THE TYPE V PICTORIAL COMPUTER WITH AUTOMATIC CHART SELECTION
PART I
DEVELOPMENT AND INITIAL TESTS

By
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The ~~Air Navigation~~ Development Board
Under
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by
CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND
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FOREWORD

The Air Navigation Development Board (ANDB) was established by the Departments of Defense and Commerce in 1948 to carry out a unified development program aimed at meeting the stated operational requirements of the common military/civil air navigation and traffic control system. This project, sponsored and financed by the ANDB, is a part of that program. The ANDB is located within the administrative framework of the Civil Aeronautics Administration for housekeeping purposes only Persons desiring to communicate with ANDB should address the Executive Secretary, Air Navigation Development Board, Civil Aeronautics Administration, W-9, Washington 25, D. C.

SUMMARY

This report describes the Type V pictorial computer and presents the results of early laboratory and flight tests The results of more extensive tests and evaluation will be presented in Part II.

The Type V computer is an airborne display of omnibearing and distance navigation information and provides continuous airplane-position and heading indications, a mechanical chart selector, and an automatic receiver-tuning mechanism The charts are printed in route sequence on a roll of 35-mm film and are projected on a ten-inch diameter, see-through-type screen. Laboratory tests indicated that the computer meets specification requirements for an accuracy of ±0 4 nautical mile in distance, ±0 5° in bearing, and ±7° in heading Flight-test results emphasize the value of the following features (1) simplicity of control accomplished by the automatic-tuning and scale-selection features, (2) an uncluttered chart due to the projected position indicator, and (3) the huge amount of chart storage available by use of film. Two features that can be improved are the contrast of the image projected on the screen and the means of replacing obsolete charts on the film roll.

INTRODUCTION

The Type V pictorial computer, see Fig. 1, is the third of three pictorial computers developed by the Technical Development and Evaluation Center of the Civil Aeronautics Administration under the sponsorship of ANDB Five units were manufactured by Arma Corporation, Roosevelt Field, Garden City, Long Island.

Previously published reports[1,2] describe the Type III portable pictorial computer and the Type IV rotatable-panel pictorial computer. These three computers were designed to evaluate the various features of pictorial displays Laboratory investigations[3] which indicated that pictorial displays possessed much merit were completed before the specifications for these computers were prepared The additional experience gained during the manufacture, installation, and testing of these computers has indicated the relative values and shortcomings of many of the various features It is now possible to design a computer for routine operation with much confidence in the technical aspects of the design Although the suitability of some of the features cannot be determined until the computer is used under actual operating conditions, changes in these features are not likely to require a major redesign of the equipment

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[1] Logan E Setzer, "The CAA Type III Portable Pictorial Computer, Part I, Development and Initial Tests," CAA Technical Development Report No 172, October 1952

[2] Logan E Setzer, "The Type IV Rotatable-Panel Pictorial Computer, Part I, Development and Initial Tests," CAA Technical Development Report No 195, May 1954

[3] Roscoe, Smith, Johnson, Dittman, and Williams, "Comparative Evaluation of Pictorial and Symbolic VOR Navigational Displays in 1-CA-1 Link Trainer," CAA Division of Research, Report No 92, Washington 25, D C , October 1950

DESCRIPTION OF THE EQUIPMENT

General

The Type V pictorial computer provides a continuous display of heading, bearing, and distance from the selected omnibearing-distance (OBD) station The display unit is designed to be mounted in an aircraft instrument panel as shown in Fig 2, so that it is clearly visible to the pilot and to the copilot This computer requires information from an omnirange receiver and from an airborne distance-measuring equipment (DME) and may be used in any area within the range of an OBD station The charts against which the position and the heading are shown are quickly selected by means of a slewing control on the front of the panel The equipment consists of two units the display unit and the amplifier unit The amplifier unit contains all relays, special power sources, and amplifiers, is designed to be mounted in the radio rack of the aircraft, and is of standard JAN-S2 outline size A diagram of the electronic circuits of the Type V computer is shown in Fig 3, and a gearing diagram is shown in Fig 4

The front panel of the display unit provides the following indications and controls

1 A power-control switch
2 An illumination-control switch
3 An alarm-indicator meter
4 A pull-out knob to bring the spare projection lamp into position
5 A chart-engaging lever to change charts
6 A fuse holder for a 115-volt, 400-cps, 3-amp fuse
7 A fuse holder for a 26-volt, 3-amp fuse
8 A screen for projecting the charts

The housing of the display unit contains the following circuits and mechanisms

1 Distance servomotor and distance repeat-back potentiometer
2 Bearing servomotor and bearing repeat-back synchro
3 Heading servomotor and heading repeat-back synchro
4 A mechanism required to transmit the output of the servomotors to the airplane-position indicator
5 Chart-changing mechanism
6 Scale-selecting and frequency-decoding mechanism

The amplifier unit contains components for the following electronic circuits

1 Distance servoamplifier
2 Bearing servoamplifier.
3 Heading servoamplifier
4 Alarm amplifier
5 Power supply
6 Scale-selection and frequency-decoding mechanism

Servoamplifiers

Three 400-cps servoamplifiers of conventional design are required for the instrumentation of the Type V pictorial computer Signals for the range servo are obtained from the shaft orientation of a potentiometer which is in the airborne DME and which indicates the distance (up to 100 nautical miles) to the OBD station to which the DME is tuned Bearing information is obtained as a single-speed,[4] 400-cps, synchro signal in the omnibearing indicator, a component of the navigation receiver, which calculates the bearing to the OBD station Magnetic-heading information is received as a 400-cps, single-speed, synchro signal from the gyrocompass

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[4]That is, the shaft of the synchro is rotated one revolution for each 360° change of bearing or heading

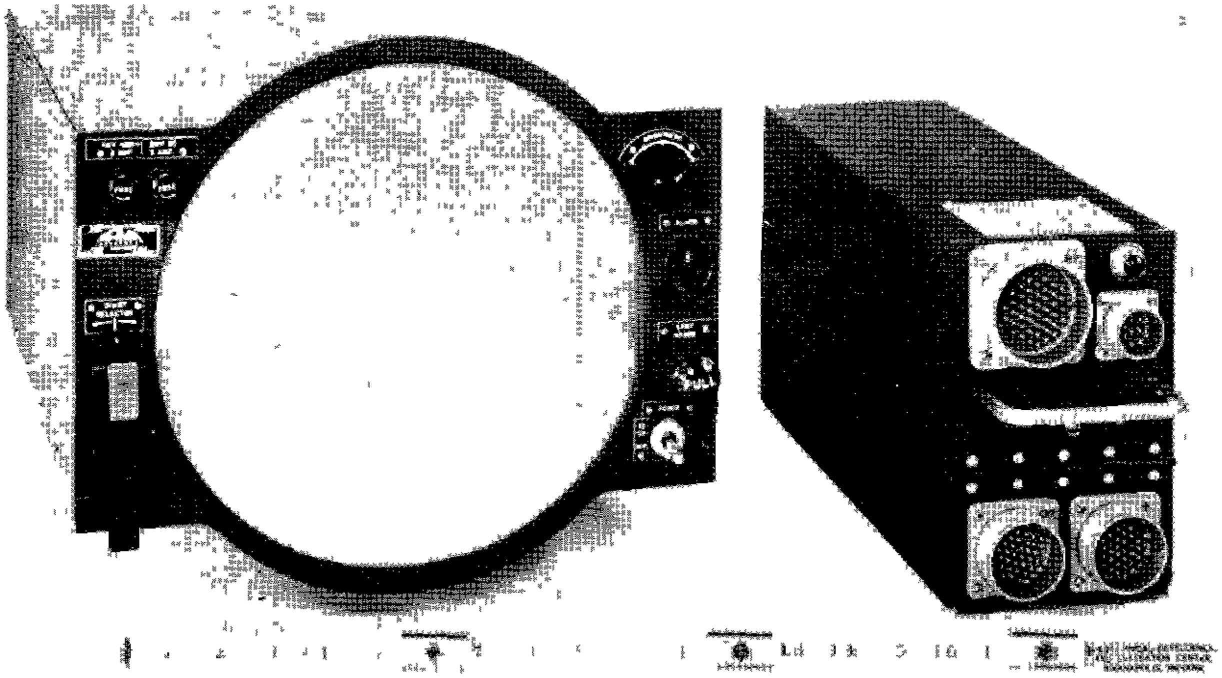

Fig 1 Type V Pictorial Computer

Operation of Display

The charts used in the Type V computer are printed photographically on 35-mm film and are projected with 10X magnification onto a 10-inch-diameter screen The center of the chart is the OBD station and is also the center of instrumentation from which the analogs of distance and of azimuth are measured Two arrangements for showing aircraft position are used in the computer One arrangement has two reticles, as shown in Fig 4, arranged so that each is in the object focal plane of the projector One reticle is engraved with bearing lines and distance circles, and the other reticle is engraved with an aircraft-heading indicator Both reticles are positioned by the azimuth-distance servos In addition, the reticle with the aircraft-heading indicator is rotated by the heading servo The image, shown in Fig 8, is the composite projection of the chart, of the position-indicator reticle, and of the heading-indicator reticle

The other arrangement has one reticle, in the object focal plane of the projector, upon which is engraved an aircraft-heading indicator This reticle is positioned by the distance-azimuth servos and is rotated by the heading servo The image shown in Figs 2 and 10 is the composite projection of the reticle and of the chart This arrangement allows a sharper and cleaner display than the first arrangement, which uses two glass reticles in the object focal plane of the projector However, the distance circles and the bearing lines of the two-reticle arrangement enable an observer to determine his position more accurately

Charts

The charts printed on the 35-mm film were prepared by the U S Coast and Geodetic Survey Features of the charts are described in a previous CAA report [5] Up to 750 charts can be stored in a 100-foot film roll Charts are printed on the film in a route-sequence order The *route sequence is made up of a series of film strips, each strip containing the* charts for OBD stations encountered on a route between two terminal cities The chart for any given station may be located in the sequence by reference to the index sheet, shown in Fig 5, which provides the number of the chart The arrangement of charts is such that the amount of film-changing required during flight is minimized and the wear on film is reduced

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[5] Roscoe, Smith, Johnson, Dittman, and Williams, op cit

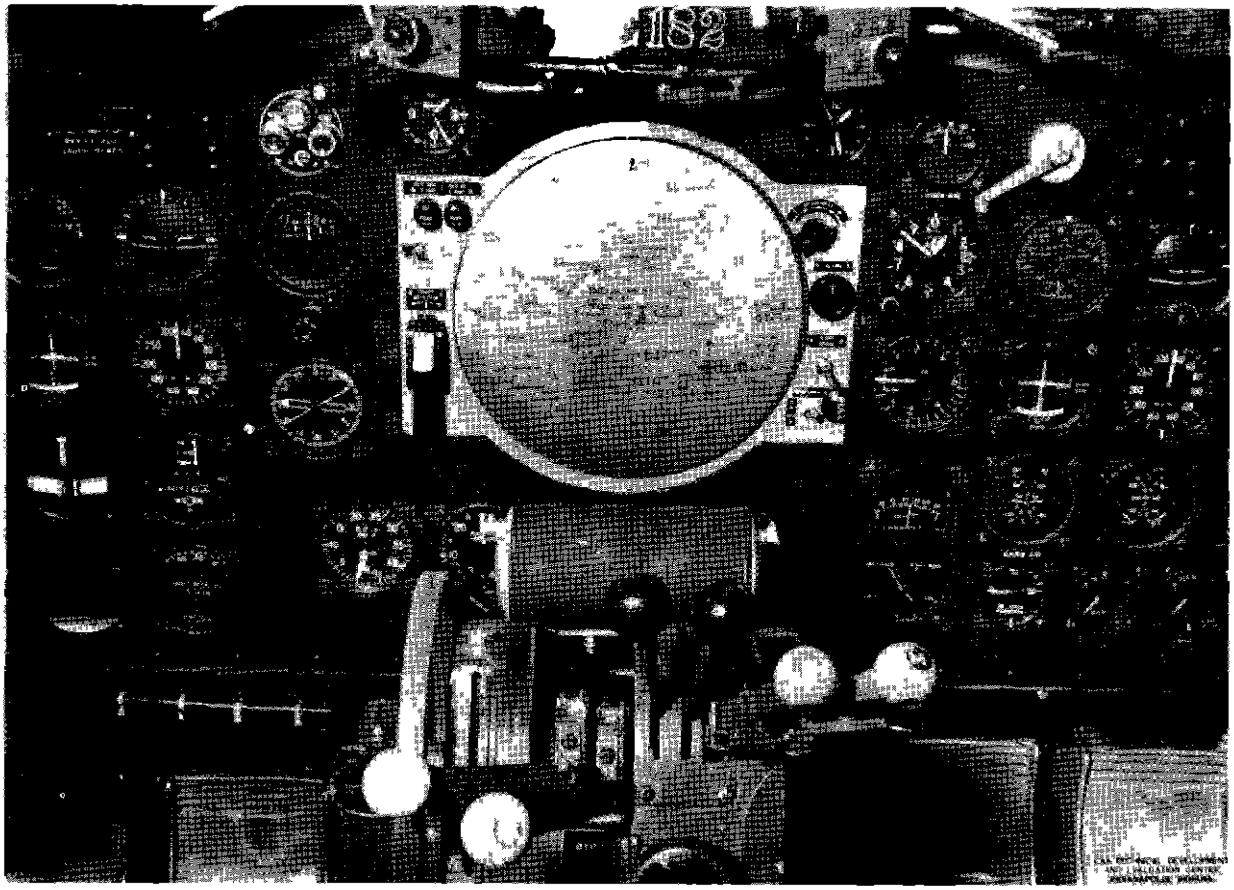


Fig 2 Type V Pictorial Computer Display Unit

The sequence shown in Fig 5 was arbitrarily chosen to include all the VOR stations in operation at the time the original film was prepared Fifty-six charts were compiled for 31 of the stations on the three routes Chicago to New York, Boston to Richmond, and Washington to St Louis Only the Chicago-to-New York route was DME-equipped at the time the charts were made Call letters, identification code, sequence number, VOR frequency, and scale factor for each station for which a chart was not compiled were printed on the film, and the tuning and scale information was punched into the film A total of 525 chart spaces were included in each of the original films

