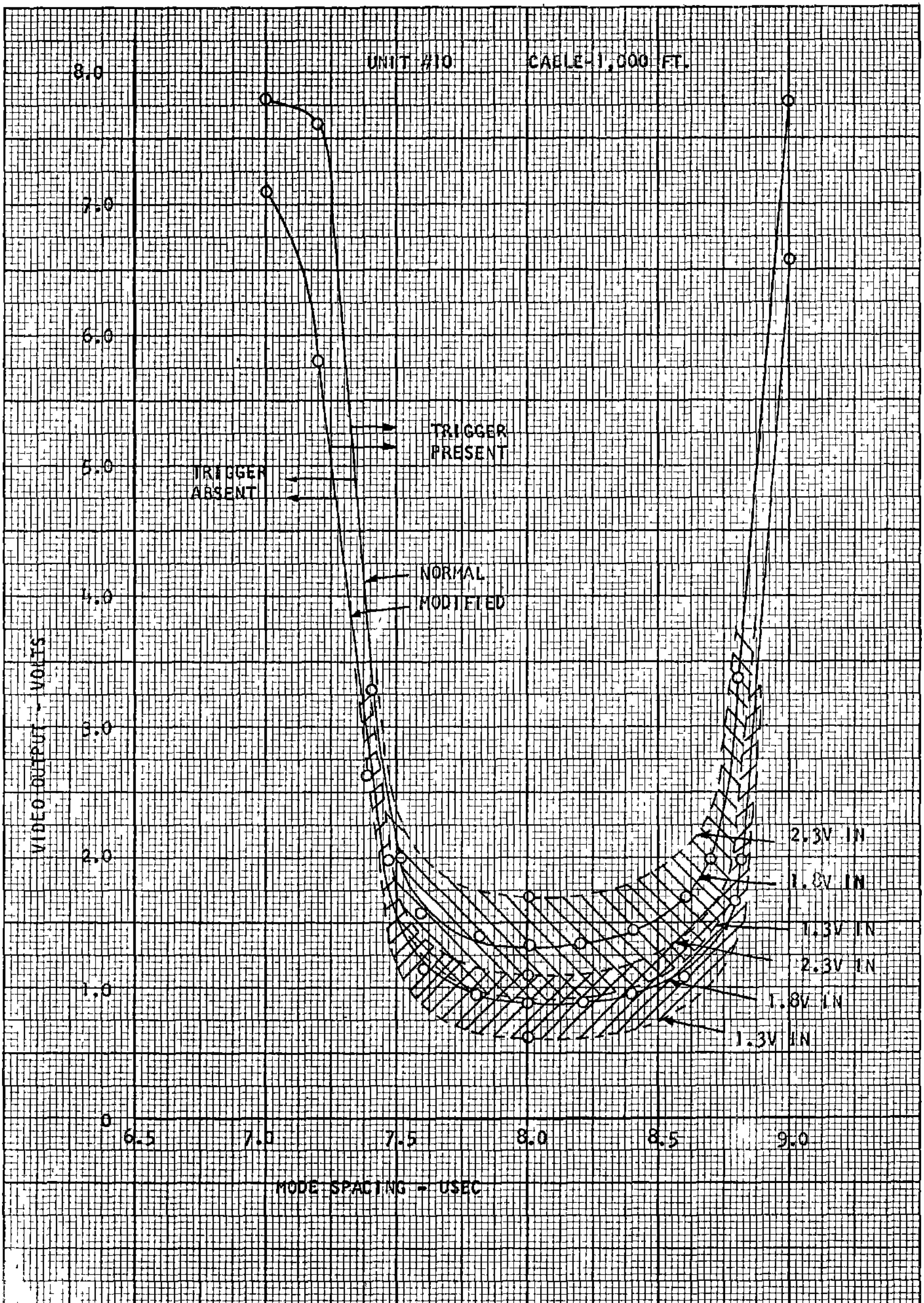


Figure 15. Trigger Output Characteristics Of Line Compensating Amplifier

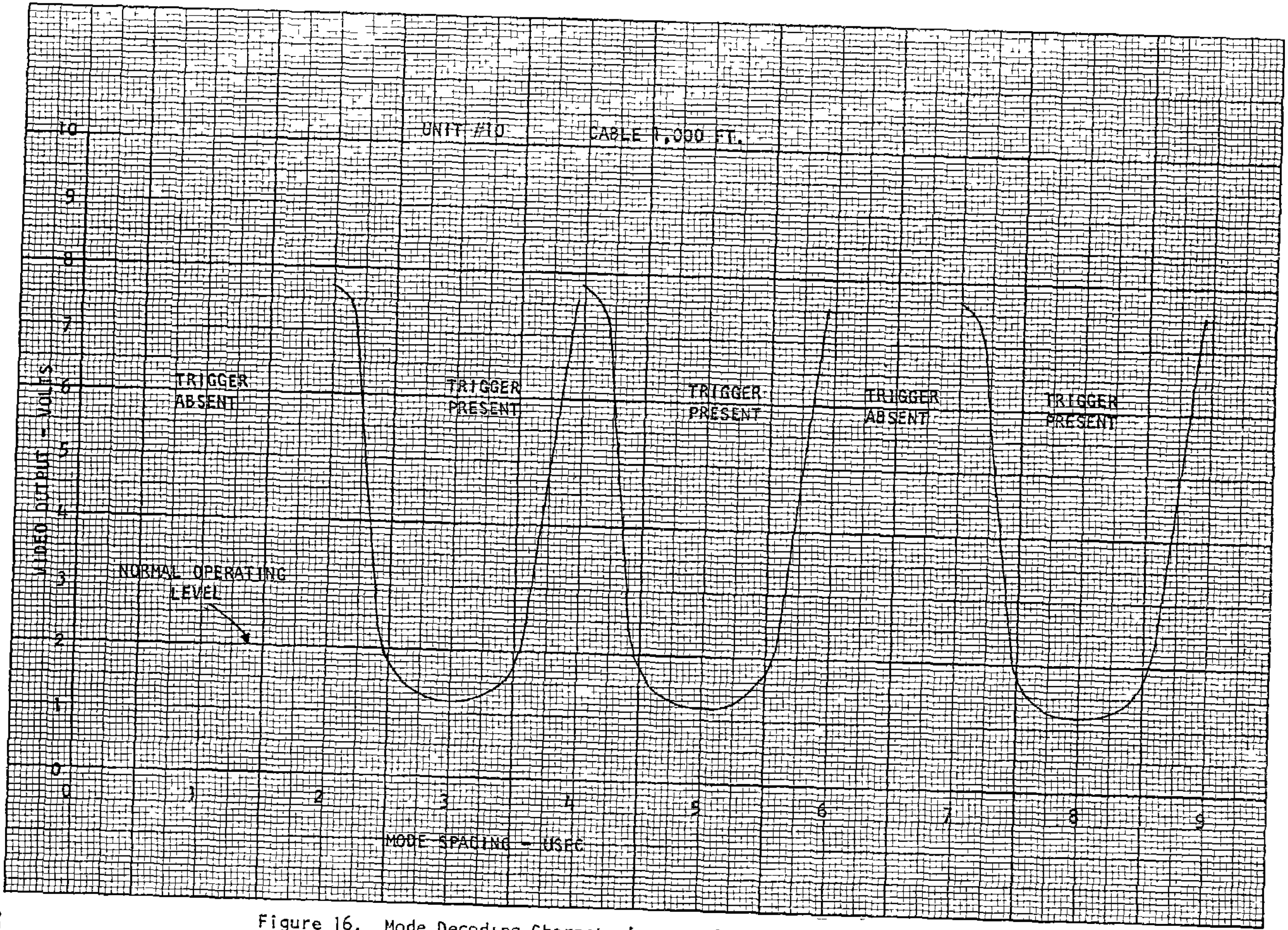


Figure 16. Mode Decoding Characteristics Of Line Compensating Amplifier

4.0 SAFETY BEACON INTERROGATOR ANTENNA

Task number two in assignment of 15 January 1958, requested a test be made of the waterproofing characteristics of the Safety Beacon Interrogator antenna that was to be installed at O'Hare Field's ASR-3 radar site.

Tests to be made, were to determine if moisture accumulated inside the antenna as the ambient temperature was varied from -20 degrees F to +110 degrees F and the relative humidity changed from ten percent to 100 percent.

Also, a direct spray test performed to simulate a heavy rain with wind velocities of 60 miles per hour.

4.1 Safety Beacon Interrogator Antenna Tests

Safety Beacon Interrogator Antenna assembly, serial no. 2, was received at Stewart-Warner Electronics on 30 April 1958. Test procedures were developed by personnel assigned to this phase in order to perform tests in the following month.

4.1.2 Preliminary Tests

The following is a report of the preliminary tests performed on the Safety Beacon Interrogator Antenna:

Purpose: To determine if the antenna is resistant to the effects of water sprayed on the unit when in its normal operating position.

Procedure: The unit was placed on its mounting plate on a stand. Water was sprayed on the unit from all positions, except that water was not sprayed directly underneath unit. Resistance readings were taken before wetting unit and 15 minutes after test. Unit was kept in normal position for subsequent measurements.

Results: Resistance readings May 12, 1958, starting with infinite ohms using Simpson Model 260, R X 10,000 Range.

After spray test:	30,000 ohms
May 13, 1958	14,000 ohms
May 14, 1958	23,000 ohms

Conclusion: Unit was not resistant to effects of water sprayed on it. Visual inspection showed that fiberglass window fastening method permitted water to enter between fiberglass and metal surfaces. Paper strips could be inserted into these spaces directly into antenna housing. Since unit was not opened, further sources of water entry could not be determined.

The end sections, where the two halves of the antenna are bolted together, had openings through which water may enter, especially if there was no gasket to seal off the joint. No water sling, or drain holes were evident on the unit through which water could be drained from the antenna housing.

Tests were held up until further notice from CAA TDC.

4.1.3 <u>Advanced Tests</u>

The following is a report of advanced tests performed on the Safety Beacon Interrogator Antenna with recommendations for corrective measures:

Purpose: To determine if the antenna water spray tests were valid, and to find by what means the water entered the antenna housing.

Procedure: The unit was checked and possible water entry holes were closed off with caulking compound. Weep holes in the lower end of the antenna matching section were closed. The connectors were sealed off with electrical tape. The unit was then sprayed and resistance measurements taken. After this test, the joint end was sealed off with tape and the unit set up for the spray test. It was turned so that the fiberglass window faced upwards. Another unit was sprayed, but was always kept in its normal position.

Results: The first unit did not show any signs of shorting out as long as it was kept in its normal operating position. When it was sprayed with the window facing upwards, enough water accumulated in the guide to permit the water to rise to the level of the water drain holes, and thus short out the matching section. The second unit did not short out, but showed about 5 megohms resistance upon completion of the test.

Conclusion: When the units are sealed properly and placed in their normal operating position the units will not short out. Water in the wave-guide section does not harm the unit if the water does not rise to the level of the matching section drain holes.

Recommendations:

(a) All screw heads should be treated with a waterproofing material.

(b) All joints, metal to metal and fiberglass to metal, should be sealed off to minimize points of water entry.

(c) Coaxial connectors should be coated with a waterproofing material when unit is installed.

(d) A water drainage hole should be provided at both ends of the antenna housing.

(e) An additional 3/16" water drain hole should be provided in the matching section, so as to provide a drain hole at each end and at the center of the section.

(f) Careful inspection of the unit should be made before installation to insure that obvious water entry points do not exist.

After approval to work on the antenna was received from TDC, the fiberglass windows were sealed with Permatex Soft Setting Compound, which also was applied to other locations as were deemed necessary to obtain a water resistant antenna.

It was planned to re-test the antenna as soon as spare jumpers were received from O'Hare Field, however, if the jumpers were not available, then the jumper connections would be capped and sealed. The final tests would then be performed.

4.1 4 Final Tests

The results of the final spray and humidity tests were as follows:

(a) Spray Test. Water was sprayed on the antenna for a period of one hour The unit resestance was checked before and after the test

Resistance of Section		1	2	3	4
Start:	(with Simpson 260)	∞	∞	∞	∞
Finish:	(with Simpson 300 VTVM)	20K	20K	8K	10K

Treated units were water resistant when placed in their normal operating position and sprayed with water

(b) Humidity Test. The units were placed in a humidity chamber and held at 50°C and 95-97% relative humidity. Distilled water was used to obtain the required humidity conditions. The antenna was then sprayed with cold water in order to determine if there was any water entry due to expansion at the joints of the unit. The cold water spray also cooled the exterior of the unit rapidly and condensed any vapor in the antenna cavity itself. The results of this test were as follows:

Legend (see Figure 17)		0	X	△	V
			Section		
Condition:		1	2	3	4
50°C 95-97% Humidity	Start:	20K	200K	8K	10K
Soak for 1 1/2 hrs and spray	Finish.	20K	200K	10K	6 5K
Condition.					
50°C 95-97% Humidity					
Soak for 21 hrs. and spray	Finish.	22K	24K	7K	3 5K
Condition					
25°C 50% Humidity					
48 hrs after final test	Finish:	11.5K	21K	7K	3 2K
Condition:					
25°C 50% Humidity					
72 hrs after final test	Finish:	75K	6.5K	3K	1.8K
Condition					
25°C 50% Humidity					
96 hrs after final test					
Pre-ship value	Finish	10K	20K	2 5K	4.0K

4.1.5 Conclusion. Moisture condensation within the antenna apparently did not seriously decrease the leakage resistance of the antenna matching section or dipoles However, it was noted that after a period of about 72 hours after the test there was a sharp decrease in the resistance reading. (See Figure 17). This may be due to oxidation by-products acting with the condensate causing formation of a conductive material. This effect slowly disappeared after the condensate evaporated It is possible that if the antenna was exposed to high humidity conditions and then rapidly cooled, so that whatever condensate did form, it has very little conductivity by itself Reaction of the condensate with the metallic portions of the antenna could produce conductive by-products. If the antenna were exposed to the sun immediately after the condensate was formed, the heated metal might possibly evaporate the condensate and prevent chemical action with the antenna materials. In the test, the antenna was kept at room temperature, indoors at all times, and may not approximate the actual operating conditions.

The lowest value to which the antenna leakage resistance may go and still maintain a useable antenna has not been determined. However, indications were that in actual use the effect of high humidity combined with rapid cooling would not seriously impair the effectiveness of the antenna.

Tests on the antenna were completed and the unit was shipped to O'Hare Field.

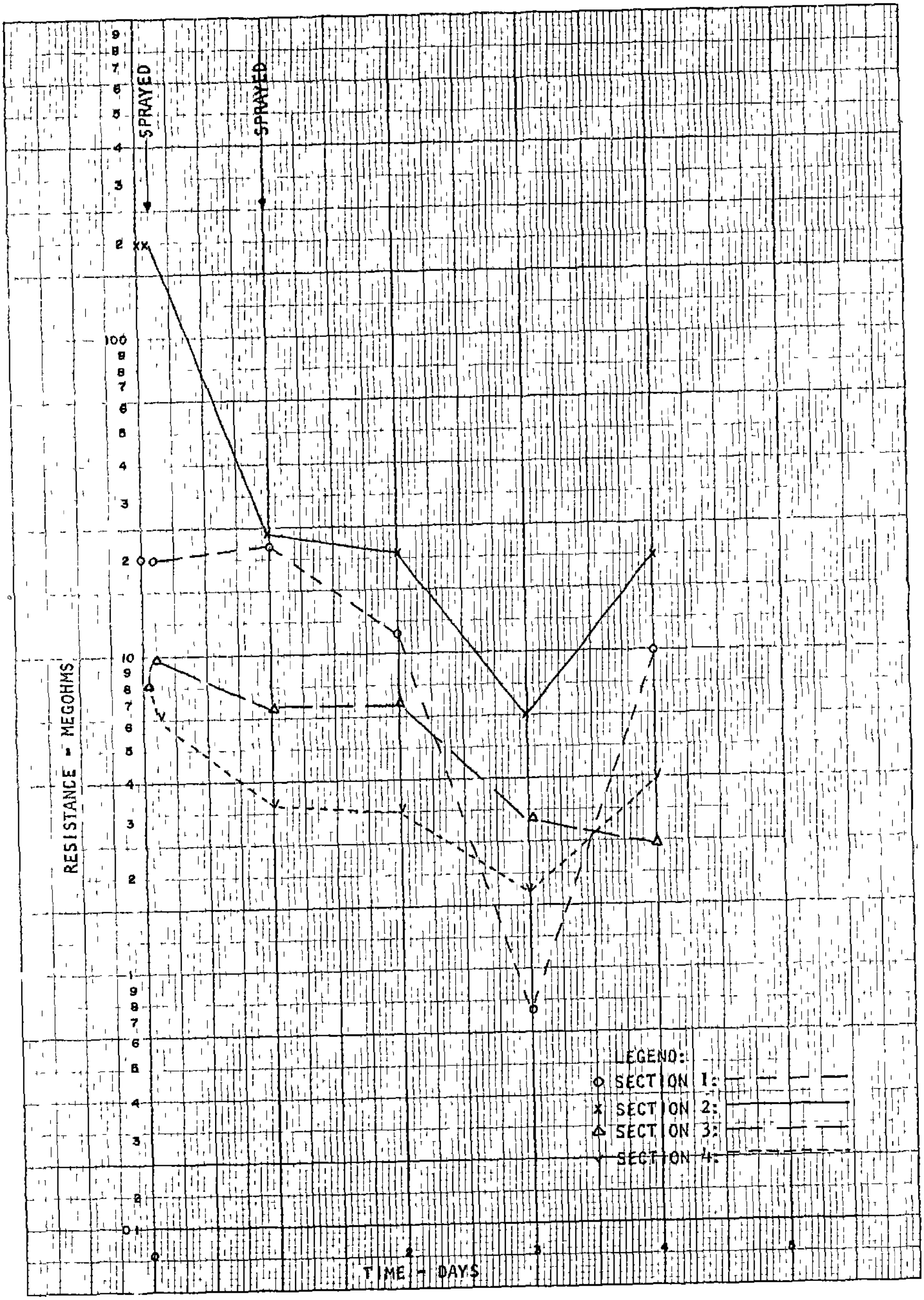


Figure 17. Safety Beacon Interrogator Test, Resistance Chart

5.0 PANORAMIC PHOTOGRAPHS OF O'HARE FIELD AND MIDWAY AIRPORT

Task number three in assignment of 15 January 1958, requested panoramic photographs be obtained from O'Hare ASR-3 and Midway FPS-8 radar antenna platforms, to be used for evaluation of the sites for beacon antenna installations.

Calibrations of a specific nature were given that had to be contained in the photos. Instructions were given that if one or both sites appear to present reflection problems, alternate beacon antenna sites should be recommended.

5 1 Problems Encountered in Obtaining Photos

In order to take pictures from the radar antenna towers at O'Hare Field and Midway Airport, the facilities had to be shut down. Specific dates had to be arranged with the regional FNF Planning Branch in Kansas City, Missouri.

A source for a panoramic camera was obtained and photos were to be taken in July 1958, however, our plant was shut down for annual vacation period and personnel to take photos were not available In the meantime, the camera was relocated to Binghamton, New York. A new date for the first week of August 1958 was set, at which time the camera would be available.

Photos were taken as instructed and two prints of each plus the negatives were submitted to CAA TDC in August 1958.

6 0 LIFE TEST OF VIDEO INTERCONNECTION EQUIPMENT

Task number one in assignment of 10 March 1958 requested an accelerated life test of the Video Interconnection Equipment (VIE) Type 2.3NS4a, be conducted with specific attention paid to the following details.

(a) Deterioration of mechanical and electrical function of the Raw-Decode, ALL A/C-C/S, Sel A/C, Ident - A/C Code Selector switches, Range Selector switches, and relays during operation for the equivalent of two years normal operation

(b) Deterioration of electrical characteristics of crystal diodes, resistors, capacitors, lamps, and electron tubes when subjected to high ambient temperatures as may be found in equipment rooms at control towers and ATC centers.

(c) Deterioration of components accelerated by operation at maximum, or excessive, current or voltage

(d) Line voltage regulator to be used for tests at a constant line voltage of 115 volts 60 cycles.

Task number two of this assignment requested a study be conducted of improvements and recommendations be made that would reduce or eliminate failures which were considered unusual or excessive to the normal life expectancy of VIE parts and components.

Task number three of this assignment requested recommendations be made, that would improve the stability, reliability, ease of maintenance and accessibility of the VIE decoder, considering only minor modifications that could be performed at operating sites including replacement of sub-assemblies with modified sub-assemblies.

6 1 Analysis of Video Interconnection Equipment

After Idlewild beacon facility maintenance reports were received in April 1958, an analysis of these reports and the VIE was made, in order to draw up an Environmental Life Test Procedure However, further data on operating conditions of the VIE was required and a visit to the New York Center was made in June 1958

Voltage and temperature readings were taken of the equipment, enabling Stewart-Warner to set up a realistic Environmental Life Test Procedure

Difficulty with the power supplies still existed and it was ascertained that part of this was due to component parts overload, expecially the 2-watt resistor supplying the -200 V rectifier which was dissipating about 2 4 watts

In setting up the cycling of the function switches, it was difficult to estimate actual operating conditions for the control boxes, since no procedure had been set for beacon operations Estimates of the frequency of operation of the controls by TDC and the New York Center were considered

During July 1958, a cycling jig for operating the toggle and rotary switches, illustrated in Fig 18 was built to be used in conjunction with the accelerated life test of the VIE In this same month, an outline of an Environmental Life Test of VIE was submitted to TDC which was accepted with a few additions by TDC

6 2 Start of Environmental Life Test of VIE

The environmental life test of the VIE was started on 21 August 1958 and continued through 29 August 1958, at which time a report and tabulation of failures to date on the equipment was submitted Since this was only a prelude to the final report, it is summarized as follows:

(a) Results to date seem to confirm the field maintenance reports as far as actual electrical circuit failures or malfunction were concerned Several tube changes were required initially to obtain required pulse and gate width requirements The gate pedestal control required several adjustments, especially with changes in temperature of the unit It was thought that the stability of the power supply was due to the fact that a line voltage regulator was used, plus changing the -200V supply resistor R301, to a higher wattage rating

(b) The mechanical failure of the rotary switches was due mainly, to the fact that the switches are dry when they are installed The switch manufacturer had recommended that lubricant be applied to the contacts when under the life test cycling This could be done because switching 28V dc,and leakage resistance due to metallic particles,was not a problem Two types of toggle switches were used and failure had to be noted in the type ST22N which had lighter construction Relay failures had not been analyzed since they had not failed completely Testing to destruction is the accepted method of life testing relays, at which time the relay could be opened and examined

After this preliminary report was submitted, it was found that the unit would have to be re-aligned before tests could continue. Circuit malfunction, due to faulty relay contact closures, gave the appearance of gain and clipping level changes. Attempts to restore circuit function, by adjustment of the various controls, only led to unit misalignment Replacement of the relays was required to verify that relay malfunction was causing the apparent circuit difficulties

Since the rotary switches in the control box were badly worn, it was decided to cycle only two relays K113 and K110 which had been replaced with a 120°C type While this was being done, an effort was made to temperature stabilize the gating circuit.

The Gate Pedestal was found to vary with changes in ambient temperature between 25°C and 50°C Gate Pedestal Adjust R116, had to be rotated 30 to 40% from the initial setting to restore operation Tests indicated that diodes CR106 and

CR105 contributed most to circuit changes with temperature These diodes were IN198 Germanium type, which showed a marked decrease in back resistance at higher temperature A decrease in back resistance of CR106 would alter the critical voltage difference between the cathodes of V103, while CR105 would pass gate voltage to the grid of V104A. Both contributed to change of gate pedestal level

To correct this situation the IN198's were replaced with Sylvania IN195 silicon diodes These diodes had a much higher back resistance and operating temperature To provide a greater adjustment range, the wire on pin 4 of R116 (fixed tap) was moved to pin 3 (see Fig 19) These modifications resulted in a satisfactory temperature stable gate circuit between 25°C and 50°C Since field service reports indicate that gate adjustments were a frequent occurrence, it was recommended that all existing units be so modified. Upon receipt of authorization, Stewart-Warner was prepared to modify the nine units from the Midway and O'hare sites, which were in Stewart-Warner's laboratories

Results of the re-evaluation of switching needs were submitted in a corrected and revised tabulation of failures These are covered in the final report on the Environmental Life Test of VIE

6.3 Continuation of Environmental Life Test of VIE

At the beginning of October 1958, all general tests on the decoder-modifier and power supply were completed Additional tests to investigate specific areas were proceeding as follows:

(a) Relay life test·

Six relays designed for dry circuit applications were installed in a test jig to simulate coder operating conditions The relays were operated in an oven to simulate the temperatures encountered by the relays on the various sub-chassis The test setup is shown in Fig 20 and relay life test schematic in Fig 20A. It was noted that after 470,000 operations, equivalent to 475 days, relays K113 and

and K110 showed no signs of imminent failure The remaining 85°C relays continued to fail Until conclusive data was obtained from the life test being conducted with dry circuit types, it was suggested that any replacements be made with Allied Control 125°C, type MHB-12D relays

(b) Rotary switch life test

Investigation of the life of silver plated brass and coin silver types of rotary switches indicated that with lubrication, the upper limit of test life was about 30,000 cycles A recommended lubricant was Beacon M-325 grease made by Standard Oil Co. Due to the high contact pressures involved, the life of the switches was mainly a function of switching speeds and contact currents A specific switch replacement program was indicated based on the switching operating procedure However, since the life test results could only be used to provide comparative data, switch replacement should be made only when the switch showed definite signs of contact wear This would occur after approximately 60,000 cycles of field use The coin silver types would give better life in terms of constant contact resistance; however, the cost of these switches was approximately fifty percent more than the silver plated brass types

(c) Life Test of 12AT7WA in Multivibrator Position

A test was proceeding to determine the life of 12AT7WA in the V126 multivibrator position under high temperature operation The environmental life test indicated that at 25°C ambient, the chassis temperature was approximately 80°C. When the ambient was raised to 50°C, the chassis temperature at V-125 and V-126 rose to approximately 115°C The use of heat dissipating shields to reduce the bulb temperatures in the tubes was being studied The problem was further complicated by the fact that a 5687, 6 3 V at 0 9A, and a 6AH6, 6 3 V at 0 45a were mounted directly below V-125 and V-126 The thermocouple readings indicated this position to have the highest chassis temperature 12AT7WA tubes in other positions have shown little or no difficulty

(d) Select Code Tests:

Variations in decoder output with changes in the Select Code were studied. The effect of delay line tap position variations on coincidence were investigated Coincidence and Killer bus leak through, could be introducing noise in the output This resulted in increasing the clipping levels which destroyed the proportionality requirements during alignment Results of the alignment experience was included in this portion of the tests.

