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A METHOD OF CODING AND DISPLAYING  
IFF REPLY SYMBOLS

By  
W. M. Furlow, Jr.  
W. L. Bulger, Jr.

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Approved by:

C. E. Cleeton, Section Head  
Security Systems Section

Dr. J.M. Miller-Superintendent,  
Radio Division No. 1

Commodore H. A. Schade, USN,  
Director, Naval Research Lab.

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## ABSTRACT

A further advancement in the coding of I.F.F. systems has been made in order to provide continuous individual-identity information for each target replying to an interrogator-responder unit. A transponder, on being interrogated, will by means of the coder equipment described herein reply with a series of pulses arranged so that, when received and viewed on a PPI or B type display, letters or numerals will be formed. No modification to existing interrogator-responder or display equipment is necessarily required, and no voice communication channel is necessary for full utilization of information available. Identity information for several targets is presented simultaneously, each target being characterized by a different group of letters.

In order to accomplish this, the traffic handling capacity of the system is less than that of a single pulse reply system. Therefore, letter coded IFF replies are not suggested for universal coding of IFF systems, but should be of greatest value in special operations requiring closely-coordinated remote control of several targets.

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## METHOD OF CODING AND DISPLAYING IFF REPLY SYMBOLS

### INTRODUCTION

1-1.1 The original purpose of an IFF system was to allow recognition of a radar target as friend or foe. Another function was quickly found, that of differentiating between friendly targets. Two examples of such use are of particular interest. In anti-submarine warfare, a plane having contact with a submarine would reply on G band frequencies as well as on the normal A band of Mark III IFF, indicating to the controlling radar the particular plane in the area which has submarine contact. The resulting elimination of confusion and saving of time were vital factors. Fighter direction was similarly aided since the exact position of a particular plane in a group could be found by requesting that plane to "Make George talk".

1-1.2 The Mk V system was designed to facilitate individual identification of friendly targets. In addition to the standard IFF operation, Personal Identity and Flight Leader Identity were obtained by special interrogation codes and Emergency or distress indicated by a characteristic reply code. Further information was transmitted by varying the reply characteristic to produce Morse code symbols (slow coding).

1-1.3 The information obtainable from the Mk V system is limited by the time required to read the "slow code", and radio communication is needed for the personal identity function. During operations requiring closely coordinated control of many units, it is highly desirable to have available continuous information regarding the individual identity of each target seen on the radar screen. This information should be available with the radar operating normally and, in particular, without stopping the antenna rotation as is necessary to read Mk V "slow code". No radio communication channel should be necessary for the complete utilization of all information.

1-1.4 The purpose of this report is to describe the development of a system for supplying, quickly and continuously, information to identify individual friendly targets. This information takes the form of letters, numerals or symbols when viewed on an intensity-modulated screen having range and azimuth as coordinates, such as the standard Plan Position Indicator.

1-1.5 Because of availability, the Mark V IFF equipments were used to demonstrate the operation of this method of coding. A transponder was modified to transmit the information by the addition of a coder. No modification to existing interrogator-responder equipment or indicators was necessary for reception and presentation of the information. Different letters may be used by each friendly unit.

1-1.6 The principal employed is the same as that used in facsimile and television, that of transmitting successively groups of pulses which form a mosaic image on a viewing screen when properly synchronized and positioned. The character of the pulse groups transmitted is determined by a coder attached to the transponder. Synchronization is obtained since each interrogation received at the transponder causes one group of pulses to be transmitted.

### Formation of Letters

1-2.1 For example, the letter "E" will be formed by the following sequence.

The first interrogation will cause the transponder to reply with five equally spaced pulses forming the first group. These pulses will be received and presented on the screen at a position such that the first pulse represents range to the target. This reply will be repeated for the following several interrogating pulses, allowing the reply to assume a definite azimuth as the antenna rotates. See Plate 1.

1-2.2 After the several interrogations mentioned above, the transponder will begin to reply with the second group of pulses, consisting of only the first, third and fifth pulses. The range represented by the first pulse is still the range to the target. Several successive interrogations will be answered by the second group of pulses, and the antenna azimuth will change during this interval.

1-2.3 The third and fourth groups of pulses duplicate the second group and are transmitted in the same manner.

The fifth group of pulses consists of the first and fifth pulse, and is transmitted in reply to several successive interrogating pulses in the same manner as the other groups.

For an interval after the transmission of the fifth group is complete, no reply pulses are transmitted in order to leave a space between letters.

1-2.4 The mosaic pattern formed by the received pulses presented on a PFI screen are shown in Plate 1(a).

### Spacing and Pulse Widths

1-3.1 There are two fundamental alternatives in the selection of letter size. A large letter may be used for direct viewing on a PFI screen, or a small letter may be used which would appear as a

thin arc on the PPI screen but would be readable on an expanded screen such as the type "B" screen employed in the VF remote indicator.

1-3.2 The pulse width may be much smaller than the pulse spacing, since the minimum spot size on a screen is usually determined by focusing characteristics. At long sweep ranges a spot may be several times as long as the pulse which produces it. Sufficient spacing between pulses should be used to prevent the spreading out of the spot from rendering the letters unreadable.

1-3.3 The minimum number of possible pulse positions required for readable transmission of a letter in general is 25, excluding the space between letters. This number of elements is obtained by using five pulse groups, each group containing five positions for the possible appearance of a pulse.

#### FACTORS DETERMINING SIZE OF LETTERS ON VIEWING SCREEN

2-1 If the characteristics of the transponder and coder are held constant, the size of the letters presented on the viewing screen becomes a function of the range scale in use, range to the target and interrogator-responder antenna rotation rate as well as screen size. Two other factors affecting letter size are pulse spacing in the transponder and the time necessary for complete transmission of a letter.

2-2 The height of the letters may be obtained by the following relation:

$$H = T_t \cdot a \quad (1)$$

where:

H = Letter height in inches

$T_t$  = Time required for transmission of all pulses in a group (See plate 1)

a = Trace sweep speed, inches per microsecond and is given by:

$$a = \frac{\text{Sweep length, Inches}}{(\text{Range in use, Miles}) K} \quad (2)$$

where:

K = 12.37 for nautical miles

K = 10.74 for statute miles.

The height of the letters is directly proportional to the physical length of the sweep and inversely proportional to the range represented by the sweep.

2-3 The width of the letters in degrees is given by the following relation:

$$W_e = T_L \cdot b \quad (3)$$

where:  $W_e$  = Letter width, degrees

$T_L$  is the time in seconds required for the complete transmission of a letter and given by:

$$T_L = \frac{60}{N \cdot \text{Coder RPM}} \quad (4)$$

where:

$N$  = Number of letters sent by one revolution of the coder cams.

Coder RPM = RPM of coder cams

and:

$b$  is the I-R antenna rotation rate, in degrees per second, given by:

$$b = 6 \cdot \text{Antenna RPM} \quad (5)$$

2-4 The width of the letters is directly proportional to the receiving antenna rotation rate.

The width of the letters in inches may be found by:

$$W = W_e C \quad (6)$$

where:

$W$  = Letter width, inches

$W_e$  = Letter width, Degrees, (from Eqn. 3)

$$C = \frac{(\text{Sweep Length Inches}) (\text{Target Ranges Miles})}{57.3 (\text{Range Scale in Use, Miles})} \quad (7)$$

Substitution of the expression for  $W_e$  in eqn. 6 yields:

$$W = \frac{2\pi}{N} \cdot \frac{\text{Antenna RPM}}{\text{Coder RPM}} \cdot \frac{(\text{Sweep Length, Inches})(\text{Target Range Mi.})}{(\text{Range Scale in Use, Miles})} \quad (8)$$

2-5 For good readability, the ratio of height to width should lie between 0.5 and 2.0. When the coder characteristics are held constant, short ranges require higher I-R antenna rotation rates than long ranges if a PPI type presentation is used.

2-6 If a screen having a constant range per inch and degrees azimuth per inch is used, for example, the type "B" scope of the VF indicator, the letters will always appear the same size regardless of range to the target. The letter width remains a direct function of antenna rotation rate.

2-7 Two sizes of letters were chosen, one to be viewed directly on the PPI screen and the other to be viewed on the type "B" scope of the VF. The large letters, designated as "Wide" (having wide spacing between pulses) use a maximum of five pulses, spaced by 8 microseconds. The small, or "Narrow" letters use five pulses spaced by 2 microseconds. The height in inches of the letters are given in Table 1 for various ranges on the VE and VF indicators.

TABLE 1  
Letter Heights, Inches

	Range in Use, Miles	Type of Indicator		
		VE 7" PPI	VF 5" PPI	VF 5" Type B
"Narrow"	4	.5	.405	1"
Letters	20	.1	.081	1"
"Wide"	20	.428	.323	Not Useable
Letters	80	.107	.081	" "
	200	.043	.032	" "

Minimum Antenna Beamwidth

2-8 As the I-R antenna rotates, it must be receptive to signals from the transponder for a sufficient length of time to allow complete reception of the letter or letters used. The minimum antenna beam width which will permit complete reception is

$$\theta_{\min} = (N + 1) W_{\theta} \quad (9)$$

$\theta_{\min}$  = Minimum antenna beam width.

N = Number of letters to be received for complete information.

$W_{\theta}$  = Letter width, degrees, given by equation 3.

Substitute for  $W_{\theta}$

$$\theta_{\min} = (N+1) \cdot T_L \cdot b \quad (10)$$

Substitute for  $T_L$  and b

$$\theta_{\min} = \left( \frac{60}{N \cdot R} \right) (6 \times \text{RPM}) \frac{(N+1)}{N} \quad (11)$$

$$\theta_{\min} = 360 \frac{\text{I-R Ant. RPM}}{\text{Coder Cam RPM}} \cdot \frac{(N+1)}{N} \quad (12)$$

2-9.1 A tabulation might also be made of letter widths in inches. It is more useful, however, to have a table showing the range over which letters with readable proportions may be obtained. Since both letter height and width are directly proportional to the screen size, the ratio of height to width is independent of screen size and a table of general values for any PPI screen may be made.

2-9.2 Readable letters are defined as having ratios of height to width between 2.0 and 0.5, and Table 2 lists the ranges to the target in miles over which letters with these proportions may be obtained for a given range scale in use.

Results of tests have indicated that the letters are actually readable, with increasing difficulty, to ranges of approximately half the minimum and twice the maximum ranges given in Table 2.

Antenna rotation rates of 5 and 10 RPM are used. Other factors are:

Coder RPM	150
Number of letters in code	3
Height of letters	From Table 1

TABLE 2  
 Ranges in Miles to target which will give letters  
 with a height to width ratio between 2.0 and 0.5  
 P.P.I. Type Screen

I.R. Antenna Rotation Rate	5 RPM	10 RPM
Range Scale in Use		
"Narrow" Letters 4 Miles	None	2.5 to 4 Miles
20 Miles	5 to 20 Miles	3 to 11 "
"Wide" Letters 20 Miles	None	11 to 20 Miles
80 "	23 to 80 Miles	12 to 44 "
200 "	22 to 85 "	11 to 43 "

Pulse Repetition Frequency

2-9.3 In order to insure satisfactory reception and presentation of the letters, each of the 6 pulse groups (including the space between letters) should be repeated a minimum of 3 times. This establishes a relation between the minimum P.R.F. of the I-R and the rate at which the coder sends letters.

$$PRF \geq \frac{18}{T_L} \tag{13}$$

$T_L$  is given by Eqn. 4 substituting:

$$PRF \geq 0.3 (N) \text{ (Coder R.P.M.)} \tag{14}$$

METHOD OF OBTAINING PULSE SPACING AND SWITCHING

3. The method used to obtain pulses at the selected spacing is to introduce a pulse into a series of 4 delay lines and at the end of each unit of delay to feed the pulse into a mixer. The output of the mixers then contains five pulses, delayed in steps from zero time to 4 times the unit delay. See Plate 2, a. One mixer is used for each pulse, and the mixers are normally made inoperative by negative grid bias. When it is desired to allow a pulse to appear, the mixer is enabled by grounding a voltage divider resistor which reduces the negative grid bias on that stage. See plate 2, b.

## FIRST MODEL OF LETTER CODER

4-1 To prove the principles involved, a model was built intended to mount directly on the front of and to take its power from an AN/APX-6 transponder. As previously stated, Mark V IFF equipment was used as a matter of convenience. Plate 3 shows a block diagram with necessary connections to the transponder. Cams were used (See plate 2a) for pulse selection, one set of five sections being used for "wide" letters and another set of five sections rotating at five times the speed of the former being used for "Narrow" letters. "Narrow" and "Wide" letters were to be transmitted simultaneously, and both consisted of the letters "CH" chosen at random.

4-2 A view of the finished coder, without case, is on plate 4. A major problem was encountered in constructing the coder sufficiently small to mount on the AN/APX-6, since delay lines occupied half the case. The available voltages from the AN/APX-6 necessitated some compromise in design. High pulse attenuation encountered in the delay lines made it a difficult problem to obtain a group of pulses of uniform voltage and shape. The negative grid bias voltage applied to the mixers proved to be critical as did the values of components in the mixer pulse selecting circuits.