Selection of Charts

To select a chart, the slewing handle is pulled out to engage the chart-changing mechanism The handle is then turned to the right or to the left, depending on the chart or scale desired The greater the amount of turn is, the greater the slewing speed, up to a maximum slewing speed of ten charts per second The slewing may be stopped completely by positioning the handle near the center, even though the chart-changing mechanism is engaged The film may readily be driven at a speed slow enough to allow the OBD-station call letters to be read directly from the chart image

Automatic Receiver Tuning

Associated with each chart on the film roll is a series of 12 on-off code locations Nine of these locations are used to identify the particular frequency combination of the OBD-station transmitters and transponders situated at the center of each chart Three of the locations are

TABLE I

MAXIMUM AND MINIMUM DEVIATION OF POSITION INDICATOR FROM A DISTANCE CIRCLE WITH CHANGE IN BEARING

Computer Serial No	Clockwise Rotation				Counterclockwise Rotation			
	Maximum Positive Deviation (inches)	Angle at Which Maximum Positive Deviation Occurred (degrees)	Maximum Negative Deviation (inches)	Angle at Which Maximum Negative Deviation Occurred (degrees)	Maximum Positive Deviation (inches)	Angle at Which Maximum Positive Deviation Occurred (degrees)	Maximum Negative Deviation (inches)	Angle at Which Maximum Negative Deviation Occurred (degrees)
2	0	0	1/32	240	1/32	0	0	150
3	1/32	0	0	-	0	-	1/64	150
4	1/32	180	0	-	1/64	250	1/64	70
5	0	-	1/64	120	0	-	1/64	120

TABLE II

DIAMETER OF CIRCLE GENERATED BY POSITION INDICATOR DUE TO CHANGES IN HEADING

Computer Serial No	Clockwise Rotation (inches)	Counterclockwise Rotation (inches)
2	1/64	1/64
3	1/64	1/64
4	0 to 1/64	0 to 1/64
5	1/64	1/64

TABLE III

DEVIATION OF THE HEADING INDICATION

Computer Serial No	Deviation (degrees)
2	1/4
3	1/4
4	0
5	1/4

TABLE IV

TIME REQUIRED TO INDICATE 180° CHANGE IN HEADING

Computer Serial No	Time (seconds)
2	12
3	12
4	10 1/2
5	13

TABLE V

ACCURACY OF HEADING INDICATION

Heading (degrees)	Computer Indication			
	Serial No 2 (degrees)	Serial No 3 (degrees)	Serial No 4 (degrees)	Serial No 5 (degrees)
0	0	0	+ 1/4	0
30	29 1/2	30 1/2	30 1/2	30
60	59	60 1/2	60	59 1/2
90	89	90	89 3/4	89 1/2
120	120	119 1/2	120	119 1/2
150	150	149	150	149 1/4
180	180	180	180	179 1/4
210	210	209	210	209
240	240	240	239 1/2	239 1/2
270	270 1/2	269	269 1/2	269 3/4
300	301	300	299 3/4	300
330	331	330	330 1/4	330
0			+ 1/4	
Maximum Error Spread	2	1 1/2	1	1

used to automatically set up the instrumentation to correspond with the scale of the chart The coded locations consist of either holes or no holes in the film roll Pawls or fingers interrogate each coded location as soon as a chart has been selected The pawls make a sequence of electrical contacts which actuates a relay network in the amplifier unit This network in turn automatically and remotely controls the autopositioner-tuning mechanisms in both the navigation receiver (bearing) and the DME (range) in such a way that after a particular chart has been selected at the display unit the associated equipment is correctly tuned to the corresponding OBD station.

Flag Alarm

A flag alarm is provided to show failure in the signal inputs to the computer, to show failure in the computer, or to indicate that the distance to the OBD station is beyond range and that signals received are below the threshold level

LABORATORY INSPECTION AND TEST DATA

All the inspections and tests described in this section were performed on computers, Serial Nos 2, 3, 4, and 5

Automatic Frequency and Scale Selection

To determine the correctness of the wiring and of the functioning of the automatic-selection circuits, the following procedures were used

A Operation of the Manual Control Unit for DME and for Navigation-Receiver Tuning With Computer OFF

With the proper cables connected and with the computer power switch in the OFF position, continuity was checked between points on the Navigation-Receiver-Frequency-Selector unit and corresponding points on the DME and on the navigation receiver Connections on all units were checked and found correct

B Operation of the Amplifier-Unit Relays

1 When the equipment was turned ON, the five relays which transfer control from the manual-control unit to the automatic-selection relays were operated in all equipment tested
2 With the tuning fingers disconnected in the display unit, the wires corresponding to the various tuning fingers were grounded one at a time, and in each case the the corresponding tuning relay was operated
3. With the tuning fingers disconnected in the display unit, the wires corresponding to the tuning fingers were grounded in groups according to the code which had been prepared to represent each 1/10-Mc frequency from 108 0 to 117 9 Mc Continuity was checked to establish whether the corresponding frequency selection would be made in the DME and in the navigation receiver All equipment operated properly on all frequencies

Optical System

The purpose of checking the optical system is to determine (1) the accuracy with which the center of rotation of the position-indicating mechanism coincided with the center of the chart, (2) the alignment of the position indicator with the center of rotation of the heading display, (3) the functioning of the brightness control, and (4) the operation of the spare projection lamp

A Alignment of the Position Indicator With the Center of the Chart

With power ON and with a chart with range circles projected, the bearing of the airplane was rotated first clockwise and then counterclockwise through 360° on a midrange circle Deviations from range circles were observed, and the maximum and minimum deviations of magnitude and bearing were tabulated See Table I

TABLE VI

TIME REQUIRED TO INDICATE A CHANGE OF 180° IN BEARING

Computer Serial No.	Time (seconds)
2	5
3	4 1/2
4	10 1/2
5	5

B. Alignment of the Heading Indicator With the Position Indicator

The heading of the airplane was rotated first clockwise and then counterclockwise at a fixed range and bearing. The diameter of the circle generated by the center of the airplane was observed. See Table II.

C. Operation of Brightness Control.

The brightness control was checked in all positions, and operation was found satisfactory.

Servo Tests

The purpose of the servo tests was to determine the performance characteristics of the heading, bearing, and distance servomechanisms.

A. Heading-Servo Operation.

1. Alignment at 0° Heading Indication.

An omnibearing-distance indicator (OBI) was used to simulate heading signals from the gyrocompass by connecting it to the synchro input of the heading servo The computer power switch was turned on. Input to the heading servo was adjusted so that there was a voltage null between terminals S1 and S3 of the heading repeat-back synchro. The distance signal was adjusted so that the airplane-position indicator was over the OBD station,and the heading indication was observed. The zeroing pin was inserted in the heading gear train, and the heading indication was again observed. The minimum measurable angle for this test was 1/4°. The difference in the indications was recorded as the deviation of the heading indication. See Table III.

2. Direction of Rotation.

The OBI was rotated, and the correspondence of the direction of rotation of the airplane with the OBI was noted and found to be correct.

3. Maximum Rate of Change of Heading Indication.

The time required for the heading indicator to turn 180° and to indicate a heading is shown in Table IV.

4. Accuracy of Heading Indication.

A transparent polar-coordinate graph was placed over the center of the airplane with 0° aligned. The accuracy of the heading indication was checked at points shown in Table V and plotted in Fig. 6.

B. Bearing Operation.

1. Alignment at Zero Indication.

The OBI was connected to the bearing-synchro input. Equipment was turned ON. The OBI was rotated to 0° (minimum voltage across S1-S3),and the alignment of the center of the airplane with the 0° bearing mark was observed and found satisfactory.

2. Direction of Rotation.

The OBI was rotated and the correspondence of the direction of rotation of the bearing of the airplane-position indicator with the OBI was noted and found to be correct.

TABLE VII

ACCURACY OF BEARING INDICATION

Bearing (degrees)	Serial No 2		Serial No 3		Serial No 4		Serial No 5	
	Computer Indication (degrees)	Deviation (degrees)	Computer Indication (degrees)	Deviation (degrees)	Computer Indication (degrees)	Deviation (degrees)	Computer Indication (degrees)	Deviation (degrees)
2	2	0	2	0	2	0	2	0
14	14	0	14	0	13 3/4	-1/4	14 1/4	+1/4
26	26 1/4	+1/4	26 1/3	+1/4	26 1/2	+1/2	26 1/2	+1/2
38	38	0	38 1/4	+1/4	38 1/4	+1/4	38	0
50	49 3/4	-1/4	50	0	50	0	50	0
62	61 3/4	-1/4	62 1/4	+1/4	62	0	62 1/4	+1/4
74	74	0	73 3/4	-1/4	74 1/2	+1/2	74 1/4	+1/4
86	86	0	85 3/4	-1/4	86 1/2	+1/2	86	0
98	97 1/2	-1/2	97 1/4	-1/2	98 1/4	+1/4	98	0
110	109 1/4	-3/4	109 1/2	-1/2	110 1/2	+1/2	110	0
122	121 1/2	-1/2	122	0	122 1/2	+1/2	121 1/2	-1/2
134	133 1/2	-1/2	133 1/2	-1/2	133 3/4	-1/4	133 1/2	-1/2
146	145 1/4	-3/4	145 1/4	-3/4	146	0	146	0
158	157 1/4	-3/4	157 1/4	-3/4	157 1/4	-3/4	157 1/2	-1/2
170	169 1/2	-1/2	169 1/2	-1/2	169 3/4	-1/4	169 3/4	-1/4
182	181 1/2	-1/2	181 1/2	-1/2	181 3/4	-1/4	182	0
194	193 1/2	-1/2	193 3/4	-1/4	193 1/2	-1/2	194	0
206	205 3/4	-1/4	206	0	205 1/2	-1/2	205 3/4	-1/4
218	217 3/4	-1/4	217 3/4	-1/4	217 1/4	-3/4	217 1/2	-1/2
230	229 1/2	-1/2	229 1/2	-1/2	229 1/2	-1/2	229 3/4	-1/4
242	241 3/4	-1/4	241 1/4	-3/4	241 1/4	-3/4	242	0
254	253 3/4	-1/4	253 1/2	-1/2	253 1/2	-1/2	253 3/4	-1/4
266	266	0	265 1/4	-3/4	265 1/2	-1/2	266	0
278	277 3/4	-1/4	277 1/2	-1/2	277 1/2	-3/4	278	0
290	289 3/4	-1/4	289 1/2	-1/2	289 1/2	-1/2	289 3/4	-1/4
302	302	0	302	0	302	0	301 3/4	-1/4
314	313 3/4	-1/4	313 3/4	-1/4	313 1/2	-1/2	314	0
326	326	0	326	0	325 3/4	-1/4	326	0
338	338	0	338	0	338	0	338	0
350	350	0	350 1/4	+1/4	349 1/2	-1/2	350 1/4	+1/4
2	2	0	2	0	2	0	2	0
Maximum Error Spread		1		1		1 1/4		1