The Final Environmental Life Test Report on the Video Interconnecting Equipment was issued in December 1958. Sufficient data was obtained by then to provide a complete report with recommendations for improving the reliability and life of the units.

6 4 Final Report on Environmental Life Test of VIE

The following final report is identical to one submitted in December 1958 and includes the addendum to Section V, Part F of the report which was submitted in February 1959 Section VI of this report covers tasks number two and three in assignment of 10 March 1958

The following is a tabular list of contents of the final report.

IV. PHOTOGRAPHS OF REFERENCE WAVEFORMS

A. Reference Waveforms

B Overall comparison of Waveforms Before and After Tests

V. ANALYSIS OF EQUIPMENT

A. Power Supply

B Main Chassis, Decoder-Modifier

C Sub-Chassis

Enabling Gate and Line Driver, Sub-chassis No 121

Radar Beacon Mixer and Decoder Mixer, Sub-chassis No.122

Select Pulse Generator and Coincidence Circuit, Sub-chassis No 123

C/S Coincidence and ALL A/C Killer Circuit, Sub-chassis No 124

Identification Pulse Generator, Sub-chassis No.125

D Video Control Unit

E. Control Cables

F Relay Life Test

VI. RECOMMENDATIONS FOR IMPROVING THE STABILITY, RELIABILITY, AND EASE OF MAINTENANCE OF THE VIE

I OBJECT OF ENVIRONMENTAL LIFE TEST

The object of the environmental life test was to determine the deterioration of electrical and mechanical functions of the Video interconnecting Equipment AND B Type 2.3Ns4a under conditions simulating two years of normal operation. The deterioration of the electrical characteristics of crystal diodes, resistors, capacitors, lamps, and electron tubes under high ambient operating temperatures and its effect in degrading equipment operation was to be investigated Upon completion of the tests recommendations are to be made for improvements to the unit that would increase its stability, reliability, and ease of maintenance.

II. TEST PROCEDURES

A. Description of Accelerated Life Test

Normal Operation: Equipment set up at room temperature 25°C ± 5°C, 50 ± 3 percent relative humidity Equipment to operate at nominal line power voltage, frequency input, output load conditions, and operating frequency for two hours.

Reference Test Data

Input: Line voltage- 115V regulated, 360 watts

Radar video- 2V positive, 10 u sec duration

Beacon video- VIE Code 00, 77, 52, 25,
0.5, 1, and 2V positive pulse, 500 pps,
0.45 ± 0 10 u sec wide

Radar trigger- 20V positive, 0 5 u sec. pulse

Beacon trigger- 5V positive, 1 u sec pulse

Output: Power supply, voltages and currents
+150V, 120ma, +250V, 130 ma;
-12 5V, +28V, 0 78; -200V

NOTE

Reference to CF, in the following description for test points, indicates a cathode follower

Beacon Video Waveforms. ALL A/C

Test Point

8 - Output of line driver, V-107

9 - ALL A/C coincidence bus, plates of CR-127 and CR-129

14 - Output of all A/C killer CF, V-124B, pin 8

53 - Output of beacon CF, V-110A, pin 3

59-1 - Output of beacon CF, V-109, pins and 3-6

72 - ALL A/C decoded video output at J-115

Beacon Video Waveforms <u>C/S</u>

Test Point

17 - C/S coincidence bus, TB-107, plates of CR-117 and CR-118

20 - Output of C/S killer amp., V-129A, pin 1

59-1 - Output of beacon CF V-109 pins 3 and 6

72 - C/S decoded video output at J-115

Select A/C

21 - Select A/C coincidence bus, plate of CR-119 or J-123-1

22 - Select A/C killer bus, plates of CR-151 and CR-154

26 - Output of select A/C killer CF, V-112B, pin 8

34 - Select A/C second pulse output at J-123-24

59-1 - Output of beacon CF V-109 pins 3 and 6

72 - Select A/C decoded video output at J-115

Ident A/C

21 - Same as Select A/C

22 - Same as Select A/C

26 - Same as Select A/C

34 - Same as Select A/C

45 - Output of cathode follower, V-117A, pin 3

51 - Ident A/C decoded output at J-122-24

48 - Output at plate of timing amp , V-120, pin 6

49 - Output of dunking pulse generator, V-122,pin 1

Beacon Mixer

53 - Output of beacon CF, V-110A , pin 3

70 - Input to plate of gating diode, CR-106

71 - Output of gated CF, V-104A, pin 3

Beacon Video Waveforms Gate Generator

Test Point

60 - Input to grid of trigger amp , V-125A, pin 2

62 - Plate output of multivibrator, V-125A, pin 6

65 - Input to grid of timing amp , V-101, pin 1

68 - Input to gate generator CF, V-104B, pin 7

70 - Input to plate of gating diode, CR-106

High Temperature Operation: Temperature, 50°C plus 5°C, minus 0°C, not with less than 90 percent relative humidity Equipment to operate at nominal line power voltage, frequency input, output load conditions, and operating frequency for two hours. Performance data to be taken for comparison with reference data

Test Cycling: Following the two hour high temperature conditioning run, equipment shall be subjected to a series of test cycles while operating in a steady state ambient temperature of 50°C plus 5°C, minus 0°C, with relative humidity to be not less than 90 percent

Test Cycling Schedule: (See Figure 21 and Table III)

Procedure in case of shut down or failure: In the event of a switch or relay failure, the type of failure and its cause will be noted The unit will then be replaced and the tests continued In the event of other component or tube failures, the circuit concerned will be restored to its normal operating condition and the tests continued A record is to be kept of all failures or malfunctioning of circuits Degradation of circuit operation will be recorded and the minimum level of satisfactory equipment function will be observed

Table III Toggle and Rotary Switch Cycling

Function	Operation	Frequency Per Hour *
On - Standby - Off	Standby to On Standby to Off	2 2
C/S - Off - ALL A/C	C/s to ALL A/C	200
Ident A/C - On		400
Raw-Decode - Check	Raw Check	60 60
Selected Code - On		400
Select Code	0 - 7 Outer Ring 0 - 7 Inner Ring	400 400
Radar Only-Mixed-Beacon Only	Radar Only - To - Beacon Only	200 200
Range Selector	6 Mi. to Remote	60
Beacon Video Gain	Full CW and Return	10
(* See Note Figure 21)		

B Cycling Procedure

The equipment was operated on a nearly continuous basis from Aug 21, 1958 through Oct 8, 1958 From the start of the test all controls and switches were operated automatically by the cycling drive unit to simulate actual use at an accelerated rate. A mechanical counter was attached to the toggle switch actuating bar to record the total number of operations The rotary switch count was obtained by recording the rotary switch drive motor operating time This was possible since the drive motor operated at nearly synchronous speed due to the light operating loads. During the test the drive shafts to the rotary switches were uncoupled at intervals to provide the required total operations The drive rate was very nearly the recommended rate of 12 cycles per minute as specified in MIL-S-3786 while maintaining the required number of operations to simulate two years of normal use

The environmental test chamber was cycled from 25°C to 50°C and back to 25°C in accordance with test cycling schedule (see Figure 21).

C Photographing Procedure

The reference photographs (Figures 22 to 27 and 28 to 33) taken at the beginning and end of the life test, are reproduced in this report which were taken with a Dumont Type 2614 Oscillograph Record Camera This camera records a mirror image of the waveform and, therefore, the time axis is from right to left. The initial reference photographs were taken during the week preceding the start of the life test on August 27, 1958. The final reference photographs were taken after the simulated two year life test was attained.

D Basis of Cycling Rates and Equivalent Days of Operation

It must be kept in mind that the basis for equivalent days of operation for any failure are based on the expected operations per hour of that particular function or switch.

However, the following is presented as being representative of normal operation for use in setting up equivalent days of operation.

ON-STDBY-OFF:	Standby to On - Once per day
	Standby to Off - Once per week
CS-OFF-ALL A/C:	5 times per hour
IDENT A/C-OFF:	12 times per hour
SELECT CODE-OFF:	12 times per hour
RAW-DECODE-CHECK	2 times per hour
SELECT CODE ROTARY SW.	12 times per hour

RADAR ONLY-MIXED-BEACON ONLY. 6 times per hour

RANGE SELECTOR 2 times per hour

These are rates that we have determined from data furnished by TDC and the New York Center. Any substantial deviation from these rates will be reflected in a change of equivalent days of operation in the life test It is not possible to assign any equivalent days of operation to components which operate continuously such as tubes, panel lamps, etc other than the actual days of operation, totaling about five weeks. Operating rates for relays are governed by the switches that control them Note that different relays are operated at different rates from the same switch, for example code relays K108-113.

III TEST RESULTS

The following summary lists the difficulties encountered in the Environmental Life Test of the Video Interconnecting Equipment Equipment and component failures, the nature of the failure, the steps taken to restore operation of the unit, and the equivalent days of simulated operation are tabulated. These test results, form the basis for the analysis of the equipment and the recommendations that follow in Section VI

Date	At 25°C 50% RH Switch or Function	Type of Failure Elec	 Mech	Adjust. Req'd	Total Operations	Equivalent Days of Operation	Comments
8/21/58	Ident A/C - Off		x		11,500	40	Replaced
8/22/58	Select Code		x		21,000	73	Replaced
	Raw-Decode-Check		x		21,000	437	Spring only replaced
	Select Code Rotary				7,480	50	(Required lubrication of contacts)
	Radar only - Mixed-Beacon				7,480	100	
	Range Selector					310	
8/23/58	Unit operating satisfactorily						
8/24/58	Unit operating satisfactorily						
8/25/58	Edge lighting lamp out	x					Replaced
	Relay K109 contact failure	x			224,000	520	Spare position wired in
	Gate pedestal adjusted			x			
	Select Code Rotary		x		32,000	220	Replaced
	Radar only - Mixed Beacon only		x		32,000	440	Replaced
	Range Selector		x		32,000	1,330	Replaced

Table IV Summary of Environmental Life Test Results

Date	At 50°C 90-95% RH Switch or Function	Type of Failure Elec.	 Mech	Adjust. Reqd	Total Operations	Equivalent Days of Operation	Comments
8/26/58	Gate pedestal adjusted			x			
8/27/58	Ident A/C - Off		x		61,160	210	Replaced
	Gate pedestal adjusted			x			
	Ident A/C						
	Select A/C		x				
	Select A/C			x			2nd pulse clipper adjusted
	All switching discontinued						All rotary switches badly worn
	At 25°C 50% RH						
8/28/58	Select A/C	x					
	Select A/C			x			Select clipper adj
	K110-B_1 Relay		x		330,000	330	Replaced
	K113-A_1 Relay		x		330,000	330	Replaced
	Code lamp out	x					
	K105 - Select A/C Relay	x			80,000	255	Double pulse in C/S - All A/C - Off

Table IV Summary of Environmental Life Test Results (cont.)

Date	At 25°C 50% RH Switch or Function	Type of Failure Elec	 Mech.	Adjust Req'd.	Total Operations	Equivalent Days of Operation	Comments
8/29/58	K104 Relay	x			80,000	280	Replaced high resistance contacts
9/2/58	All adjustments			x			Alignment
9/3/58	All adjustments			x			Alignment
9/4/58	All adjustments			x			Alignment
	K109 - B_2 Relay		x		330,000	765	Faulty, but not replaced.
9/5/58	All adjustments			x			
9/8/58	Unit operating satisfactorily						
9/9/58	V126	x					Replaced
	K105 Relay Select A/C		x		80,000	255	High contact resistance
9/10/58	Pwr. Supply Voltages adjusted						
	<u>At 50°C 50% RH</u>						
	Gate pedestal adjusted			x			

Table IV Summary of Environmental Life Test Results (cont.)

Date	At $25^{o}C$ 50% RH	Type of Failure		Adjust.	Total	Equivalent Days	Comments
	Switch or Function	Elec.	Mech.	Req'd	Operations	of Operation	
9/11/58	Select	x					
	CS, All A/C	x					
	Gate pedestal adjusted			x			
	K113 & K110 only, started cycling						
	At $25^{o}C$ 50% RH						
	Gate adjusted			x			
9/12/58	Unit operating satisfactorily						
9/15/58	V114 2nd Select pulse amp	x					Replaced
	Adjust 2nd Select pulse amp.			x			
	Adjust gain and clipper			x			
	Range Switch		x		15,270	635	Repaired by paralleling 2nd deck
9/16/58	Unit operating satisfactorily						
9/17/58	Unit operating satisfactorily						
	Gate circuit modified						

Table IV Summary of Environmental Life Test Results (cont.)

Date	At $50^{o}C$ 50% RH Switch or Function	Type of Failure Elec	 Mech	Adjust. Req'd	Total Operations	Equivalent Days of Operation	Comments
9/18/58	Unit operating satisfactorily						
9/19/58	V126	x					Replaced
9/22/58	Unit operating satisfactorily						
9/23/58	Unit operating satisfactorily						
	At $25^{o}C$ 50% RH						
9/24/58	Unit operating satisfactorily						
	K113 & K110				200,000	195	OK
9/30/58	K113 & K110				325,000	320	OK
10/1/58	R252 Raw Video Gain			x			Adjusted
	Relay K107 Decode-Raw		x		2,700	7 yrs	Sticking
10/6/58	Unit operating satisfactorily*						
10/7/58	Final Reference Photos						
10/8/58	Cycling Relays K113 and K110 stopped				477,000	475	OK
	Life Test Concluded						

*Except for relays previously indicated as faulty but not replaced

Table IV Summary of Environmental Life Test Results (cont)

Table IV Summary of Environmental Life Test Results (cont)

Power Supply Voltage Readings						
Test Points		Junction of R304 & R305	J306	J303	J307	J304
Voltage Specified		-200	-12.5	250	150	28
Voltage at 25°C	Max,	-205	-10.	256	152	24 5
	Min.	-205	-9 6	252	150	24 5
Voltage at 50°C	Max.	-204	-9 9	255	152	25 3
	Min	-203	-9 6	252	150	24 8

Note: All readings taken from points indicated to ground using a 20,000 ohms-per-volt voltmeter

IV REFERENCE PHOTOGRAPHS OF WAVEFORMS

A <u>Reference Waveforms</u> Figures 22 to 27 are reference photographs taken at the start of the Environmental Life Test The time axis is from right to left Figures 28 to 33 are reference photographs taken at the conclusion of the Environmental Life Test, simulating two years of normal use The time axis is from right to left

Since it would not appear practical to completely analyze circuit deficiencies using the reference photographs, Section V presents comments and recommendations which are based on failures and changes encountered during the life test They are broken down into Power Supply, Main Chassis, Sub Chassis, and Control Box, and discussed in that order

B <u>Overall Comparison of Waveforms before and after Tests</u>

Careful comparison of all photographs revealed only small amounts of circuit degradation In all cases discernible changes could be traced to tube aging, a tube replaced during the life test, or slight variations in alignment The unit was aligned before the start of tests and once during the life test, after a high humidity-high temperature run The following is a tabulation of changes noted

Table V Percentage Change in Amplitude, after Life Test

Test Point No	Percentage Change in Amplitude After Life Test			Comment
	* 2 V	* 1 V	* 5 V	
8	0	0	0	OK
9	0	0	0	OK
14	0	0	0	OK
17	-20	-20	30	Output of V105, V106, and V107 down
20	-11	-7	15	Output of V105, V106, V107, and V109 down
21	-10	-5	5	Output of V105, V106, and V107 down
22	0	0	0	No change
26	-6	-6	-6	V112 output down slightly
34-1	20	15	0	R189 gain adjusted
34-2	-70	-50	-100	R189 gain adjusted
45	0	0	0	No change
48-1	0			
49	0			

* Indicates video input volts

Table V Percentage Change in Amplitude, after Life Test (cont)

Test Point No.	Percentage Change in Amplitude After Life Test			Comment
	*2 V	*1 V	* 5 V	
51	0	0	0	No change
53	-10	-11		R290 gain adjusted, V129 weak
59-1	45	80	50	Poor alignment originally
60	0			
62	40			V125 replaced during life test
65-1	0	0	0	Decay time 1-1/2X, V125 replaced
65-2	0	0	0	Decay time 1-1/2X, V125 replaced
68	0	0	0	Pulse length increased 56%
70-1	-20	-20	-20	Decay time decreased 3 X, diode change
70-2	-20	-20	-20	Decay time decreased 3 X, diode change
71-1	5	0	-100	Poor alignment originally
72-1	-30	0	-100	V129 gain down, replaced
72-2	-30			Limiter set lower
72-3	-30	-30		Limiter set lower
72-4	-30	-30		Limiter set lower

*Indicates video input volts

V. ANALYSIS OF EQUIPMENT

A Power Supply

Three changes were made on the power supply before the start of the life test Lamp voltage dropping resistors R268 and R269 were changed from 68 ohms, 1 watt to 390 ohms, 2 watt to lengthen pilot lamp life, Resistor R301, part of the minus 200 volt reference voltage power supply, was changed from 56K ohms, 2 watts, to wire wound 55K ohms, 20 watts

Previously, resistor R301 was exceeding its rated power dissipation, and consequently changing its resistance value. This caused the minus 200 volt reference voltage to fluctuate With resistor R301 replaced, and the unit operated from a regulated 115 volt source, no further trouble was experienced with the power supply for the duration of the life test It was found necessary to adjust voltage levels only once, and regulation of all voltages was better than 5 percent for the length of the life test. Results indicated, that when a regulated source was used, very little trouble would be encountered in the power supply No difficulty was experienced with the thermal delay relay, K302, under any operating condition Field reports had indicated that this relay was causing some equipment malfunction

B Decoder-Modifier, Main Chassis

Lamp resistors R268 and R269 were changed from 68 ohms 1 watt to 390 ohms 2 watts to increase pilot lamp life No further problems were encountered on the main chassis.

C Sub-Chassis

Enabling Gate and Line Driver, Sub-chassis No 121

This sub chassis contains the gate circuit modification described in the September, 1958 report. This was a very hot chassis. While the diode change to silicon high temperature type had eliminated gate pedestal shift, it did not reduce the operating temperature of this chassis At 50°C ambient, the chassis temperature near the top reached 109°C. At 25°C ambient, this was reduced to 84°C. With a total of nine tubes, mounted in an area 2-1/2 inches by 8-1/2 inches, there was little that could be done, short of package re-design, to reduce the operating temperature of this chassis. Figure 34 indicates the various temperatures encountered. With such high operating temperatures, reduced tube life must be expected, even with heat dissipating tube shields. It is recommended that IERC TR6-6020H tube shields be installed on tubes V107, V126, and V125. No other cause of reduced tube life, could be found in the circuits associated with V125 and V126.

Radar Beacon Mixer and Decoder Mixer, Sub-chassis No. 122

There were no modifications made on this sub chassis. The only problems encountered during the life test, were failure of the All A/C relay K104, and the Select relay K105. These relays failed, as the contact resistance increased from a few tenths to several thousand ohms. Failure occurred at 80,000 operations for both relays. These relays were Allied Control Company, type MH-12D, rated at minus 55 to plus 85°C, which were used throughout the equipment. These relays will be completely discussed under the relay life test section of this report.

Subsequent to the environmental life test, it was found that the response of the unit, in the RAW VIDEO position, varied with the change in coding. In adjusting the unit to meet proportionality requirements at 0.5 volt input, Code 00, the signal leak-through, with Code 77, was above limits. Adjusting the limiter potentiometer decreased the leak-through of the signal, but this in turn reduced the Code 00 output below the 2 volts limiter value. Increasing the gain control, increases the pulse width, to a point where the pulse spacings are eliminated.

Observations of the pulses at the end of the delay line Z-101, indicated that the pulse amplitudes varied with different codes. At Code 00 the amplitude was 1 6 volts, whereas the average amplitude for Code 77 was about 2 8 volts This condition was found to be due to the loading effect on the delay line of the killer bus resistor R640 (1000 ohms) through - 12 5 volts to ground, R179 (1000 ohms), the ALL A/C Killer bus to ground, and R672 (680 ohms), the alternate Killer bus, to ground. Unloading the delay line, when it is used to pass the RAW VIDEO signals by removing the above resistors, resulted in the following.

1 All codes were passed through the delay line with equal amplitudes

2 Proportionality requirements were easily met with no critical adjustments.

3 The RAW VIDEO output pulses from the decoder were of similar shape, width, and amplitude regardless of code setting

Modification of the unit involves the moving of relay K107 (DECODE-RAW VIDEO) to the main chassis and the use of the three unused relay poles This modification unloads the delay line in the RAW VIDEO position of relay K107 and restored the delay line loads at the DECODE position Fig 35 shows the wiring changes required This involves the following changes.

(1) The addition of nine additional wires (three per relay pole) and four standoff terminals

(2) Repositioning former wiring of relay K107

(3) Relocating four resistors to positions on the K107 terminals and bracket, (see Fig 36)

Modification, alignment, and test of the unit, indicated improved performance could be obtained without affecting existing circuit operation

Select Pulse Generator and coincidence circuit, Sub-chassis No 123

There were two problems encountered in sub-chassis 123 One was the failure of code relays K108 through K113 which would develop intermittent high contact resistances after about 300,000 operations As these relays would fail, multiple replies could be detected from a single code input, as the select killer would become inoperative These were again Allied 85°C type, and will be discussed under the relay life test section

The second problem concerned the appearance of noise at the video output on the 200 mile range This was caused by a slight positive overshoot of the second select pulse before it traveled the round trip on the 20 3 u sec delay line, DL102 This positive overshoot appeared at the grid of V114 (see Figure 37) Since it was positive, it would not be removed by the clipping network, R190 and diode CR142 By lengthening the time constant of coupling network, C195 and R187, the overshoot was eliminated and the noise was removed To increase the time constant, change R187 from 100K ohms to one megohm. This change in no way affects the operating point of the tube or its bias

C/S Coincidence and ALL A/C Killer Circuit, Sub-chassis 124

No problems were encountered with sub-chassis 124

Identification Pulse Generator, Sub-chassis 125

The only difficulty experienced with sub-chassis 125, was during alignment, when attempting to extend the ident pulse to the proper length for each range Replacing V122 and adjusting C132 corrected this condition It was necessary to adjust C132 again, when the unit was re-aligned during the test, to compensate for tube ageing characteristics Variations in tube characteristics affected the multivibrator time constants

D Video Control Unit

Except for lamp resistor R407, which was changed from 5 ohms 10 watts to 20 ohms 5 watts troubles found in the control box were of a mechanical nature. Increasing the resistance of R407, increased the life of the edge lighting lamps, particularly the code lamp Mechanical troubles encountered were, breakage of the toggle switches and contact wear of the rotary switches

The toggle switches were found to last anywhere from 11,500 operations, to an excess of 150,000 operations. The lighter construction type, ST22N, used in the Select code and Ident A/C 9S404 and S405) positions, failed short of the desired two year life When failure occurs at the installation they should be replaced with a heavier duty type, ST52N. The remaining toggle switches are a heavier type, and since they are used fifty percent less than switches S404 and S405, no trouble should occur

There is no definite answer to rotary switch wear As mentioned in the life test summary, failure may be expected after 60,000 operations even with lubrication The RADAR ONLY-MIXED-BEACON ONLY switch, will last the desired two years since it is used only six times per hour The RANGE SELECTOR switch, which is used only twice per hour, will also last without difficulty The SELECT CODE rotary switch however, may not last one year. It would be beneficial if the switches were lubricated every four months, at which time inspection of wear could be made and switch life extended by this procedure. There is no switch of a similar construction, that will outlast the type now used A change to a Daven precision rotary step switch would entail considerable mechanical changes in the box At this time, a four month inspection and lubrication program of rotary switches, in the control box, is the best answer Standard Oil Company, Beacon M325 grease, is recommended as a MIL approved lubricant for the contacts

E. Control Cables

No difficulty was experienced with the control cables Due to the method of control switching employed, the effect of drops in the cabling did not affect unit performance

F Relay Life Test

Relays proved to be the source of most failures in this unit Tests on the equipment, indicated, that the proper relays for the dry circuit application were not used. As a result, the relay contacts form a film that, under low voltage and current conditions, does not permit the flow of current

The nine units received for alignment, contained 22 per unit, of 85°C, type MH-12D, Allied Control relays In fact, there was a mixture of 85°C types This was in disagreement with Farnsworth's part list, which indicates -55° to 125°C type MHB-12D relays. It has been found that the 85°C type would not be durable in a 50°C ambient temperature Since the relays continued to fail with different total operations, but at about the same time, it was probable that the failure resulted from an organic film, rather than from tarnished or pitted contacts In the relays examined, there was a thin film deposited on the contacts that were used for the various circuits.

In an effort to find a suitable dry circuit relay, a life test of four different types of relays began on October 27, 1958 and was concluded on February 3, 1959 At that time, the relays had been cycled one million times

The resistance values indicated are for each pole of the relay turned both "on" and "off" In the cycling test, readings were taken at 10,000 operation intervals For every reading, each relay was operated several times, and the highest resistance value in each position was recorded Table VII condenses this data to the highest resistance recorded for every 50,000 operations In the test, a Simpson 260 VOM was used to record the resistance values. Due to the resistance of the leads, and the range of accuracy of the meter, resistance values of less than 0 5 ohms are not considered significant Contact resistances of less than 10 ohms should not effect equipment performance in these dry circuit applications

At the conclusion of the test, the relays were dismantled and each relay was examined under a microscope Table VI lists the failures that occurred during the test, and the reason for it, based on visual inspection. In addition, the following information noted about each relay may prove helpful

Relay No 1 The Union Switch and Signal relay has radially mounted poles with contact edges perpendicular to the base. They are actuated by a rotating armature A soft carbon-like substance was found to have collected on the contacts, but it is apparently not detrimental to contact conductance

Relay Nos 2 and 3. Allied relays have contacts which are parallel to the base. Action of the armature is up and down. This relay would not be most suitable for mounting in an upright position, since any debris could not fall free of the contacts

Relay Nos 4 and 5 Filtors relays have upright contacts, activated by a rotating armature A slight amount of contact pitting was noted, but no residue was left

Table VI Analysis of Failures

Relay No	Pole No.	Position	Comment
2	12	ON	Misalignment of moving contact caused contact to strike on edge Burning and pitting of both contacts resulted
2	14	OFF	Small amount of burning and pitting evident.
3	11	ON	Contact pitted and burned Resulting "ash" apparently builds up and causes failure
5	10	---	Movable contact leaf broken Failure due to metal fatigue.