4-3 Tests of the coder under simulated conditions, not connected to an AN/APX-6, showed that readable letters could be obtained. (See Plate 5).

4-4 Operation when connected to the AN/APX-6 was not satisfactory for the following reasons:

- a. Since both input and output pulses were negative, ring-around resulted from the sensitive bootstrap input circuit picking up a small amount of the output pulses.
- b. The AN/APX-6 could not be reliably triggered with intervals less than 8 microseconds between pulses. The "Narrow" letters could not be transmitted.
- c. Voltage regulation on the negative grid bias circuits was not sufficiently good.

4-5 Considerable effort was expended to improve the operation of the coder, and both the AN/APX-6 and the coder were modified. The only trouble that could not be corrected was item b above, and a redesign of the AN/APX-6 modulator seemed to be required to eliminate this. The model was not considered satisfactory for flight tests and consequently it was abandoned.

## SECOND MODEL CODER

5-1 A second coder was designed to overcome the difficulties encountered in the first model. This coder was to be mounted separately and contain its own power supply. The cam system of pulse selection was replaced by a commutator and switching arrangement to allow rapid selection of nearly any letter, numeral or symbol. The coder will be discussed as three units, the Coder Unit, Commutator Unit, and Letter Selector Unit.

### Coder Unit

5-2 For a block diagram of the Coder Unit, refer to Plate 6. The input negative pulse from the AN/APX-6 is fed into a blocking oscillator. In order to minimize ring around, the recovery time of this circuit was made about 100 microseconds. The positive pulse from the blocking oscillator is fed into two groups of delay lines, one with 8 microsecond units of delay for "Wide" letters and the other with 2 microsecond units of delay for "Narrow" letters. From points along these lines, pulses are fed into the "Wide" and "Narrow" mixers. These mixers are made inoperative by the application of high negative grid bias and are enabled when an arm of the individual negative voltage divider in the grid circuit is grounded. A selector switch allows either the "Wide" or "Narrow" mixers to be operative, not both simultaneously. The train of positive pulses from the mixers is amplified and used to trigger a timed blocking oscillator. Positive pulses 0.8 microseconds in duration and 90 volts in amplitude are fed from this blocking oscillator to the modulator driver in the AN/APX-6. For wiring diagram, refer to Plate 7.

### Commutator Unit

5-3 The Commutator Unit consists of five motor-drive rotary switch sections; each with twenty positions. Each section controls the grid bias of one mixer. If a commutator bar is grounded by means of a switch, the mixer connected to that section will be enabled during the time the brush is in contact with the grounded bar. Thus the time for one revolution of the commutator is divided into twenty intervals, and a mixer can be made operative for any desired combination of these intervals by setting twenty switches. There are sufficient intervals to allow three letters to be set up leaving a space between letters. For wiring diagram, refer to Plate 8.

### Letter Selector Unit

5-4 The function of this unit is to ground any desired commutator bar. It consists of four sections, each section containing 25 push button switches arranged in a square, thus providing switching for four letters. Due to commutator limitations, only three sections are used in this model. When a push button is pressed, it locks into position and grounds the lead connected to it. At

the same time the lucite cap of the button is illuminated to indicate that the switch is grounding. Each switch is connected to a commutator bar in an arrangement that causes the coder output pulses when viewed on a PPI screen to form a facsimile of the illuminated switch positions. The push button caps for different letters are colored differently to aid in setting up letters. Almost any character may be quickly punched into the unit, and a release button allows rapid changing of characters. The finished unit is illustrated on Plate 11. For wiring, refer to Plate 8.

### Connections to AN/APX-6

5-5 Consideration was given to simplifying the connections to the transponder. A trigger output to the coder, pulse input from the coder and one relay control lead are the only connections required. One relay was added to allow the AN/APX-6 to function normally or with the coder. Refer to Plate 9 for a diagram of interconnections.

### Construction

5-6 The Coder Unit and Commutator Unit were each built on a standard half-size ATR chassis. Cables connecting the two units are detachable. The Letter Selector Unit is in a separate unit connected with soldered leads to the Commutator Unit. No effort was made to minimize either the size or weight of this model.

### RESULTS OF PRELIMINARY TESTS

6. Tests with the coder connected to a modified AN/APX-6 showed that satisfactory operation could be obtained. The amplitude of the r-f pulses from the AN/APX-6 decreased progressively in a train of pulses spaced by 2 microseconds, the fifth pulse being from 1 to 1.5 db below the power level of the first pulse. This condition was apparently due to inherent characteristics of the AN/APX-6 modulator, and no attempt was made to eliminate it. Most letters and numbers were easily readable.

### FLIGHT TESTS

7-1 Results of flight tests showed that the "Wide" letters were readily readable on the VE and VF PPI screens from 10 to 80 miles. When the 200 mile range scale was used the letters were too small to be read easily. Confusion was noted between the letters O and Q, C and G, D and O. Refer to Plates 13 through 18 for photographs taken of the indicator screen of the VE.

7-2.1 A comparison of plates 13 and 14 shows that the letters are more easily readable when the spacing between letters is increased.

Plate 15 is a display of numerals illustrating the versatility of the system.

7-2.2 Plate 16 shows the "Wide" letters viewed on the 80 mile range sweep, while Plate 17 shows the "Wide" letters presented on the 20 mile sweep. Plate 18 was taken a moment after Plate 17, with the coder switched to "Narrow" letters.

7-3.1 The "Narrow" letters could be read on the 4 and 20 mile range scales of the PPI screens and at any range on the VF expanded type B screen. Refer to Plates 19, 20, and 21 for photographs of the type B screen.

7-3.2 Plates 19 and 20 show the presentation on both the VE PPI and the VF type B indicators. The letter coded reply appears as an arc until it is expanded.

7-3.3 Plate 21 shows the presentation of two other letter groups and illustrates a fault of the present model. The action of the commutator unit is not sufficiently good; consequently some pulses are missing from their proper positions and other pulses appear where there should be none. A redesign of the commutator bars and brushes is necessary to remedy this condition.

7-3.4 The same confusion between certain letters was noted as with the "Wide" letters. An additional element of confusion results from the presence of long pulse tails on saturated signals caused by over-loading of the video amplifier in the VF indicator. At long ranges, the "Narrow" letters appeared as a narrow arc on the PPI screen much the same as a standard I.F.F. reply, but, on examination with the VF type B scope, the letters become more nearly readable. However, the letters are still not satisfactory and the direction of future work is clear. The spacing between pulses must be reduced until the construction of the letters is no longer apparent on a fast sweep, and the cause of over-shoots on saturating pulses found and corrected in the amplifier.

#### Effects of Echoes

7-4.1 It was expected that a pulse arriving at the receiving antenna over more than one path (having been reflected from an object) might be a source of clutter and tend to obscure the desired pulse pattern. Little evidence of such interference was encountered with the "Narrow" letters, none with the "Wide".

7-4.2 Assume that a pulse can reach the receiving antenna over two paths, one being the direct path from Transponder to I-R and the other path from Transponder to an object and then to the I-R. The latter path will be the longer, and the pulse arriving over it will appear at a time  $S$  after the direct path pulse. If the

difference  $S$  in the time of arrival of the pulses is such that the reflected pulse falls in the time allocated to other pulses, interference will result. Refer to Plate 22a for illustration. A reflected pulse arriving at a time less than  $S_1$  after its direct path component will not cause interference, nor will a reflected pulse arriving at a time greater than  $S_2$  after its direct path component, since these echoes do not fall in a space where another direct path pulse should appear.

7-4.5 A series of reflecting points located so that a constant difference exists between the direct Transponder to I-R distance  $D$  and the distance  $D + S$  from Transponder to the reflecting point to I-R will lie on an ellipse whose semi-minor axis given by  $\left[\frac{SD}{2}\right]^{1/2}$ . The foci of this ellipse are the Transponder and I-R.

7-4.6 Two ellipses can be drawn as in Plate 22b such that the constant path differences are  $S_1$  and  $S_2$ . The path difference from the Transponder to a point  $A$  inside both ellipses to the I-R will be less than  $S_1$ , therefore an object at  $A$  will not cause interfering echoes. Similarly, the path difference for a reflection from point  $B$  outside both ellipses will be greater than  $S_2$ , and no interference will result. Any object lying between the two ellipses, as at point  $C$ , will be capable of producing an interfering echo.

7-4.7 These ellipses are ellipsoids of revolution about an axis passing through the Transponder and I-R. Objects beyond the I-R may cause interfering reflections, but reflections from these points are discriminated against by the directional characteristics of the I-R antenna. The greatest source of interfering echoes is expected to be from reflections arising near the Transponder. These may be caused by other ships or aircraft in the formation and are accepted by the I-R antenna.

7-4.8 Echoes from objects on the ground can cause interference when the Transponder and I-R are close together, that is, within a distance determined by the line-of-sight horizon on the earth from the I-R antenna.

#### Discussion of Results

7-5.1 Results of the flight tests were satisfactory in proving the possibilities of letter coding and also in demonstrating the limitations predicted.

7-5.2 The system allowed positive and unique identification of the test plane at all times, and other information (altitude, flight plan, aerological conditions, etc.) could be transmitted by the use of preassigned code letters.

7-5.3 The rotation rate of the I-R antenna was limited to a definite range of values, depending on the distance to the Transponder. However, two speeds took care of most conditions encountered.

7-5.4 Two planes transmitting letters will yield an overlapping and unreadable letter pattern on a viewing screen if their ranges and azimuths are nearly the same. For "Wide" letters, range differences less than 3 miles or azimuth differences less than 15 degrees will result in such interference. For "Narrow" letters, the range separation must be at least 1500 yds and azimuth separation at least 10 degrees to avoid overlapping patterns.

7-5.5 The traffic handling capacity of the letter coded system is less than that of the Mk V system, since more time is required for each reply. The azimuth discrimination of the I-R antenna also must not be narrower than a calculable minimum.

7-5.6 Likewise, the transponder transmitter duty cycle is increased since more pulses are used in the reply than are normally used with the Mk V system. This means an increase of average transmitter power is required to maintain the same peak r-f power output, or a reduction in peak power output if the average power is not to be increased.

7-5.7 Most, if not all, of these limitations may be removed by the use of very narrow pulses spaced very close together.

Several advantages are thereby obtained:

(a) Traffic handling capacity of the system is increased since less time is consumed by one reply.

(b) Replying targets may be close together and still yield distinct and readable letters.

(c) Transponder duty cycle is decreased, and higher peak power may be obtained from the transmitter for a given average power input.

(d) Range and azimuth readings may be made with greater accuracy.

(e) Size of the coding equipment may be reduced by the use of shorter delay lines.

7-5.8 In investigating the small letters, difficulties may be encountered:

(a) Receiver bandwidths, both I.F. and Video, may need to be increased to satisfactorily handle very short pulses.

(b) Transmitter starting time and delay time must be minimized. Both the r-f oscillator and modulator must be capable of yielding undistorted short pulses with close pulse spacings.

#### Application for Fighter Direction

7-6.1 The number of friendly planes in the air over a sector will depend on many factors and may vary from a small combat air patrol to as many interceptors as the fighter directors can handle. Should a raid be detected, certain aircraft must be vectored to the raid as quickly as possible. With a letter-coded IFF system in use, the identity of aircraft best positioned to intercept the raid is instantly available without continuous tracking. Thus, vectors can be given to the proper aircraft almost as soon as the raid is detected.

7-6.2 There is neither the time delay inherent in systems requiring identification of planes one by one (Mk III, Mk V) nor the enormous labor and possibility of error found in systems requiring continuous tracking.

#### Application for Aircraft Traffic Control

7-7. It may be necessary to control many aircraft in a congested area under conditions of poor visibility. The IFF reply sent by an aircraft could then consist of one letter for squadron or air group identification, one or two letters for plane identification, and one letter automatically controlled to indicate altitude. A squadron would be assigned a definite area and altitude for rendezvous until it could land. The identity of any plane straying out of its assigned position will be instantly known and that plane can then be vectored back into position. The probability of collision is lessened since aircraft may be warned immediately of impending danger. Should two aircraft indicating the same altitude approach too closely, their identity is known immediately and they can be vectored out of danger. An aircraft in trouble can be identified on the scope and given directions for landing immediately.

#### CONCLUSIONS

8-1. The models built and tested proved that this scheme of coding is workable. In these tests no special equipment was needed to receive and display the letter coded reply and the restrictions placed on the receiving equipment were not abnormal.

8-2. If this system were to be applied to the Mk V IFF system for purposes of air control, satisfactory presentation of three "Wide" (five one microsecond pulses spaced 8 microseconds) letters



would be possible with an AN/UPA-3 antenna rotating at about 4 RPM and the display on such typical PPI scopes as the VE and VF. With the commutator operating at 150 RPM, letters with a height to width ratio between 2.0 and 0.5 would be obtained when the target range is from about 20 to 80 miles.

8-3. The AN/UPA-6, 7 and 8 antennas would give the above results, as would the AN/UPA-12 antenna also if it were rotated at 2 RPM, other conditions being unchanged. If the commutator were operated at 300 RPM, the AN/UPA-12 antenna could be rotated at 4 RPM.