TABLE VIII

LINEARITY OF DISTANCE INDICATION

Range (Air-plane Position) (nm)	Serial No	Scale	Increasing Range: Resistance (ohms)	Increasing Range: Difference (ohms)	Increasing Range: Departure From Linear Indication (nm)	Decreasing Range: Resistance (ohms)	Decreasing Range: Difference (ohms)	Decreasing Range: Departure From Linear Indication (nm)
2	2	1 250,000	27 30			27 31		
				26 03	+0 06		24 58	-0 05
4			53 33			51 89		
				24 5	-0 06		25 96	+0 06
6			77 83			77 85		
				24 47	-0 06		24 55	-0 06
8			102 3			102 4		
				26 1	+0 07		24 5	-0 05
10			128 4			126 9		
				25 9	+0 05		27 4	+0 17
12			154 3			154 3		
				23 1	-0 17		24 6	-0 09
14			177 4			178 9		

$\frac{\text{Resistance 14 miles - resistance 2 miles}}{12}$ = 12 63 ohms per mile

Data for other scales for Serial No 2 are not available

Range (nm)	Serial No	Scale	Inc. Resistance (ohms)	Inc. Difference (ohms)	Inc. Departure (nm)	Dec. Resistance (ohms)	Dec. Difference (ohms)	Dec. Departure (nm)
2	3	1 250,000	33 50			31 92		
				22 84	-0 06		25 47	+0 17
4			56 34			56 39		
				23 10	-0 04		23 07	-0 04
6			79 44			79 46		
				24 61	+0 09		25 14	+0 14
8			104 05			104 6		
				22 95	-0 05		23 9	+0 03
10			127 00			128 5		
				23 20	-0 03		21 7	-0 15
12			150 20			150 2		
				24 40	+0 07		23 0	-0 04
14			174 60			173 2		

$\frac{\text{Resistance 14 miles - resistance 2 miles}}{12}$ = 11 76 ohms per mile

Range (nm)	Serial No	Scale	Inc. Resistance (ohms)	Inc. Difference (ohms)	Inc. Departure (nm)	Dec. Resistance (ohms)	Dec. Difference (ohms)	Dec. Departure (nm)
5	3	1 500,000	86 66			86 61		
				59 04	-0 04		59 09	-0 03
10			145 7			145 7		
				60 60	+0 09		59 2	-0 03
15			206 3			204 9		
				59 30	-0 02		60 7	+0 10
20			265 6			265 6		
				59 2	-0 03		59 1	-0 03
25			324 8			324 7		

$\frac{\text{Resistance 25 miles - resistance 5 miles}}{20}$ = 11 9 ohms per mile

Range (nm)	Serial No	Scale	Inc. Resistance (ohms)	Inc. Difference (ohms)	Inc. Departure (nm)	Dec. Resistance (ohms)	Dec. Difference (ohms)	Dec. Departure (nm)
10	3	1 1,000,000	136 2			132 8		
				119 2	-0 09		119 8	-0 04
20			255 4			252 6		
				122 7	+0 20		122 6	+0 19
30			378 1			375 2		
				121 4	+0 09		122 6	+0 22
40			499 5			497 8		
				118 0	-0 19		118 4	-0 16
50			617 5			616 2		

$\frac{\text{Resistance 50 miles - resistance 10 miles}}{40}$ = 12 03 Ohms per mile

TABLE VIII (Continued)

LINEARITY OF DISTANCE INDICATION

Range (Airplane Position) (nm)	Serial No	Scale	Increasing Range Resistance (ohms)	Increasing Range Difference (ohms)	Increasing Range Departure From Linear Indication (nm)	Decreasing Range Resistance (ohms)	Decreasing Range Difference (ohms)	Decreasing Range Departure From Linear Indication (nm)
20	3	1 2,000,000	265 5	241 2	+0 03	267 0	239 0	-0 15
40			506 7	240 6	-0 02	506 0	242 6	+0 23
60			747 3	242 5	+0 14	748 6	239 6	-0 10
80			989 8	239 2	-0 13	988 2	238 8	-0 17
100			1,229 0			1,227 0		
$\frac{\text{Resistance 100 miles - resistance 20 miles}}{80}$ = 12 04 ohms per mile								
2	4	1 250 000	26 1	24 5	+0 02	27 7	23 0	-0 11
4			50 6	24 5	+0 02	50 7	24 4	+0 01
6			75 1	24 5	+0 02	75 1	23 2	-0 09
8			99 6	24 5	+0 02	98 3	24 6	+0 02
10			124 1	24 5	+0 02	122 6	24 6	+0 02
12			148 6	23 2	-0 09	147 2	23 1	-0 10
14			171 8			170 3		
$\frac{\text{Resistance 14 miles - resistance 2 miles}}{12}$ = 12 15 ohms per mile								
5	4	1 500,000	62 3	66 1	+0 29	65 0	60 7	-0 14
10			128 4	62 0	-0 04	125 7	64 8	+0 18
15			190 4	62 1	-0 03	190 5	60 5	-0 16
20			252 5	61 9	-0 05	251 0	62 0	-0 04
25			314 4			313 0		
$\frac{\text{Resistance 25 miles - resistance 5 miles}}{20}$ = 12 5 ohms per mile								
10	4	1·1,000,000	142 9	129 8	+0 35	142 8	125 6	+0 02
20			272 8	125 7	+0 02	268 4	128 2	+0 22
30			398 5	123 6	-0 06	396 6	124 0	-0 11
40			522 1	125 4	0 0	520 6	122 4	-0 24
50			647 5	122 3	-2 5	643 0	124.0	-0 11
60			769 8			767 0		
$\frac{\text{Resistance 60 miles - resistance 10 miles}}{50}$ = 12 5 ohms per mile								

TABLE VIII (Continued)

LINEARITY OF DISTANCE INDICATION

Range (Airplane Position) (nm)	Serial No	Scale	Increasing Range Resistance (ohms)	Increasing Range Difference (ohms)	Increasing Range Departure From Linear Indication (nm)	Decreasing Range Resistance (ohms)	Decreasing Range Difference (ohms)	Decreasing Range Departure From Linear Indication (nm)
20	4	1 2,000,000	299 9			294 2		
40			552 5	252 6	+0 21	547 2	253 0	+0 24
60			806 5	254 0	+0 32	800 0	252 8	+0 22
80			1,054 0	247 5	-0 20	1,051 0	251 0	+0 08
100			1,300 0	246 0	-0 32	1,298 0	247 0	-0 24
$\frac{\text{Resistance 100 miles - resistance 20 miles}}{80}$ = 12 5 ohms per mile								
2	5	1 250,000	1,044 0			1,044 5		
4			1,025 0	19 0	+0 06	1,025 0	19 5	+0 12
6			1,006 0	19 0	+0 06	1,006 0	19 0	+0 06
8			988 6	17 4	-0 11	989 0	17 0	-0 15
10			969 6	19 0	+0 06	970 0	19 0	+0 06
12			951 6	18 0	-0 04	952 0	18 0	-0 04
14			933 6	18 0	-0 04	933 0	19 0	+0 06
$\frac{\text{Resistance 14 miles - resistance 2 miles}}{12}$ = 9 2 ohms per mile								
5	5	1 500,000	1,019 0			1,019 3		
10			973 0	46 0	+0 03	973 6	47 7	+0 21
15			927 0	46 0	+0 03	928 5	45 1	-0 07
20			881 0	46 0	+0 03	881 3	47 2	+0 16
25			836 0	45 0	-0 08	836 0	45 3	-0 05
$\frac{\text{Resistance 25 miles - resistance 5 miles}}{20}$ = 9 15 ohms per mile								
10	5	1 1,000,000	962 0			959 8		
20			859 5	102 5	+0 16	858 7	101 1	+0 02
30			759 5	100 0	-0 09	758 7	100 0	-0 09
40			658 4	101 1	+0 02	655 7	103 0	+0 21
50			558 3	100 1	-0 08	559 5	96 2	-0 47
$\frac{\text{Resistance 50 miles - resistance 10 miles}}{40}$ = 10 09 ohms per mile								

TABLE VIII (Continued)

LINEARITY OF DISTANCE INDICATION

Range (Airplane Position) (nm)	Serial No	Scale	Increasing Range			Decreasing Range		
			Resistance (ohms)	Difference (ohms)	Departure From Linear Indication (nm)	Resistance (ohms)	Difference (ohms)	Departure From Linear Indication (nm)
20	5	1 2,000,000	871 0			874 5		
				202 0	-0 18		205 7	+0 19
40			669 0			668 8		
				206 7	+0 28		205 4	+0 16
60			462 3			463 4		
				204 8	+0 10		203 5	-0 03
80			257 5			259 9		
				202 0	-0 18		204 65	+0 07
100			55 5			55 25		

$$\frac{\text{Resistance 100 miles} - \text{resistance 20 miles}}{80} = 10\ 19 \text{ ohms per mile}$$

TABLE IX

DISTANCE ERROR REQUIRED TO OPERATE FLAG-ALARM INDICATION

Computer Serial No	Distance (miles)
2	1 8
3	1 8
4	1 8
5	1 5

TABLE X

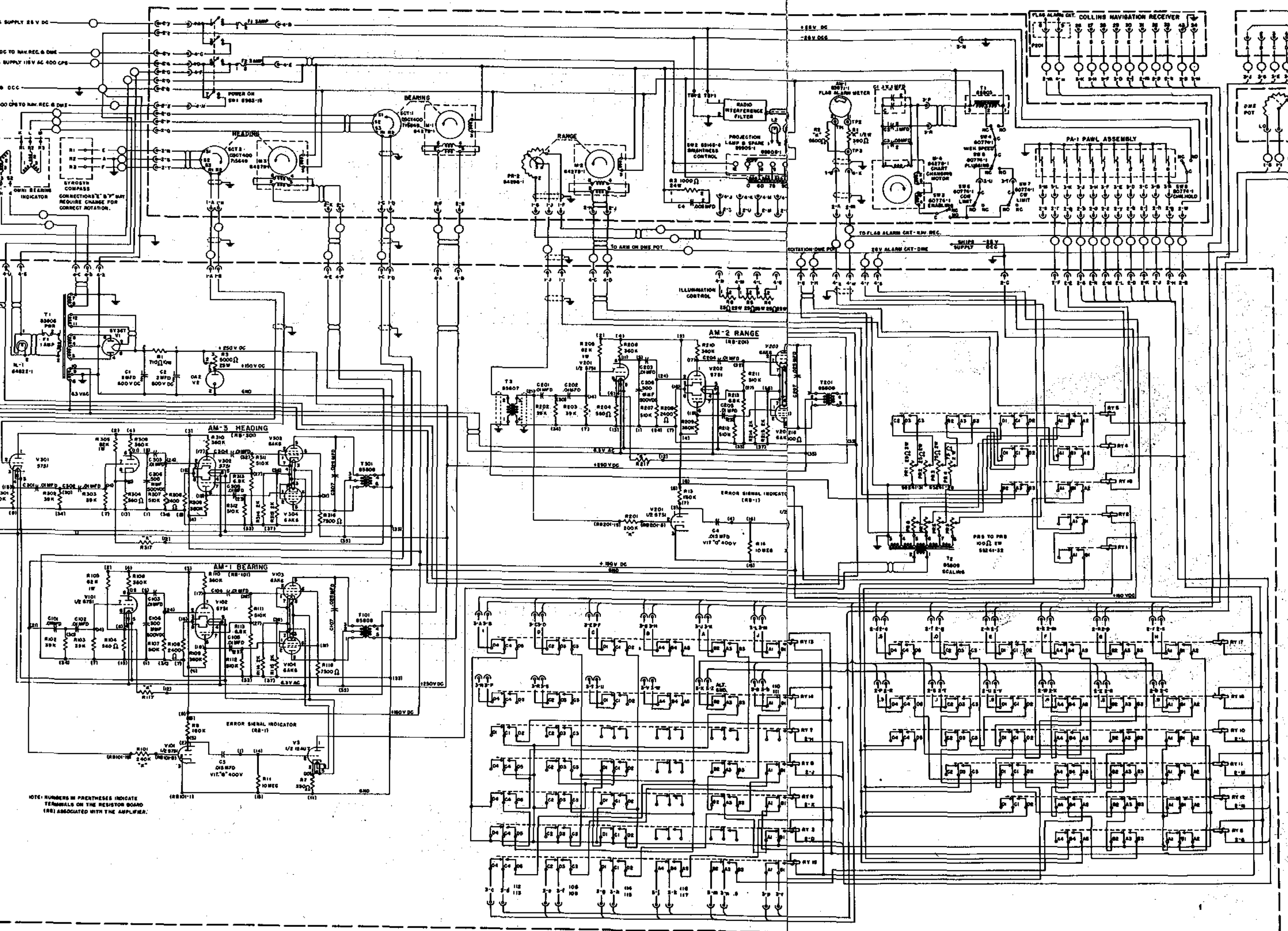
DISTANCE ERROR PRESENT WHEN ALARM FLAG DISAPPEARED

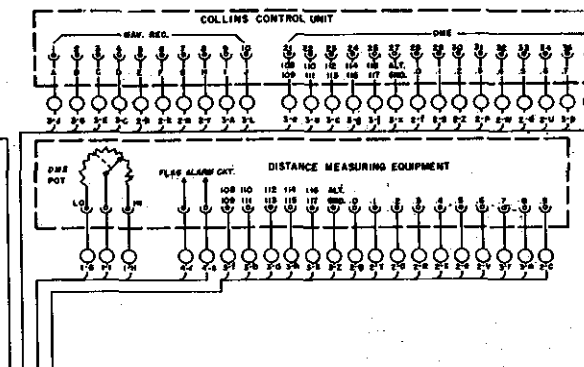
Computer Serial No	Distance (miles)
2	0 9
3	1 5
4	1 0
5	0 5