Evaluation of Data: Considering that a contact resistance of less than 10 ohms does not constitute a failure, relays No. 1, 4, and 6 successfully completed the life test Relay No. 3 comes close to this criteria, but might show some circuit degradation, since a maximum contact resistance 16 ohms was noted on Pin 11

For any failures that occur however, we would recommend replacement with Filtors Inc , type 26WDK12S, relay, and socket assembly WDK12 This plug-in type, with the socket mounted from above the chassis, offers the advantages of direct mechanical and electrical replacement for all Allied relays, K102 through K123, now used in the equipment

Performance of the two Filtors Inc relays in the life test confirms this decision. The fatigue failure in No. 5 may have been caused by a flaw in the metal and possibly, is an unusual case Contact resistance does not seem to be an important factor with these relays. In addition, since the socket will fit firectly in existing mounting holes, installation is much simpler than for the other plug-in types.

Conclusion: For future equipment needs, the relays which are best suited should be specified The Union Switch and Signal relay performed well throughout the test. It is a six pole plug-in type of slightly larger size than the Filtors or Allied types Only one unit was available for testing, and so data may not be conclusive It requires a 1-1/8 inch mounting hole

The Allied Control relays performed better in the life test than they did in the unit Even so, high contact resistance continues to be a problem. The mounting socket requires one inch mounting hole, but needs 1-3/16 inches clearance above the chassis.

The Filtors Inc relays are available in four or six pole plug-in types The No 4, four pole type tested here, proved satisfactory The socket requires a one inch mounting hole, making it suitable for compact equipment

The Guardian Electric relay performed very well but is not of the plug-in type It is also physically larger than any of the other relays, measuring 1-3/16 x 1-3/16 x 2 inches If space problems are not critical, and the plug-in feature were not desired, this relay would be suitable

The plug-in feature of the Filtors relay increases the price only slightly, and permits rapid future servicing of the equipment, should another failure occur This feature would be especially desirable for the code relays K108 through K113, so that they could be interchanged periodically to equalize the number of operations performed On any equipment to be built in the future, it would be advisable to use plug-in type relays

The two remaining relays K101 and K124 are Filtors Inc , 6PDT, type 26SM18B. The suffix B appears on the relays in the units, but not on the parts list, which indicates that they are a special type. Since these relays are rated from minus 65 to plus 125°C, and are apparently a special order, they may be satisfactory No trouble was noted during the life test cycling of K101 However if failure occurs, we recommend replacement with Filtors plug-in relays, type 26WDK-185, and WDK18 socket assembly. This is the type that should be used for dry circuit application

VI. RECOMMENDATIONS FOR IMPROVING THE STABILITY, RELIABILITY, AND EASE OF MAINTENANCE OF THE VIE.

In order to report results to TDC as soon as failures or malfunctions occurred, circuit or component changes were recommended periodically In this section a summary of the recommendations with the reason for the recommendations are listed

RECOMMENDATION	REASON
1 Install 390 ohm 2 W carbon resistors in series with power supply and decoder-modifier indicator lamps, in place of 68 ohm resistors.	1 Extend pilot lamp life while maintaining sufficient indicator brightness
2. Install 55K, 20 W wire wound resistor in place of 56K 2 W composition resistor, R301, in -200 volt reference	2 Stabilize power supply output voltages due to overheating of 2 W

RECOMMENDATION (cont)	REASON (cont)
2 (cont) supply.	2 (cont) resistor dissipating over 2 4 watts
3. Move 115V input on T302, from pin 3 to pin 4	3. This will reduce the 28 volt DC supply voltage to approximately 26.5 V DC and 29 5 V RMS which will provide longer relay coil and pilot lamp life Original tap position resulted in a measured 28 V DC and a 32.5 V RMS value.
4. Use of a constant voltage line power regulator.	4 This will maintain power supply voltages within the rated limits
5 Toggle switches of the ST22N types, (S404, S405), replaced with ST52N types when switches fail	5 The heavier construction of the ST52N type will provide greater life
6 Rotary switch contacts should be lubricated and inspected for wear every four months Beacon M325 grease made by the Standard Oil Co is recommended.	6 Switch life will be extended and imminent failure detected
7 Control box edge lighting and code lamp dropping resistor	7 Extend edge lighting and code lamp life while

RECOMMENDATION (cont)	REASON (cont)
7 (cont) R407, 5 ohm 10 watt changed to 20 ohm 5 W wire wound resistor.	7. (cont) maintaining sufficient illumination
8. Stabilize the Gate Pedestal Adjust circuit operation by changing CR105 and CR106 from IN198 germanium types, to IN195 silicon point contact types. The wire from pin 4 of R116 (the fixed tap) is moved to pin 3.	8. At the higher ambient temperature and normal operating temperature rises, the germanium diode characteristics shift causing a Gate Pedestal change The high temperature silicon diode is more stable in this condition and does not show this Gate Pedestal level change
9. Heat dissipating tube shields IERC, Type TR-6020H, should be installed on tubes V-125, V-126, and V-107	9 These shields reduce the tube bulb temperatures and contribute to longer tube life and stable operation It is possible that at the high ambient temperatures, manufacturer's ratings may be exceeded unless steps are taken to reduce these temperatures
10 Change Select Second Pulse Amplifier grid bias resistor, R187, from 100K to 1M.	10 Pulse overshoot with noise superimposed by the delay line on the 200 mile round trip position causes this

RECOMMENDATION (cont)	REASON (cont)
10	10 (cont) noise to appear in the output Removal of the overshoot brings this noise below the base line and eliminates it from being amplified and appearing in the output
11 Relocate and rewire RAW VIDEO-DECODE relay, K-107, to provide improved raw video output	11 This change provides a means of unloading the delay line DL-101 This allows the raw video pulses to pass through, without changing amplitude, when different codes are selected Raw video pulses thus appear nearly equal in amplitude, width, and shape
12.(a) Relays K102 to 123 of the Allied MH-12D type, replaced with Filtors Inc , type 26WDK12S relay, and WDK12 relay, and WDK12 socket assembly when relays fail (b) Relays K101 and K124 of the Filtors Inc , type 26SM18B replace with Filtors Inc type 26WDK18S relay, and WDK 18 socket assembly, if these relays should fail	12 (a) Allied relay has only plus 85°C rating, and will not stand up at high temperatures Direct replacement plug-in type are easier to service (b) Direct replacement plug-in type are easier to service

TABLE VII RELAY LIFE TEST (RESISTANCE - OHMS)

NUMBER OF OPERATIONS			0-50M		50-100M		100-150M		150-200M		200-250M		250-300M		300-350M	
NO.	RELAY TYPE	POLE NO	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
1	UNION SWITCH AND	1	.15	18	.18	18	.18	18	.18	18	18	18	18	18	18	18
	SIGNAL UN324362	2	15	18	18	.18	.18	18	.18	.18	18	.18	18	18	18	18
	STYLE DM 26.5 V	3	.15	18	1.0	.15	1.0	18	1.0	.18	1 0	18	1 0	18	1 0	18
	-65°C +125°C	4	.15	18	.15	.15	18	.18	18	.18	18	18	18	18	18	18
		5	2	2	.18	18	.18	.18	18	.18	18	.18	18	18	18	18
		6	15	2	18	18	18	18	.18	.18	18	18	18	.18	.18	18
2	ALLIED CONTROL CO.INC	9	15	15	18	.18	.18	18	18	.18	.18	.18	18	18	18	18
	MHBUO-12D 26.5 V	11	15	15	18	18	18	.18	18	.18	18	18	.18	18	18	18
	CODE AS348	12	15	15	18	18	.18	.18	18	18	18	18	18	18	18	18
		14	15	15	18	18	18	18	18	18	18	18	18	18	18	18
3	ALLIED CONTROL CO INC	9	15	18	.18	18	18	18	18	18	18	.18	18	18	18	18
	MHBUO-12D 26 5 V	11	15	18	.18	18	.18	18	18	.18	18	18	18	18	.18	18
	CODE AS348	12	15	18	18	18	.18	.18	18	18	18	18	18	18	18	18
		14	.15	18	18	.18	18	18	18	.18	18	18	18	18	18	.8
4	FILTORS INC	4	12[illegible]	18	130	18	130	.18	130	18	130	18	130	18	130	18
	26 WDK 12S 26 5 V	10	15	18	18	.18	18	.18	18	18	18	18	.18	18	18	18
	LOW LEVEL -65°C +125°C	13	15	18	.18	.18	.18	.18	18	18	18	18	18	18	18	18
	SERIAL NO. 98707	19	15	18	18	18	.18	.18	18	18	18	18	18	18	18	18
5	FILTORS INC.	4	15	18	.18	18	18	.18	18	18	18	18	.18	18	19	.18
	26 WDK 12S 26 5 V	10	15	18	.18	18	.18	18	.18	.18	18	18	18	.18	.18	18
	LOW LEVEL 65°C +125°C	13	15	18	.18	.18	18	18	.18	.18	18	.18	.18	18	18	18
	SERIAL NO 98706	19	15	18	18	.18	.18	18	18	18	18	18	18	.18	.18	18
6	GUARDIAN ELECTRIC	3	.21	2	18	18	18	18	.18	18	18	18	18	18	.18	18
	MFG. CO.	6	21	2	.18	18	18	18	.18	18	18	18	18	18	18	18
	G-5700	9	21	2	.18	18	18	18	18	18	18	18	.18	18	18	19
		12	21	2	.18	.18	18	18	18	18	18	.18	18	18	18	18
		15	21	.2	.18	.18	.18	18	.18	18	18	18	.18	18	18	18
		18	21	2	.18	18	18	.18	.18	18	.18	18	18	.18	18	18

TABLE VII. RELAY LIFE TEST (RESISTANCE - OHMS) (cont)

NUMBER OF OPERATIONS			350-400M		400-450M		450-500M		500-550M		600-650M		650-700M	
NO.	RELAY TYPE	POLE NO.	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
1	UNION SWITCH AND	1	.18	.18	.18	.18	.2	.2	2	2	2	2	2	2
	SIGNAL UN324362	2	.18	18	18	.18	.3	3	2	2	2	2	2	.2
	STYLE DM 26.5 V	3	1.0	.18	1 0	18	1 0	.2	1.0	2	8	2	1 2	2
	-65°C +125°C	4	18	.18	.18	.18	2	2	2	2	2	2	.2	2
		5	18	.18	.18	18	.2	2	.2	2	2	.2	2	2
		6	18	18	18	18	.2	.2	2	2	2	.2	.2	.2
2	ALLIED CONTROL CO INC.	9	.18	18	.18	18	.3	.6	.2	.2	2	2	2	.2
	MHBUO-12D 26 5 V	11	18	18	.18	.18	2	.2	.2	2	.2	2	2	.2
	CODE AS348	12	18	18	.18	18	2	2	.2	.3	2	4	2	4
		14	18	.18	.18	18	3	3	2	2	2	2	2	2
3	ALLIED CONTROL CO. INC.	9	18	18	18	18	18	8	2	4	2	2	.2	.2
	MHBUO-12D 26 5 V	11	18	18	.18	18	5	.2	5 5	3	7 0	3	6 0	.4
	CODE AS348	12	18	18	18	18	18	.18	.4	3	2	2	4	.2
		14	18	18	.18	18	18	18	3	.5	.2	2	.2	2
4	FILTORS INC	4	18	18	130K	18	18	18	4	4	4	.4	4	.3
	26 WDK 12S 26 5 V	10	18	.18	.18	18	18	2	3	3	3	3	3	3
	LOW LEVEL -65°C +125°C	13	.18	18	18	18	18	18	3	3	3	3	4	4
	SERIAL NO 98707	19	18	18	18	18	18	18	4	4	4	4	3	3
5	FILTORS INC.	4	18	18	.18	.18	7	.18	.4	4	.4	4	.4	.4
	26 WDK 12S 26.5 V	10	18	.18	18	18	.18	.18	.4	4	5	5	4	4
	LOW LEVEL -65°C +125°C	13	.18	18	18	18	.18	.18	.3	4	.4	4	.3	4
	SERIAL NO 98706	19	18	.18	.18	18	18	.18	3	4	4	4	4	4
6	GUARDIAN ELECTRIC	3	18	.18	.18	18	.18	.18	.4	4	4	4	.4	.4
	MFG. CO.	6	18	18	18	.18	18	.18	.4	4	6	4	.4	4
	G-5700	9	18	18	18	.18	18	18	4	.4	.5	.5	.5	.5
		12	18	.18	18	18	18	18	6	.4	.6	4	6	.4
		15	.18	18	18	.18	2	2	.4	4	.4	.4	5	5
		18	18	18	18	.18	2	.18	.4	4	5	5	4	4

TABLE VII. RELAY LIFE TEST (RESISTANCE - OHMS)(cont)

NUMBER OF OPERATIONS			700-750M		750-800M		800-850M		850-900M		900-950M		950M-1M	
NO.	RELAY TYPE	POLE NO.	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF	ON	OFF
1	UNION SWITCH AND SIGNAL UN324362 STYLE DM 26 5 V -65°C +125°C	1	.2	2	.2	2	.2	2	.2	.2	2	2	2	.2
		2	.2	.2	2	.2	.2	2	.2	.2	2	2	2	2
		3	2 6	3	3.4	3	3 4	.3	5 0	4	.2	2	2 2	2
		4	.2	2	.2	2	.2	.2	.2	2	2	2	2	.2
		5	.2	.2	2	.2	2	2	.3	.3	2	2	3	3
		6	2	.2	2	2	2	.2	3	3	2	2	2	2
2	ALLIED CONTROL CO INC. MHBUO-12D 26 5 V CODE AS348	9	2	2	2	2	2	.2	.2	2	.2	2	.2	2
		11	.2	2	.2	2	.2	.2	.2	2	2	2	.2	2
		12	.2	5	3	3	3	3	2	130K	2	130K	2	130K
		14	2	2	.2	2	2	.2	.3	3	2	.6	2	2.8
3	ALLIED CONTROL CO INC MHBUO-12D 26.5 V CODE AS348	9	2	2	.3	3	2	2	.3	3	.3	3	3	3
		11	6 0	.4	10.0	3	7.0	3	16.0	3	5 0	3	9 0	.3
		12	.2	2	2	2	2	2	.3	3	2	2	2	2
		14	.2	2	2	2	.3	3	3	3	2	2	.2	2
4	FILTORS INC 26 WDK 12S 26.5 V LOW LEVEL -65°C +125°C SERIAL NO 98707	4	3	3	.3	3	3	5	.4	4	.4	4	4	4
		10	3	3	3	3	3	.3	4	4	5	5	3	.6
		13	3	3	.3	3	3	3	3	3	5	5	3	6
		19	4	4	4	.4	6	3	6	3	4	4	3	.5
5	FILTORS INC 26 WDK 12S 26.5 V LOW LEVEL -65° +125°C SERIAL NO. 98706	4	.4	4	.4	4	6	.4	.4	4	6	6	4	8
		10	5	5	.5	5	50K	50K	130K	130K	130K	130K	130K	130K
		13	.3	.3	4	.4	4	4	4	4	4	7	4	8
		19	3	3	4	4	6	.4	.4	.4	3	6	.5	1 1
6	GUARDIAN ELECTRIC MFG CO. G-5700	3	.4	.4	5	.5	5	.5	.6	.6	.6	6	6	6
		6	4	.4	5	.5	.5	5	1.2	6	5	6	9	9
		9	.6	.6	6	.6	.6	.6	1 2	7	7	7	8	8
		12	.5	.5	5	5	5	.5	6	6	6	6	6	6
		15	5	.5	6	.6	.6	6	6	6	8	8	.8	8
		18	5	5	6	.6	5	.5	6	5	5	5	.7	7

6 5 Modification of Video Interconnection Equipment ANDB Type 2.3 NS4a For Raw Video Operation

In the Final Report on the Environmental Life Test of the Video Interconnection Equipment, recommendation number 11, recommended that RAW-DECODE relay, K107 be relocated and rewired to provide improved raw video output

This modification consisted of removing relay K107 from Radar Beacon Mixer and Decoder Mixer, subchassis number 122, and relocating it onto the Decoder Modifier main chassis This included the necessary rewiring, adding wires, and relocating four resistors. Also the tube shields for V107, V125, and V126 were removed and replaced with type IERC TR6-6020H tube shields

This change provided a means of unloading the delay line DL101, and allowed the raw video pulses to pass through without changing amplitude when different codes were selected Therefore the raw video pulses appeared similar in amplitude, width, and shape regardless of code setting

A modification was performed on one unit in Stewart-Warner laboratories and the procedure was recorded This procedure, with a parts list, was submitted to FAA for evaluation