8-4. The AN/UPA-13 antenna with its comparatively narrow beam width would give the same results when rotating at 2 RPM with the commutator rotating at 300 RPM. If the antenna RPM were 4, letters with a height to width ratio between 2.0 and 0.5 would be obtained when the target range is between 10 and 40 miles.

8-5. Results predicted for the system when used with the SR radar are the same as for the VE indicator.

8-6. The SX radar with its larger PPI scope should give a more easily read presentation when used with this system and the "Wide" letters. The combinations of IFF antenna types, rotation rates, commutator rotation rates and target ranges given in the paragraphs above apply for this case also. The type E scope would allow the "Narrow" letters to be read at any range.

8-7. If an IFF system were designed around this coding system the increase in scope clutter and decrease in traffic handling capacity and other disadvantages could be largely eliminated. This would require narrow pulses closely spaced and special display.

8-8. It should be noted that if a variable range scale is used with a PPI scope, the height to width ratio of the letters does not change as the range scale is changed.

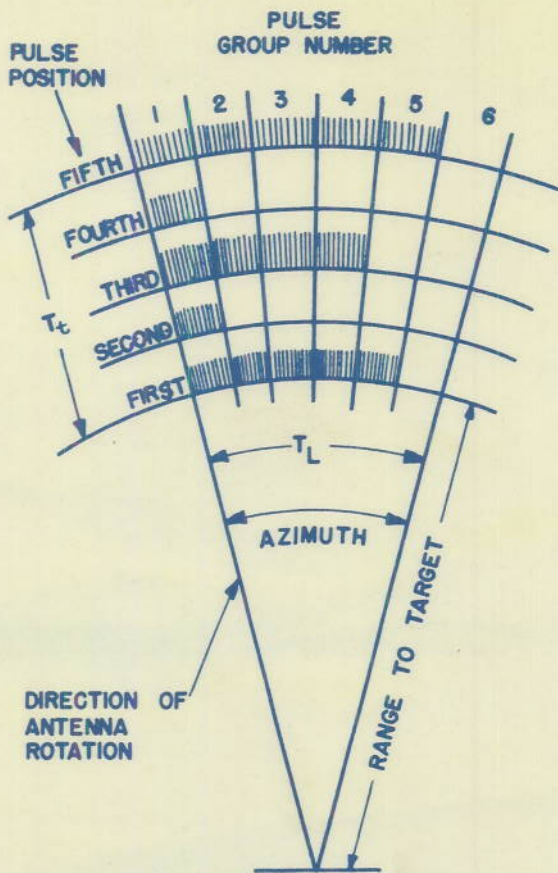
#### RECOMMENDATIONS

9-1. Further study is recommended in order to establish optimum design parameters and operating conditions. Attention should be directed toward the possibility of using very small letters composed of extremely short pulses. Technical improvements in the methods used for coding should be sought, in particular for the elimination of all mechanical contacts.

#### ACKNOWLEDGEMENTS

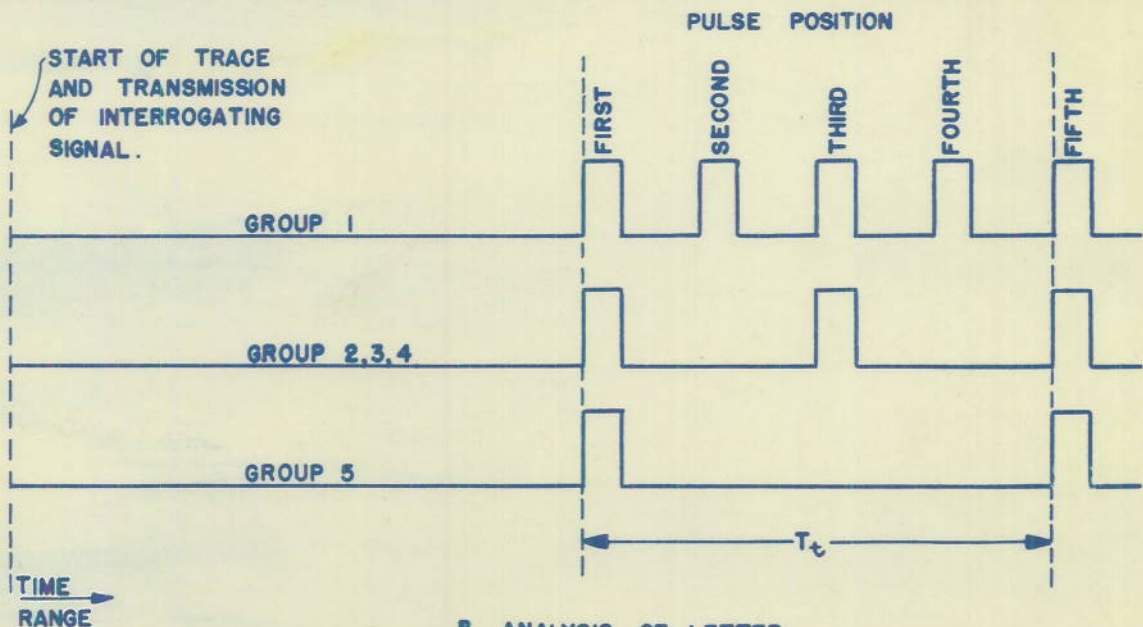
9-2. Work on this project was begun by L. W. Peay and C.C. LeGrand, who carried it through the construction of the first model coder.

Design of the Commutator Unit and Letter Selector Unit and supervision of their construction was done by E. C. Bean and C. H. Doersam.

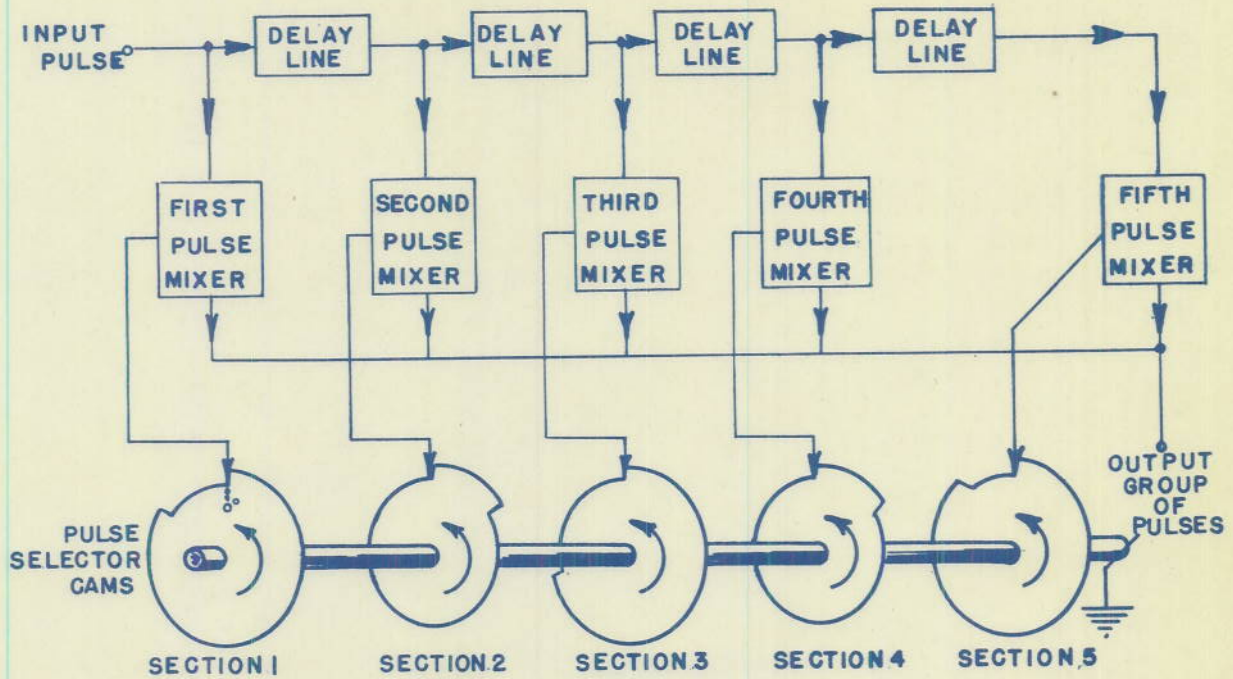


SEGMENTS REPRESENT TIME INTERVALS DURING WHICH A GROUP OF PULSES IS REPEATED AND THE CHANGE IN ANTENNA AZIMUTH DURING THIS INTERVAL.

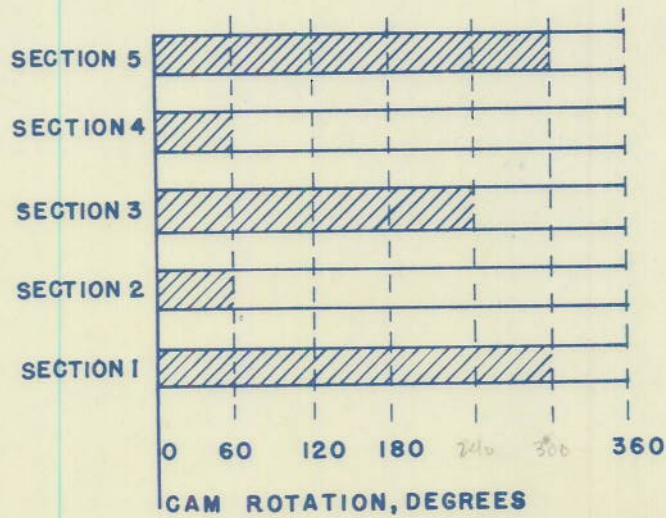
A. FORMATION OF A LETTER ON A P.P.I. TYPE SCREEN BY PULSES TRANSMITTED BY A TR AND RECEIVED BY AN IR.



B. ANALYSIS OF LETTER BY PULSE GROUPS AS VIEWED ON A TYPE "A" SCREEN.



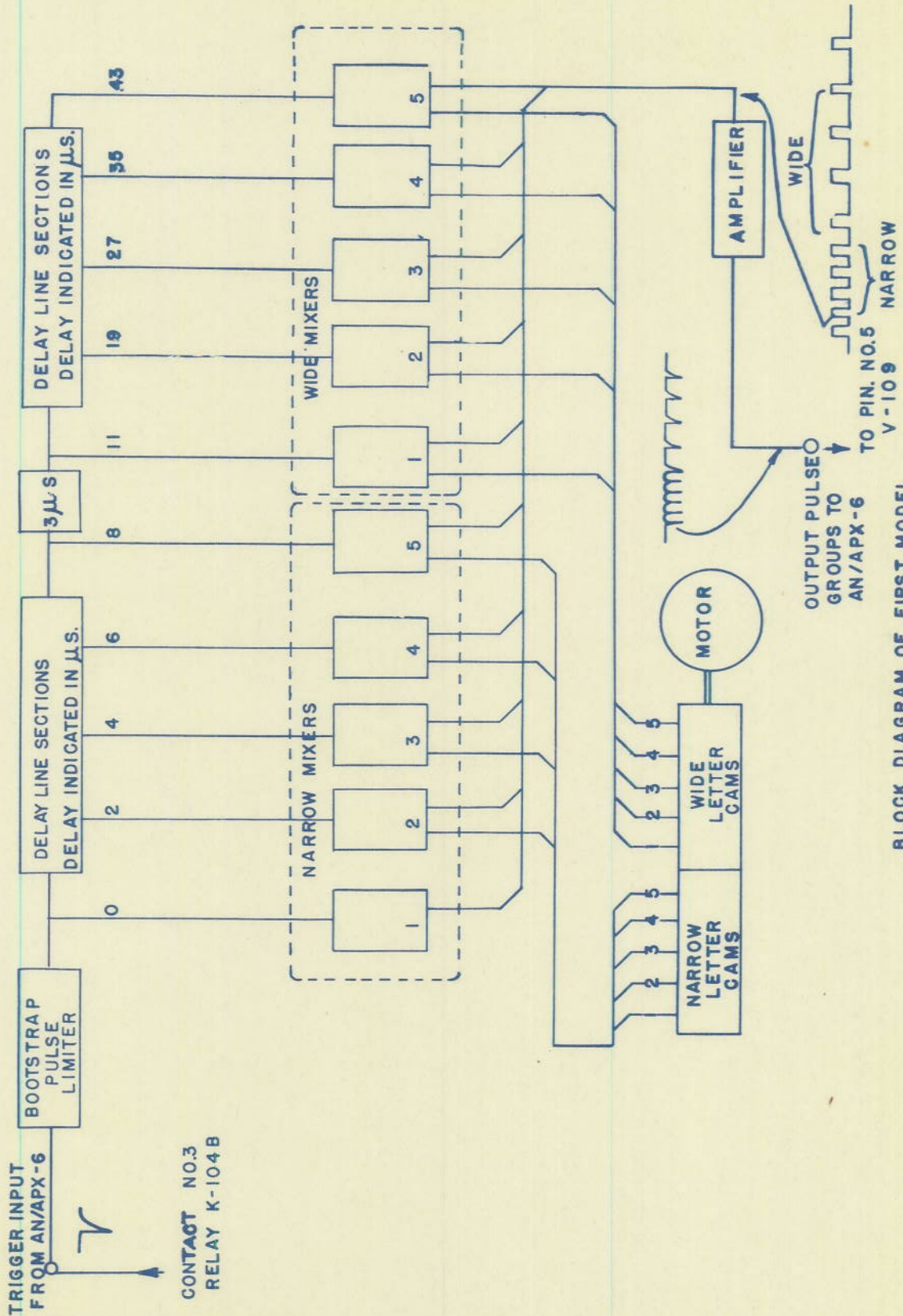
A. METHOD OF DELAYING AND SELECTING PULSES. CAMS WILL PRODUCE LETTER "E"