TABLE XI

BEARING ERROR REQUIRED TO OPERATE FLAG-ALARM INDICATOR

Computer Serial No	Error (degrees)
2	2
3	2
4	±2
5	2





NOTES:

1. ALL RELAYS ARE SHOWN IN THE DEENERGIZED POSITION.
2. MICROSWITCHES ARE SHOWN FOR THE FOLLOWING CONDITIONS:
   (a) SW3, SW4, SW5, & SW6 – CHART CHANGING HANDLE AT "OFF" AND IN POSITION.
   (b) SW6 & SW7 – FILM CENTERED-NEITHER LIMIT REACHED
3. UNLESS OTHERWISE SPECIFIED:
   ALL RESISTORS ARE 1/2 WATT
   ALL CONDENSERS ARE 600 V-DC VITAMIN "Q".
4. MINIMUM SIZE WIRE IS No. 22 AWG, LARGER SIZE WIRE IS USED WHERE REQUIRED DEPENDING UPON CURRENT AND VOLTAGE DROP IN ACTUAL POINT TO POINT WIRING.
5. CIRCUIT SYMBOLS:
   3-A CONNECTION TO POINT "A" ON PLUG & SOCKET "3".
   1-B CONNECTION TO POINT "B" ON AN CONNECTOR "1".
   TB1-3 CONNECTION TO POINT "3" ON TERMINAL BLOCK "1".
   JUNCTION BOX TERMINAL
6. DME AND NAV. REC. ARE TUNED TO PROPER FREQUENCY FOR SELECTED CHART BY GROUNDING TUNING FINGERS a, b, c, d, e, f, g, & h IN ACCORDANCE WITH THE FOLLOWING TABLE'S: (x = GROUND)

TUNING FINGER	MEGACYCLES									
	108	109	110	111	112	113	114	115	116	117
a		X		X		X		X		X
b	X	X	X	X						
c	X	X			X	X			X	X
d							X	X	X	X

TUNING FINGER	MEGACYCLES									
	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
e	X		X			X	X			
f		X		X			X	X		
g			X		X			X	X	
h				X		X			X	X

7. PROPER SCALING FACTOR FOR CHOSEN CHART IS SELECTED BY GROUNDING TUNING FINGERS 1 & 2 IN ACCORDANCE WITH THE FOLLOWING TABLE:

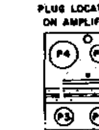
SCALE FACTOR	FINGER
1: 2,000,000	1 & 2
1: 1,000,000	1
1: 500,000	2
1: 250,000	

8. DIRECTION OF ROTATION IS SHOWN AS FOLLOWS:
   (a) INCREASING CLOCKWISE CHANGE IN BEARING AND HEADING WHEN VIEWED FROM SHAFT ENDS OF SERVO MOTORS & S C.T.'S
   (b) INCREASING RANGE AT 180° BEARING WHEN VIEWED FROM SHAFT ENDS OF MOTOR & POT.
   (c) FOR A CLOCKWISE ROTATION OF CHART CHANGE CONTROL HANDLE WHEN VIEWED FROM SHAFT END OF CHART CHANGING MOTOR.

INSTALLATION INSTRUCTIONS:

PLUG No.		CONNECTOR TYPE	No. WIRES
AMPLIFIER	1	AN 3106 B-18-1S	10
	2	AN 3106 B-28-21S	36
	3	AN 3106 B-28-21SW	28
	4	AN 3106 B-34-10S	16
DISPLAY	1	AN 3106 A-18-1S	7
	2	AN 3106-36-10S	33

PLUG LOCA[TION] ON AMPLIF[IER]



JUNCTION BOX TERMINALS REQUIRED ——— 99
DME FREQUENCY CONTROL DESIGNED FOR COLLINS 6 WIRE CONTROL MUST BE CONVERTED TO 10 WIRE CONTROL IF FEDERAL DME IS USED.

MANUFACTURED FOR: THE AIR NAVIGATION DEVELOPMENT BOARD
UNDER CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT AND EVALUATION CENTER
CONTRACT NO C13ca-316
BY ARMA CORP 254-36th ST. BROOKLYN 32 N.Y.