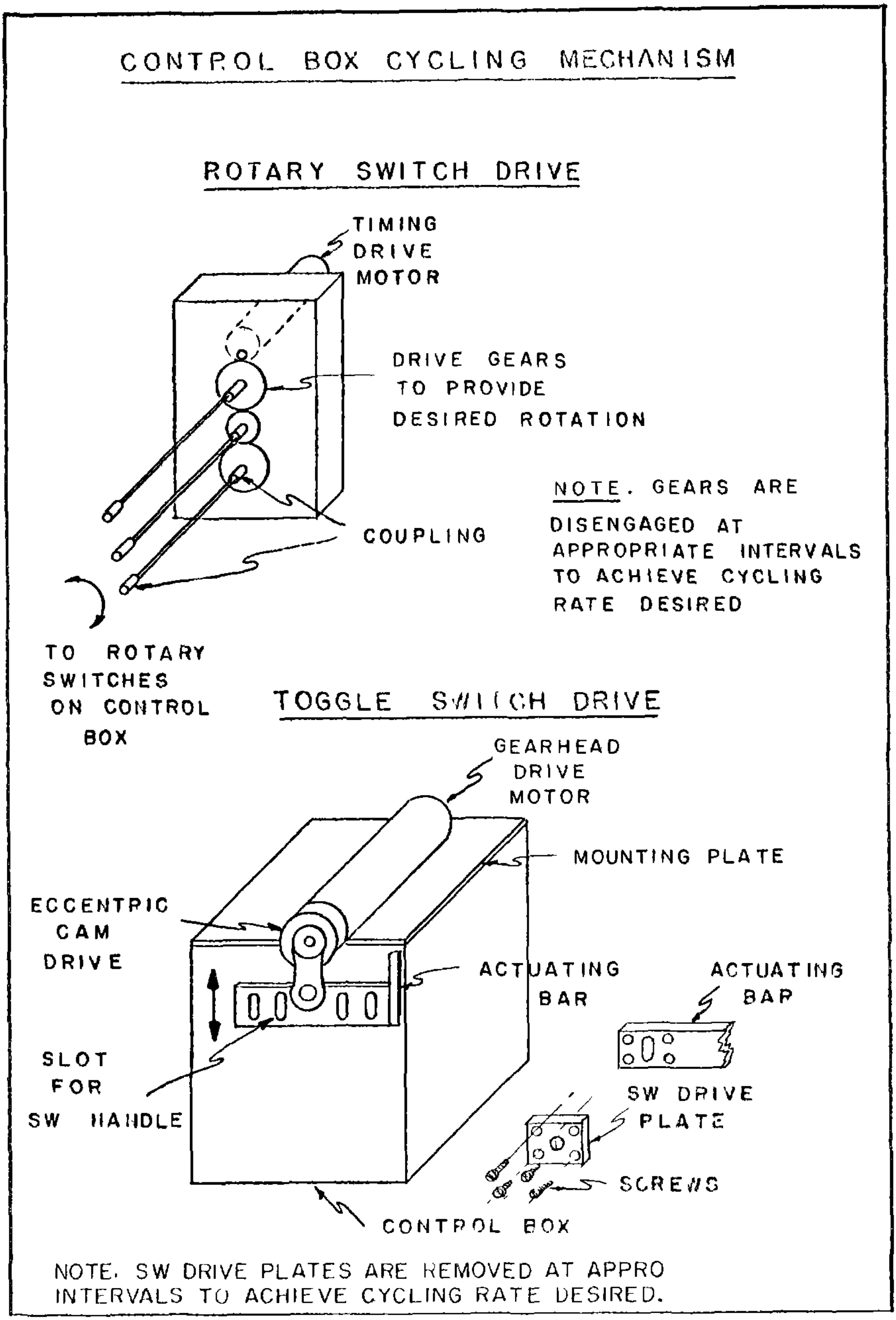


Figure 18 Control Box Cycling Mechanism

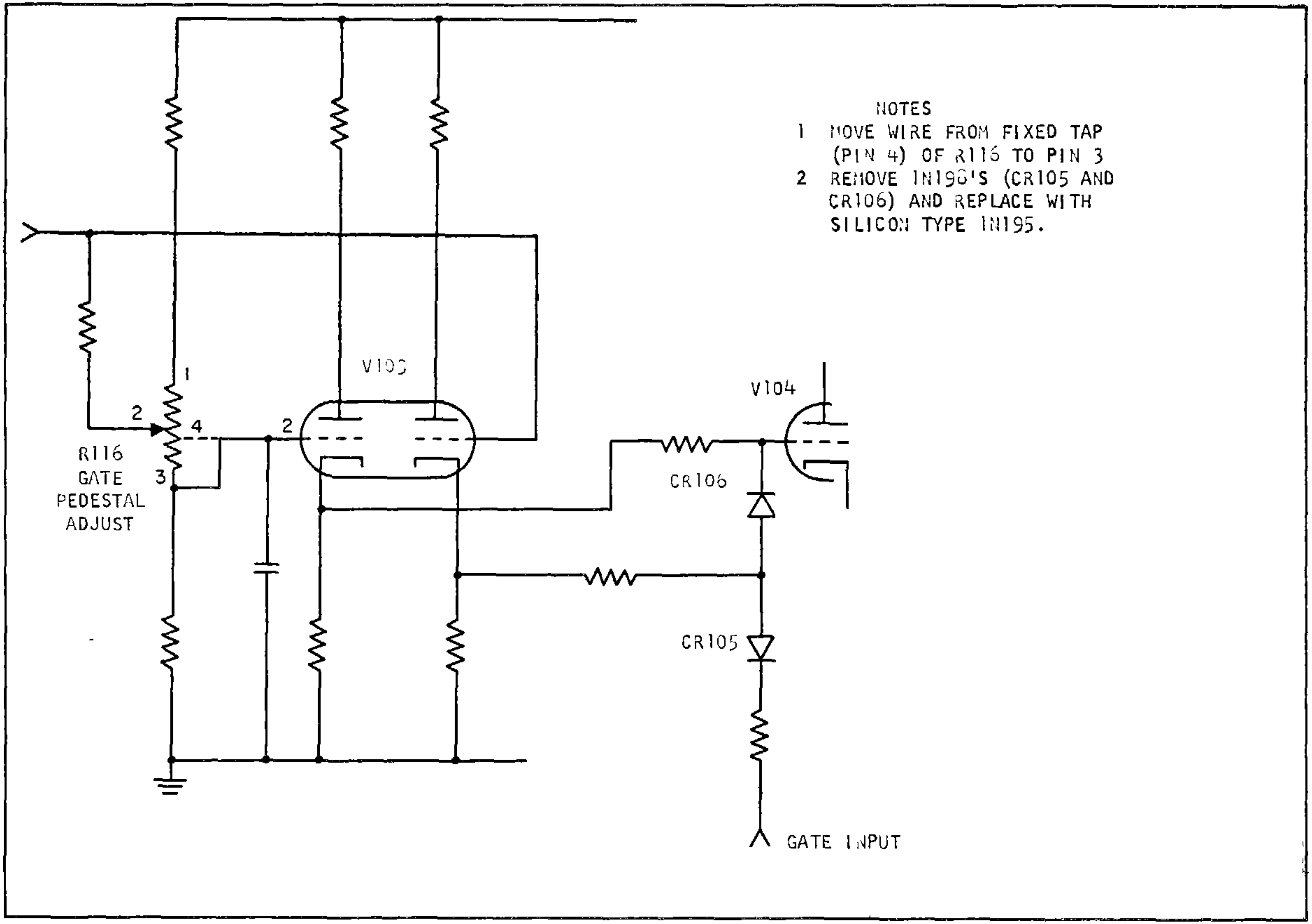


Figure 19. Gate Circuit Modification, Schematic

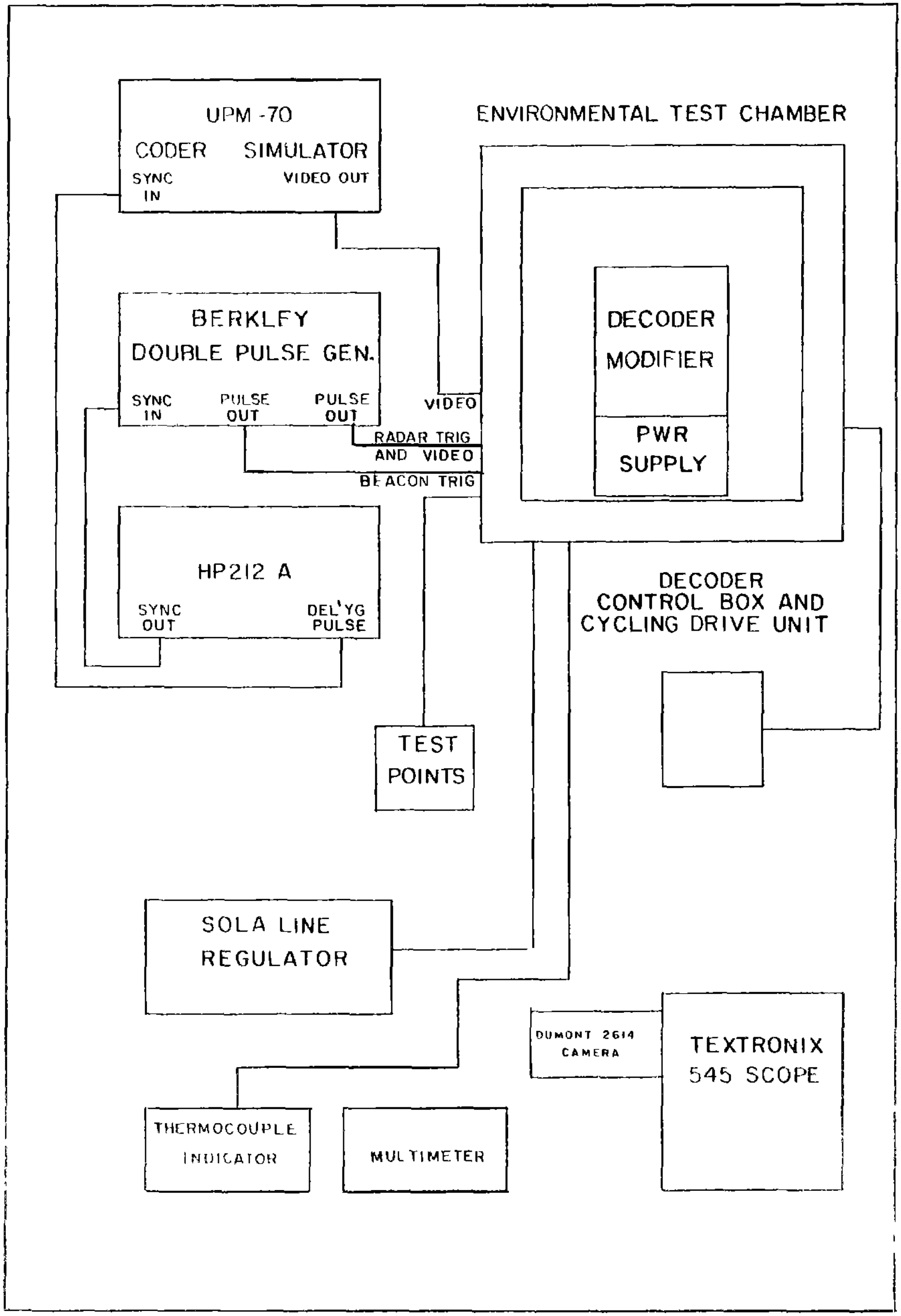


Figure 20. Environmental Test Setup

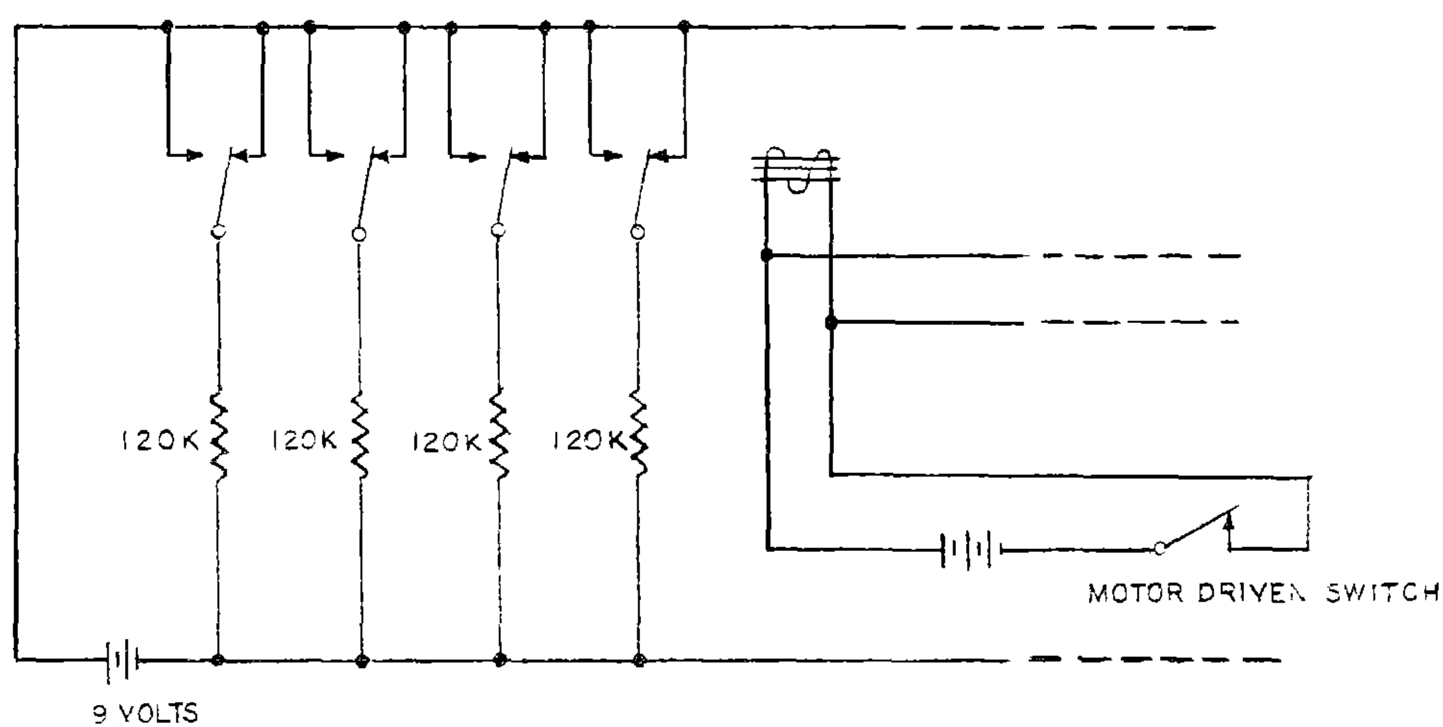


Figure 20A Relay Life Test, Schematic

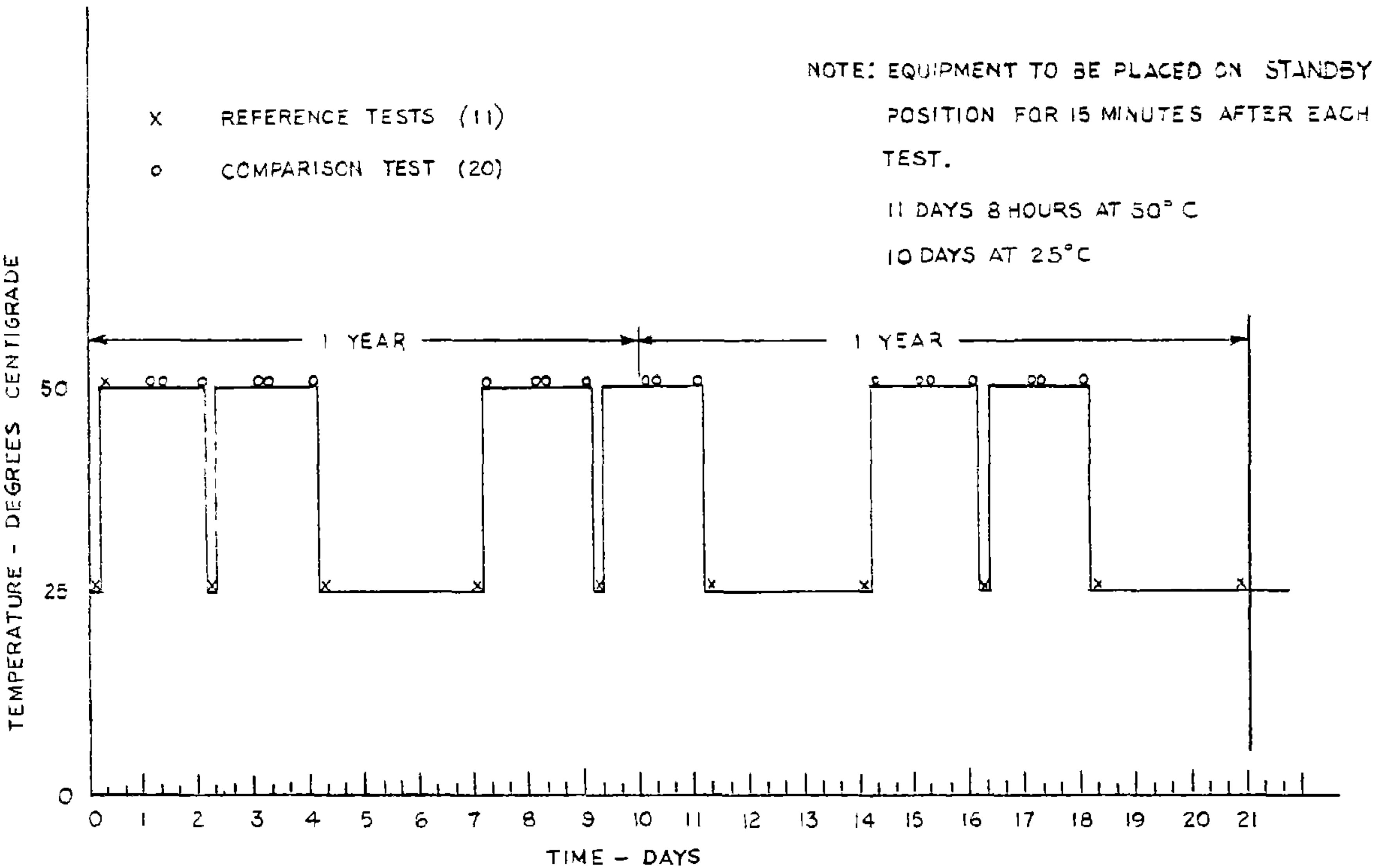


Figure 21 Environmental Chamber Test Cycling

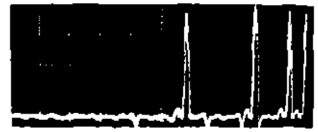
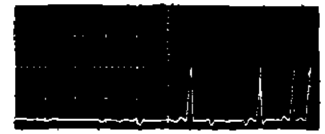
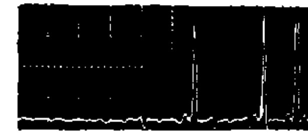
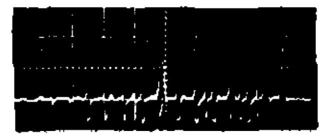
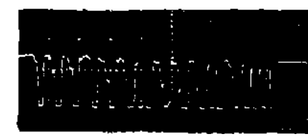
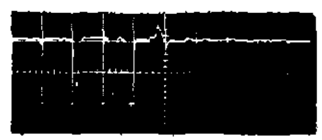
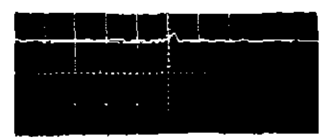
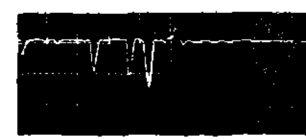
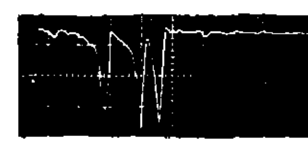
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts 2.0	0.5	1.0
8.	Output of line driver, V-107 and input to decoding lines	ON	10.0	5.0			
9.	All A/C coincidence bus, subchassis 124, plate of diodes CR-127 and CR-129	ON ALL A/C-ON CODE-50	1.0	5.0			
14.	Output of All A/C killer cathode follower, V-124B, pin 8	ON ALL A/C-ON	5.0	5.0			
17.	C/S coincidence bus, TB-107, plates of diodes CR-117 and CR-118	ON C/S-ON	5.0	5.0			
20.	Output of C/S killer amplifier, V-129A, plate pin	ON C/S-ON CODE-50	5.0	5.0			

Figure 22. Reference Waveforms, Before Environmental Life Test

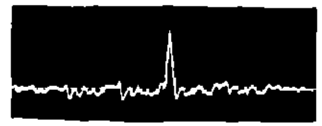
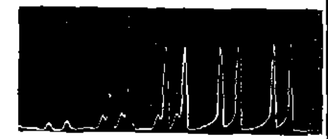
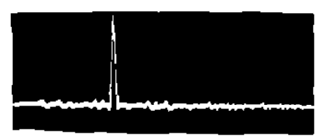
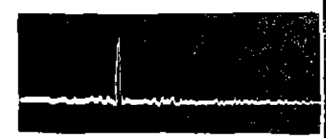
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts 2.0	0.5	1.0
21.	Select A/C coincidence bus at plate of diode CR-119 or J-123-1	ON SELECT A/C-ON CODE-55	2.0	5.0			
22.	Select A/C killer bus, subchassis 123, plate of diodes CR-151 and CR-154	ON SELECT A/C-ON CODE-55	5.0	5.0			
26	Output of Select A/C killer cathode follower, V-112B, pin 8	ON SELECT A/C-ON CODE-55	2.0	5.0			
34-1.	Select A/C second pulse output at J-123-24	ON SELECT A/C-ON CODE-50 RANGE- 60 miles	1.0	5.0			
34-2.	Same as 34-1.	ON SELECT A/C-ON CODE-50 RANGE- 200 miles	1.0	5.0			

Figure 23 Reference Waveforms, Before Environmental Life Test

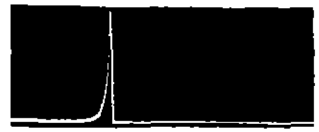
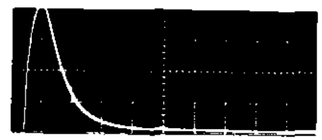
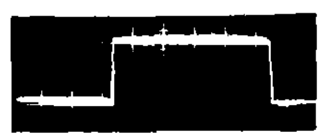
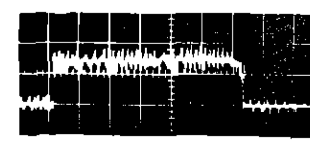
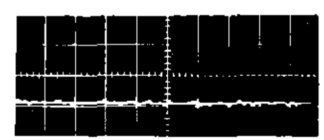
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts 2.0	0.5	1.0
45.	Output of cathode follower, V-117A, pin 3	ON IDENT A/C- ON CODE-50	10.0	2.0			
48-1.	Output at plate of timing amplifier, V-120, pin 6	ON IDENT A/C- ON CODE-50 RANGE- 6 miles I/P	20.0	2.0			
49.	Output of dunking pulse generator, V-122, pin 1	ON IDENT A/C- ON RANGE- 60 miles	10.0	5.0			
51.	Ident A/C decoded output at J-122-24	ON IDENT A/C- ON CODE-50 RANGE- 200 miles	2.0	10.0			
53.	Output of beacon cathode follower, V-110A, pin 3	ON ALL A/C- ON CODE-50	0.5	2.0			

Figure 24 Reference Waveforms, Before Environmental Life Test

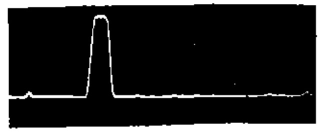
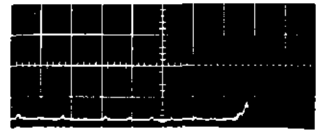
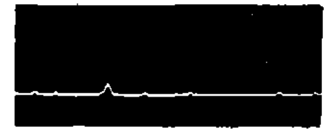
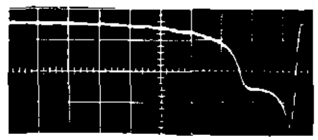
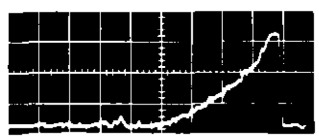
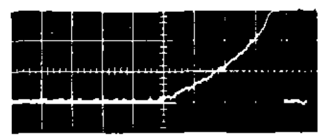
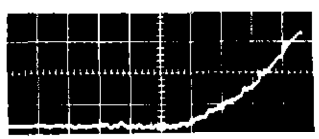
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts		
59-1.	Output of video output cathode follower, V-109, pins 3 and 6 or J-122-8	ON ALL A/C-ON CODE-50 BEACON ONLY	0.5	2.0	2.0 	0.5 	1.0 
60.	Input to grid of trigger amplifier, V-125A, pin 2	ON	2.0	1.0			
62.	Plate output of multivibrator, V-125A, pin 6	ON GATE DELAY-Minimum	10.0	2.0			
65-1.	Input to grid of timing amplifier, V-101, pin 1	ON GATE DELAY-Minimum RANGE- 30 miles	2.0	5.0			
65-2.	Same as 65-1	ON GATE DELAY-Minimum RANGE- 200 miles	2.0	5.0			

Figure 25. Reference Waveforms, Before Environmental Life Test

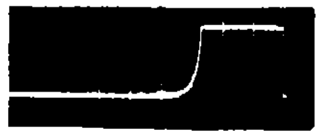
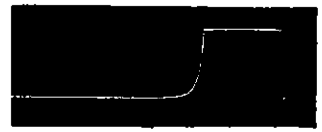
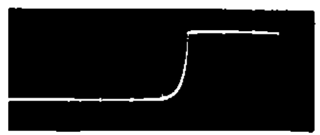
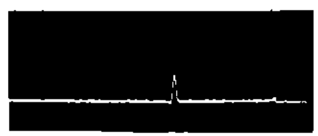
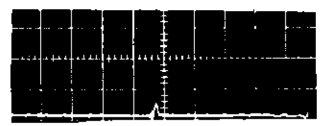
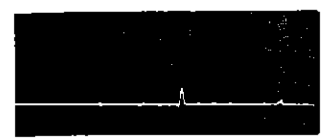
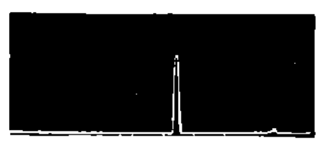
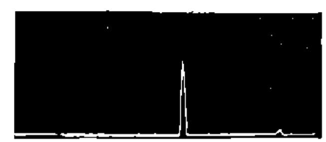
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
68.	Input to gate generator cathode follower, V-104B, pin 7	ON GATE DURATION - Minimum	10.0	50.0			
70-1.	Input to plate of gating diode, CR-106	ON GATE DURATION - Minimum RANGE- 30 miles	1.0	50.0			
70-2.	Same as 70-1	ON GATE DURATION - Minimum RANGE- 200 miles	0.5	50.0			
71-1.	Output of gated output cathode follower, V-104A, pin 3	ON GATE DURATION Minimum RANGE- 30 miles	0.5	5.0			
72-1.	All A/C decoded video output at J-115	ON ALL A/C- ON CODE-50 RANGE- 10 miles	1.0	5.0			

Figure 26 Reference Waveforms, Before Environmental Life Test

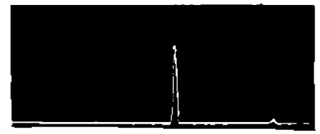
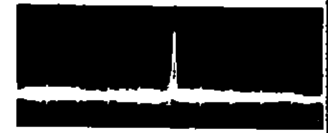
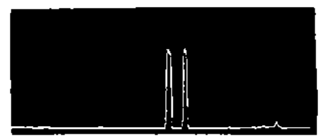
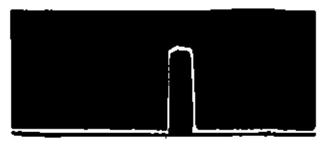
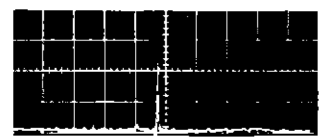
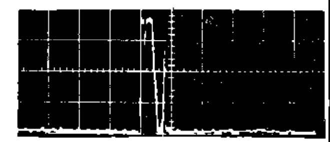
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
72-2.	C/S decoded video output at J-115	ON C/S-ON CODE-50 RANGE- 10 miles	0.5	5.0			
72-3.	Select A/C decoded video output at J-115	ON SELECT A/C-ON CODE-50 RANGE- 10 miles	0.5	5.0			
72-4.	Ident A/C decoded video output at J-115	ON IDENT A/C-ON CODE-50 RANGE- 10 miles	0.5	5.0			

Figure 27 Reference Waveforms, Before Environmental Life Test

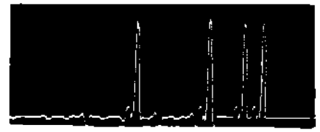
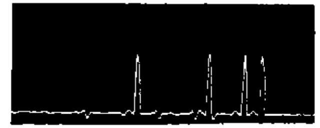
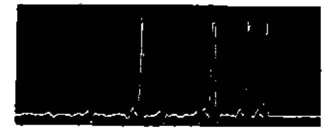
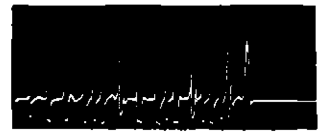
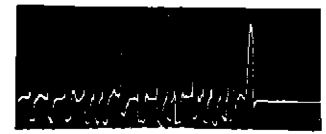
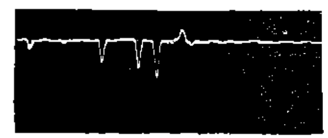
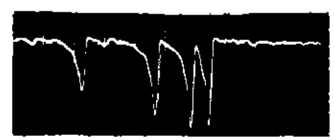
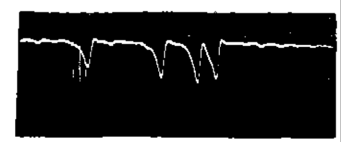
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
8.	Output of line V-107 and input to decoding lines	ON	10.0	5.0			
9.	All A/C co-incidence bus, subchassis 124, plate of diodes CR-127 and CR-129	ON ALL A/C-ON CODE-50	1.0	5.0			
14.	Output of All A/C killer cathode follower, V-124B, pin 8	ON ALL A/C-ON CODE-50	5.0	5.0			
17.	C/S coincidence bus, TB-107, plates of diodes CR-117 and CR-118	ON C/S-ON CODE-50	5.0	5.0			
20.	Output of C/S killer amplifier, V-129A, plate pin	ON C/S-ON CODE-50	5.0	5.0			

Figure 28. Reference Waveforms, After Environmental Life Test

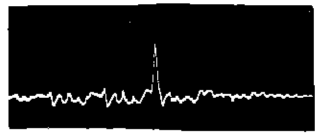
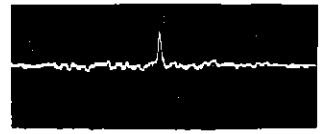
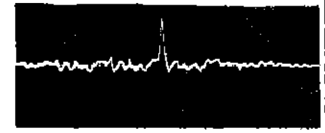
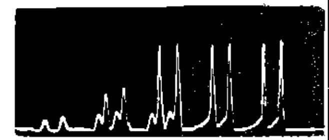
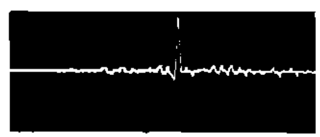
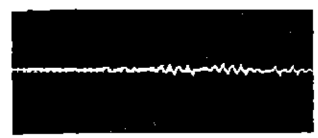
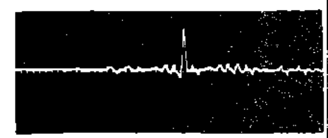
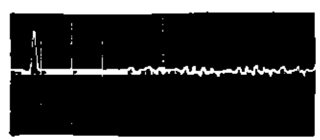
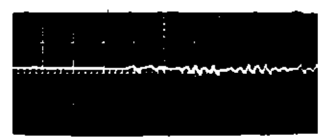
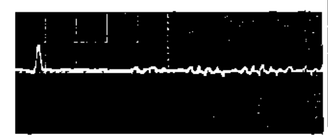
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
21.	Select A/C coincidence bus at plate of diode CR-119 or J-123-1	ON SELECT A/C-ON CODE-55	2.0	5.0			
22.	Select A/C killer bus, subchassis 123, plates of diodes CR-151 and CR-154	ON SELECT A/C-ON CODE-55	5.0	5.0			
26.	Output of Select A/C killer cathode follower, pin 8	ON SELECT A/C-ON CODE-55	2.0	5.0			
34-1.	Select A/C second pulse output at J-123-24	ON SELECT A/C-ON CODE-50 RANGE- 60 miles	2.0	5.0			
34-2.	Same as 34-1.	ON SELECT A/C-ON CODE-50 RANGE- 200 miles	2.0	5.0			

Figure 29. Reference Waveforms, After Environmental Life Test

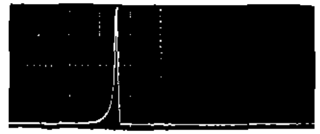
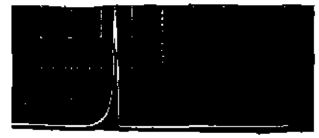
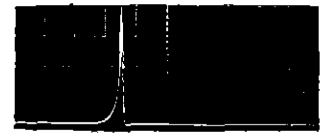
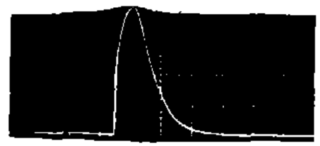
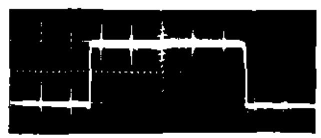
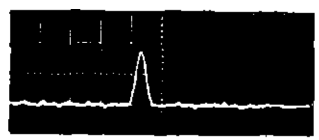
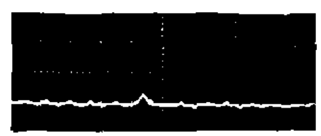
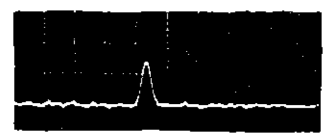
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
45.	Output of cathode follower, V-117A, pin 3	ON IDENT A/C-ON CODE-50	10.0	2.0			
48-1.	Output at plate of timing amplifier, V-120, pin 6	ON IDENT A/C-ON CODE-50 RANGE- 6 miles I/P	20.0	2.0			
49.	Output of dunking pulse generator, V-122, pin 1	ON IDENT A/C-ON CODE-50 RANGE- 0 miles	10.0	5.0			
51.	Ident A/C decoded output at J-122-24	ON IDENT A/C-ON CODE-50 RANGE- 200 miles	2.0	10.0			
53.	Output of beacon cathode follower, V-110A, pin 3	ON ALL A/C-ON CODE-50	0.5	2.0			

Figure 30. Reference Waveforms, After Environmental Life Test

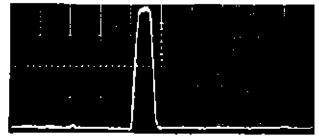
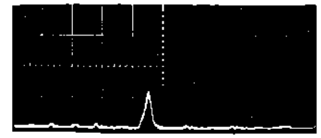
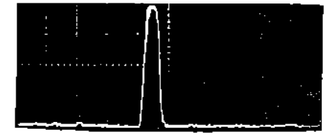
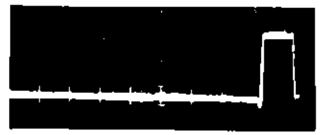
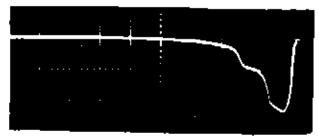
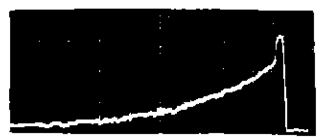
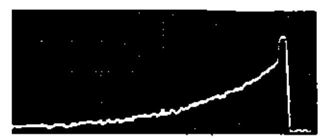
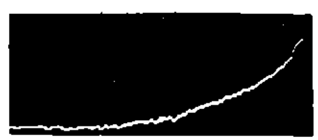
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts		
59-1.	Output of video output cathode follower, V-109, pins 3 and 6 or J-122-8	ON ALL A/C-ON CODE-50 BEACON ONLY	0.5	2.0	2.0 	0.5 	1.0 
60.	Input to grid of trigger amplifier, V-125A, pin 2	ON GATE DELAY- Minimum	2.0	1.0			
62.	Plate output of multivibrator, V-125A, pin 6	ON GATE DELAY- Minimum	20.0	2.0			
65-1.	Input to grid of timing amplifier, V-101, pin 1	ON GATE DELAY- Minimum RANGE- 30 miles	2.0	5.0			
65-2.	Same as 65-1	ON GATE DELAY- Minimum RANGE- 200 miles	2.0	5.0			