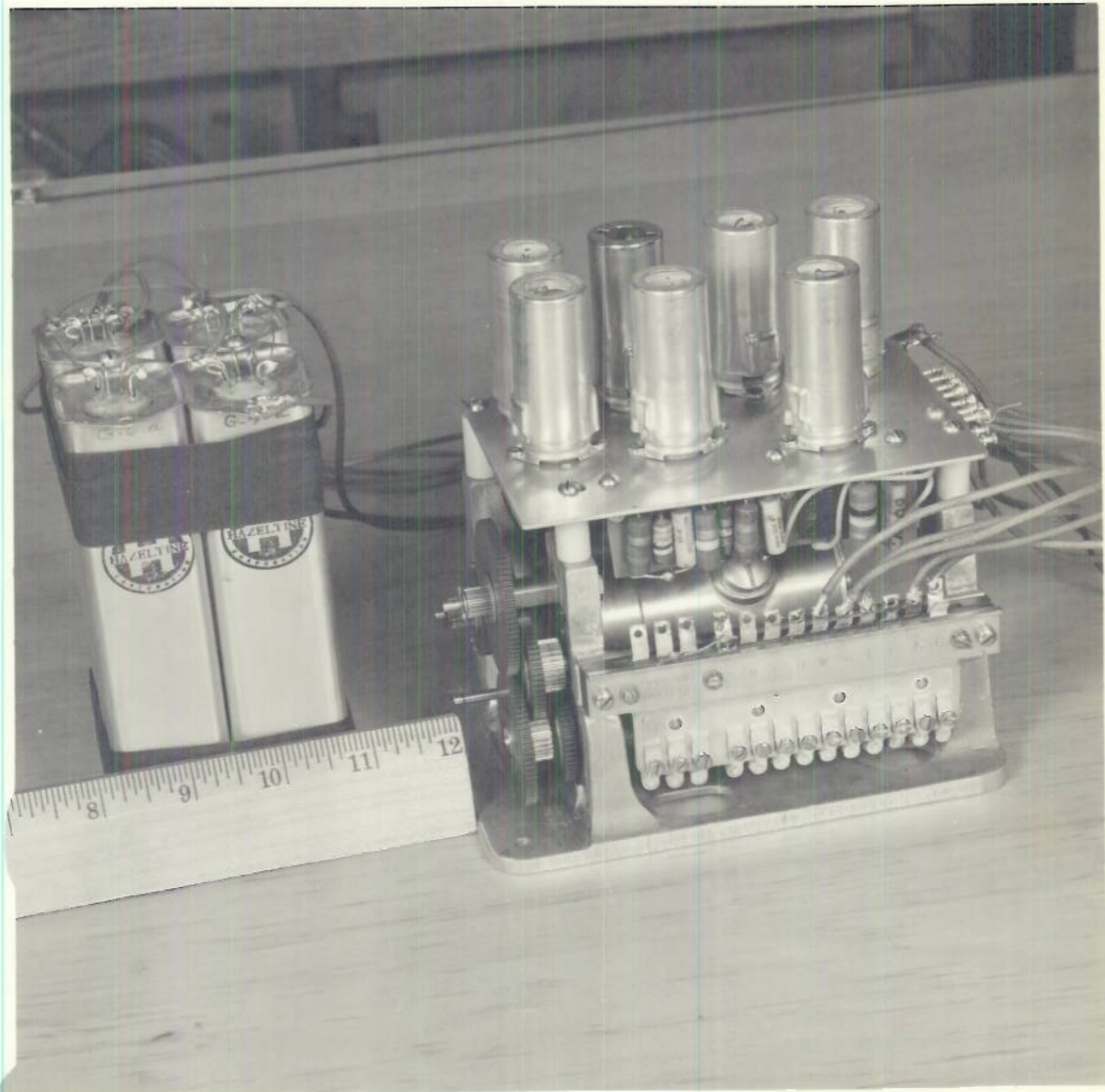
SHADED AREAS INDICATE CAM POSITIONS WHICH GROUND SWITCH CONTACT AND THUS ENABLE THE CORRESPONDING MIXER.