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

Fig. 3 Schem

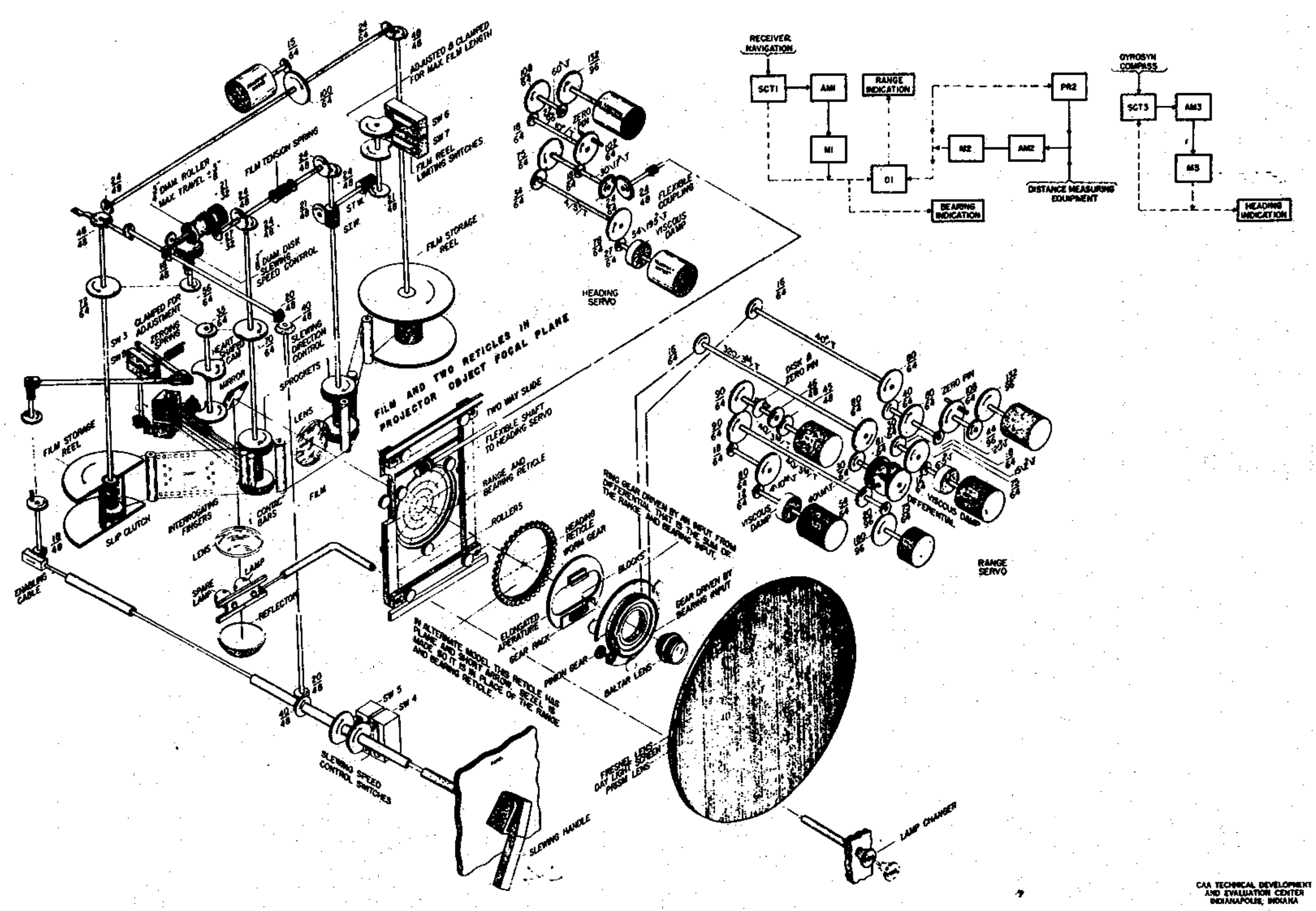


Fig. 4 Mechanical Schematic and Block Diagram of Type V Pictorial Computer

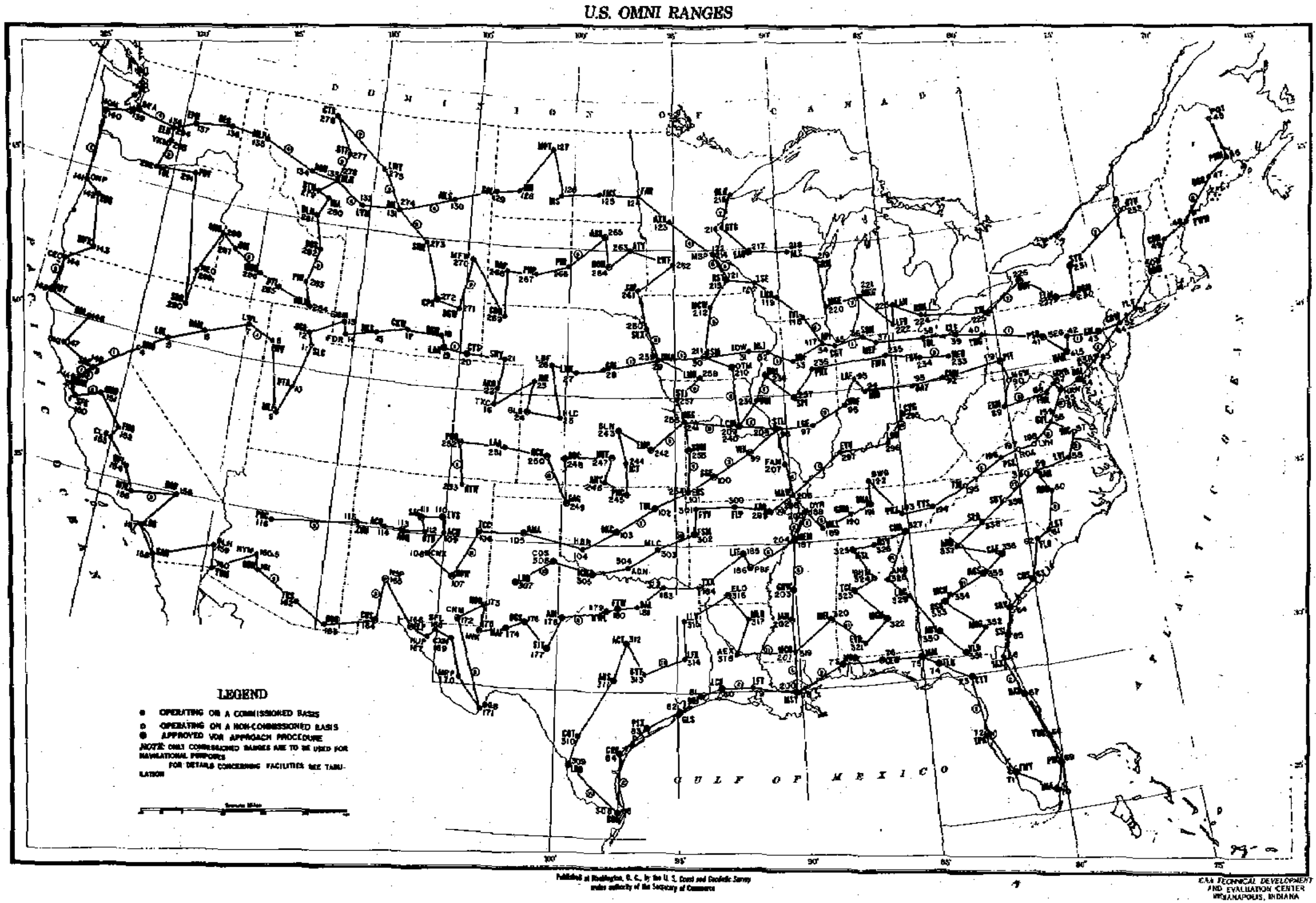


Fig. 5 Route and Serial Sequences of Charts

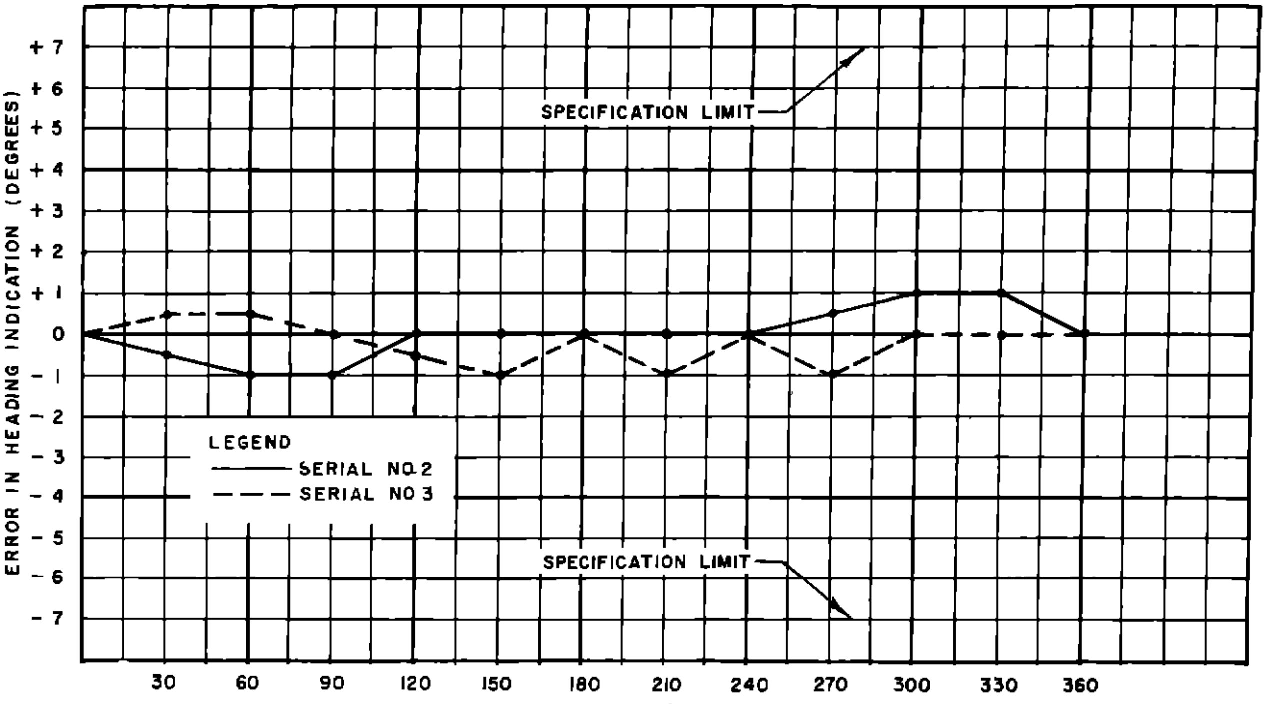


FIG 6A

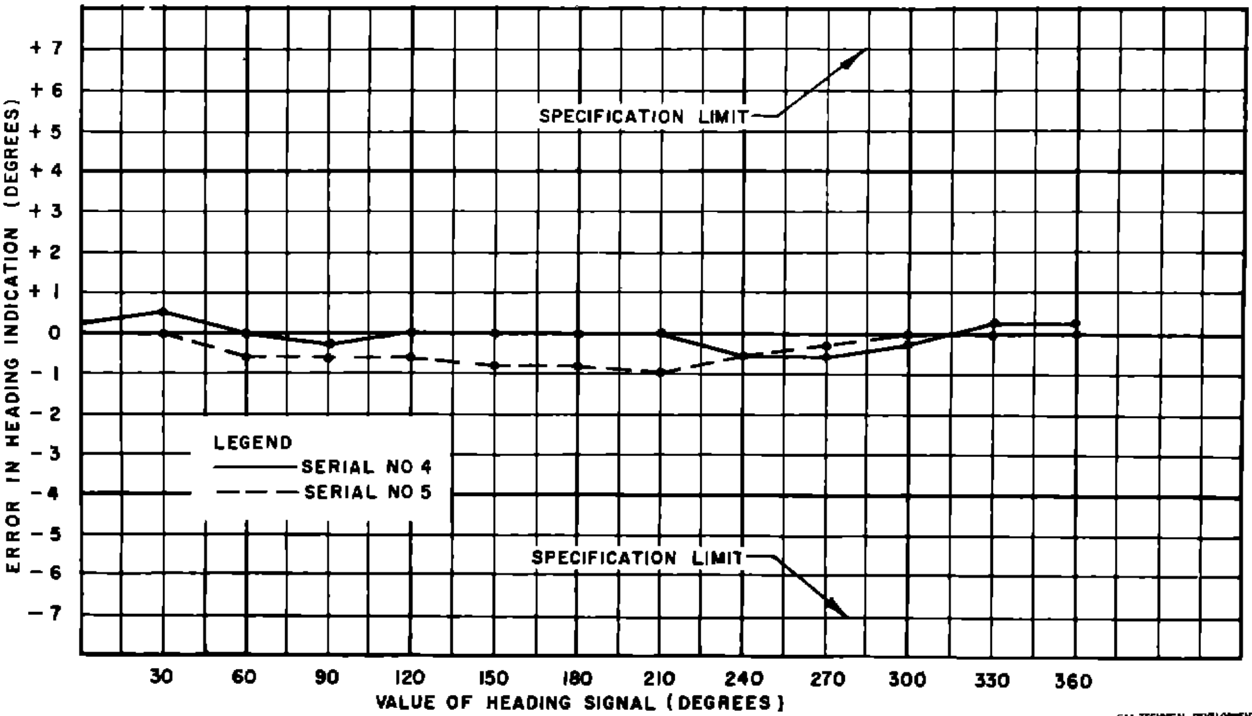


FIG 6B

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Fig 6 Accuracy of Heading as Presented by the Airplane-Position Indicator

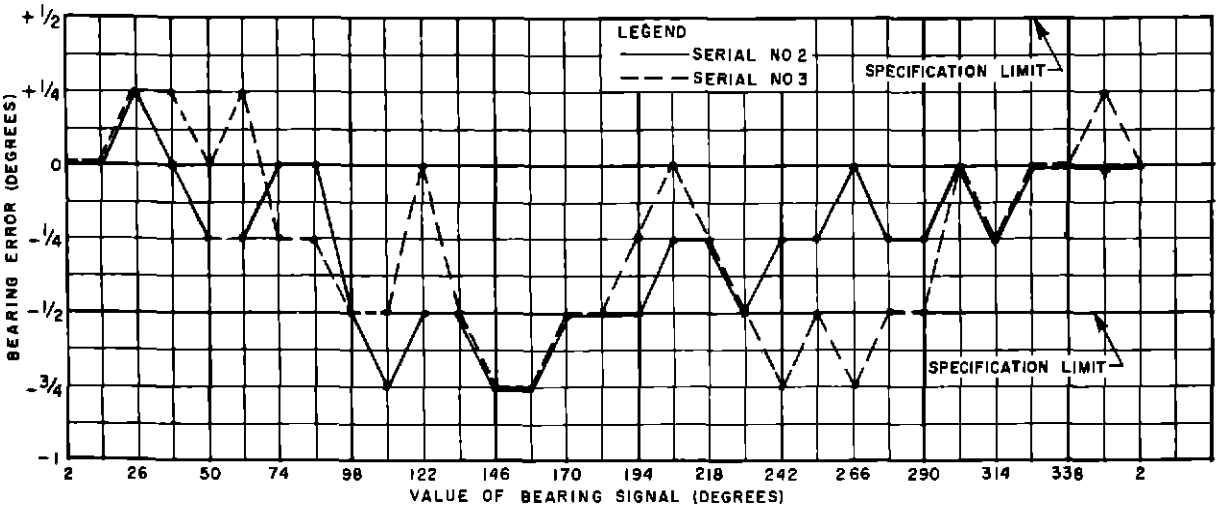

FIG 7A

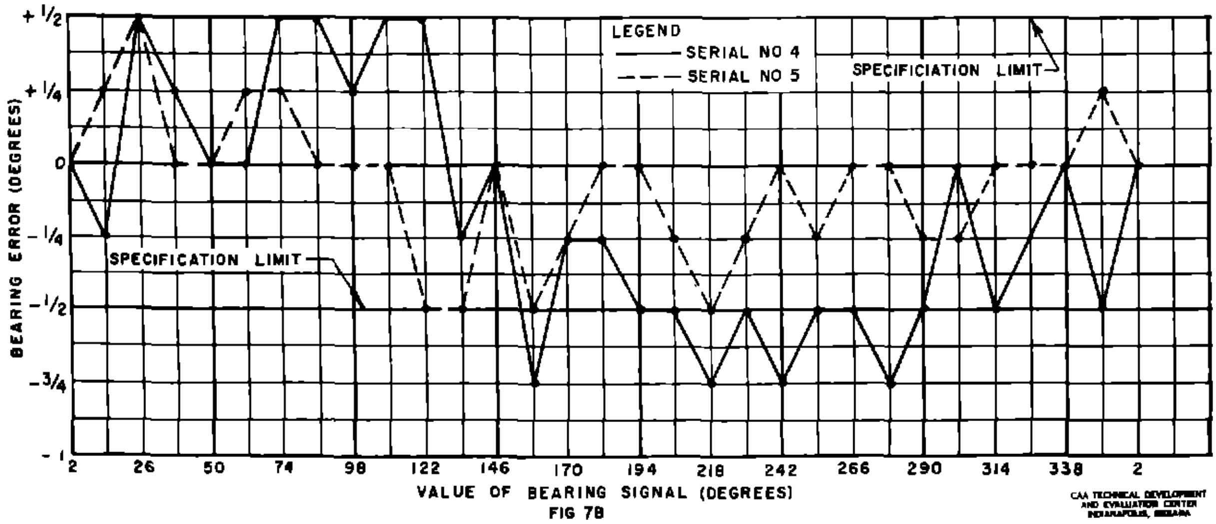

FIG 7B

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Fig 7 Pictorial Computer Bearing Error