Figure 31. Reference Waveforms, After Environmental Life Test

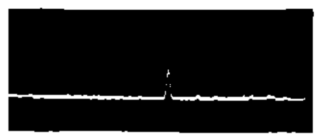
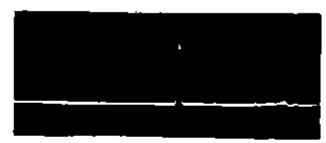
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	Oscilloscope us/div.	Waveform Video Input Volts 2.0	0.5	1.0
68.	Input to gate generator cathode follower, V-104B, pin 7	ON GATE DURATION - Minimum	10.0	50.0			
70-1.	Input to plate of gating diode, CR-106	ON GATE DURATION - Minimum RANGE- 30 miles	1.0	50.0			
70-2.	Same as 70-1	ON GATE DURATION - Minimum RANGE- 200 miles	0.5	50.0			
71-1.	Output of gated output cathode follower, V-104A, pin 3	ON GATE DURATION Minimum RANGE- 30 miles	0.5	5.0			
72-1.	All A/C decoded video output at J-115	ON ALL A/C-ON CODE-50 RANGE- 10 miles	1.0	5.0			

Figure 32. Reference Waveforms, After Environmental Life Test

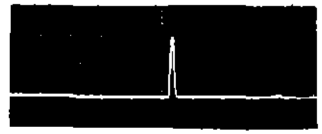
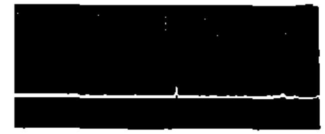
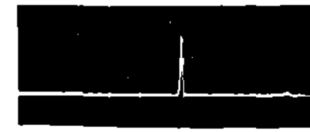
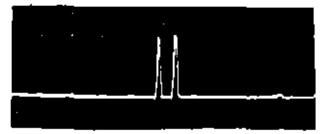
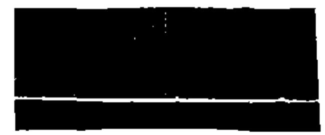
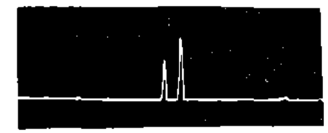
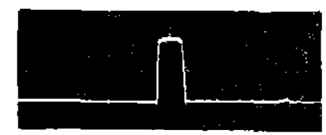
Test Point	Description	VIE Circuit Conditions	Oscilloscope V/div.	us/div.	Waveform Video Input Volts		
					2.0	0.5	1.0
72-2.	C/S decoded video output at J-115	ON C/S-ON CODE-50 RANGE- 10 miles	0.5	5.0			
72-3.	Select A/C decoded video output at J-115	ON SELECT A/C-ON CODE-50 RANGE- 10 miles	0.5	5.0			
72-4.	Ident A/C decoded video output at J-115	ON IDENT A/C-ON CODE-50 RANGE- 10 miles	0.5	5.0			

Figure 33. Reference Waveforms, After Environmental Life Test

WITH REGULAR SHIELD

TUBE	SHIELD TEMP	TUBE TEMP
V101	72	80
V107	105	155
V125	68	80
V126	68	92

WITH HEAT DISSIPATING SHIELD

TUBE	SHIELD TEMP	TUBE TEMP
V101	75	80
V107	99	116
V125	68	68
V126	68	74

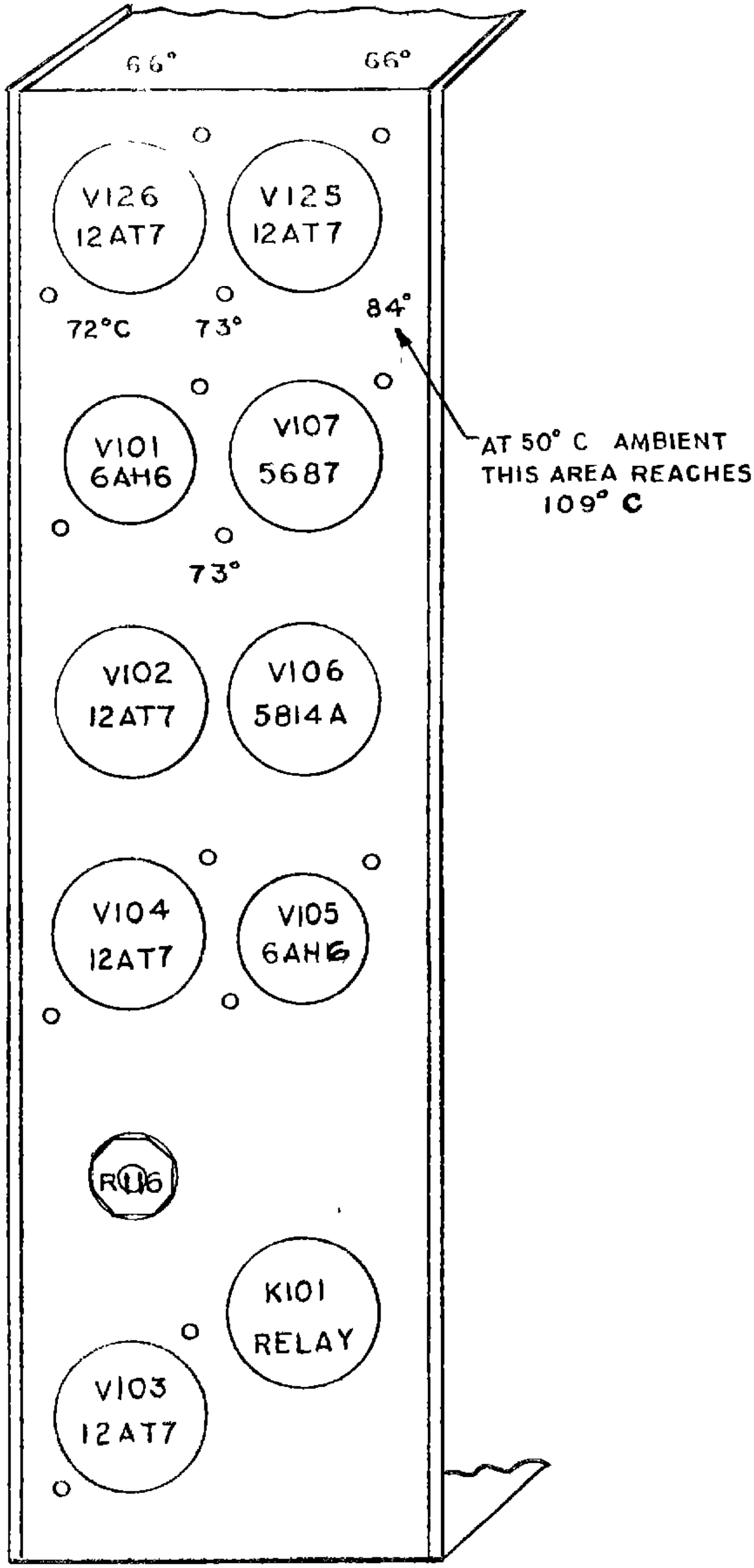


Figure 34. Enabling Gate and Line Driver Sub-Chassis, Operating Temperatures

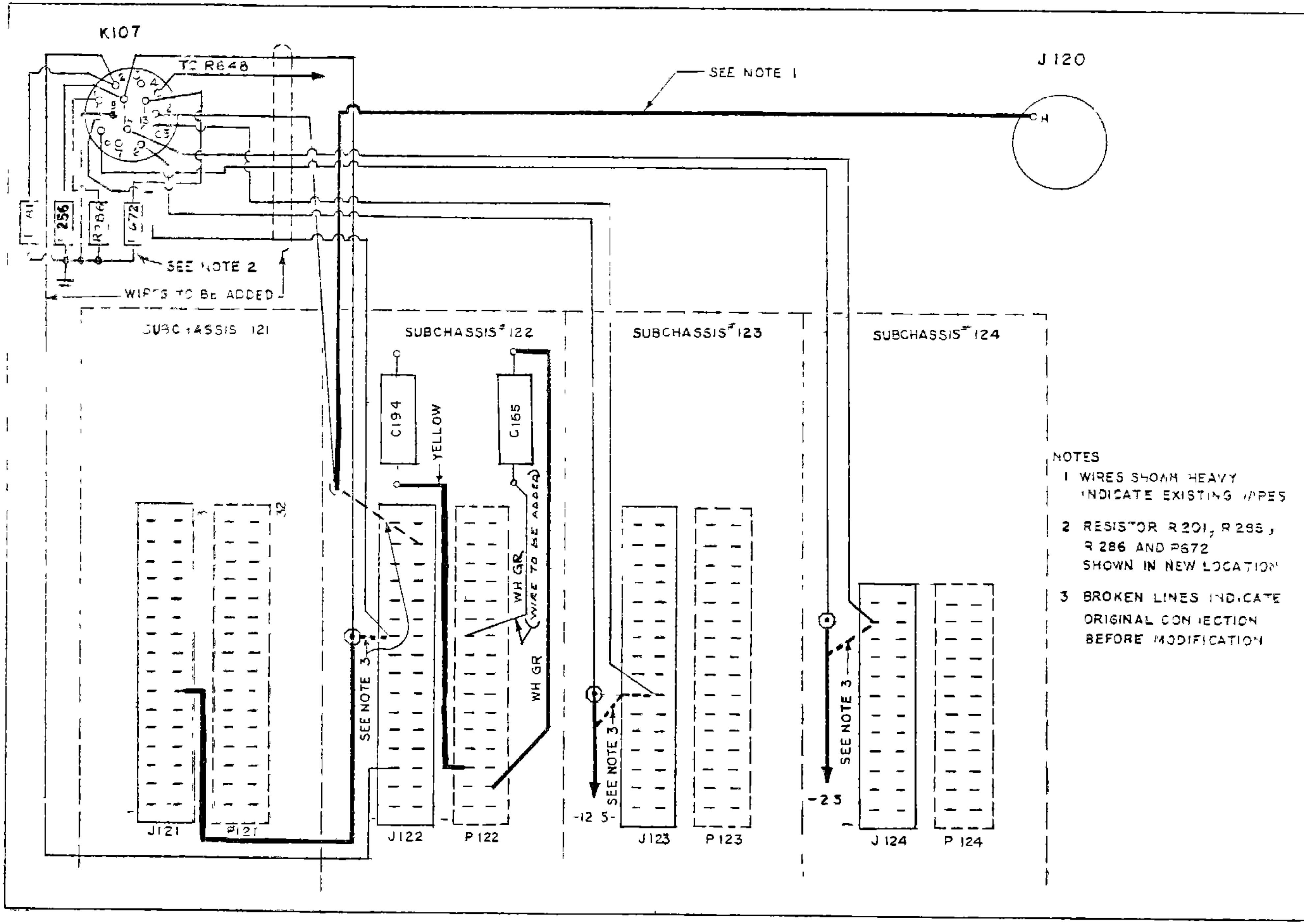


Figure 35 Raw Video Channel Modification, Wiring Diagram

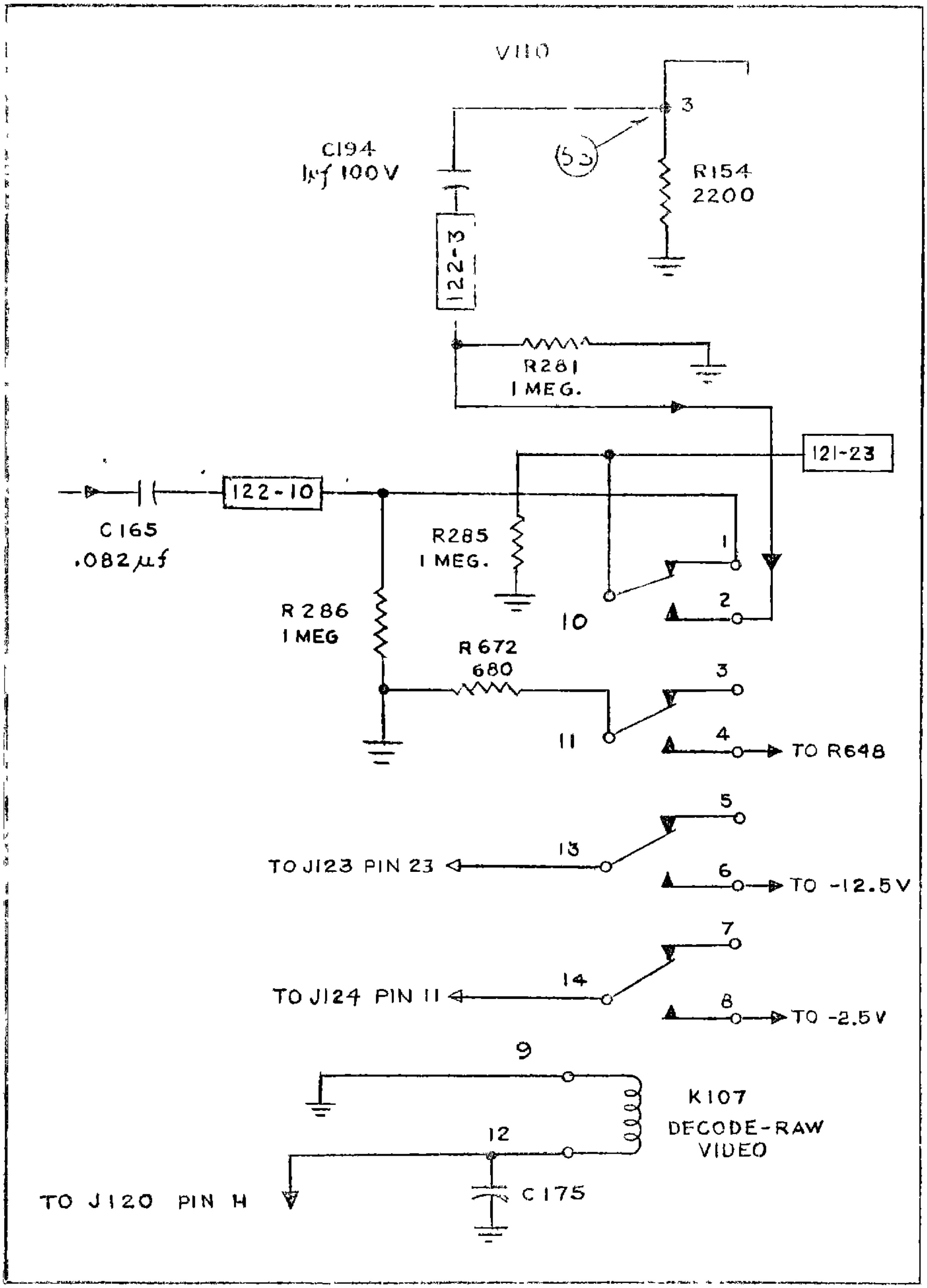
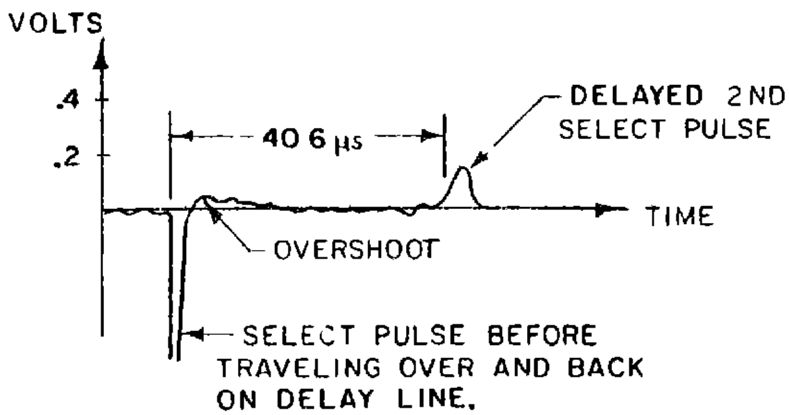


Figure 36 DECODE RAW VIDEO Relay K107 Circuit, Schematic

BEFORE MODIFICATION



AFTER MODIFICATION

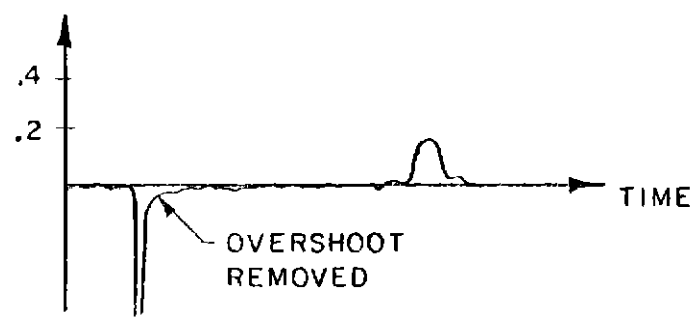


Figure 37. Second Select Pulse Formation, Before and After Modification

/ 0 ELECTROMAGNETIC DELAY LINE STUDY

The assignment of 23 October 1958 requested two tasks to be performed The requirements of the first task were as follows

Task Number One· Make a survey to determine the sources, characteristics, size, and cost of delay lines best suited to delay radar video from four to 20 microseconds A request was made that the delay line characteristics regarding deterioration of resolution and signal-to-noise ratio be at a minimum Tests of the most promising type of line having a delay of approximately 20 microseconds were to be made to determine the following

(a) Bandwidth

(b) Attenuation

(c) Effect on pulse shape and resolution

(d) Effect on signal-to-noise ratio (peak signal to average peak noise ratio of 4 . 1)

(e) Need for base-line clipping to remove spurious delay line responses and consequent effect on signal-to-noise ratio

In the survey to determine the source, characteristics, size, and cost of delay line best suited to delay radar video from four to 20 u sec, an electromagnetic delay line study was chosen and the following steps were taken

1 Some characteristics of the joint-use military radar equipment and associated video pulse information was obtained from TDC Washington, D C. In addition, typical radar video data was obtained from other sources to assist us in determining the required delay line characteristics

2. Five delay lines of different manufacture, having delays of from four to 20 u sec, were obtained and certain tests were run on these lines

3 Using the data obtained from the delay line tests, and considering the radar video delay requirements, the optimum delay line characteristics were formulated. (For typical output pulse waveforms, see Figure 38)

The following is a summary of data for the steps indicated above.

7.1 Step 1, Characteristics of Radar Video

		Radar 1	Radar 2
1	Pulse length	2 u sec	6 u sec
2.	Bandwidth	1 to 2 MC.	250 KC
3.	Impedance	≈50 ohms	≈50 ohms
4.	Repetition rates	350 to 400 pps	350 to 400 pps
5.	Signal to noise ratio	4 to 1	4 to 1
6.	Amplitude	2.5 to 4V	2.5 to 4V

DELAY LINE SOURCES

ECS Corp.
534 Bergen Blvd.,
Palisades Park, New Jersey

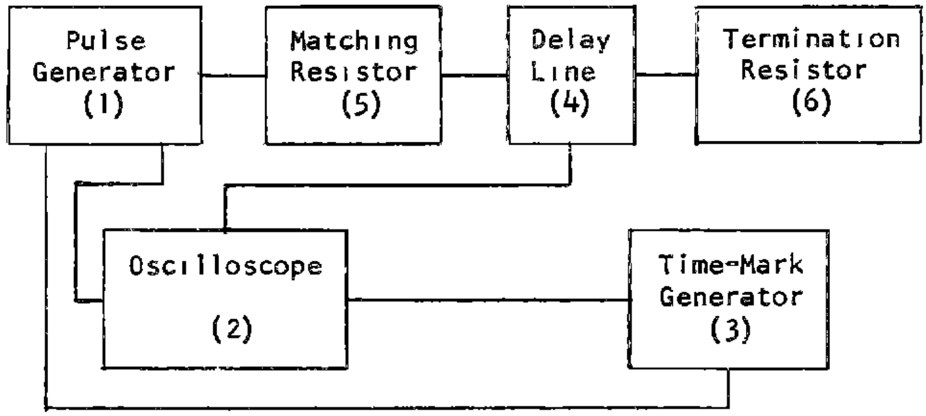
Epsco, Inc.
108 Cummington St ,
Boston 15, Massachusetts

Richard D Brew & Co., Inc.
Airport Rd.,
Concord, New Hampshire

Stewart-Warner Electronics
1300 N. Kostner Ave ,
Chicago 51, Illinois

7.2 Measurement Technique·

(a) Measurement of Rise Time, and Ripple, Output and Undershoot Voltages.



(1) H-P 212A

(2) Tektronix 545, Type 53/54C Plug in, P410 Probe

(3) Tektronix Type 180-52

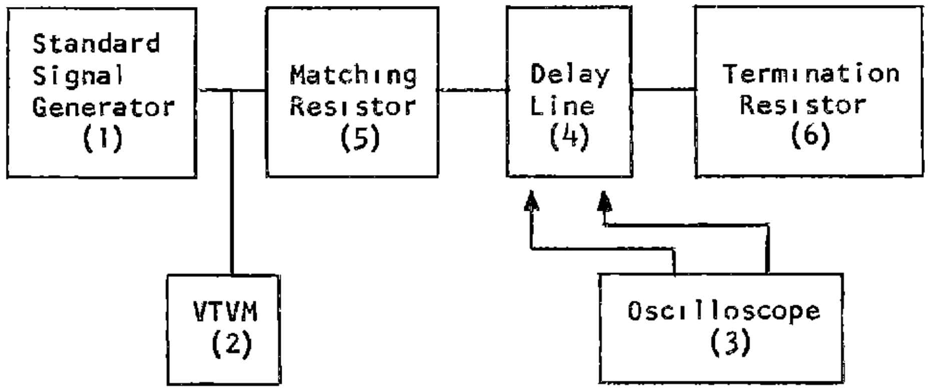
(4) Delay Line	(5) Matching Resistor	(6) Termination Resistor
ESC	1000 ohms	1000 ohms
EPSCO	130 ohms	180 ohms
BREW	130 ohms	180 ohms
SW G-577951	150 ohms	200 ohms
SW G-577955	120 ohms	168 ohms
SW G-577959	150 ohms	200 ohms

Notes: A. All connecting cables are type RG-58 A/U

B. Pulse Length: 1 u sec

C All measurements taken "one way "

(b) Measurement of Bandwidth



(1) Measurements Corp. Model 65-B

(2) HP 410B VTVM

(3) Tektronix 535, Type 53/54K Plug-in, P410 Probe

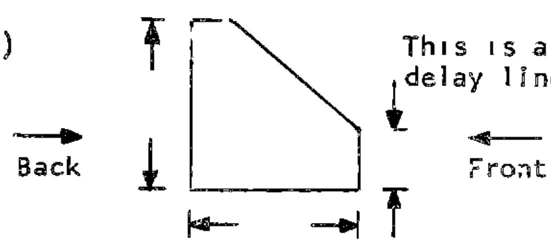
(4) Delay Line	(5) Matching Resistor	(6) Termination Resistor
ESC	1000 ohms	1000 ohms
EPSCO	180 ohms	180 ohms
BREW	180 ohms	180 ohms
SW G-577951	200 ohms	200 ohms
SW G-577955	168 ohms	168 ohms
SW G-577959	200 ohms	200 ohms

Note: All data taken with a 2V RMS input voltage

(c) Physical Characteristics

Delay Line Type	Dimensions (in.)			Weight (lbs.)	Number of Taps Available
	Length	Width	Height		
ESC (Back (1) (Front)	7 3/4 7 3/4	8 1/2 8 1/2	7 1/4 3 1/4	7.75	0-50.1 u sec delay, adjustable in steps of 0.1 u sec.
EPSCO	8	4	2	2.25	24 u sec delay, 14 taps available
BREW	8	4	2	2.0	20.3 u sec delay, 13 taps available
SW G-577951	4 7/16	3 3/4	3 9/16	2.75	21 u sec delay, 17 taps available
SW G-577955	4 7/16	3 3/4	3 9/16	3.0	10 u sec delay, 17 taps available
SW G-577959	3 5/8	4 3/8	1 7/8	1.6	24 u sec delays, 17 taps available

Note. (1)



This is a laboratory use adjustable delay line.

7.3 Step 2, Summary of Electrical Characteristics of Delay Lines

Delay Line Type (1)	Time Delay (5)	Characteristic Impedance	Rise Time (2)	Ripple (3)	Output (3)	Undershoot (3)	Bandwidth 3 db	Bandwidth 6 db	Cost per u sec (4)
	u sec	Ohms	u sec	percent	percent	percent	MC.	MC.	dollars
ESC 250	4	1000	0.50	6	96	6	0.90	1.16	3.80
	20	1000	1.04	6	58	5	0.37	0.52	
EPSCO	4	180	0.50	5	94	7	0.70	1.16	4.00
	20	180	1.02	5	70	15	0.57	0.73	
BREW	4	180	0.35	5	87	5	1.1	1.56	4.00
	20	180	1.10	6	55	5	0.44	0.70	
SW G-577951	4	200	0.22	7	92	1	1.9	2.6	9.00
	20	200	0.38	6	68	1	1.1	1.4	
SW G-577959	4	200	0.36	10	94	2	1.3	1.7	4.50
	20	200	0.52	12	85	2	1.0	1.5	
SW G-577955 (6)	4	170	0.1	8	78	1	3.4	4.7	28.50
	10	170	0.15	4	55	2	2.3	3.0	

Notes:

(1) Lines tested were readily available samples.

(2) Measured with an input pulse width of 4 u sec. (See 7.4 (g).

(3) Values represent a percentage of input pulse amplitude.

(4) Based on the cost for 20 u sec. line.

(5) Time Delay Range:

Nominal	Actual	Range
4 u sec.	4.36 u sec.	±8%
10 u sec.	9.96 u sec.	±3%
20 u sec.	20.92 u sec	±4%

(6) Only a 10 u sec. long line was available.

7.4 Step 3, Optimum Characteristics for Radar Video Delay Lines

Type: Distributed Constant Delay Line

Distributed constant delay lines are not suitable for this application due to their low bandwidth characteristic. In addition, a high percentage of ripple and distortion is usually present in such delay lines, rendering them less satisfactory in maintaining a good signal-to-noise ratio. Therefore, in this study only lumped constant delay lines were tested.

Type. Lumped Constant Delay Line

A lumped constant delay line can be designed to have low ripple, high stability, during temperature variations, high frequency response or fidelity, reasonable size, and attenuation. Furthermore, it is readily tapped, and can be manufactured with considerable uniformity in successive units.

A summary of optimum characteristics for radar video delay lines is as follows:

(a) Characteristic Impedance:

Just as a transmission line has a characteristic impedance determined by its distributed inductance and capacitance, so the delay line has its characteristic impedance. Also, the characteristic impedance of the delay line is determined by inductance and capacitance quantities, except that these may now be "lumps" of capacity and inductance properly related. Since the characteristic impedances are determined by essentially pure reactances, the proper termination of the delay line at both input and output ends must be pure resistance and have the magnitude of the characteristic impedance of the delay line.