B. CAM CONTACT OPERATION FOR THE LETTER "E"

**SECRET**



BLOCK DIAGRAM OF FIRST MODEL CODER, SHOWING CONNECTIONS TO AN/APX-6



FIRST MODEL LETTER CODER  
CASE REMOVED

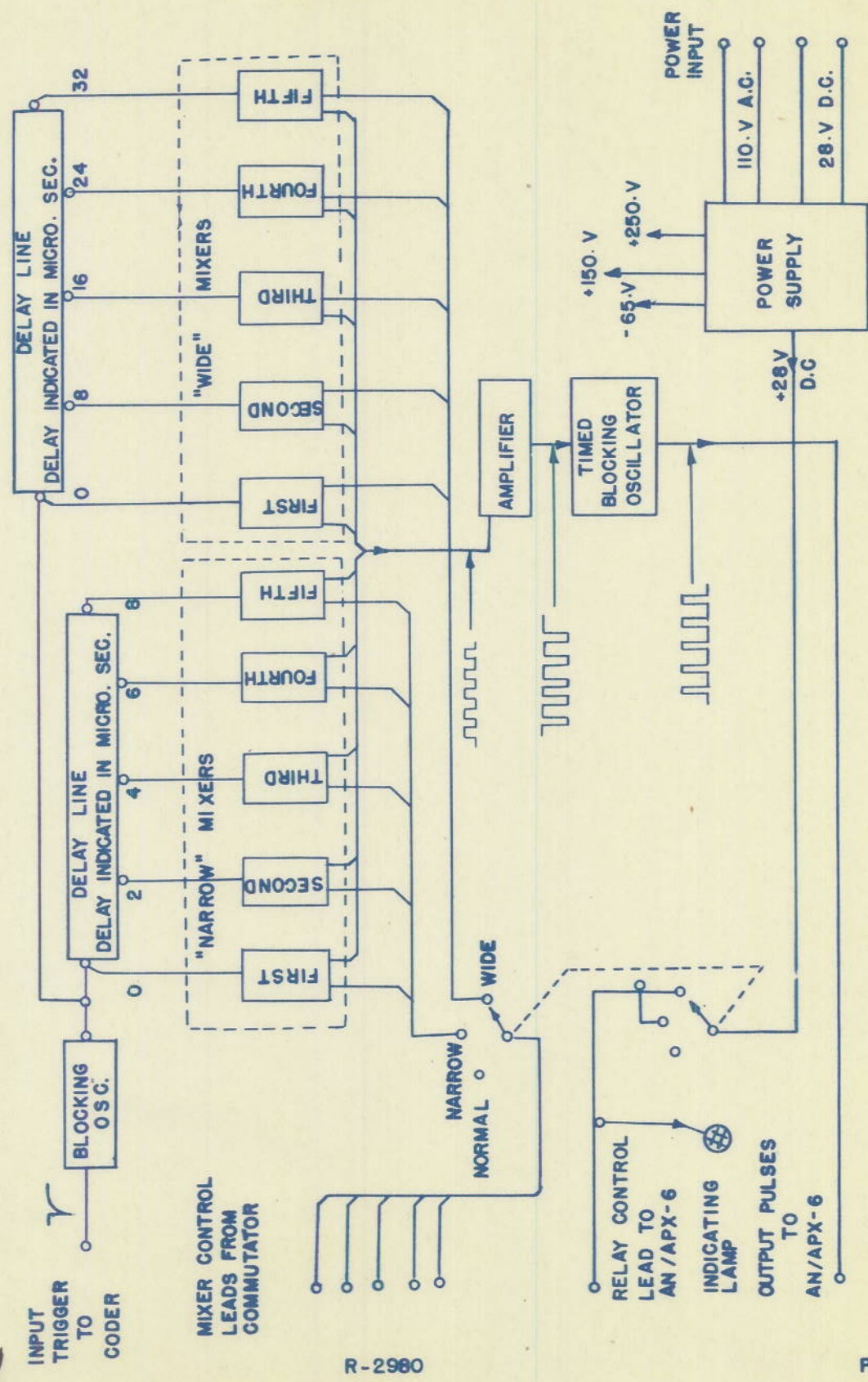
**SECRET**

PLATE 4



"WIDE" LETTERS "CH" VIEWED ON VE INDICATOR  
SIMULATED CONDITIONS  
RANGE SCALE 80 MILES

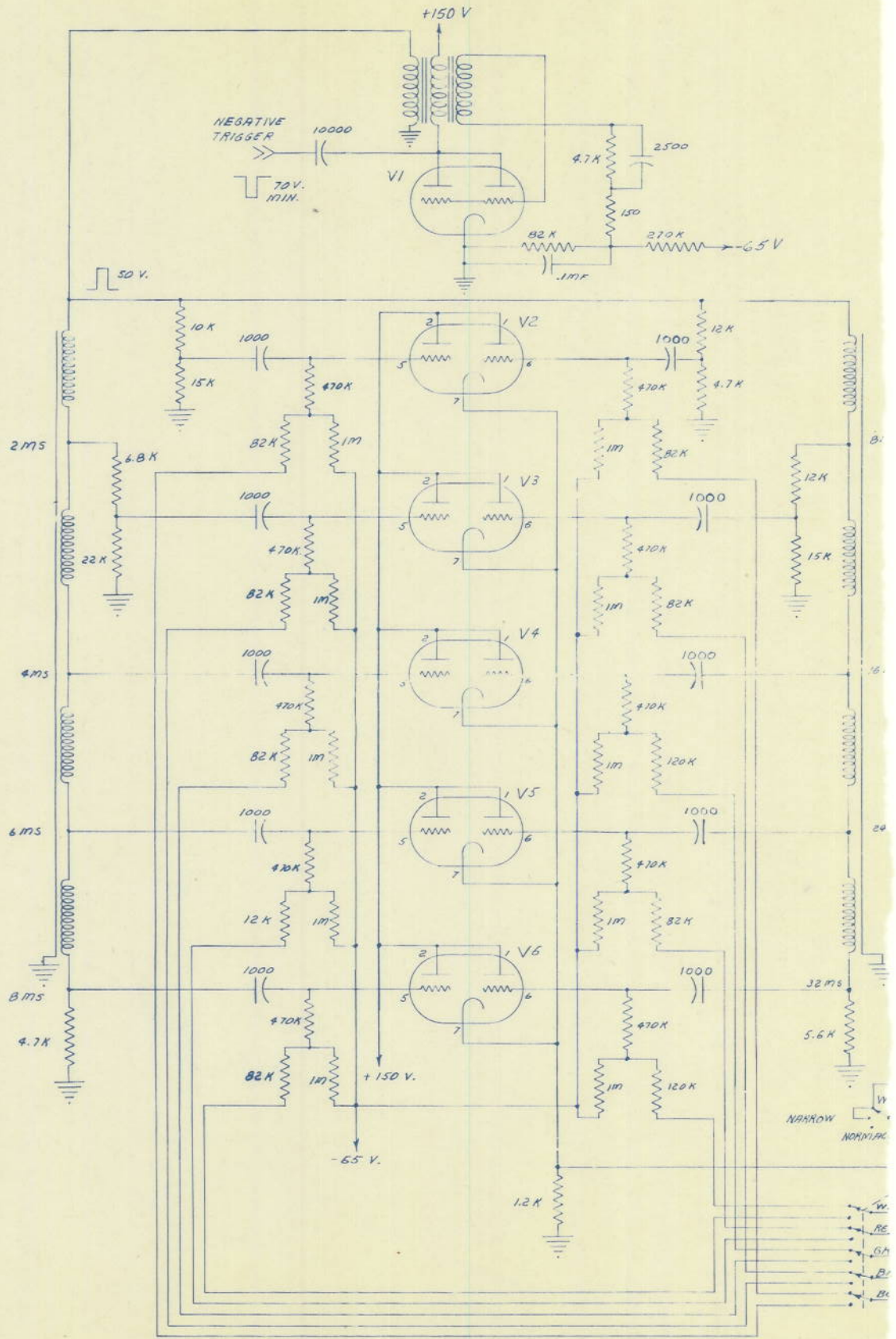
SECRET



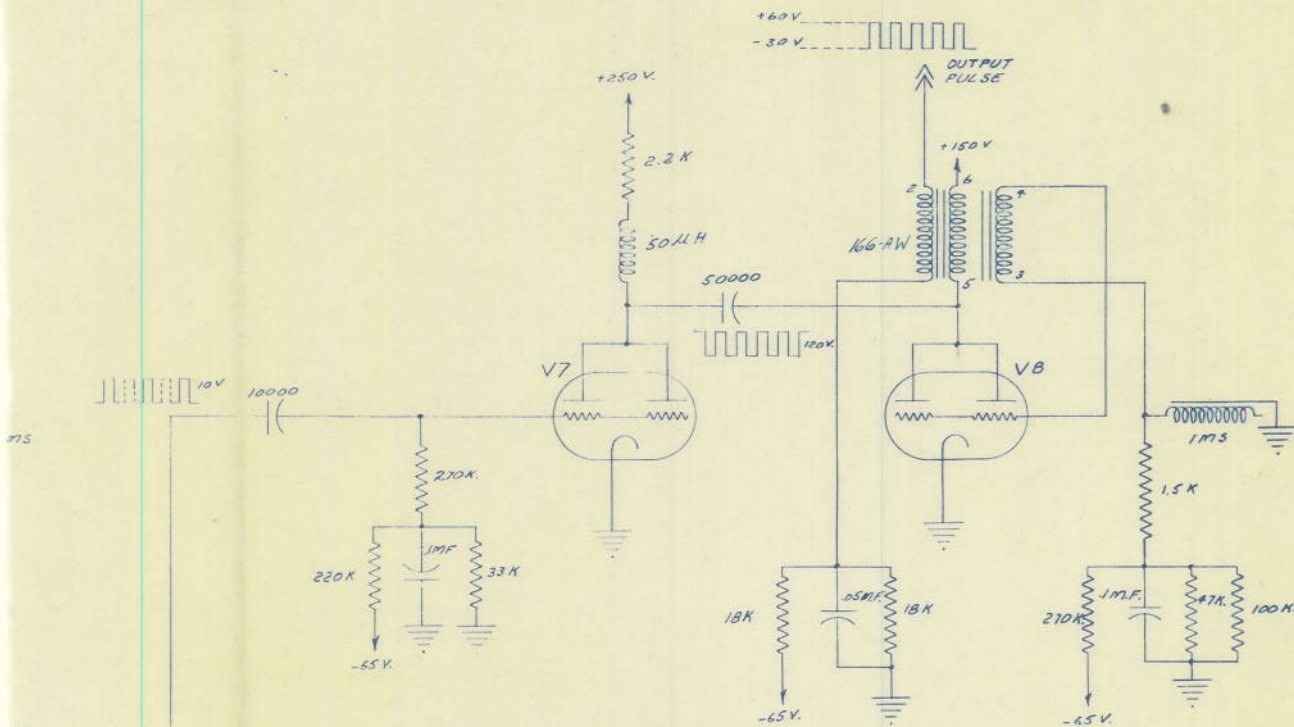
R-2980

PLATE 6

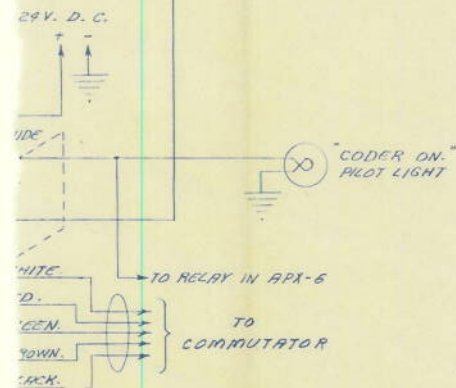
BLOCK DIAGRAM  
SECOND MODEL CODER UNIT



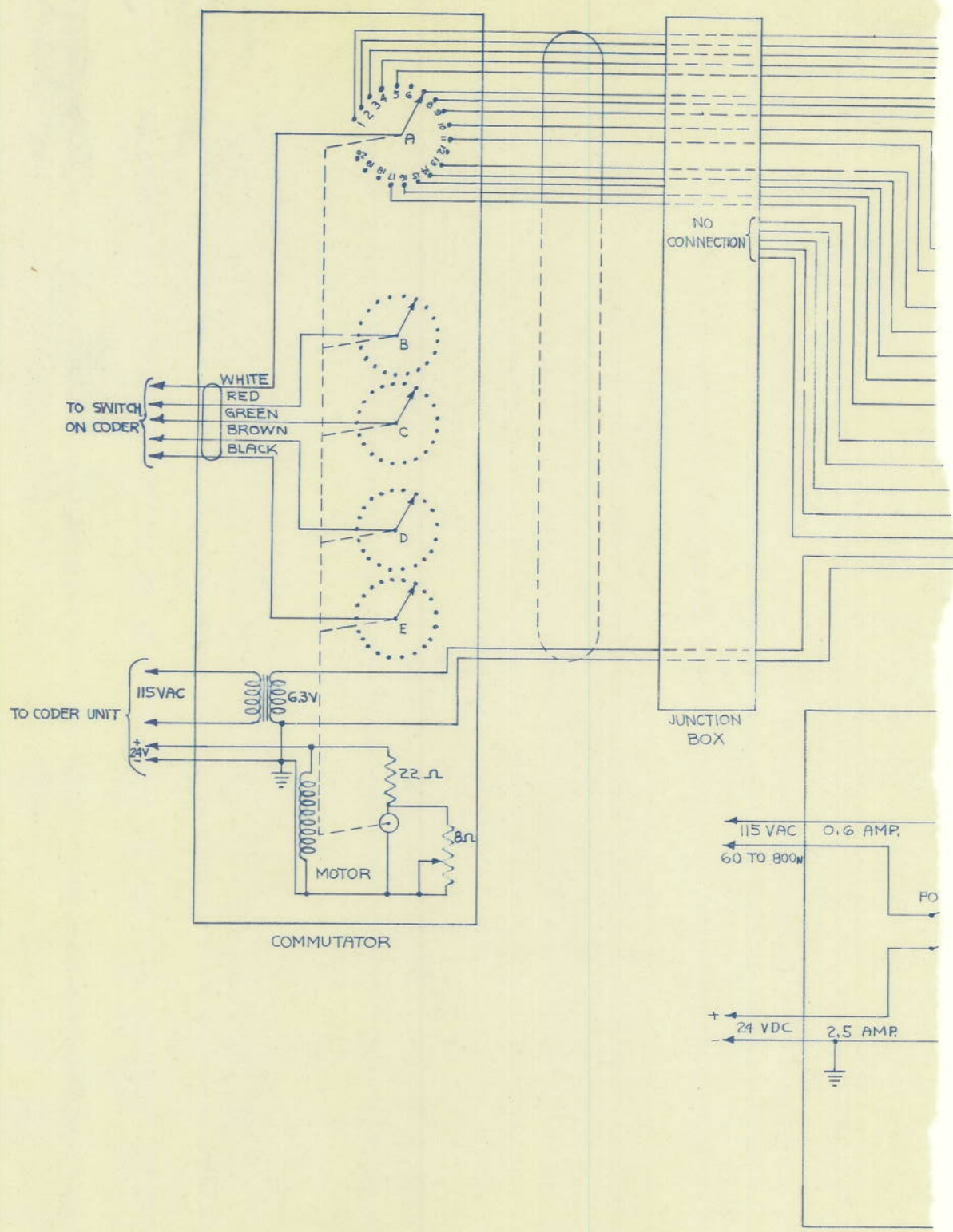
ET

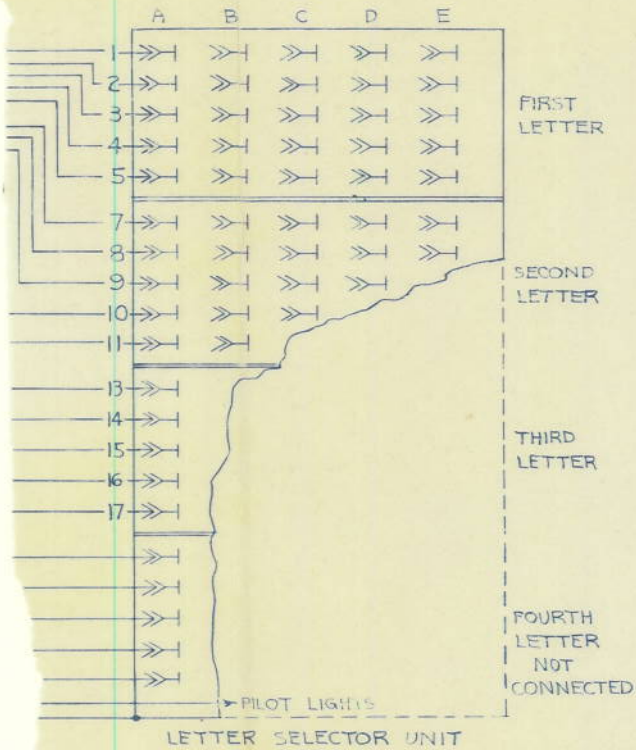


ALL TUBES 6J6  
 ALL CAPACITORS IN MICRO MICRO FARADS  
 UNLESS OTHERWISE SPECIFIED  
 POWER SUPPLY NOT SHOWN ON THIS DRAWING SEE PLATE 8



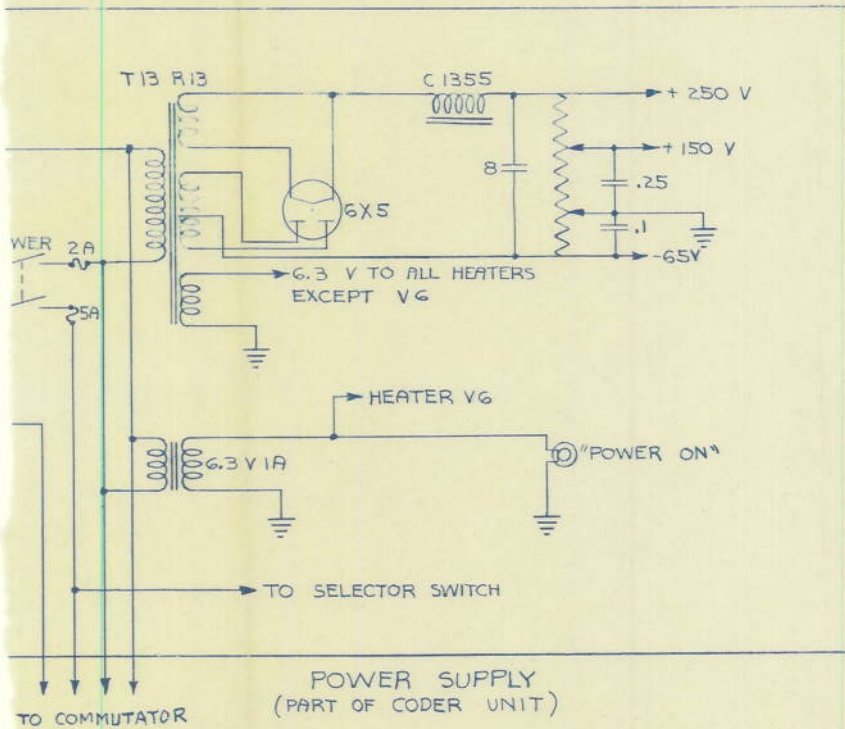
SCHEMATIC DIAGRAM  
 CODER UNIT





NOTE: SWITCH DECK "A" IS SHOWN WIRED TO ROW "A" OF THE LETTER SELECTOR UNIT. SWITCH DECKS B, C, D, & E ARE CONNECTED IN LIKE MANNER TO ROWS B, C, D, & E OF THE LETTER - SELECTOR UNIT.