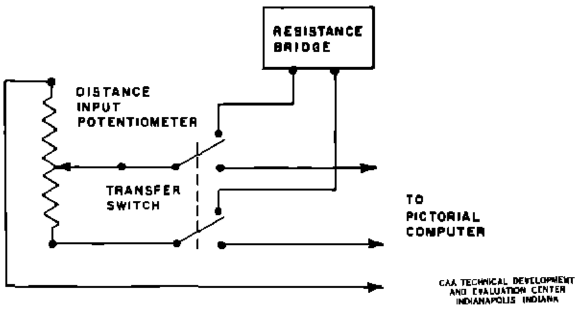

Fig 8 Schematic Diagram Test Setup for Distance Linearity

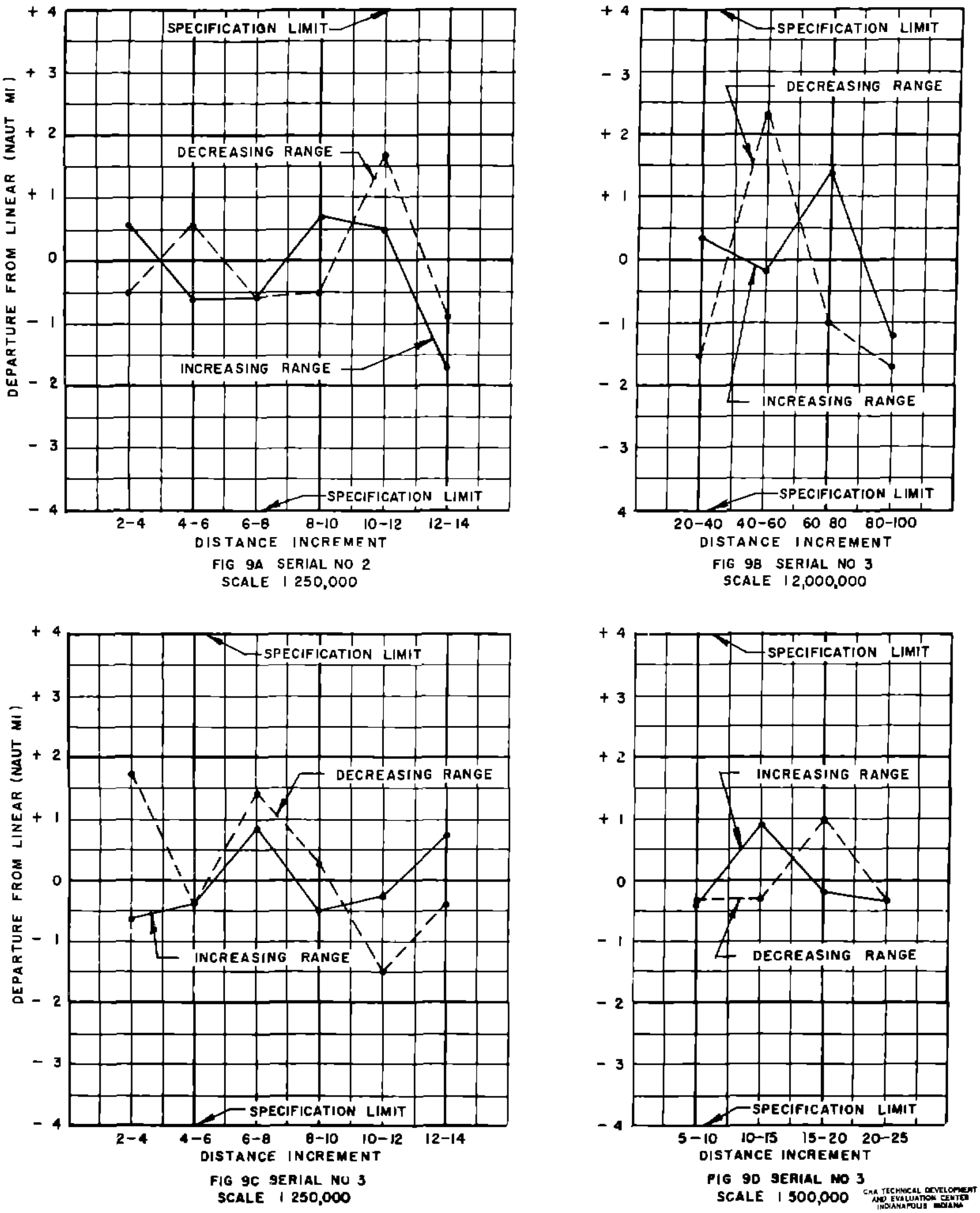

Fig 9 Linearity of Airplane-Position-Indicator Response

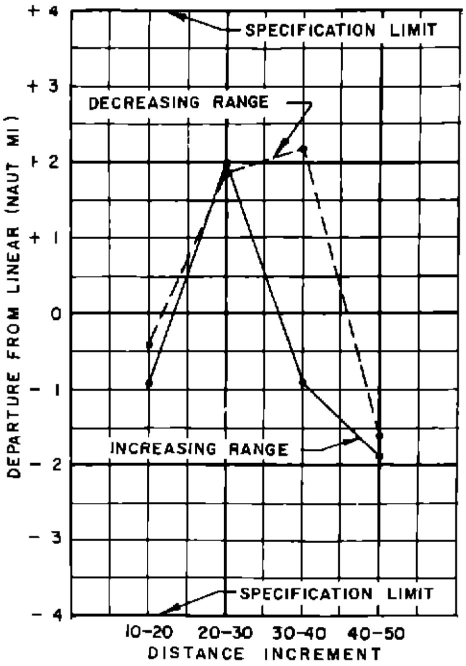

FIG 9E SERIAL NO 3
SCALE 1 1,000 000

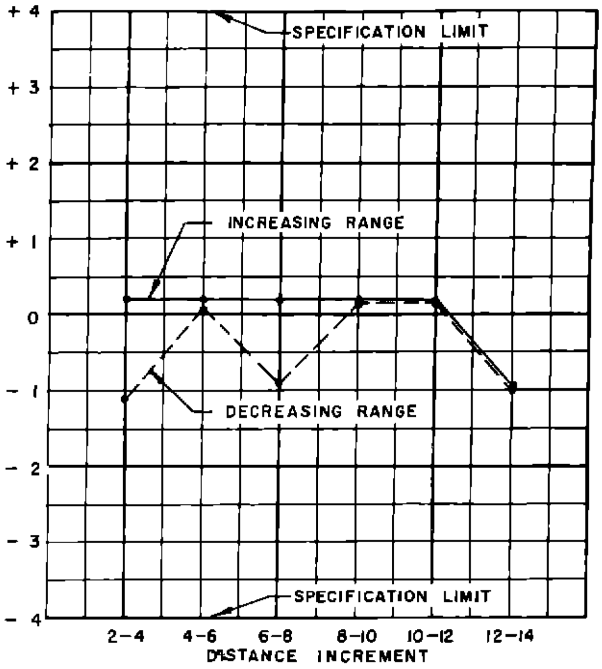

FIG 9F SERIAL NO 4
SCALE 1 250,000

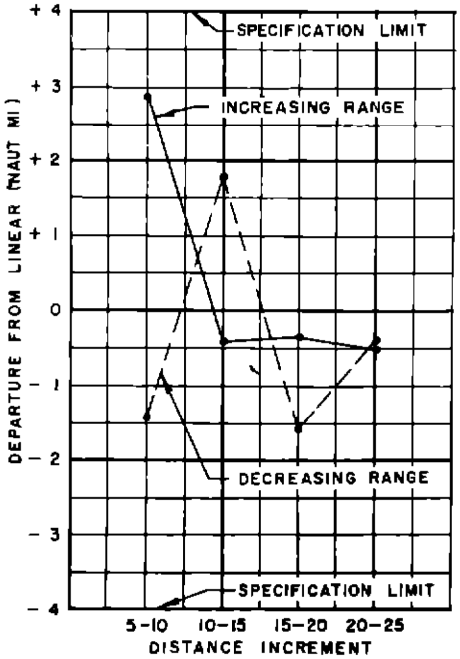

FIG 9G SERIAL NO 4
SCALE 1 500,000

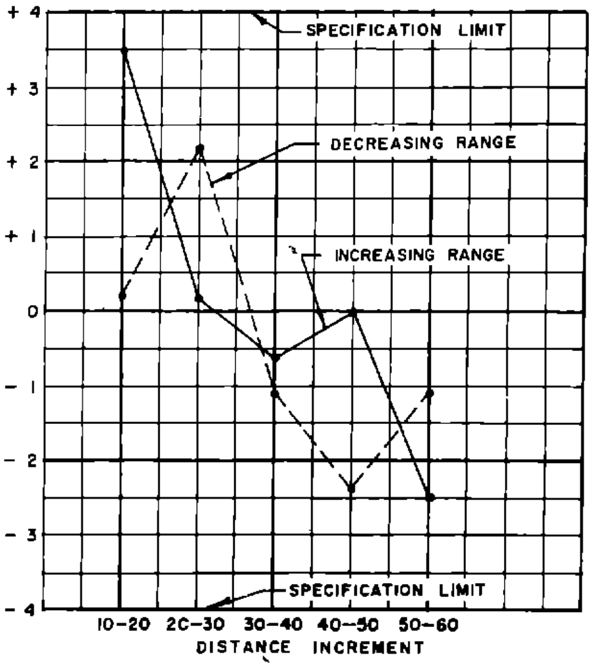

FIG 9H SERIAL NO 4
SCALE 1 1,000,000

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Fig 9 (Continued) Linearity of Airplane-Position-Indicator Response

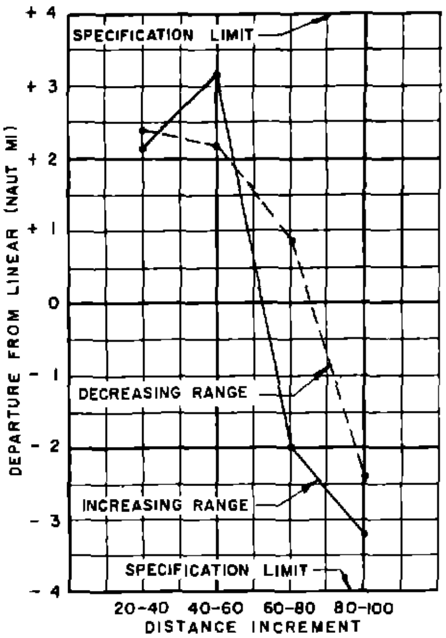

FIG 9I SERIAL NO 4
SCALE 1 2 000,000

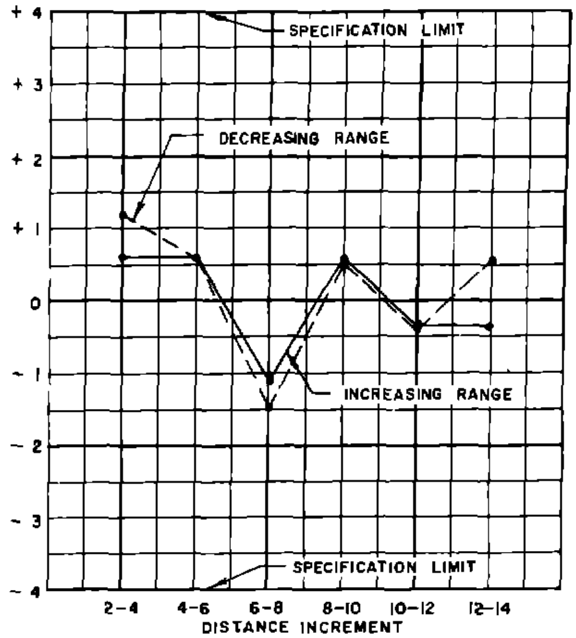

FIG 9J SERIAL NO 5
SCALE 1 250,000

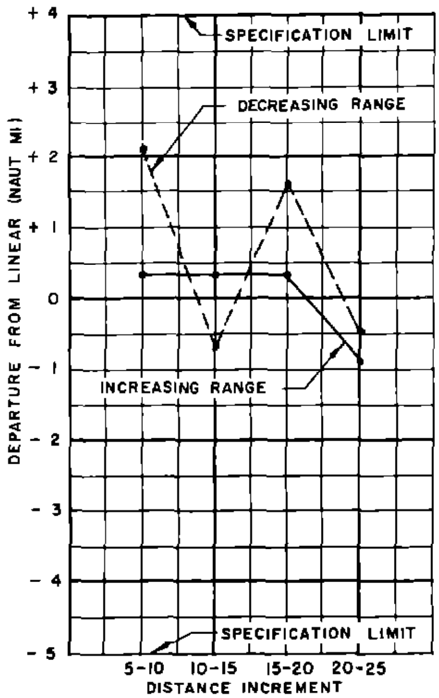

FIG 9K SERIAL NO 5
SCALE 1 500,000

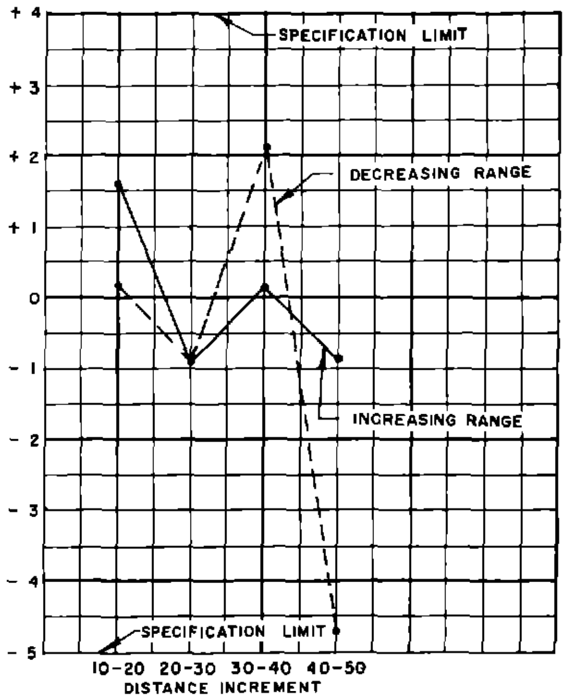

FIG 9L SERIAL NO 5
SCALE 1 1,000,000

Fig 9 (Continued) Linearity of Airplane-Position-Indicator Response

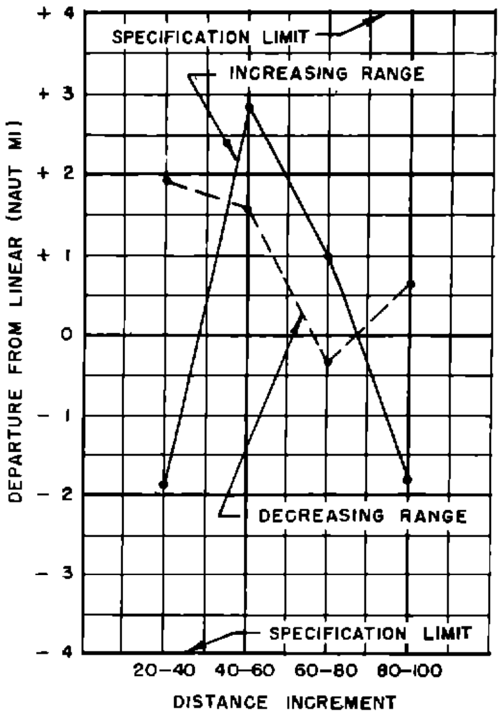

FIG 9M SERIAL NO 5
SCALE 1 2,000,000

Fig 9 (Continued) Linearity of Airplane-Position-Indicator Response

3 Maximum Rate of Change of Bearing Indication

The time required to indicate a change of 180° in bearing is shown in Table VI

4 Accuracy of Bearing Indication

The position indicator was placed on the outer bearing circle of a chart Accuracy was checked at the points indicated in Table VII and plotted in Figs 7a and 7b