An impedance range from 50 to 1000 ohms will provide the best delay line characteristics for this application. The fidelity and physically small size of delay lines above this range is more difficult to obtain. The use of electrical networks, both passive and active. allows impedance matching methods to be used with a particular line. A low impedance line requires more careful matching and formation, but the loading on the taps can be of considerably lower impedance before losses in amplitude are incurred. A high impedance line offers more latitude in matching and termination, but the taps can not be loaded with low impedances or considerable losses in amplitude would occur in successive taps

(b) Bandwidth and Rise Time:

Rise time is usually measured in microseconds, which is the time required for a pulse or signal increase, in amplitude, between its 10% and its 90% amplitude points. Rise time is customarily given for the pulse which appears at the end of a delay line, however it can be determined for any pulse along the delay line or the input pulse into the delay line.

The test data shows the effect on a pulse of delay lines with different bandwidths. The relation between bandwidth and rise time is Bandwidth X Rise Time = 0 35 to 0 45, 0.35 is the value to use for overshoots of 5% or less.

Although a bandwidth of 2 MC would be desirable in the radar video line, the cost of such a line is nearly double that of a 1 MC line However, if rise time requirements dictate a 2 MC or better bandwidth at 20 u sec., such lines could be designed

Increasing the delay from 4 to 20 u sec., or five fold, means a decrease in bandwidth from 40 to 80% of the 4 u sec. value. This decrease is a function of the quality of the delay line sections, with better quality delay lines furnishing the smaller decrease in bandwidth

The time delay is usually measured in microseconds between the 50% amplitude points of the input and output pulse.

(c) Ripple:

If, in the construction of a delay line, the characteristic impedance from section to section, or lump to lump of the delay line is allowed to vary, the points at which these variations occur are known as discontinuities. As a pulse travels down a delay line having these variations, abrupt changes in energy levels must occur in amplitude, which show up as ripple. Loose tolerances, on either or both the capacity or inductance of the elements, often produce high levels of ripple. Shorted turns in the inductors, shorts to ground, and wrong value capacities, are also productive of high ripple peaks.

Ripple should be kept to 10% or less of the input pulse. This means that with 6 db. attenuation of the delay line, a signal-to-noise ratio of five to one can be approached.

Since a delay line does contribute some noise to an incoming signal, it is advisable to clip any existing noise in the signal input, and if necessary, amplify the result before it is used to drive the delay line. Post delay clipping may also be employed if desirable. However, pre-delay clipping and amplification should provide the best results.

The ripple inherent in the delay line may add to, or subtract from, the noise of the incoming signal in a complex fashion. This may result in a somewhat greater overall distortion of the signal. Since noise is a random phenomenon, the combination of incoming noise with the ripple, may result in severe noise peaks or may even provide cancellation. To minimize the effects, pre-delay noise clipping is highly recommended.

(d) Attenuation:

As a pulse or signal progresses down a delay line, some of its energy is lost or dissipated due to resistance encountered, plus losses within the materials with which the delay line is built. When energy is lost in this manner, the pulse amplitude decreases, as the pulse progresses along the delay line. This loss of amplitude is the attenuation of the delay line and is expressed in db with the input pulse being used as a reference.

Attenuation in the delay line should be kept below 6 db. This is necessary, so that with the prescribed amount of ripple, the signal-to-noise ratio can be held to nearly 5 to 1 If pre-delay clipping and amplification is utilized, the actual amplitude of the signal from the delay line can be considerably higher than the original video signal as received.

(e) Stability:

This important delay line characteristic is, its ability to withstand change, even though subjected to considerable variations in temperature. The stability of a delay line is often given as the change in the delay time for finite conditions of temperature and time; for example: 0.00005 parts per microsecond, per degree centigrade, between $-55^{o}C$ and $+85^{o}C$.

The temperature stability required of a delay line depends a great deal on the tapping tolerance and ambient operating temperature. Tapping tolerances enter into the picture since the tolerance must be maintained under operating conditions. The more tightly the tolerance on time delay is held, the greater the temperature stability must be. Typical stability of a delay line is, 0.0005 u sec., per u sec., per degree centigrade. Better stabilities than this can be maintained with high quality lines.

(f) Distortion.

Distortion is a term applied to the pulse shape. It is usually composed of two types of special distortion as follows:

(1) Phase distortion which occurs because high frequencies and low

frequencies do not travel along a delay line at the same rate of speed. Therefore, the low-frequency components of a pulse are not at the proper place along the delay line in combination with the high-frequency components, and whay may have started out as a rectangular pulse, now has distorted leading and trailing edges. Proper design can eliminate or minimize phase distortion to reasonable levels.

(2) Attenuation distortion which occurs because high frequencies and low frequencies do not receive equal attenuation as they progress along the delay line. Therefore, the low-frequency components of a pulse and the high-frequency components, when combined, show a pulse which no longer is rectangular, even though it started out that way. Attenuation distortion usually shows up on the leading and trailing edges of the pulse, which is indicated as the rounded off corners at the top and bottom of what was once a sharp step function. Attenuation distortion is an important reason for poor rise time characteristics.

(g) Pulse Length:

The operation of any delay line is dependent on whether the pulse length at which the delay line is measured, is sufficiently great to produce a full output pulse. Usually a pulse length of at least twice the rise time is required for this. A pulse length three or four times as long would be desirable.

(h) Tolerances:

The delay line, time delay tolerances, must be specified. Present day high quality delay lines maintain tolerances of ±0.05 u sec., depending upon the total time delay. Tolerances tighter than this will increase the cost of the delay lines.

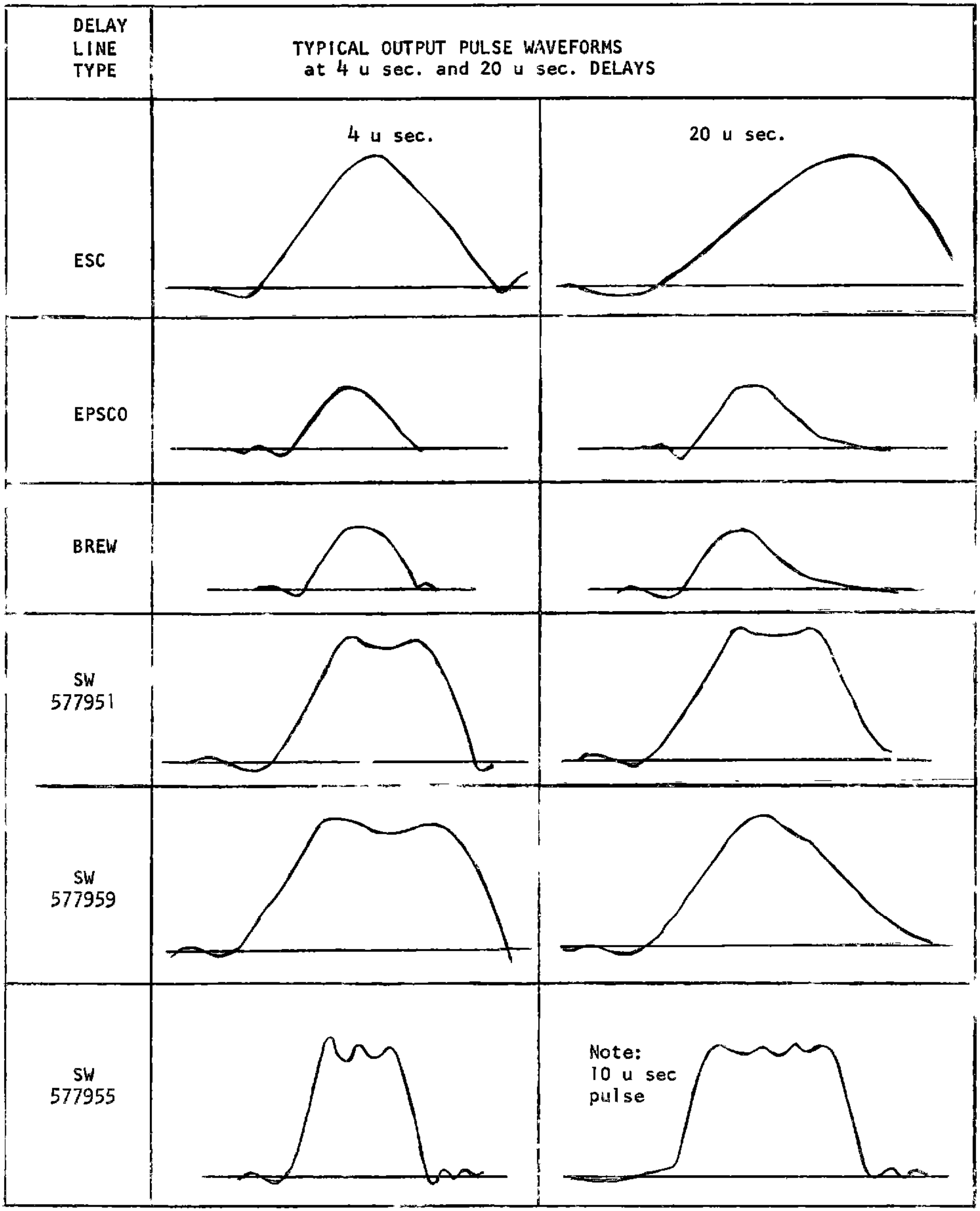


Figure 38 Typical Output Pulse Waveforms

8 0 SCAN CONVERSION DISPLAY DECODER GATING STUDY

Task number two in the assignment of 23 October 1958 requested a written study be made to determine if it was practical to use a co-ordinate conversion system to obtain the active beacon decoder gating function when scan conversion display systems were used For this study, it was assumed that the position of the gate would be indicated on the television type displays and that the gate would not be written on the storage tube target. Also, it was assumed that the horizontal and vertical linearity of the television display is one percent. The objective of the study was to determine the following:

(a) Approximate number of tubes required and number of critical circuits which may require frequent adjustment.

(b) Minimum size of gate required, as displayed on a 22-inch television monitor, to insure gating of beacon replies, which are associated with the selected target, into the beacon decoder.

(c) Other approaches to the problem which would be less complex, or have a greater accuracy, stability, etc.

A system to coordinate Active Readout Gating from a scan conversion display was under study. In this system, a joy stick positions a spot on a target on the TV presentation, and the spot appears on each frame. As the radar sweep approaches the target, the system will gate the decoder for an adjustable length of time The following is a description of the two sweep presentations, and how the system coordinates them to read the desired target.

8.1 Radar PPI Display

For any given repetition rate, the sweep speed of the radar display will be determined by the range setting. The time lapse between the emission of a pulse from the transmitter and the receipt of the corresponding echo is 12 366 u sec for a distance of one nautical mile (6,080 yards). The maximum pulse rate frequency is governed by the range desired

For pulses and echoes not to overlap on the 200 mile range, (maximum that was to be used), the spacing between pulses would have to be greater than 200 X 12.366 = 2470 u sec. Allowing for re-trace and recovery time, this would indicate a maximum PRF of about 400. This would give 2500 u sec. for a complete sweep cycle The pulse length of the sweep for the 200 mile range is 2470 u sec. In the same manner, the sweep length for the shortest range of six miles would be 6 X 12.366 = 74.2 u sec. About 11 u sec are needed for re-trace time, and the time between pulses (to a minimum of 11 u sec.) would be determined by the PRF setting.

There are two common methods of obtaining a radial presentation of the radar sweep on a PPI display. The first is to rotate the deflection yoke in synchronism with the radar antenna. It is this method that is used in the INTEC MODEL TI-440 scan converter equipment. As the yoke is rotated, the sweep is rotated, and a radial presentation is obtained. The second method uses stationary x and y axis deflection plates or coils, with the amplitude of the sweep varied as a sine and cosine function (see Figure 39).

With these deflection voltages, a circular sweep can be obtained from stationary deflection coils. In Figure 39 the time duration of the sweep voltage with respect to antenna rpm has been exaggerated. The sine wave frequency corresponds to the speed of antenna rotation, and may be from 5 to 30 rpm.

The latter type of sweep voltages must be made available for the proposed active readout system. As there are several methods, both electrical and mechanical, of obtaining the sine and cosine sweeps, Stewart-Warner will investigate which type will be most suitable to install in existing FAA equipment.

8 2 Scan TV Display

In the scan conversion or TV type presentation, the horizontal and vertical sweep speeds remain constant regardless of range setting In the system under consideration, 30 frames per second are presented, each made up of 625 lines. The horizontal repetition rate is then 18,750 sweeps per second. A complete horizontal scanning cycle will then occur in $\frac{1}{18,750}$ seconds, or 53.4 u sec. Of this time, approximately 11 u sec. is needed for the retrace

At the same time there are only 60 vertical sweeps per second. About 20 X 53 4 = 1068 u sec. are needed for each vertical retrace, and the vertical scanning cycle will be $\frac{1}{60}$ = 16.66 m sec.

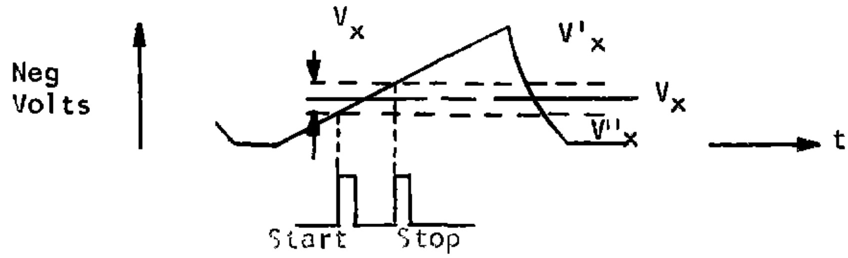
The different sweep times to be encountered then are as follows:

TV		RADAR		
HORIZ.	VERT.	RANGE MAX	RANGE MIN.	PRF MAX
42.4 u sec.	16.7 m sec.	2470 u sec.	74.2 u sec	11K to 400

The maximum PRF for the six mile range will be limited by the duty cycle of the transmitter A nominal PRF would be 1200, which is the repetition rate used at the Midway tower site.

The Active Readout Gating from the scan conversion display will have to translate between the two sweep systems. This may be accomplished in the following manner (see Figure 40).

A joy stick will control four reference voltages, V_{RX}, V_{RY}, K_1V_{RX}, and K_2V_{RY} in the x-y plane. One pair, V_{RX} and V_{RY} will be used to reference four multiars into which are fed the TV sweep voltages The remaining pair, K_1V_{RX} and K_2V_{RY}, are used to reference the four multiars into which are fed the sine and cosine modulated radar sweep voltages The multiars provide start and stop pulses at some voltage levels during each sweep. The center level is determined by a voltage differential around the reference voltages (see illustration below).



Consider the X (horizontal) sweep of the TV system A negative output pulse will result from a multiar as levels V'_x and V''_x are reached by the sweep These pulses are put through an "OR" type circuit and then used to turn a bistable multivibrator on and off. This will happen each time the proper X coordinate (or sweep level) is reached An identical setup is used for the Y (vertical) sweep of the TV. When the two bistable multis are turned on at the same time, an "AND" circuit provides an output pulse to brighten the trace and spot the target In this manner, the target will be spotted on each frame of the TV presentation The size of the spot (time duration) is governed by a setting of V_x and V_y

A similar system using the reference voltages from the joystick K_1V_x and K_2V_y is applied to the radar sweep Assuming that the deflection characteristics of the Radar and TV kinescopes are linear, and K_1 and K_2 are constants, an output gate will result from the radar PPI portion coincident circuits at the proper time. This gate occurs as the radar trace crosses the spotted target and is used to open the decoder It should be noted that even though the radar sweeps are sinusoidally modulated, the circuit behavior is identical with that of the constant unmodulated TV sweep.

A suitable multiar and some associated circuitry has been constructed and some preliminary tests were made. The circuit design will accept sweep durations as short as 10 u sec., and provides an output pulse of 0.4 u sec. rise time and 1 u sec. duration.

8.3 Description, Problems, and Characteristics of Proposed System

The following paragraphs contain a description, and characteristics of the proposed system. Also, the problems likely to be encountered should further design work be desired.

A basic multiar circuit was completed, and initial tests on it were performed. The tests and design work led to the circuit configuration shown in Figure 41. This circuit could serve as the basic module for the block diagram in Figure 40, since it is repeated six times. Minor changes in circuit values would make this circuit suitable for each sweep application.

Some indication of the complexity of the circuit and number of components can be realized by multiplying each component of the basic multiar module (Figure 41) by six. Considering this and the remaining circuits, the following estimate of necessary tubes and diodes can be made:

NO.	TYPE	WHERE USED
6	12AT7	Cathode follower in module
12	6AU6	Multiar
6	6AL5	Multiar
16	2C51	Bistable Gate and Multi
86	Diodes	"OR", "AND", Bistable Multi, Module

These are considered minimum figures, and do not include the Power Supply, Joy Stick, Gate Size Control, and Comparator components.

8.3.1 Multiple Displays

Each TV display would have its own joy stick (spot position control) which was compensated for, non-linearities of that set. A spot positioned over a particular target by one TV set and its associated joy stick may not appear exactly over the plane on another set. This is caused by the non-linearities in each set, which are compensated for, by its particular joy stick.

It would be desirable to have the spot appear only on the set whose joy stick is interrogating at that time. The other joy sticks would be disabled, with a panel lamp lit to signify that the active readout was in use

With this arrangement any non-linearities of the scan display units could be adequately compensated. There was no study effort directed at a time shared system,where more than one joy stick could be used at the same time. However, it was generally felt that such a system could be possible, should it be found necessary to operate more than one readout position simultaneously.

8.3.2 Gating Accuracy

There were three factors which would effect the accuracy of the gating with this system. These were, thermal stability, rise time and width, and jitter of the output pulse from the multiar and associated circuitry.

Time did not permit thermal stability tests to be performed on the breadboard circuitry. It was noted that the greatest amount of thermal drift arose from the thermionic diode in the multiar. By using dual diodes in the same envelope for two different multiars, the associated multiars could be made to drift together. For example, each multiar of the TV sweep system would be made to drift with the multiars of the radar sweep system. For the system pictured in Figure 40, a dual diode would be located with each multiar of the radar portion.

The unused half of each positive and negative multiar set would be paralleled, and used as the diode for its corresponding multiar in the TV portion. Even though there might be thermal drift in the circuitry, a one-to-one correspondence could still be maintained between the TV and radar portions of the Active Readout Gating System By keeping thermal drift at a minimum, the TV and radar system would be kept still closer in their correspondence. This might be accomplished by careful regulation of all filament and d-c power supplies.

The amount of jitter, that a multiar would present, is a function of the slope of the sweep input voltage. Measurements were made on a multiar breadboard using the circuit of Figure 41, and resulted in the following representative data of Table VIII

Table VIII. Multiar Output Pulse

Sweep Input			Multiar Output			
Length u sec.	Amp. Volts	Slope Volts/u sec.	Amp. Volts	Jitter u sec.	Millivolts of Sweep per jitter	Rise time u sec.
40	33	0.83	3.8	0.03	25	0.6
1200	40	0.033	3 8	1	33	0.6
2500	27	0.018	3.6	3	54	0.7
10,000	24	0.0024	3.4	20	48	0.8
17,000	22	0 003	3 5	80	108	0 9

The millivolts per jitter column represents the voltage differential for a particular sweep slope around which the multiar is unstable and jitter occurs.

The longest sweep to be encountered in this equipment would be the 17 millisecond vertical sweep of the TV presentation. From rise time and jitter considerations, if we chose a minimum allowable sweep slope to be 0.03 volts per microsecond, then the amplitude of the vertical sweep voltage as applied to the multiar should be at least 500 volts This magnitude of sweep voltage is readily available in the vertical sweep circuitry of the scan converter displays. This would provide an output pulse from the multiar with a rise time of 0.6 u sec. and a jitter of 1 0 u sec., which is a jitter of less than 0.006 percent of the sweep length. Actually, this condition would not be realized as there would be some jitter in the sweep system.

The shortest sweep time of 42 microseconds, was the horizontal sweep in the TV presentation. If the allowable jitter determines the sweep slope, a horizontal sweep voltage of 80 volts amplitude would give a slope of 1.9 volts/u sec. This would suffice to keep the jitter to less than 0.03 u sec , or less than 0.07 percent of the sweep length.

A more important problem at this short sweep duration was the rise time and width of the output pulse from the multiar. The multiar constructed was found to have for its output pulse, a rise time of 0.6 u sec. and a pulse width of 0 8 u sec. This would indicate that the minimum time, between on and off pulses from the horizontal TV sweep (X_{TV} sweep), would be at least 0.8 u sec. for this circuit design. This amounts to 1.9 percent of the horizontal sweep. In considering a 21" viewer (15 inches high by 17 inches wide), the radar presentation on the TV screen would have a maximum radius of 7-1/2 inches. The minimum horizontal size (width) of the spot would be 0.019 X 17 = 0.323 inches for this size screen. This amounts to $\frac{0.323}{7.5}$ X 100 = 4.3% of the radar radius. This spot would remain the same size, regardless of range setting for the radar On the longer ranges, the spot may prove too large, in width, to position over an individual plane in a close group. For example, on the 200 mile range, 0.323 inches represents 8.6 miles. The spot height may be made as small as desired, due to the longer vertical sweep time of 17 u sec.

Another source of gating error may be the Bistable Multi preceeding the "AND" circuits No development work was performed on a high speed bistable multi. With proper design, the introduced rise time could be kept to 0 2 u sec giving the gate a total rise time of 0 8 u sec Some gate widening may also result from the Bistable Multi.

The radar sweep voltage timing, ranges from 74 u sec for the shortest range of six miles, to 2470 u sec for the longest range of 200 miles A different problem arose with the radar sweep, as the sweep voltage slope was continuously changing

The PPI presentation X and Y deflection voltages are represented in Figure 39, as they would have to be furnished for the o eration of this active readout system The sine wave frequency corresponds to the speed of antenna rotation, and may be from 5 to 30 rpm. The sweep duration is shown here much longer than actual, with respect to antenna rpm.

The sweep voltage slope, since it is sine and cosine modulated, would then vary from some maximum down to zero This would occur to both the X and Y axis, sweep voltages Regardless of the sweep slope at maximum amplitude, this slope would decrease to zero 90^{o} later. This decrease in slope may result in some gate jitter in radial direction when reference voltages are set near the axis This would correspond to placing the spot in the direction near due North, South, East and West A radial jitter will occur, since only one sweep is at minimum, while the other is at maximum (see Figure 42).

For the longest sweep (the extreme case) of 2,470 u sec occurring on the 200 mile range, an average resolution might be 1 percent, or two miles This would correspond to 25 u sec as a desirable size for the gate This is long enough to accept the pulse train. A pulse jitter of one tenth this amount or less would be necessary for accurate gating From Table VIII this would indicate a minimum sweep slope of 0.02 volts/u sec If 500 volts were chosen as a maximum amplitude of sweep voltage for a sweep time of 2,470 u sec , then there would be excessive radial jitter in the regions where the amplitude fell to less than 0.02 X 2,470 = 49.4 Volts. This would occur when sine θ or Cos θ = $\frac{49.4}{500}$ The region then where gate jitter occurred was ±5.7° around each axis for the 200 mile range

Although the sweep duration decreases proportionally with decreasing range, it is necessary to maintain a gate size of 25 u sec , in order to admit the complete pulse train to the decoder The pulse train length remains constant at 20.3 u sec plus, at intervals, a caboose pulse spaced 4 35 u sec from the bracket pulse.

For the 100 mile range, the same minimum sweep slope of 0.02 volts/u sec would be desired. The sweep time is 1,235 u sec , and the minimum sweep amplitude for less than 2 5 u sec jitter is 0.02 X 1,235 = 24.7 volts. Jitter is excessive for the 100 mile range in the regions where sine θ and Cos θ $\leq \frac{24.7}{500}$, which is ±2 8° about each axis. Table IX tabulates the jitter regions for various ranges

Table IX . Jitter Regions For Various Mile Ranges

Range Miles	Sweep Ts u sec	Min. Amp. 0.02 X Ts Volts	A min 500	Jitter θ° Region	Percent Viewing Area
6	74.2	1.48	0 003	0 017	0 038
10	123 7	2.47	0.005	0.025	0 055
20	247.0	4.94	0 01	0.57	1.27
30	371.0	7 42	0.015	0.86	1 9
60	742.0	14 8	0.03	1 72	3 82
100	1,235.0	24.7	0.0493	2.83	6.28
200	2,470 0	49 4	0.0988	5.67	12.6

A plot of these regions for the 200 and 100 mile ranges is represented in Figure 42 As the sweep time was shortened for shorter ranges, the jitter region becomes smaller, since the maximum amplitude is constant Active readout is still maintained in these regions, but the area of interrogation is expanded by the amount of jitter It may be necessary to widen the gate to approximately 30 u sec., to insure that the entire train is admitted to the decoder in these regions.

Since this was in effect an analog system, there would always be some error between the position of the spot on the TV presentation, and the actual area of interrogation in the radar system The gate size may have to be expanded to compensate for this tolerance By feeding the decoder gate back into the Radar Video, (push to test calibration on Figure 40), the operator can have a quick check on the system This is done by noting whether the spot (gate) as it appears on the Radar "picture" once each sweep, falls directly over the spot controlled by the joy stick Any slight drift may be compensated by an operator's "touch up" control two or three times per day

8 4 Explanation Of System (Figure 40)

The joy stick provides four d-c voltages, V_{RX}, V_{RY}, KV_{RX}, and KV_{RY}, which are used as reference voltages for the multiars These voltage magnitudes vary in direct proportion to the X and Y position of the joy stick control K is some constant depending upon the deflection voltage relationship between the TV viewer and the writing (Radar) portion of the Scan Conversion System. The control of V_{RX} and V_{RY} may be compensated for non-linearities in the particular TV viewer deflection characteristics

The reference voltages from the joy stick are fed to the ΔV Gate Size Control Supply This supply provides an adjustable incremental plus and minus voltage, for each reference voltage, thus establishing a total of eight reference voltages. The size of the spot on the TV viewer is controlled by varying the voltage increments of V_{RX} and V_{RY} This in turn will vary the voltages to the Radar portion, and also increase the gate size. For different Radar ranges, the voltage differential of KV'_y and KV''_y, KV'_y and KV''_x must be changed to maintain the same gate duration regardless of sweep time. This gate time is changed only with manual adjustment of the operator's gate size control, and must be maintained to at least 25 u sec.