THE SYMBOL  $\gg\text{---}|$  INDICATES A PUSH-BUTTON SWITCH WHICH GROUNDS THE LEAD CONNECTED TO IT WHEN THE BUTTON IS DOWN



SCHEMATIC DIAGRAM  
COMMUTATOR, JUNCTION BOX  
LETTER SELECTOR UNIT  
AND POWER SUPPLY

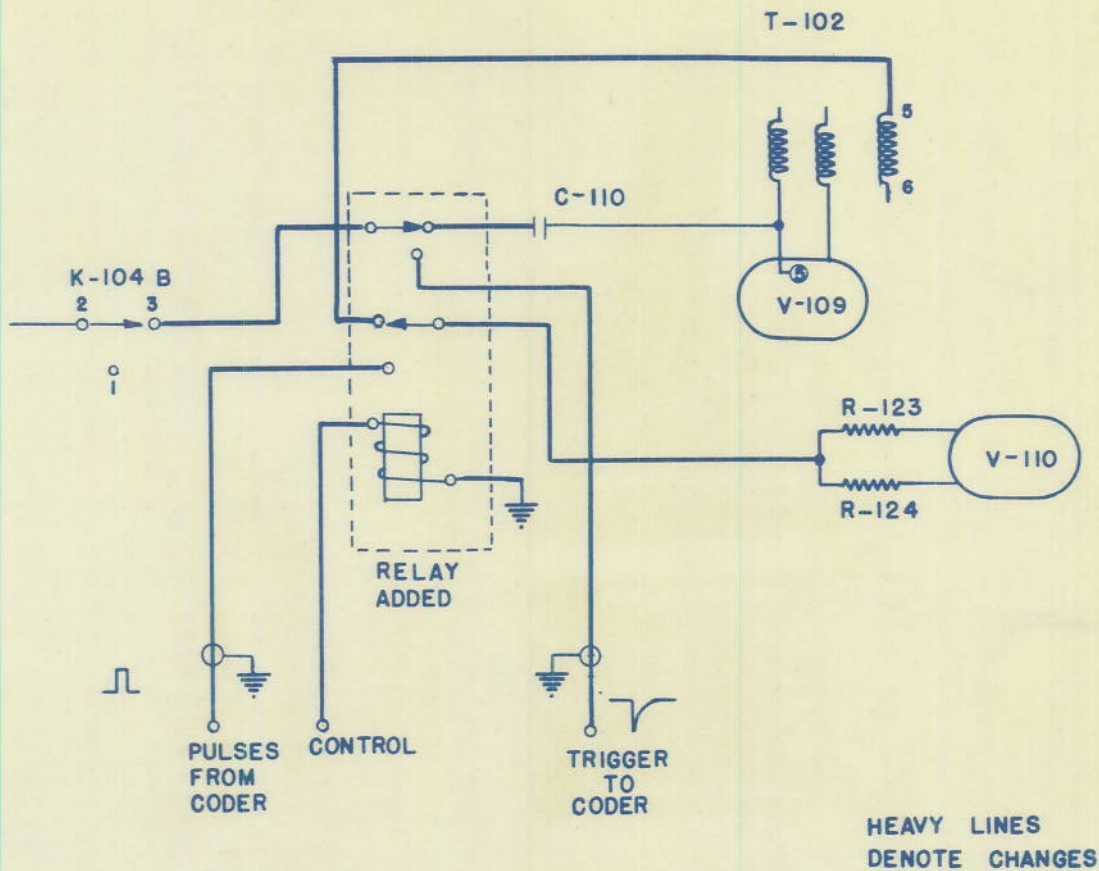
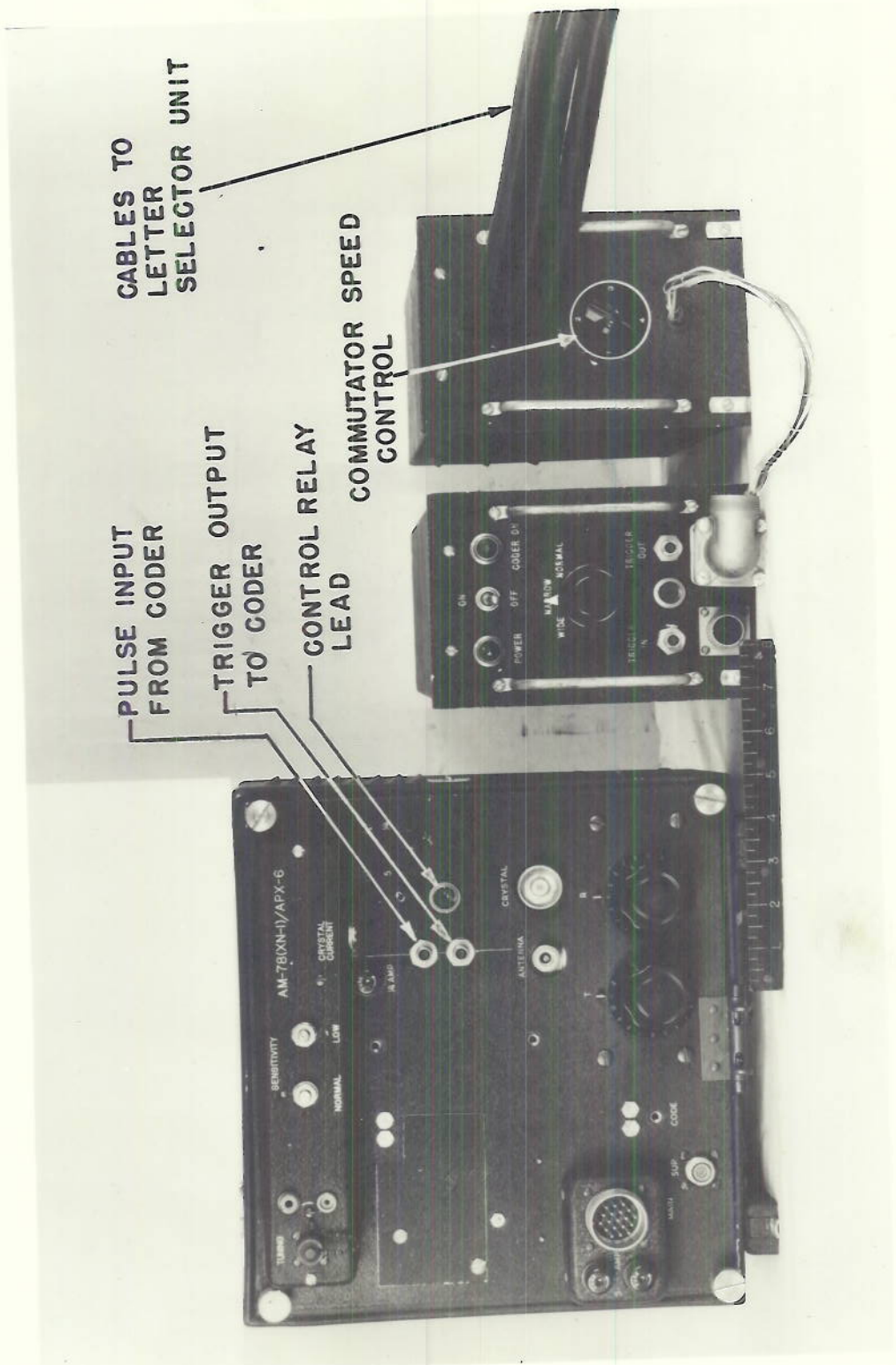


DIAGRAM OF CONNECTIONS  
AND CHANGES IN AN/APX-6 FOR  
USE WITH SECOND MODEL CODER

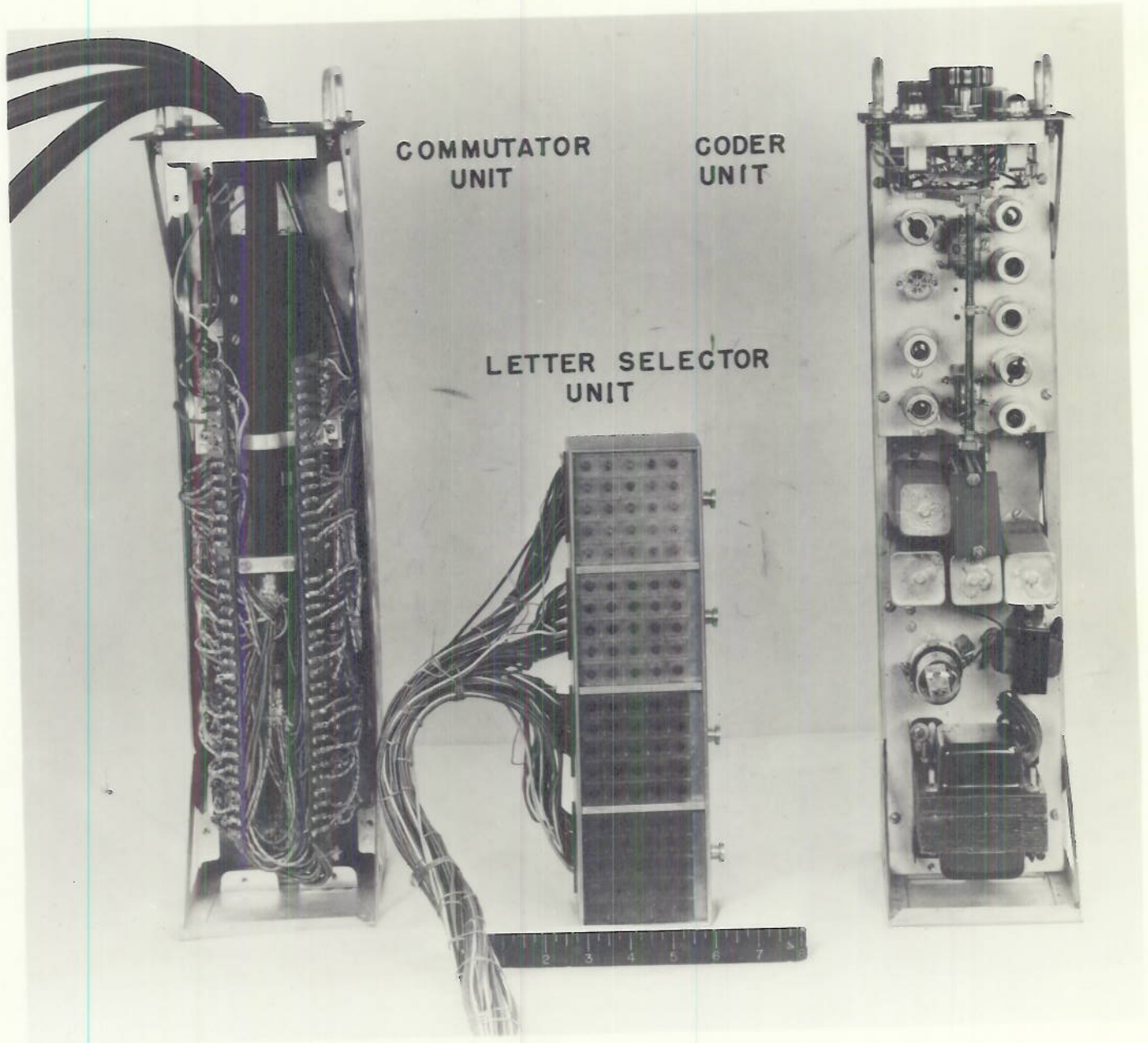
~~SECRET~~

R-2980

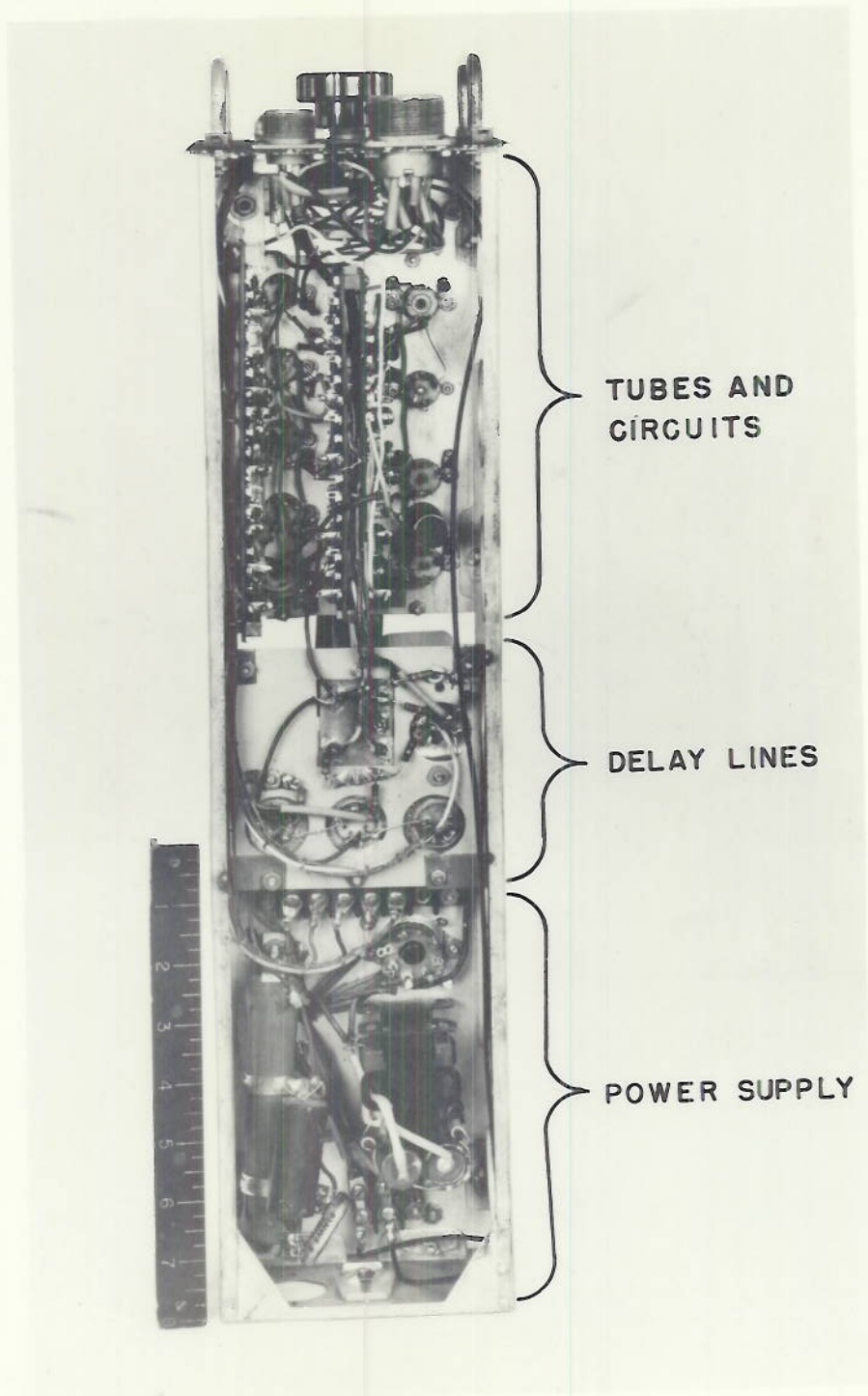
PLATE 9



**MODIFIED AN/APX-6, CODER UNIT AND COMMUTATOR UNIT**



CODER UNIT AND COMMUTATOR UNIT-COVER REMOVED, AND LETTER SELECTOR UNIT, TOP VIEW



CODER UNIT, COVER REMOVED, BOTTOM VIEW



"WIDE" LETTERS, "CEC", VIEWED ON VE INDICATOR  
RANGE TO TARGET 45 MILES  
ANTENNA RPM 6, RANGE SCALE 80 MILES  
CODER CAM RPM 150