C Distance-Servo Operation

Only linearity of distance indication was measured A bridge-switching circuit was connected to the range input as shown in Fig 8 The equipment was turned ON, and a chart with range circles was projected The resistance of the input potentiometer was measured for positions of the airplane-position indicator See Table VIII The departure from a linear indication was converted to nautical miles and was plotted in Figs 9a to 9m, inclusive The direction of travel of the airplane was the same for consecutive readings The airplane was prevented from overshooting the position for measurement

Flag Alarm

A Comparison of Computer and Course-Deviation Flags

When the equipment was on, the flag alarm on the navigation receiver was adjusted so that the edge of the alarm flag was just visible The alarm on the pictorial computer was also just visible

B Distance-Error Alarm Operation

A chart with 1 250,000 scale was projected The flag alarm was out of view The reading of the airplane-position indicator was noted, and the indicator was then moved manually by rotating the range gear until the flag returned to sight The distance traveled by the airplane-position indicator was recorded See Table IX

TABLE XII

BEARING ERROR PRESENT WHEN ALARM FLAG DISAPPEARED

Computer Serial No	Error (degrees)
2	± 1
3	1/2
4	± 1
5	1

The position indicator was allowed to return slowly to the servo balance position The distance from the normal airplane position to the point where the flag disappeared was recorded See Table X

C Bearing-Error Alarm Operation

The operation to determine distance error was repeated except that the bearing was changed by rotating the bearing gear The number of degrees the airplane-position indicator moved before the flag reappeared was noted The position indicator was allowed to return slowly to the balance position for the servo The number of degrees of departure from normal airplane position before the flag disappeared was recorded See Table XII

Operation of Film-Limit Stops

The film-limit stops were set, and the motor was slewed into each stop The limit-switch operation was checked and found to be correct

FLIGHT TESTS AND RESULTS

The computer used for the flight tests was installed in a DC-3 type airplane Flights were made in the Indianapolis area, and charts of each of the four scales provided were used The desired course was plotted on a 1 500,000-scale reference chart which the pilot used The flights were made in good weather under visual-flight-rule (VFR) conditions, and the selected courses were flown accurately enough so that any course deviation was neglected A transparent film was taped over the computer screen, and the copilot marked the track of the airplane-position indicator on the film with a grease pencil After the flights, the track of the position indicator was transferred, for comparison with the desired course, to charts corresponding to the charts used in the computer during the various tests. The results of these flights are shown in Figs 10, 11, 12, and 13

For the most part, the charts are self-explanatory All flights originated at and returned to the Indianapolis Weir Cook Municipal Airport Two flights were made with the use of the 1 250,000-scale chart, and the charts of these flights are shown in Fig 10 In addition to the results of the flights, Fig 10 shows the theoretical region of error due to various equipment used in pictorial-computer flights The results of flight using a 1 500,000-scale chart are shown in Fig 11 This chart also illustrates the two-reticle position indicator The flight results shown in Fig 12 were obtained using a 1 1,000,000-scale chart This chart also illustrates the theoretical regions of error due to the various equipment The concluding flight (see Fig 13) was made at a distance of from 80 to 90 miles from the OBD station, with the use of a chart with a scale of 1 2,000,000 Sufficient altitude was maintained so that the airplane was within line of sight of the airport at all times during the flight However, on some turns, the DME lost the signal for short periods of time The VOR signal was also lost for short periods, especially during flight through some areas of severe scalloping

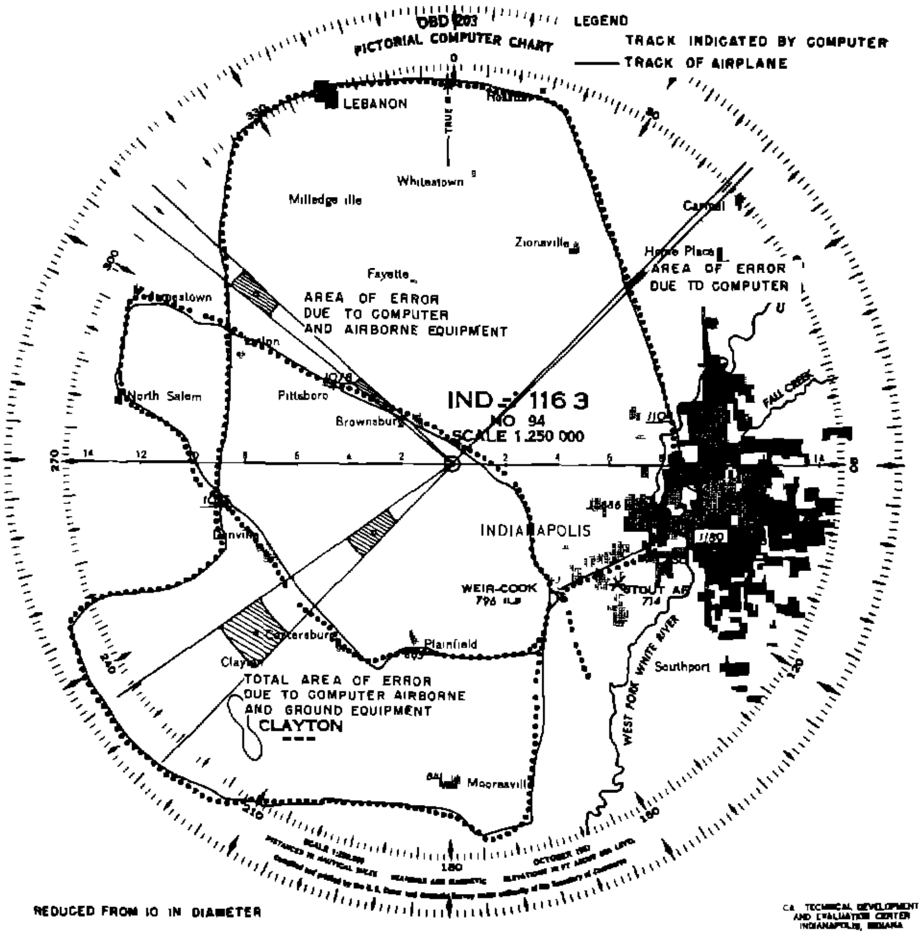

Fig 10 Chart of Flight With Type V Pictorial Computer

DISCUSSION

The foregoing parts of this report describe those features of the Type V computer which lend themselves to quantitative measurement. Some of the features are of a qualitative nature rather than quantitative and for that reason require detailed discussion.

In considering this discussion, it should be borne in mind that the computer was designed to investigate certain features of the display rather than to arrive at a preproduction design. Therefore, the comments concerning design improvement are not to be regarded as a criticism of the design. They are prompted by the knowledge gained from laboratory and flight tests on the experimental models and are intended to encourage and direct further computer development. The intended operational use is also considered in the discussion of the features of the computer. Therefore it will be assumed, except where otherwise indicated, that the computer is to be used by a scheduled airline for routine flights along a specified course.

The outstanding feature of the Type V computer is the simplicity of its operation. By making only two manipulations, turning on the power switch and selecting the desired chart, the operator has a display of his position and heading before him. With other pictorial computers tested at this Center, it was necessary to turn on three power switches (VOR receiver, DME, and computer) to select and insert a previously prepared chart of the proper scale and to select the OBD frequency. This simplicity of operation is very important and should be available to the operators of aircraft which can carry this type of equipment.

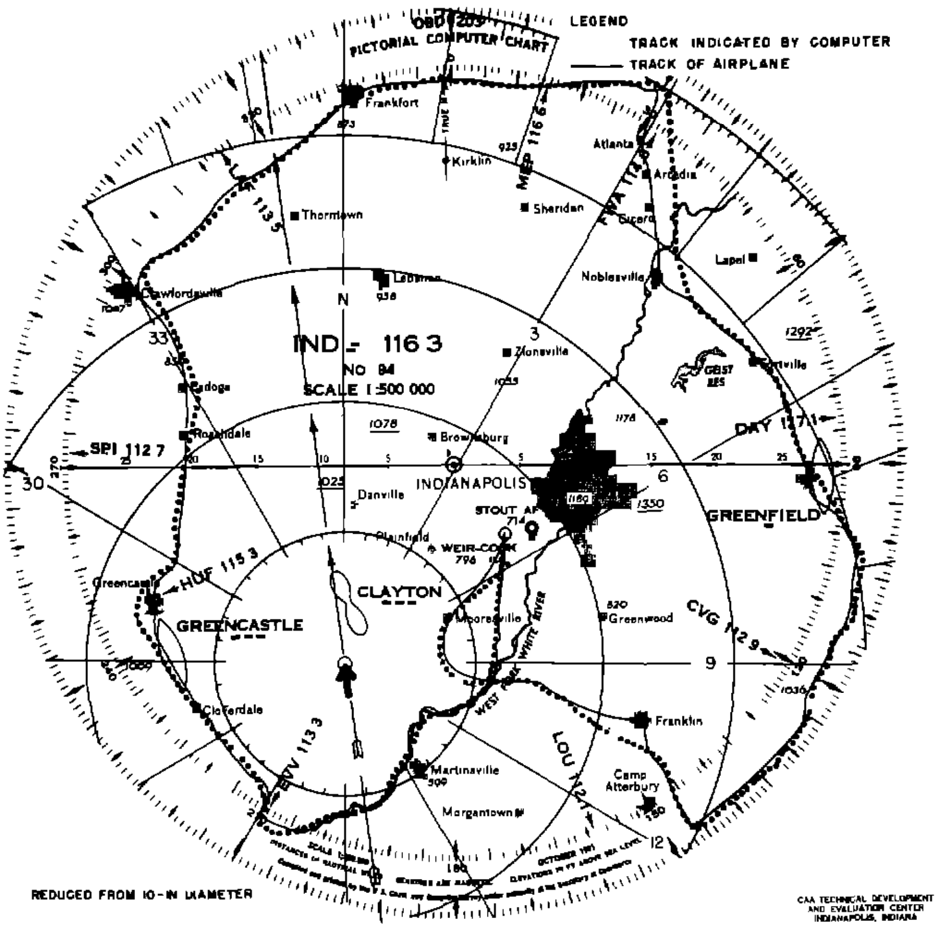

Fig. 11 Chart of Flight With Type V Pictorial Computer

It may be possible to improve the chart-storage arrangement. The charts are printed on a single 100-foot roll of 35-mm film in a series of route sequences. This film will hold 750 charts, or two charts for each of the 358 operating VOR stations in the United States and more than 30 additional charts. This storage of a huge amount of information in a volume of only 15 cubic inches is a remarkable accomplishment. Although the operation is simple, the associated mechanism has an undesirable complexity and the long film roll has disadvantages The design of the computer is such that either the changing of the film or the replacement of burned-out projection lamps requires access to the rear of the computer. This access requires the opening of the nose section of the DC-3 in which the computer is installed at this Center. Access from the front of the computer to all components requiring replacement or adjustment is very desirable. Some difficulty in splicing the film was experienced because the projection mechanism could not handle the extra thickness caused by a simple lap splice. Butt splices were not strong enough. The solution arrived at was a tapered lap splice which provided sufficient strength without an appreciable increase in thickness. The long film strip makes frequent splicing necessary, because it is not economical to print an entire film to replace only five or ten obsolete charts Also, the long film causes much wear on the charts that are not used but which must be passed over in going between two stations that are adjacent geographically but are on different route sequences on the film. For routine flying along an established route, this is not an important problem, but for itinerant flying, it would be impractical to prepare a film having the charts in sequence for every possible flight, and