From the Δ V supply, the reference voltages are applied to twelve multiars; four in the TV portion, and eight in the Radar portion. The following explanation is given for the TV portion of the system. The basic multiar module contains a start multiar, a stop multiar, and two bistable gates. For a negative going sweep voltage (this is preferred, since the multiar is better suited to negative going sweeps), V'_x is slightly more positive by ΔV_x volts than V''_x, and the multiar referenced by V'_x will be fired first The multiar referenced by V''_x fires Δ V volts later on the sweep slope, corresponding to some time, T_x, later. The negative pulse, from the multiar referenced by V'_x, is used to turn a bistable multi to an "ON" position, after proceeding through a bistable gate. The function of the gate, here and elsewhere in the system, is to permit only one pulse from the multiar, for each sweep, to appear at the bistable multi, and in this case it is the first pulse The gate is opened by the X_{TV} sync, and closed by the first pulse allowed to pass through. In this manner, the bistable multi will be turned "ON" only once during each sweep.

In the same manner, the multiar referenced by V''_x produces a negative pulse, T_x u sec. later, to turn the bistable multi back to an "OFF" position. The X_{TV} sync is used to insure that the bistable multi starts each sweep from an "OFF" position.

Consequently, the bistable multi in the X sweep portion has produced a pulse that is T_X u sec. wide, and positioned in time with respect to the X_{TV} sweep at a point determined by the setting of the joy stick in the X plane, and the resulting value of V_{RX}. Since $V'_x = V_{RX} + \frac{\Delta V_x}{2}$, and $V''_x = V_{RX} - \frac{\Delta V}{2}$, T_s has been fixed by the value of ΔV_X.

In the same manner, the multiars, referenced by V'_y and V''_y and fed the Y_{TV} (vertical) sweep, will produce a gate of length T_y u sec., and positioned in time with respect to the start of Y_{TV} sweep by the setting of the joy stick control in the Y plane. When coincidence of the two bistable multi outputs occur, the "AND" circuit will provide an output the length of the coincidence. This will occur some N times in one vertical sweep, while N of the horizontal sweeps in a raster, will provide coincidence only once. The number N, or height, will be determined by the ΔV_y setting. The ΔV_x setting will determine the width. The coincidence output from the "AND" circuit is superimposed on the TV video to produce a box and thus locate the position of the decoder gate. The box will appear on each frame of the TV picture.

There are four remaining reference voltages, KV'_y, KV''_y, KV'_x and KV''_x. These are used to reference the eight multiars used in the Radar portion of the system. Although the design of the Radar portion is more complex, the theory of operation is the same as the TV portion.

In order to present a circular PPI display for the Radar portion using an X and Y deflection system, sinusoidally modulated sweep voltages, such as shown in Figure 39 are needed. These voltages are obtained from the single radial radar sweep either by electronic or mechanical means, coupled to the rotation of the radar antenna Since each sweep voltage contains both positive and negative slope sweep voltages, in 360 degrees of antenna rotation, two multiars are needed for each reference voltage.

In the first 180 degrees of the X deflection voltage, the radar sweeps have a positive slope. Consider then the multiars referenced by KV''_X. If the reference voltage magnitude is such that it falls within the magnitude of some of the sweeps in this first 180 degrees, this would correspond to a gate positioned in the right half of the screen. As each sweep reaches the reference voltage KV''_X, the Positive Ramp Multiar will provide a negative pulse. Following this first pulse, the multiar will free run since it is fed a positive slope sweep voltage. The bistable gate passes only the first pulse, and then disables the multiar until the beginning of the next sweep The Positive Ramp Multiar referenced by KV'_X follows with its pulse $K \triangle V_X$ volts later on the X deflection voltage. The two pulses pass through an "OR" circuit, and provide "ON-OFF" triggers for the bistable multi. The reset feature insures that the multi always will start each sweep from an "OFF" position.

With the reference voltages unchanged, consider the action of the Negative Ramp Multiars referenced by KV'_X and KV''_X. Since the reference voltage is effectively above the negative ramp baseline, the multiars would be free-running The Bistable Gate prevents this action by not turning "ON". It is held in an "OFF" position by the Comparator, a circuit heretofore unmentioned.

The Comparator receives the reference voltages KV_{RX} and KV_{RY} from the joy stick. The Comparator functions in such a manner that whenever a reference voltage approaches very nearly the baseline of the sinusoidal envelope, or changes sign completely, the multiars, that as a result would free run constantly, are gated "OFF". The Comparator output voltages are applied through "OR" to the Bistable Gates, keeping them "OFF" until the reference voltage is changed to a point where the multiars are again needed. The action of the Comparator then disables the Negative Ramp Multiars during the entire cycle of the sweep voltage when a positive or zero reference voltage with respect to the baseline, is present. Conversely, it will disable the Positive Ramp Multiars during the entire cycle of the sweep voltage when a negative or zero reference voltage is present. No study effort was directed toward the Comparator, but it should be noted that it may be coupled to the joy stick either electrically, thru KV_{RX} and KV_{RY}, or mechanically. The mechanical version would employ a precision switch ganged to the joy stick directly.

Referring to the multiars referenced by KV'_x and KV''_x, and their magnitude falling within the magnitude of some of the sweeps in the last 180 degrees, the action of the circuits is as follows:

Since the sweeps in the last 180 degrees are negative going, and KV'_x is more positive than KV''_x, the KV'_x multiar fires first, utilizing the Negative Ramp Multiars As before, the two pulses from the multiars provide "ON-OFF" triggers for the Bistable Multi. This time the Comparator gates "OFF" the Positive Ramp Multiars.

The action of the remaining multiars referenced by KV'_y and KV''_y is exactly the same. In this case of the radar sweep system, the sweep times are even identical for the X and Y deflection The joy stick again provides a reference voltage KV_{RY} corresponding to some position in the Y direction, and a bistable multi is turned "ON" and "OFF" at the related time. As described in the TV explanation, when coincidence occurs, an output results from the "AND" circuit This output is connected to the decoder gate, and occurs just as the radar sweep reaches the spotted target. Active readout is initiated, and the target in question is identified.

The feedback loop through the Push To Test switch serves as a visual check to the operator, that the gate is occurring where the spot shows it should be located.

This concludes the study of the Scan Conversion Display Decoder Gating.

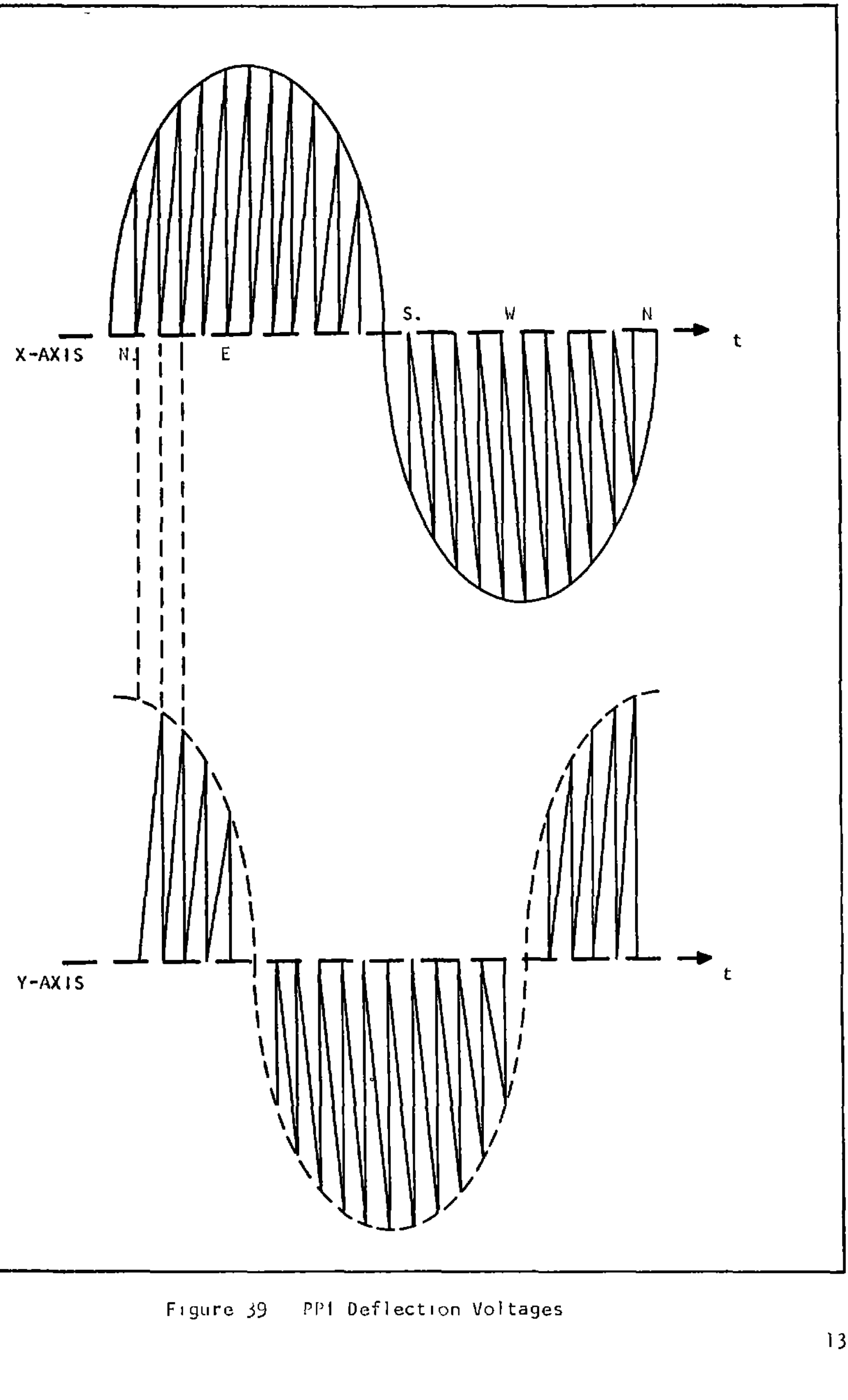


Figure 39 PPI Deflection Voltages

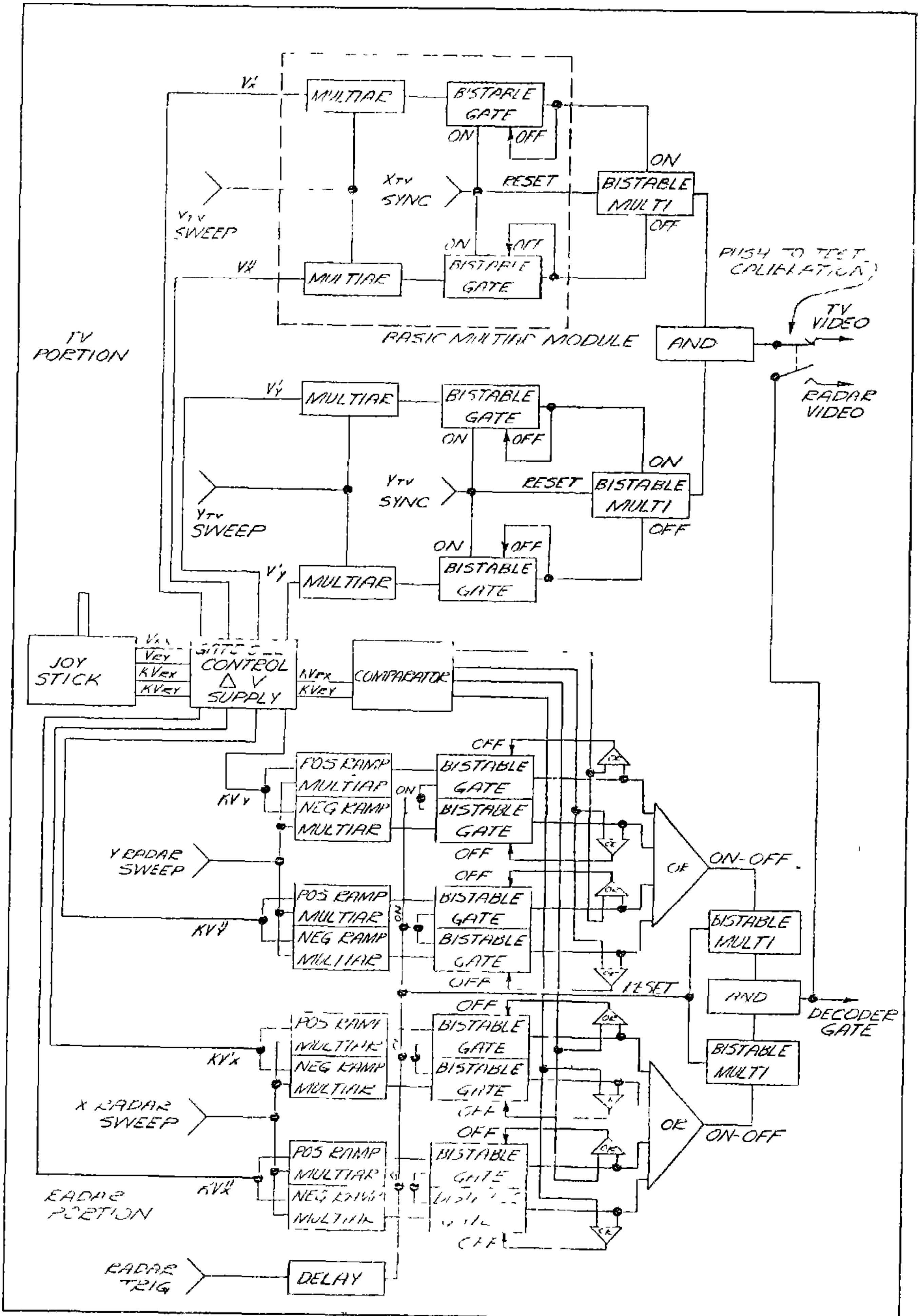
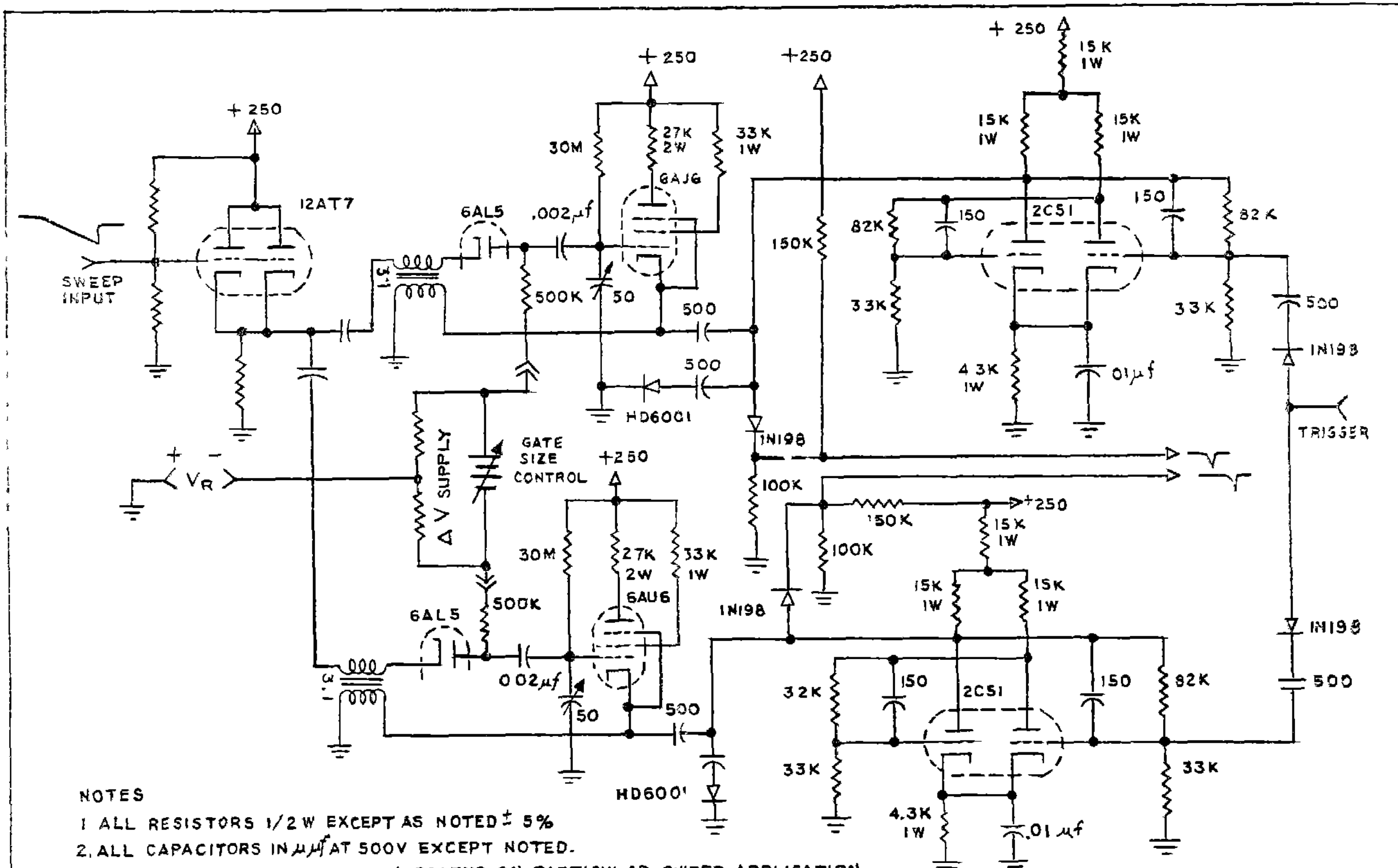


Figure 40 Active Readout Gating For Scan Conversion System, Block Diagram



NOTES

1 ALL RESISTORS 1/2 W EXCEPT AS NOTED ± 5%

2. ALL CAPACITORS IN µµf AT 500V EXCEPT NOTED.

3 CIRCUIT VALUES NOT SHOWN DEPEND ON PARTICULAR SWEEP APPLICATION.

4 FOR POSITIVE GOING SWEEPS, REVERSE DIRECTION OF 6 AL5 DIODES AND POLARITY OF REFERENCE VOLTAGE V_R.

Figure 41 Basic Multiar Module, Schematic Diagram

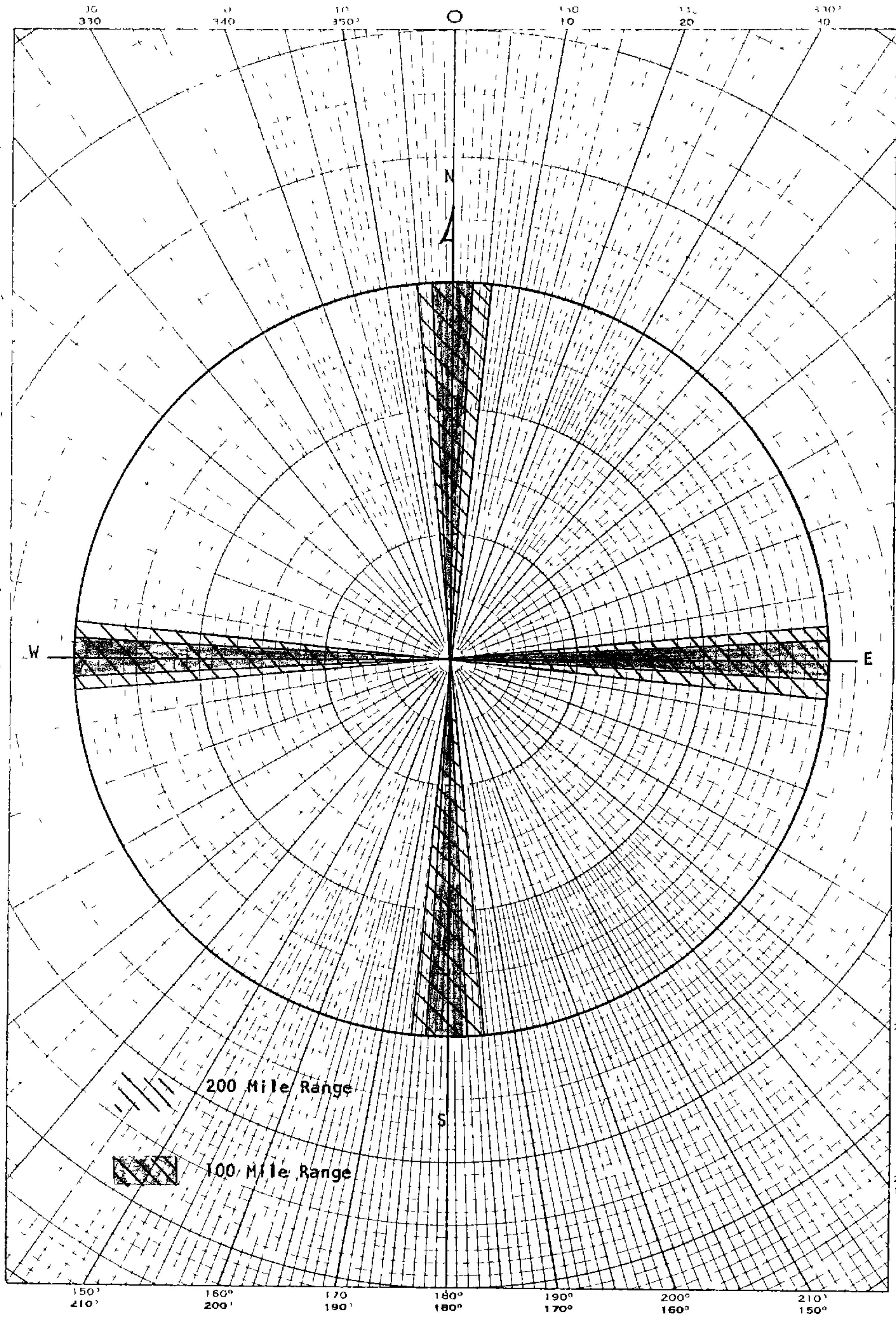


Figure 42 Regions Of Gate Jitter Chart

9.0 SETRIN CIRCUIT FOR SIDE LOBE SUPPRESSION

Side-lobe effects in short range radar beacon work have hindered progress in this field for many years. In the work being conducted under the ATC Common Safety Beacon program, a system of side-lobe suppression which is both practical and reliable is in high demand. One system which has been presented is that of Mr. M. Setrin of the Rome Air Development Center. This system involved the addition of a special suppression circuit to the transponder. A portion of the modification work conducted by Stewart-Warner under this contract involved the installation of this circuit in twenty ANDB Type III transponders. In effect this circuit is a sensing element which enabled the transponder to determine whether or not the information it is receiving at any instant is main beam or side-lobe information. This was accomplished by adding a third pulse to the existing MARK X interrogation code. This pulse is transmitted over a separate antenna pattern, providing a variation of relative signal strength between the interrogation and reference signals received by the aircraft.

In order to provide a measure of effectiveness of the modification a series of tests were devised and were carried out under this contract. These tests involved the determination of the reply and no reply points when the relative amplitudes of the interrogation pulses and reference pulses are varied Curves were taken for several pulse spacing and delay line tap combinations. The data obtained from such tests should prove useful in predicting system performance as well as providing a basis for future system specifications.

9.1 Description of Tests

Rather than the usual laboratory pulse generators, the tests were performed with two transmitter units (AN/UPX-6), to provide the Mark X and Reference pulses. This method provided pulses which lack the sharp rise and decay times of laboratory instrument pulses Also these units were easily modified to operate from a single RF oscillator This insured exact tuning and representative behavior of the beacons.

A block diagram of the test setup appears in Figure 43 Both transmitters were fed from the same crystal oscillator and were triggered according to the coded pulse spacings for proper suppression. The r-f output pulses which could be varied in width were attenuated some 50 to 60 db before being fed to a calibrated variable attenuator. The signals were fed to the beacon through a matching "tee". The transponder under test was prevented from replying by removing the modulator driver type. Indications of a reply were obtained by counting the pulses that appeared at the grid of this tube.

The test procedure may be summarized by the following steps:

(1) Tune the transponder to the frequency of the transmitter.

(2) Set up and adjust the spacing and width of the pulses.

(3) Determine beacon sensitivity with a calibrated Hazeltine test rack.

(4) Determine a correction factor for each of the variable attenuators.

(5) Set the attenuation of the IR signal near threshold and vary the attenuation of the reference signal until the transponder fails to reply. Record the upper and lower limits of reply (full reply and no reply).

(6) Repeat step (5) for IR signal values up to 25 db below 1 volt.

(7) Set and adjust new pulse spacings and delay line tap.

(8) Repeat steps (5) and (6) for this new setting, etc

The concluding curves from the tests on six of the beacons are shown in Figs 44, 45, and 46. The results of these tests indicate that less reference pulse power was required at the beacon to cause suppression to take place. Over the major portion of the side lobe range, suppression took place with 10 to 12 db less power in the reference signal than in the interrogation signal.

9 2 Progress and Shipment of Modified ANDB Type III Transponders

One modified ANDB Type III transponder was delivered to TDC in May and nine in June, 1958. At this time, six more units were in the process of being modified, with a tentative delivery schedule of four in July, 1958 and two after the two week plant vacation period.

The remaining four out of the twenty units to be modified were not received at the plant. Three units were located at TDC and one at AMB. These units were received in the month of July, 1958, making a total of ten units on hand to be modified

A letter was received from TDC in the third week of July 1958, stating that a decision was made to postpone modifications to five of the ten units on hand with a final decision to be made within ten days. The remaining five units were to be modified and shipped to TDC as soon as possible. This shipment was made during the first week of August 1958.

After a final decision was made to modify the five units in question, a final shipment was made in the last week of August 1958, to complete this portion of the contract.