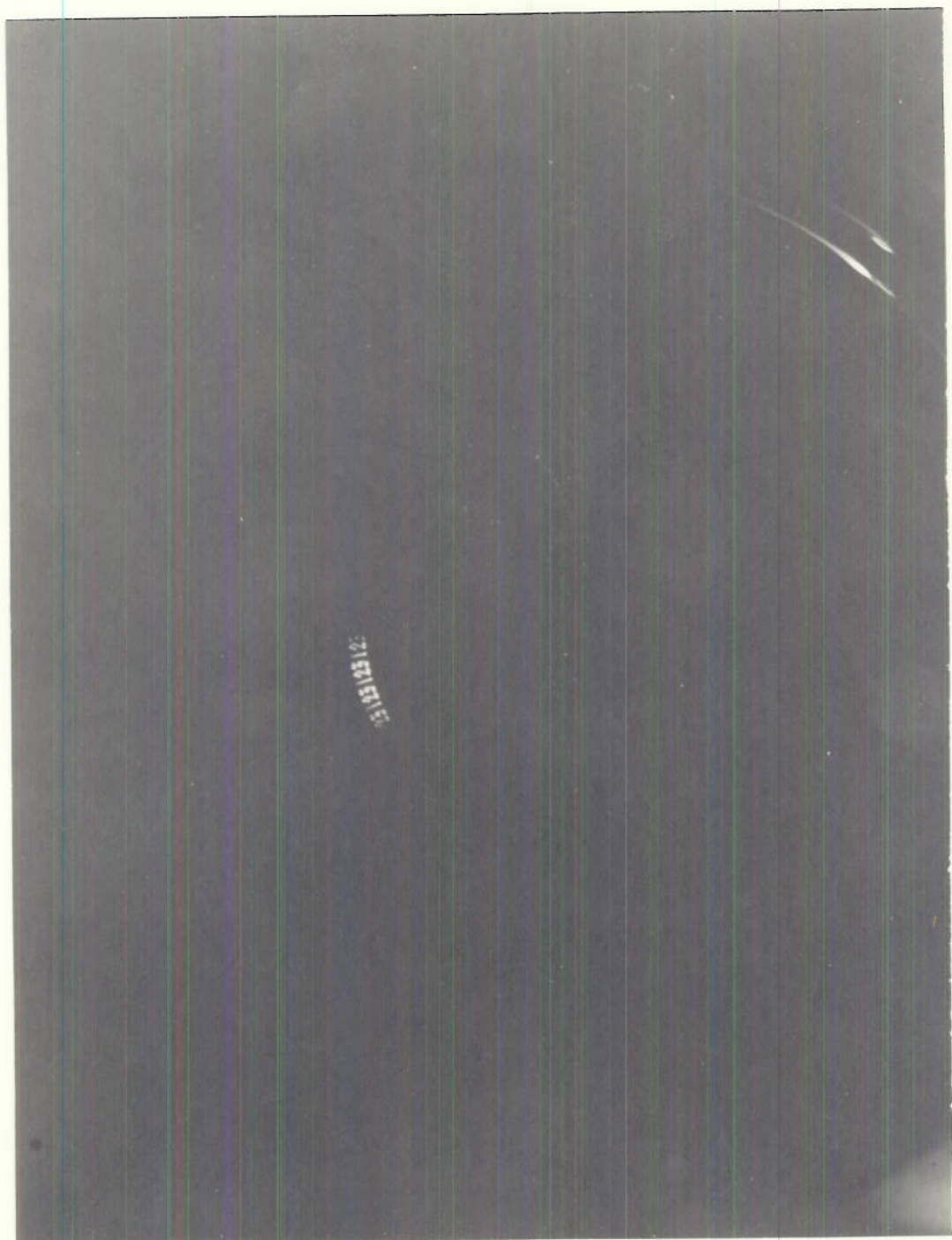
~~SECRET~~

PLATE 13

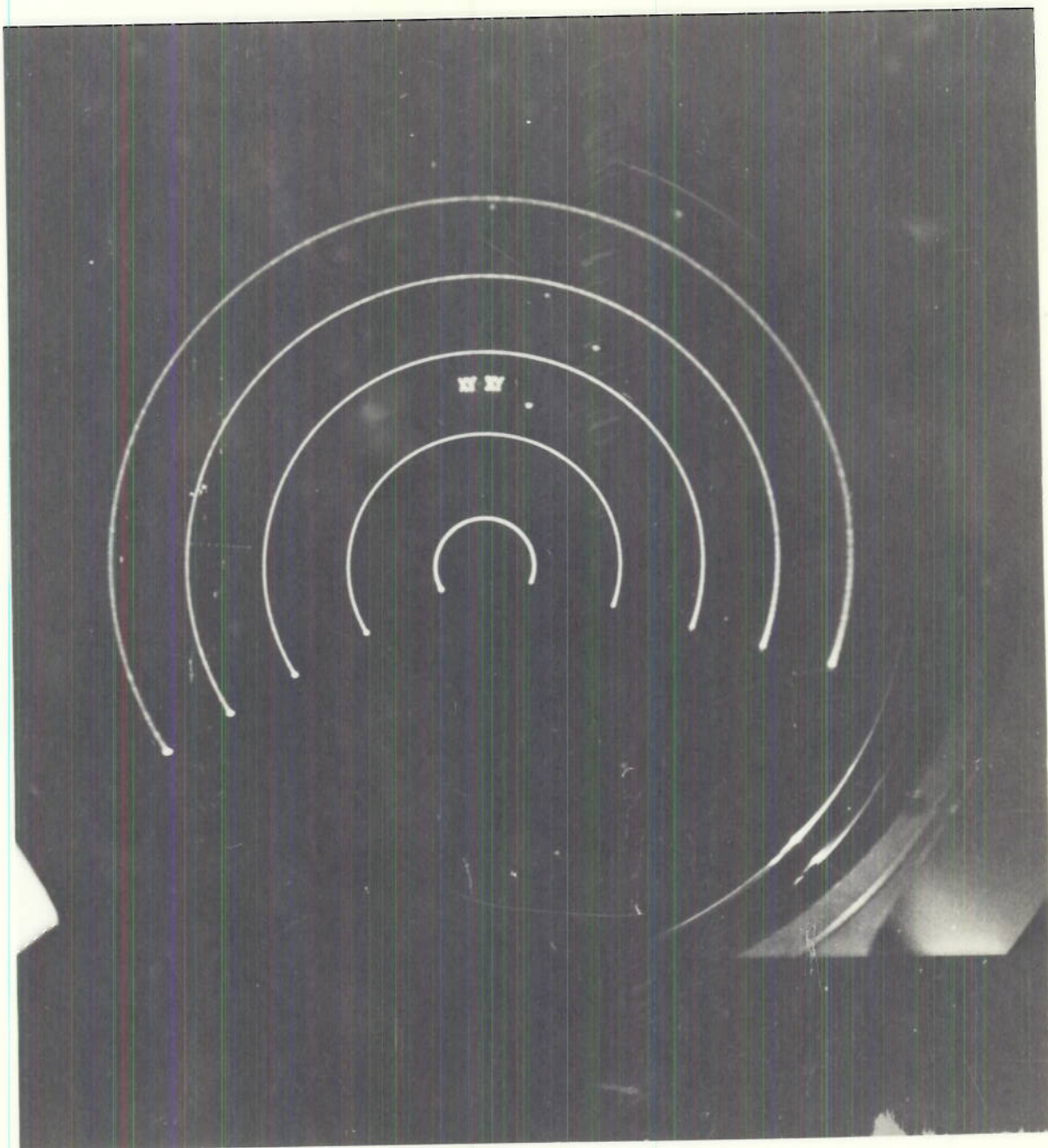


"WIDE" LETTERS "FC" VIEWED ON VE INDICATOR  
RANGE TO TARGET 50 MILES  
ANTENNA RPM 6, RANGE SCALE 80 MILES  
CODER CAM RPM 150

**SECRET**



"WIDE" NUMERALS, "1 2 3" VIEWED ON VE INDICATOR  
RANGE TO TARGET 35 MILES  
ANTENNA RPM 6, RANGE SCALE 80 MILES  
CODER-CAM RPM 150



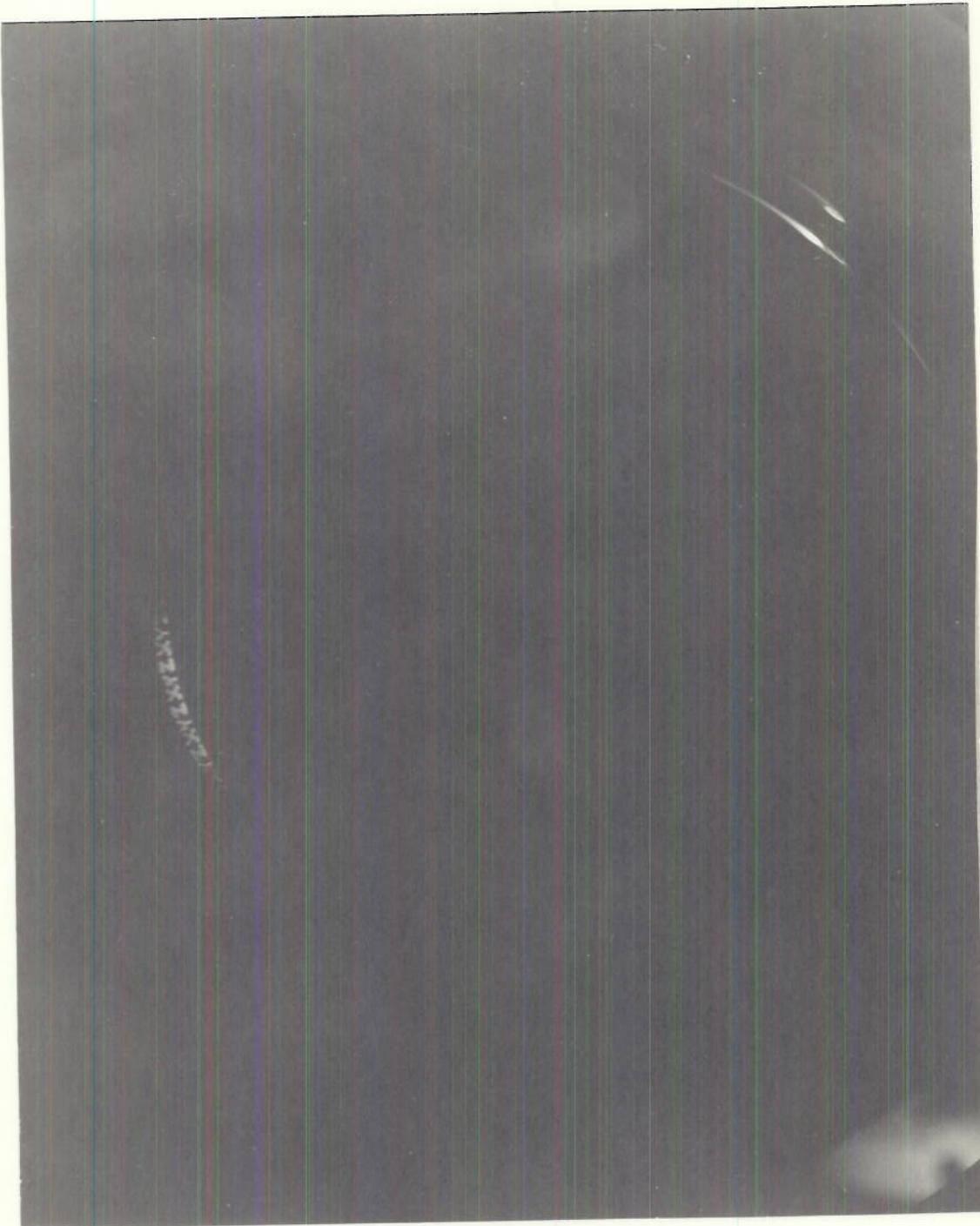
"WIDE" LETTERS "XY" VIEWED ON VE INDICATOR  
RANGE TO TARGET 33 MILES  
ANTENNA RPM 6, RANGE SCALE 80 MILES  
CODER CAM RPM 150