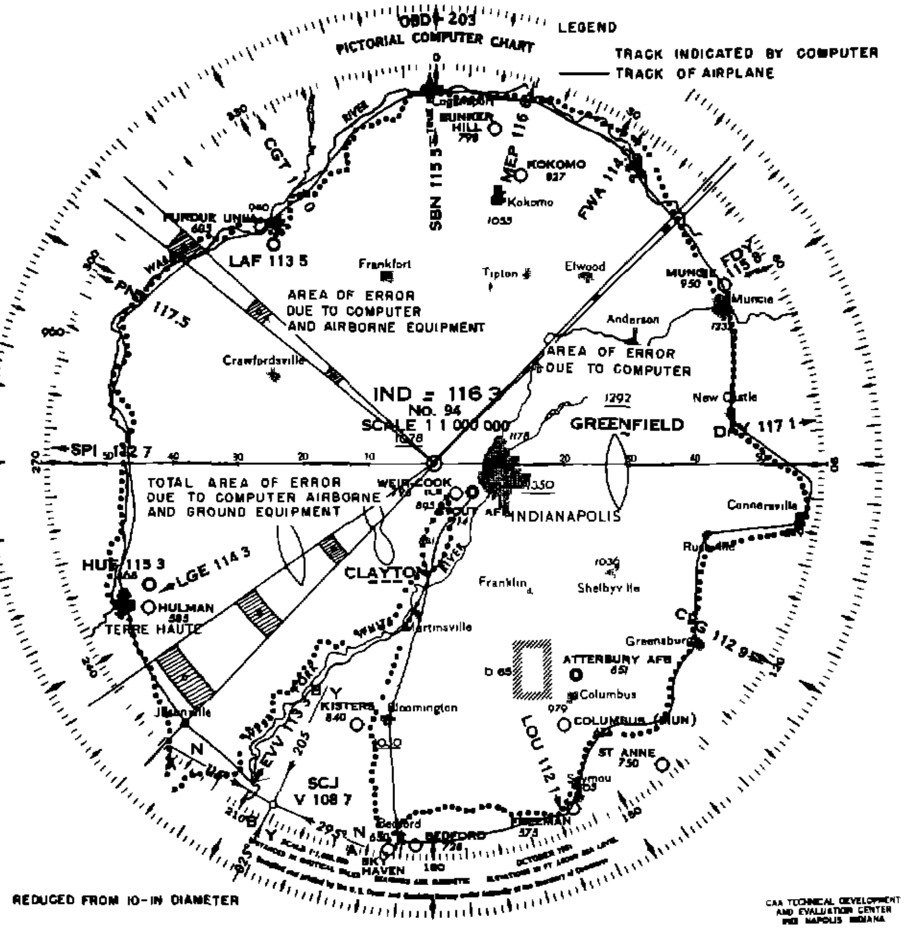

Fig. 12 Chart of Flight With Type V Pictorial Computer

the chart selection would require a large amount of time if the present route sequence is used. Thus, an arrangement that would use a number of short route-sequence films, or better a number of individual charts, would reduce film wear and would save chart-changing time. The use of a number of small magazines, each holding a single route sequence of individual charts, would provide the advantages of simple selection, ease of replacement of obsolete charts, and flexibility in rearranging the charts when a new route is to be flown.

The automatic scale selection and frequency selection are important features which have been achieved with nominal equipment complexity. In a broad sense, the chart is the source of information for the area it covers. Ordinarily, the information is taken from the chart by the operator reading the chart. In the case of the pictorial computer, the chart can be thought of as a key, since it must be installed in the computer, and, as a key, it should unlock to the computer as much information as the computer can use to perform automatically any function which would ordinarily require the attention of the operator This broad concept must be limited by a practical consideration of operational flexibility and equipment complexity.

Thus, automatic adjustment of the scale mechanism to agree with the scale of the chart is very logical. With manual scale selection, the operator must select the chart scale twice, once when he selects the chart, and again when he makes the mechanism-scale adjustment. Failure to make the scale adjustment results in an erroneous position indication.

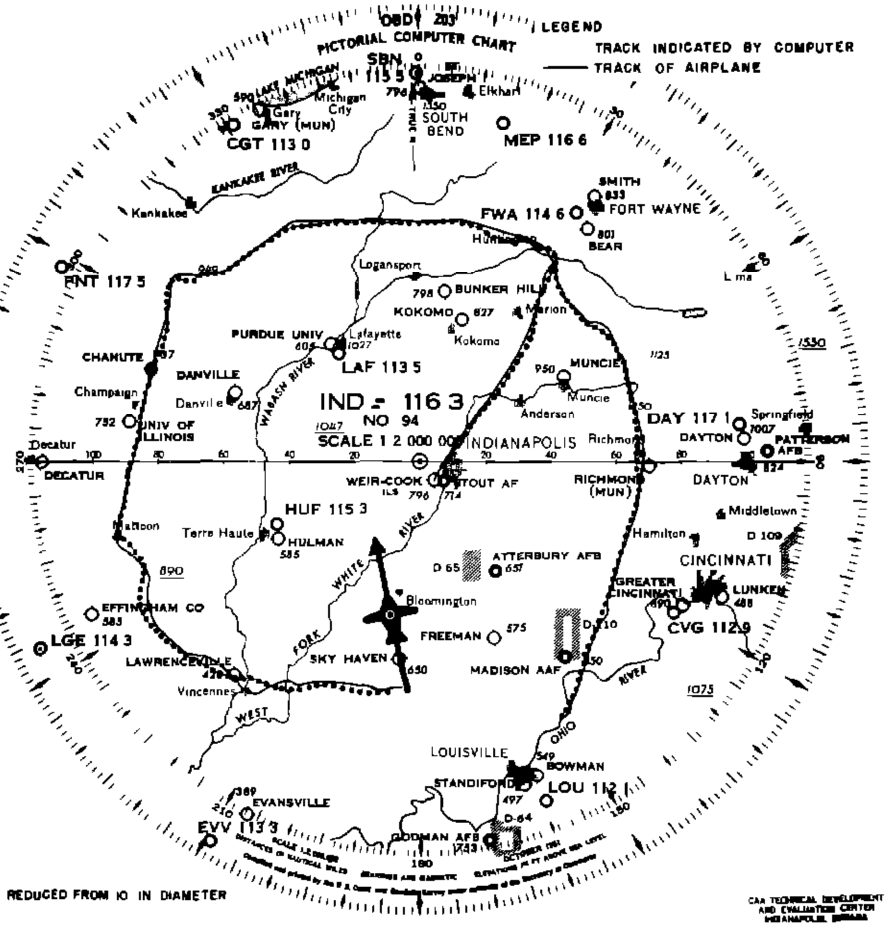

Fig. 13 Chart of Flight With Type V Pictorial Computer

The case for automatic frequency selection is complicated by the fact that the navigation receiver covers frequencies outside of the 112- to 118-Mc band which has been set aside for VOR. In the installation of the Type V computer at TDEC, provision was made for transferring control to the manual frequency selector when the computer power is turned off This complicated the installation greatly. The logical solution seems to be to provide a method of manually selecting frequencies outside the VOR band as a part of the computer.

Further consideration of this problem suggests that the computer might provide a display of ILS information. This suggestion is supported by the fact that many glide-slope sites are expected to be equipped with DME. Such a pictorial presentation of the ILS information might eliminate the need for the course-deviation indicator and might provide a larger, more usable indication.

Much interest has centered around the accuracy requirements for the computer. Two factors made it difficult for the computer to meet the accuracy requirements. First, comparatively long gear trains were placed between the sensing devices and the indicators, and backlash and nonlinearity in the gear trains appeared as position errors in the indications Second, the projection system magnified any error present by a factor of ten.

The specification requirements of 1/2° in bearing and 4/10 mile in distance were arrived at from consideration of available component accuracies. Autosyns having an accuracy of 1/3 degree and potentiometers having linearities accurate within 1/4 of 1 per cent are commercially available The remainder of the error was allowed for backlash and for nonlinearity in the mechanism When compared with the accuracy of the OBD information (± 3 1/2° for the VOR ground station, ± 1 1/2° for the Collins 51R VOR receiver, and ± 1/2 mile or 3 per cent for the Type DID airborne DME), these requirements seemed reasonable. Thus, the total errors in the display under the worst conditions would be ± 5 1/2° in bearing and ± 9/10 mile, or ± 3 per cent plus 4/10 mile. The area of error for various locations on a 1 1,000,000-scale chart is shown in Fig 9 For traffic-control problems, when all aircraft are using the same OBD facility, the ground-station error can be neglected since it is common to all aircraft The DME ground-station error is small enough to be neglected. Most traffic control is based on a guaranteed minimum separation of three miles and on an approach speed of 120 to 150 mph If the OBD station is assumed to be on the airport and if the control data are based on the maximum errors at 20 miles, the fastest landing rate would be one aircraft every three minutes. This time can be allocated as follows 1.5 minutes due to the three-mile required separation, 0.8 minute due to the airborne DME error, and 0.2 minute due to the computer error. Thus, the computer error would be responsible for 6.6 per cent of the total delay.

These conditions are pointed out here to show the relative error due to each equipment. In actual practice, provision for checking the accuracy of the system should be made, in order to reduce the delay due to system error.

The projected display used in the Type V computer has attracted much attention. The use of an image projected on a screen suggests time sharing of the screen with functions other than the navigation display. For example, some indicating instruments which require only occasional attention could be arranged to have their images projected on the screen when they are needed. Such indications as battery-charging rate, hydraulic pressure, and outside temperature would be suitable for this kind of presentation Private-line data probably could be superimposed on the navigation display. Airborne radar indications also could be projected on the screen.

The feature of the display which needs the most improvement is the contrast on the screen. At present, the display is usable under all conditions of cockpit lighting However, under bright-sunlight conditions, the projected image suffers from loss of contrast and, therefore, from a loss of chart detail. This situation can be improved by making the front glass of a material which has less reflective power and by making the screen of a material which will show greater contrast. Increasing the size of the projector lamp from 100 to 300 watts improved the image substantially but increased the power consumption of the computer correspondingly.

In the Type V computer, the charts were oriented north up. By use of a dove prism, the display could have been optically rotated so that the course would be up the chart. This feature is especially valuable to beginning pilots, and consideration should be given to its inclusion in the computer.

The flag alarm was displayed on a meter mounted on the computer panel. The action of the flag is quite satisfactory. However, a more effective presentation would have been to have the flag appear on the screen.

In the design of lamp housing, it was possible to save some space by mounting the projection lamps on their sides. This is not in accordance with the recommendations of the lamp manufacturer and results in some shortening of the life of the lamp when the computer is installed in the airplane

CONCLUSIONS AND RECOMMENDATIONS

1. The Type V computer meets the specification requirements for an accuracy of ± 0.5° or 1/32 inch, whichever is larger, in bearing, of ± 0.4 nautical mile in distance, and of ± 7 0° in heading. The servomechanism responses are slightly underdamped but are not objectionably so. The computer is almost free of flimsy mechanisms and has therefore required a small amount of maintenance.
2. The Type V computer requires less manipulation for its operation than any of the other various types of pictorial computers require. The simplicity of the controls is an excellent feature.
3 Automatic scale selection is desirable because it prevents errors due to manual selection of the improper scale. Its inclusion is recommended for all future pictorial computers.

4. Automatic frequency selection is preferable to manual frequency selection if the required space and weight can be justified. If automatic frequency selection is included, an auxiliary method of manually tuning the navigation receiver and the DME when the computer is off must be provided as part of the computer.

5. The means of selecting charts should (a) provide flexibility of arrangement in route sequence, (b) provide a ready means of replacing obsolete charts, (c) avoid wear on charts not being used, and (d) provide an easy and accurate method of inserting and removing the charts.

6. More attention should be given to reducing the size, weight, and complexity of the computer. It is especially important that the repeat-back sensing units be mechanically geared close to the position indicator.

7. The use of a lens-and-prism arrangement to control the uniformity and the direction of brightness is to be commended. Further work needs to be done in getting the brightness directed toward the pilot and copilot and in improving the contrast on the screen by the choice of better screen materials and possibly by printing the charts on 70-mm film.

8. A dove prism to provide a manual chart-rotating feature should be considered for inclusion in the optical system.

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