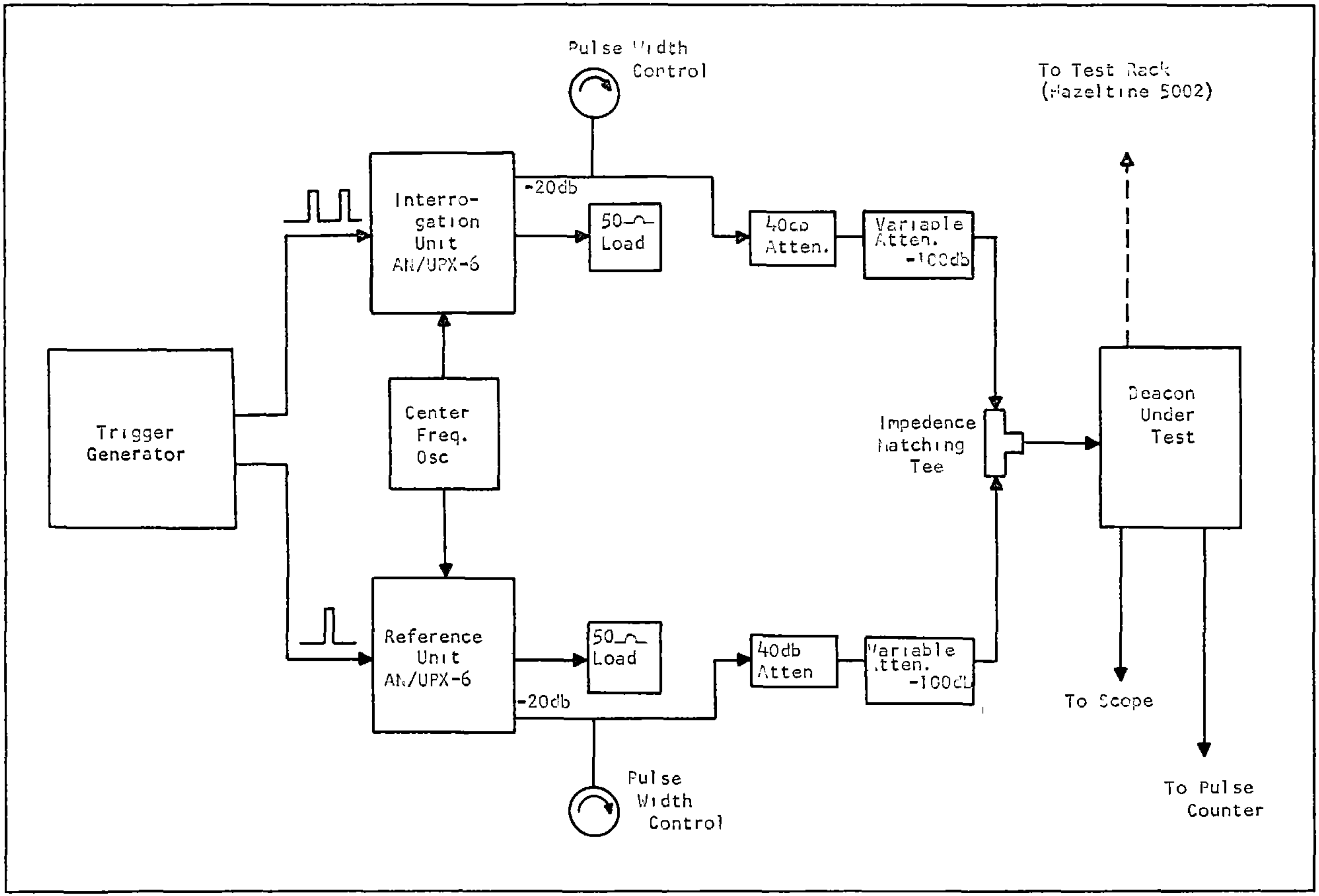


Figure 43 ANDB Type III Transponder Suppression Characteristics Test Setup, Block Diagram

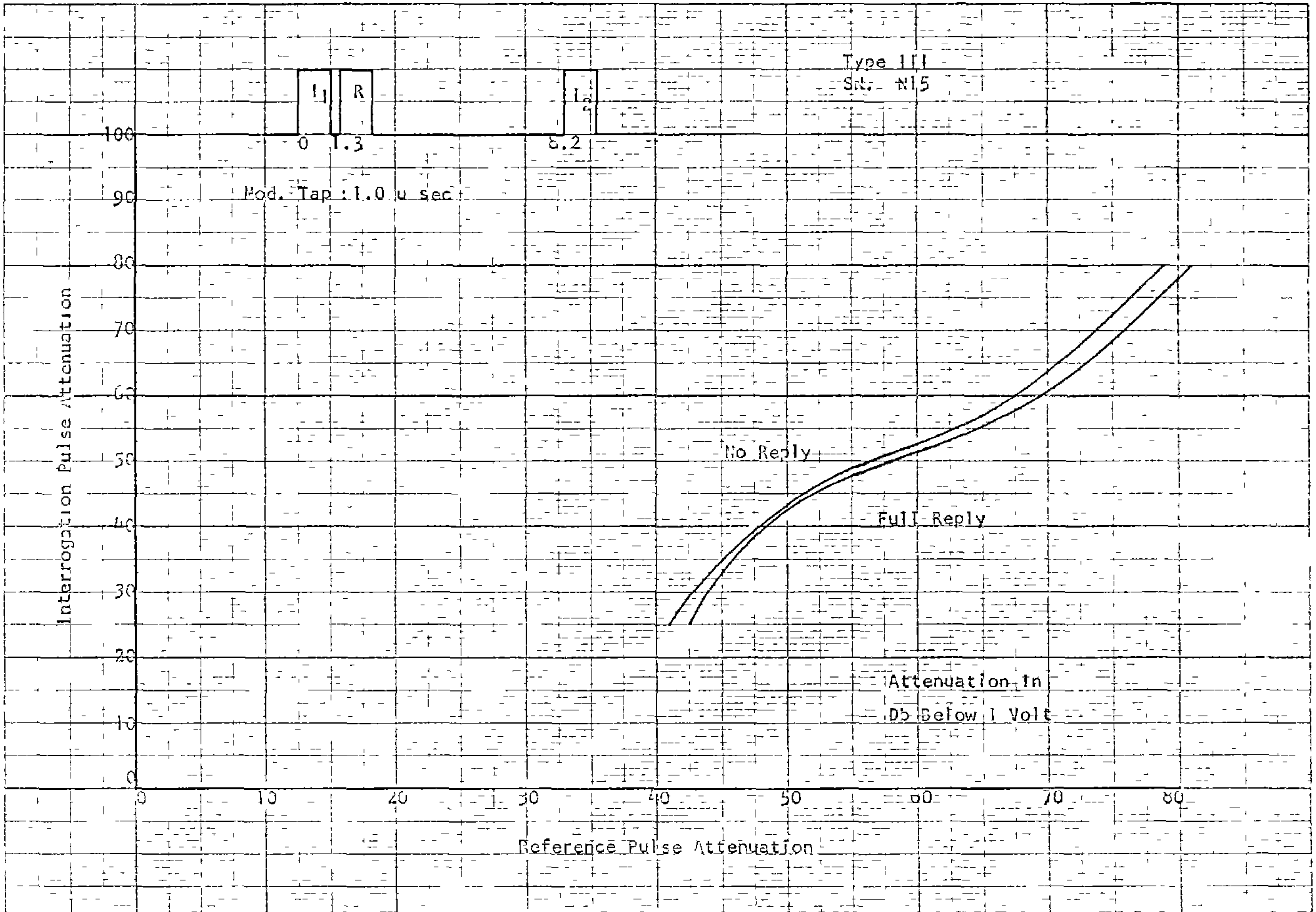


Figure 44. Interrogation Pulse Versus Reference Pulse, With 1.0 u sec Mod. Tap, Attenuation Chart

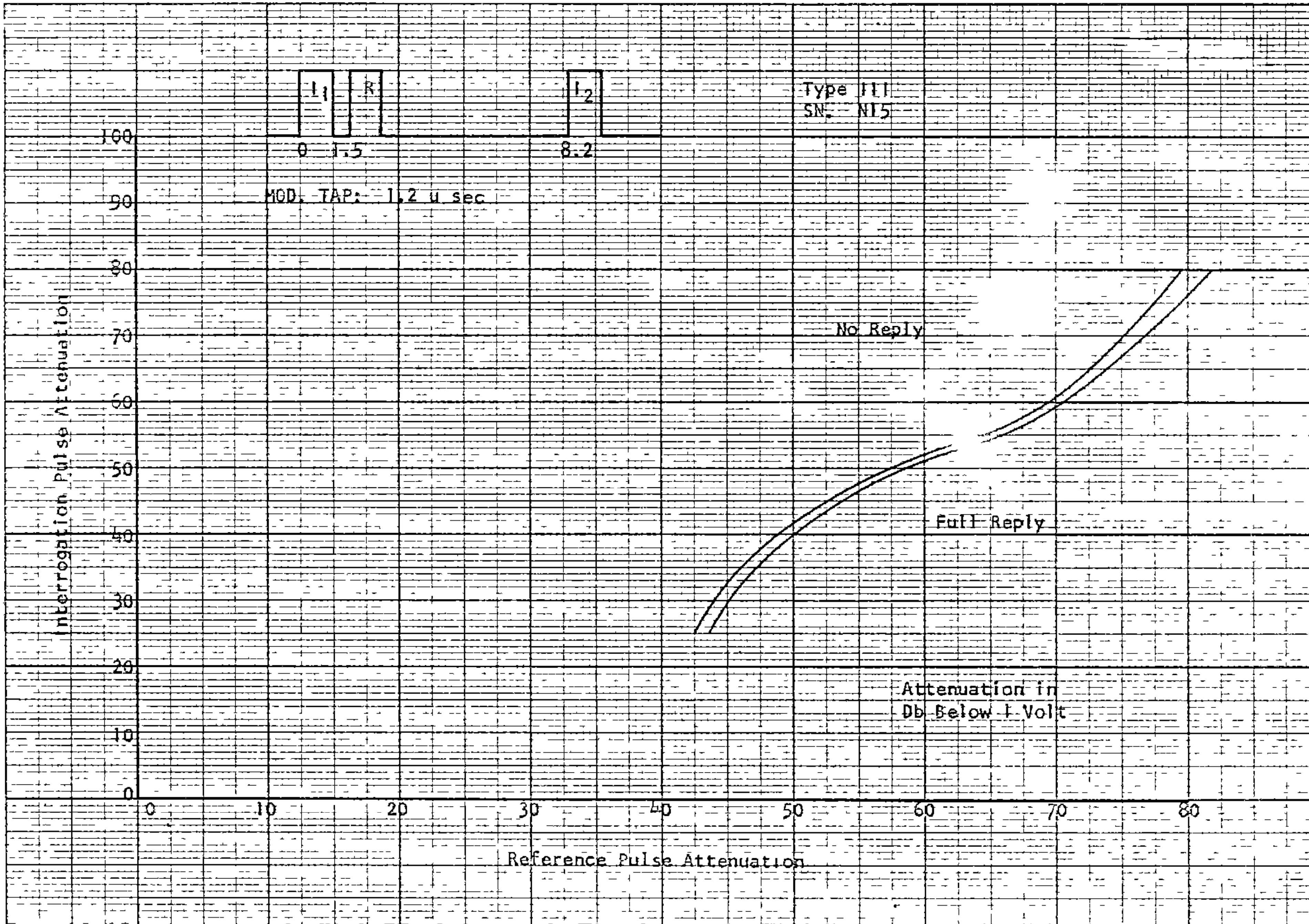


Figure 45. Interrogation Pulse Versus Reference Pulse, With 1.2 u sec Mod. Tap, Attenuation Chart

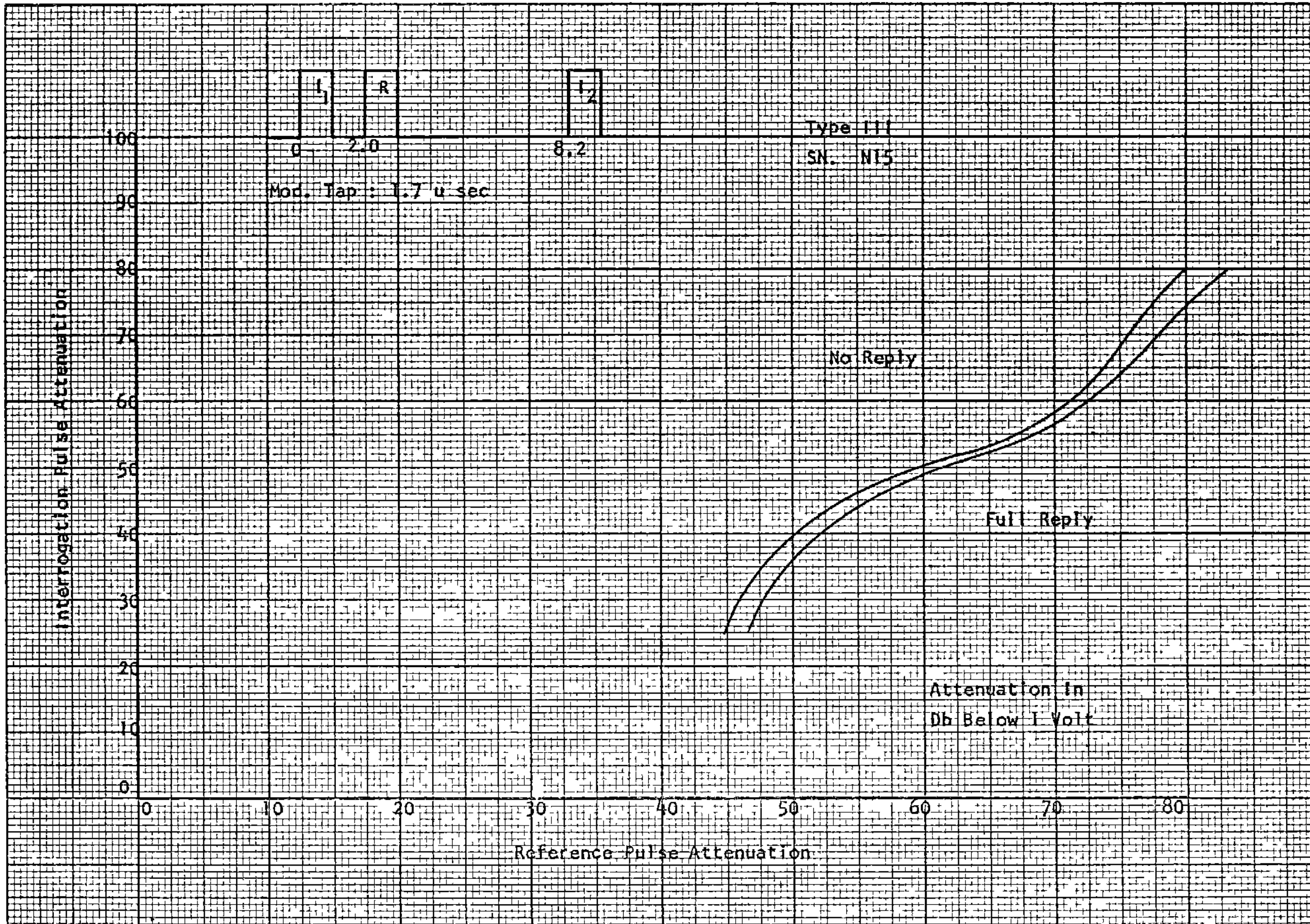


Figure 46. Interrogation Pulse Versus Reference Pulse, With 1.7 u sec Mod. Tap, Attenuation Chart

10.0 ENGINEERING ASSISTANCE

A field engineer was assigned to provide engineering assistance to the FAA installation and maintenance groups at Midway and O'Hare Field, following a visit to these sites during the first portion of September 1958. After contacting the installation group, Stewart-Warner obtained six decoders and power supplies from Midway and three decoders and power supplies from the O'Hare site The field engineer was engaged in aligning the units so that they would be ready for operation when installed at the sites. Also, the field engineer was acquainting himself with the other units of the beacon system in order to provide engineering assistance at each site during the installation period Since test coders were not available at the sites, the alignment work was performed in Stewart-Warner's laboratories, using classified test coders. This precluded any extensive field tests until the required test coders became available In the meantime, Stewart-Warner conducted as much inspection, test, and alignment of incoming beacon equipment in the laboratories as was practicable, so that a minimum of field adjustments would be required at the sites.

Stewart-Warner made three minor modifications, which did not include gate circuit modification, to the decoders and power supplies during the test and alignment of the units since they could be done easily at this time Stewart-Warner recorded and tabulated the difficulties encountered in working with the units so as to provide a guide for the installation and maintenance groups

10.1 Engineering Assistance Progress For The Period of October 1 to October 31, 1958

The Stewart-Warner engineer made contacts with the Midway and O'Hare Field FAA personnel regarding the beacon equipment installation. As the decoders and power supplies were checked out and aligned, they were delivered to the respective sites for installation in the rack mounts In this manner, Stewart-Warner was able to keep abreast of developments at each site and keep the field personnel informed as to equipment operation.

Several of the decoders were checked and aligned. A difficulty which had shown up in all units was the alignment of the Select Code. The units would not quite fall within the proportionality requirements for all codes selected without allowing a small amount of noise through at normal signal amplitudes As a result the units were aligned to a maximum response - minimum noise compromise position The different requirements at each site would probably require readjustments when the units are operated under normal field conditions.

The video line drivers and line compensating amplifiers were checked and aligned. It was found that plug-in filter capacitors C-18A and C-18B of the line driver, and C-36A and C-36B of the line compensator power supplies respectively, had negative charges built up on their outer shell These charges were from 200 to 300 volts to ground and were dangerous to personnel Stewart-Warner installed tube base clamps on the chassis, at the plug-in capacitor sockets, to ground the outer shells of the capacitors This prevented the charges from building up

O'Hare Field reported that the ASR-3 pre-trigger modification did not operate satisfactorily and that they returned the units to the source of supply. The location of the mod kit near high wattage resistors changed the time constant of the multivibrators causing pulse jitter They placed the ASR-3 in operation without the pre-trigger unit and were awaiting further installation information.

10 2 <u>Engineering Assistance Progress For The Period of November 1 to November 30, 1958</u>

The VIE units and associated control boxes for O'Hare Field were modified, checked out, and returned to the site.

All but three VIE units and one control box were returned to Midway One of the remaining units, VIE No.26, required a delay line, DL101. The delay line was found to have an open circuit between points 127-25 and 127-26, the A, and START taps.

The decoding delay lines Z201 in the Line Compensating Amplifiers were re-tapped. The overall delay measured about 8.7 u sec with the other taps measuring about 5 5 and 3.2 u sec. Both units No 9 and No. 10 were corrected to provide the proper 8, 5, and 3 u sec values

The Stewart-Warner engineer made a trip to the New York Center at Idlewild to observe the high density tests. However due to inclement weather the high density tests were postponed. A visit was made to the New York Center installations, and operation of the equipment observed with the few beacon equipped aircraft in the area.

10.3 <u>Engineering Assistance Progress For The Period of December 1 to December 31, 1958</u>

The Video Line Driver and Line Compensating Amplifier were returned to Midway and the O'Hare units were ready for delivery immediately there after Also two of the three remaining VIE units were ready for delivery to Midway. The defective delay line in unit No 26 (reported previously) was not available from the normal spares and one was placed on order

The pre-trigger modification for the ASR-3 at O'Hare Field was received and installed by the FAA installation group.

The FAA installation group were waiting for connectors or flexible cables for the terminal ends of the beacon antenna cabling at the FPS-8 site at Midway To this date, no further beacon equipment was received by either site.

A brief ring out of the beacon equipment was made at Midway. A double pulse generator and a single pulse generator were used to feed common mode triggers and a 1.0 u sec. video pulse into the Video Line Driver at the transmitter site. The line compensating network in the Line Compensating Amplifier was adjusted using these trigger and video pulses as received from the Video Line Driver over the interconnecting underground coaxial cable The common Mode Trigger output and Video output from the Line Compensating Amplifier were fed to a VIE unit and the "Video Output" for the P.P.I. was observed on an oscilloscope

This limited operational check was succesful after a few minor adjustments and cable changes.

The spare parts delay line (Z201) for the Line Compensating Amplifier was obtained from the spares at Midway It was checked out and found to be too long in its mode spacings It was re-tapped for better spacing and returned to the spare parts. The line spacings for the two units and the spare line were measured to be as follows, with the corrected spacings also given.

Tap Spacing	Unit No.9			Unit No.10			Spare Parts Line		
Original Spacing (in u sec)	3.25	5 50	8.71	3 27	5.55	8 73	3 26	5.52	8.72
Corrected Spacing (in u sec)	2.91	5.00	8 02	2 92	5 01	8.03	2 92	5 00	8.03

It should be noted that the exact mode spacings could not be obtained This was due to the time increments between taps which varied from 0 21 u sec. to 0 27 u sec. The tap closest to 3, 5, and 8 u secs was chosen

10.4 Engineering Assistance Progress For The Period of January 1 to January 31, 1959

The remaining VIE units, Video Line Drivers, and Line Compensating Amplifiers were returned to Midway and O'Hare Fields, with the exception of the VIE unit No 26 that has the defective decoding delay line To date this delay line has not been received.

Midway and O'Hare Fields have received their Defruiters and the test equipment for their Interrogators. The Midway Defruiter was bench checked and aligned

10.5 Engineering Assistance Progress For The Period of February 1 to February 28 1959

Midway Airport received its VIE test set and it was installed in the equipment rack. Further system checks were being carried out

The only equipment still required at Midway was the Interrogator, otherwise the status regarding what was to be completed was as follows:

1 Installation of the Defruiter

2. Installation of the antenna connectors

3 Receipt and installation of the decoding delay line for VIE No.26

4. Thorough system "ring out".

The beacon antenna at O'Hare Field was accidentally damaged due to contact with a DF antenna mounted near by It was believed that the antenna would have to be sent back to the manufacturer for repairs and re-alignment The end sections were gashed and bent slightly The FAA installation group was awaiting word on what action to take in regards to repairing or replacing the antenna

The status of what remained to be completed at O'Hare Field other than the antenna was as follows:

1 Receipt and installation of the Interrogator.

2. Receipt and installation of the VIE test set

3. Installation of the Defruiter

4 Thorough system "ring out"

Replacement relays were obtained and installed in the VIE(unit No.28) that was used in the environmental life test Filtors type 26WDK12S were used to replace relay K-101 These were relays that failed during the environmental life test as discussed in Section 6.0.

The location of all Nike Sites in the Chicago area was obtained by the Stewart-Warner Engineer, and a map indicating their positions was sent to TDC Indianapolis, as per their request.

10 6 Engineering Assistance Progress For The Period of March 1 to March 31, 1959

(a) Progress at Midway Airport:

The cabling and control circuits for the VIE units at Midway were checked and corrected where needed The units were set up as follows No's. 22, 23, and 24 were routed to the present three VG indicators Unit No. 25 was routed to a fourth position, however no indicator was installed there These four positions will be equipped with scan conversion units that have been received but not installed to date The FPS-8 scope in the operations room and the maintenance scope in the equipment room require a small amount of additional cable wiring before they are completed. Units No. 26 and 27 will be routed to these two indicators

In accordance with the installation drawings, only common trigger, alternate trigger, and beacon video were fed into the VIE units with the video output being fed to the system video mixer units The Defruiter was installed and the control circuits were being checked out

The antenna cable connector at the pedestal was installed The connector at the interrogator end of the cable will be attached during the installation of the interrogator

It was found that the decoding delay line (DL-101) from VIE unit No 26 was required for a replacement The defective delay line was removed and returned

(b) Progress at O'Hare Field:

The Defruiter was installed at O'Hare Systems checks could not be made until the arrival of the test set.

10.7 Engineering Assistance Progress For The Period of April 1 to May 15, 1959

(a) Progress at Midway Airport.

The interrogator for the Midway installation was received and installed Preliminary tuning and adjustments were made and the unit was put on the air for short periods of time. The receiver output was monitored and several raw video replies were observed on an A scope and on a P P.I. Very good returns were received.

Defruiter operation was checked with signals obtained from the interrogator test set. Tracking and Defruiter operation were obtained for a short period of time, however after the Defruiter was completely warmed up, specifically the quartz delay lines, the radar trigger and the tracking circuitry were not compatible At this point, it was found that the FPS-8 Radar MTI quartz delay lines have had their heaters disconnected due to the failures that have occurred throughout the field from over heating

Data was taken on the FPS-8 trigger and the independent operation of the DE-fruiter. The radar operated from 358.7 to 358.9 prf, while the Defruiter with the heaters operating, had a tracking range from 359 2 to about 359 9 prf which was just a little higher than that which is required for proper operation With the Defruiter heaters not operating, the range was found to be from 357 9 to 358 5 prf which is just a little too low for proper operation. It was realized that the thermostats on the Defruiter can be adjusted, however this was not done, nor will it be done, until further direction is received. It was understood that work is presently being done for the correction or replacement of the thermostats in the FPS-8 units Until full time operation is required, the Defruiter heaters can be manually controlled to maintain the specified temperature and the Defruiter in operating condition

All circuits and controls were preliminarily checked out and adjusted The more thorough, final tune-up procedure was being performed

One of the 20 u sec pre-trigger delay lines for the FPS-8 Radar was found to be erratic in its operation. It was removed and was being checked by the delay line group at Stewart-Warner Electronics.

The replacement delay line for VIE No.26 has not been received to date. With the exception of this unit and the above mentioned pre-trigger delay line all equipments were received, installed, and checked out at the Midway installation.

(b) Progress at O'Hare Field

The replacement antenna shipped from TDC for the O'Hare site was received and installed Still required for completion of the installation were the interrogator and the two test sets

10 8 <u>Engineering Assistance Progress For The Period of May 15 to July 15, 1959</u>

(a) Progress at Midway Airport

The final tune-up procedure and the joint inspection of the Air Traffic Control radar beacon equipment at Midway was completed. The complete system, with the exception of the Defruiter, was turned over to the maintenance personnel. The Defruiter is incompatible with the FPS-8 Radar unheated MTI quartz delay line prf, as mentioned in Section 10.7. To date a "fix" for the thermostatic controls of the MTI was not received

The 20 u sec pre-trigger delay line for one of the FPS-8 Radars was found to be internally shorted to ground by the delay line group at Stewart-Warner Electronics It was repaired, returned, installed, and was operating normally

The defective decoding delay line (DL-101) in VIE unit No.26, was replaced with the delay line taken from VIE unit No.28. Unit No.28 was used by Stewart-Warner Electronics in the environmental life tests. The delay line, which was originally on order as a replacement for unit No.26, was received at a later date

(b) Progress at O'Hare Field:

All of the Air Traffic Control radar beacon equipment was received for the O'Hare Field installation and was installed The preliminary ring out and tune-up was being performed

The same MTI quartz delay line thermostat problem that existed at Midway, exists at O'Hare.

10.9 <u>Engineering Assistance Progress For The Period of July 15 to September 30, 1959</u>

(a) Progress at Midway Airport:

The Air Traffic Control Radar Beacon System installation at Midway Airport has been commissioned as of August 25, 1959.

Delivery of the new 28 foot antenna is not expected for several months. The present 18 foot antenna will be used until the 28 foot replacement is received

(b) Progress at O'Hare Field:

The joint inspection of the Air Traffic Control Radar Beacon System at O'Hare field was completed. This site was commissioned as of October 5, 1959.

During the tune-up procedure at O'Hare Field, considerable trouble was encountered with diode failures in pulse pair generator portion of the interrogator set Several diode replacements had to be made in the mode selection circuitry in order to obtain proper mode output operation. The replacement delay line (DL-101) was installed in the VIE environmental life test unit No.28, still located at Stewart-Warner Electronics. This unit will be returned to the FAA as directed

This completed all Engineering Assistance as required under this contract