**SECRET**

PLATE 16



"WIDE" LETTERS "XYZ" VIEWED ON VE INDICATOR  
RANGE TO TARGET 17. MILES  
ANTENNA RPM 8, RANGE SCALE 20 MILES  
CODER CAM RPM 150



"NARROW" LETTERS, "XYZ" VIEWED ON VE INDICATOR  
RANGE TO TARGET 18. MILES  
ANTENNA RPM 6, RANGE SCALE 20 MILES  
CODER CAM RPM 150

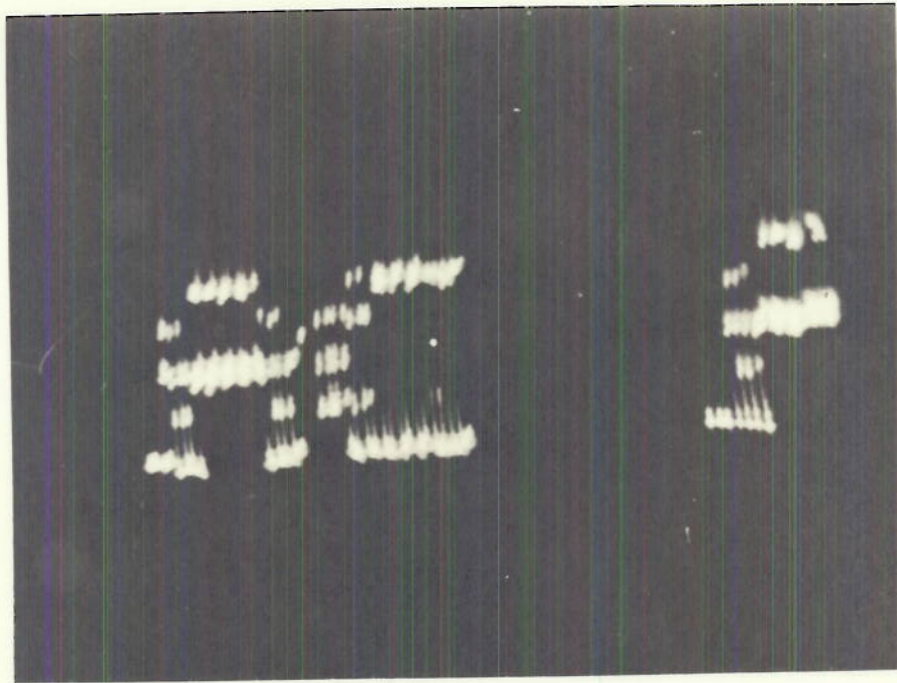
~~SECRET~~



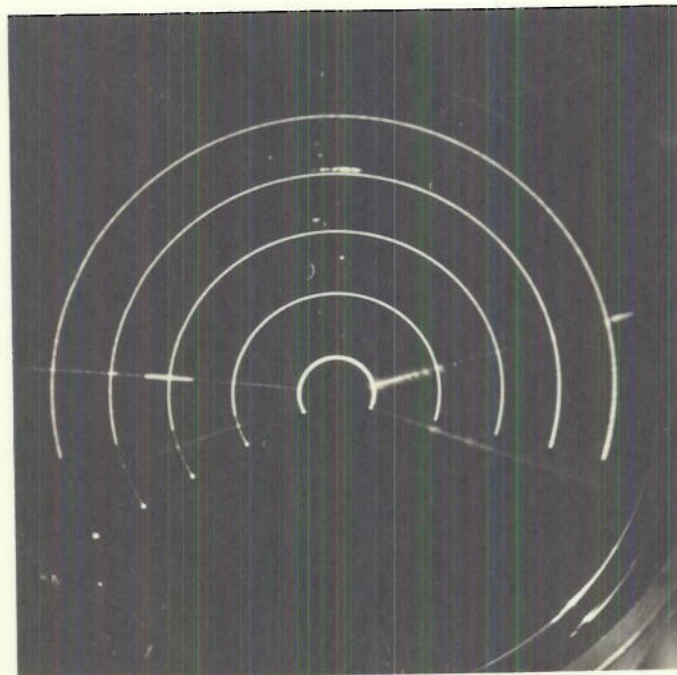
"NARROW" LETTERS "FS" VIEWED ON VF TYPE B INDICATOR  
RANGE TO TARGET 45 MILES  
ANTENNA RPM 7, CODER CAM RPM 150



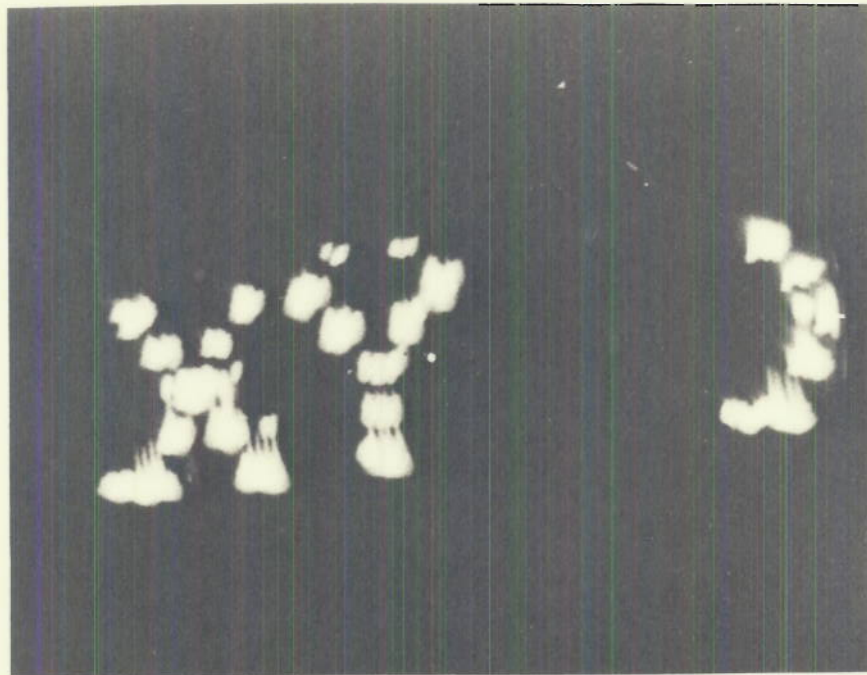
THE SAME LETTERS AND CONDITIONS AS ABOVE, SEEN AS AN ARC ON  
THE VE PPI INDICATOR.  
RANGE SCALE 200 MILES



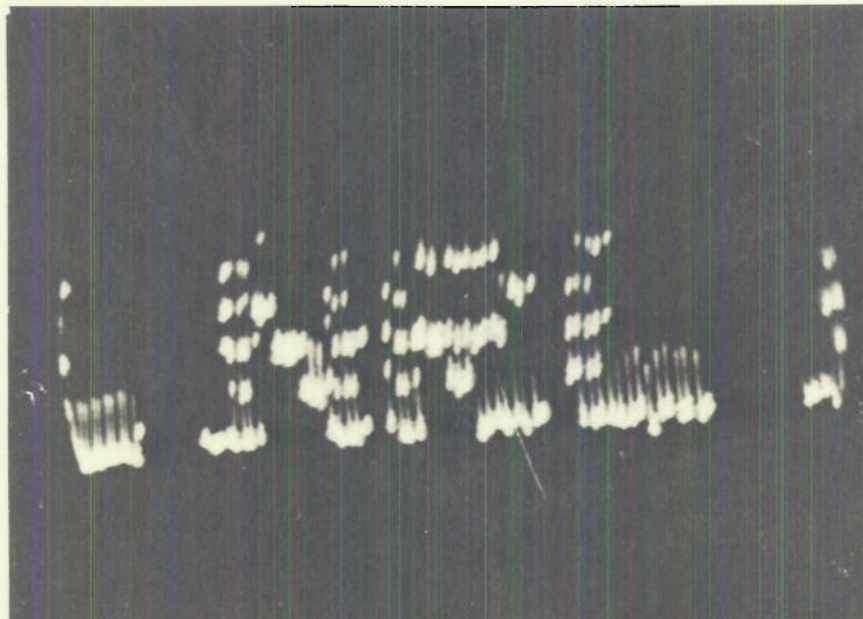
"NARROW" LETTERS "AC" VIEWED ON VF TYPE B INDICATOR  
RANGE TO TARGET 63 MILES  
ANTENNA RPM 7, CODER CAM RPM 150



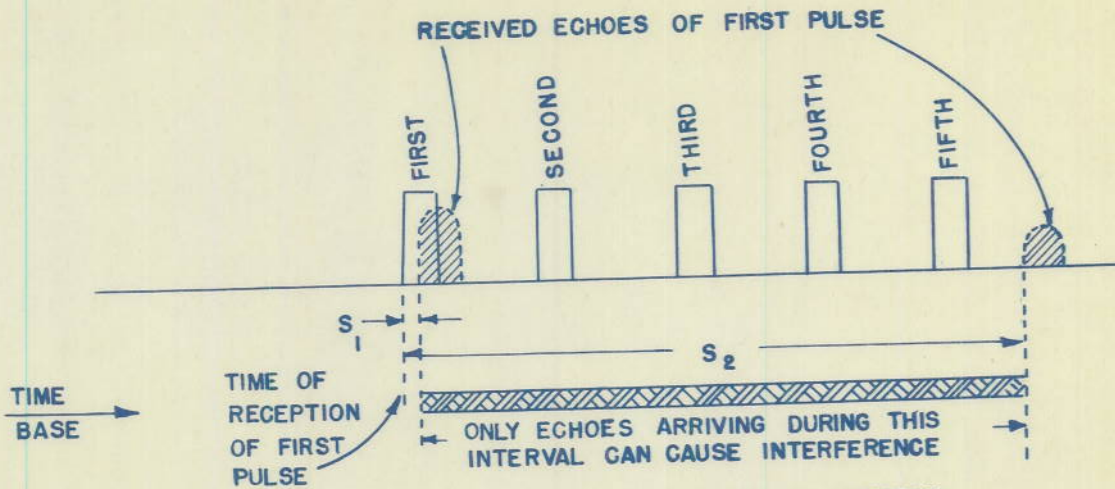
THE SAME LETTERS AND CONDITIONS AS ABOVE, SEEN AS AN ARC ON  
THE VE PPI INDICATOR.  
RANGE SCALE 80 MILES



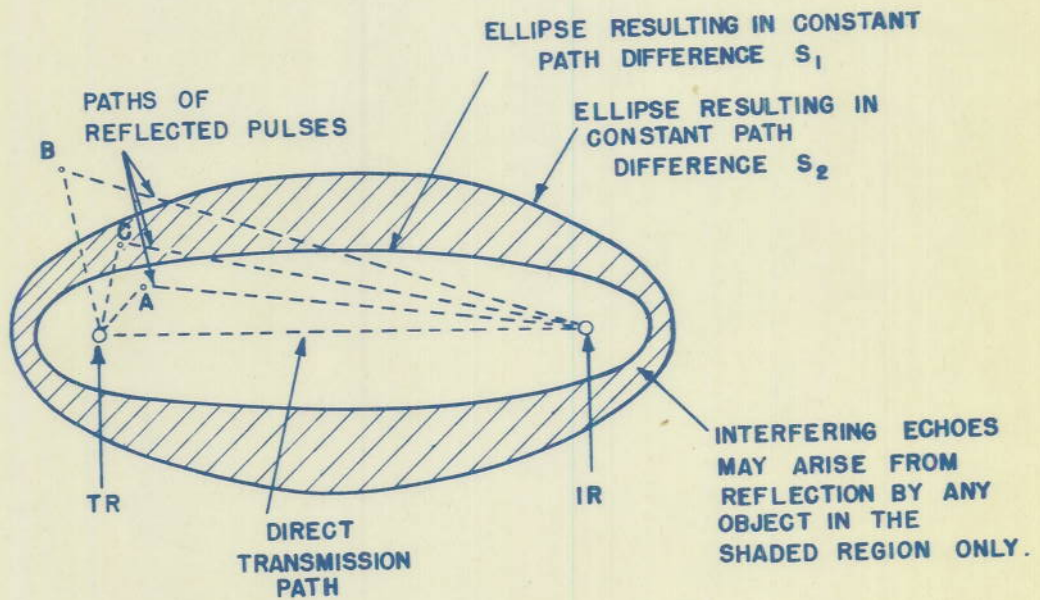
"NARROW" LETTERS "XY" VIEWED ON VF TYPE B INDICATOR  
RANGE TO TARGET 40 MILES  
ANTENNA RPM 10, CODER CAM RPM 200



"NARROW" LETTERS "HRL" VIEWED ON VF TYPE B INDICATOR  
UNDER SAME CONDITIONS AS ABOVE



a. RECEIVED PULSE PATTERN WITH ECHOES PRESENT



b. LOCUS OF REFLECTING POINTS WHICH MAY CAUSE INTERFERING ECHOES.

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