THE CAA TYPE III PORTABLE PICTORIAL COMPUTER

PART I
DEVELOPMENT AND INITIAL TESTS

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PART I

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SUMMARY

This report presents a description of the CAA Type III portable pictorial computer together with a discussion of some of the early modifications made to the computer, the results of early tests, and some general comments on pictorial displays.

Laboratory tests indicate that, when the computer was properly adjusted, maximum errors of one-half degree in azimuth indication and one-fourth nautical mile (nm) in distance indication may be attributed to the computer. When the computer was used within 15 nm of the omnibearing distance (OBD) station, a maximum over-all system error in position of less than 1 1/4 nm was experienced during the flight tests.

Five Type III computers were built by Aero Electronics Company, Chicago, Illinois, on contract with the Technical Development and Evaluation Center of the Civil Aeronautics Administration. The development was sponsored by the Air Navigation Development Board.

INTRODUCTION

Since 1946, engineers at the TDEC have been engaged in the improvement of the cockpit display of OBD information.[1] This work has included improvements in the basic indicating instruments and the development of the course-line and pictorial computers.

Earlier studies of course-line computers have shown that a computer is a worthwhile navigational aid when the desired course is not a radial through, or an orbit about, an OBD station.[2,3] However, to receive accurate indications from a course-line computer with respect to a desired course, the operator must have accurate knowledge of three items of geographical data (way-point azimuth co-ordinate, way-point distance co-ordinate, and course) and must set the data accurately on the controls of the computer. This necessary manipulation of controls greatly reduces the value of the course-line computer for terminal area operation. Efforts to provide storage of the geographical data so that the co-ordinates could be set into the computer automatically have resulted in large and complicated equipment and in restriction of the flight to preselected courses.

The course-line computer indications, including deviation from the desired course and distance to the way point, are displayed symbolically on the same indicators that are used for the basic OBD indications. This represents a saving in airborne instruments. However, before the data can be used most effectively for navigational purposes, the pilot should convert this information to a mental picture of the aircraft position. An even better method is to replace the symbolic indications with a pictorial display of the aircraft position on a map.

Considering these characteristics of course-line computers, it appeared desirable to examine the practicability of using the OBD information to plot position of the airplane on a chart to be contained in the

[1]H. C. Hurley, S. R. Anderson, and H F. Keary, "The Civil Aeronautics Administration VHF Omnirange," Proceedings of the Institute of Radio Engineers, Vol. 36, No. 12, December 1951.

[2]Francis J. Gross and Hugh A. Kay, "Initial Flight Tests and Theory of an Experimental Parallel Course Computer," CAA Technical Development Report No. 83, September 1948.

[3]Hugh A. Kay, "Development and Flight Tests of the CAA Type VI Course Line Computer," CAA Technical Development Report No. 143, May 1951

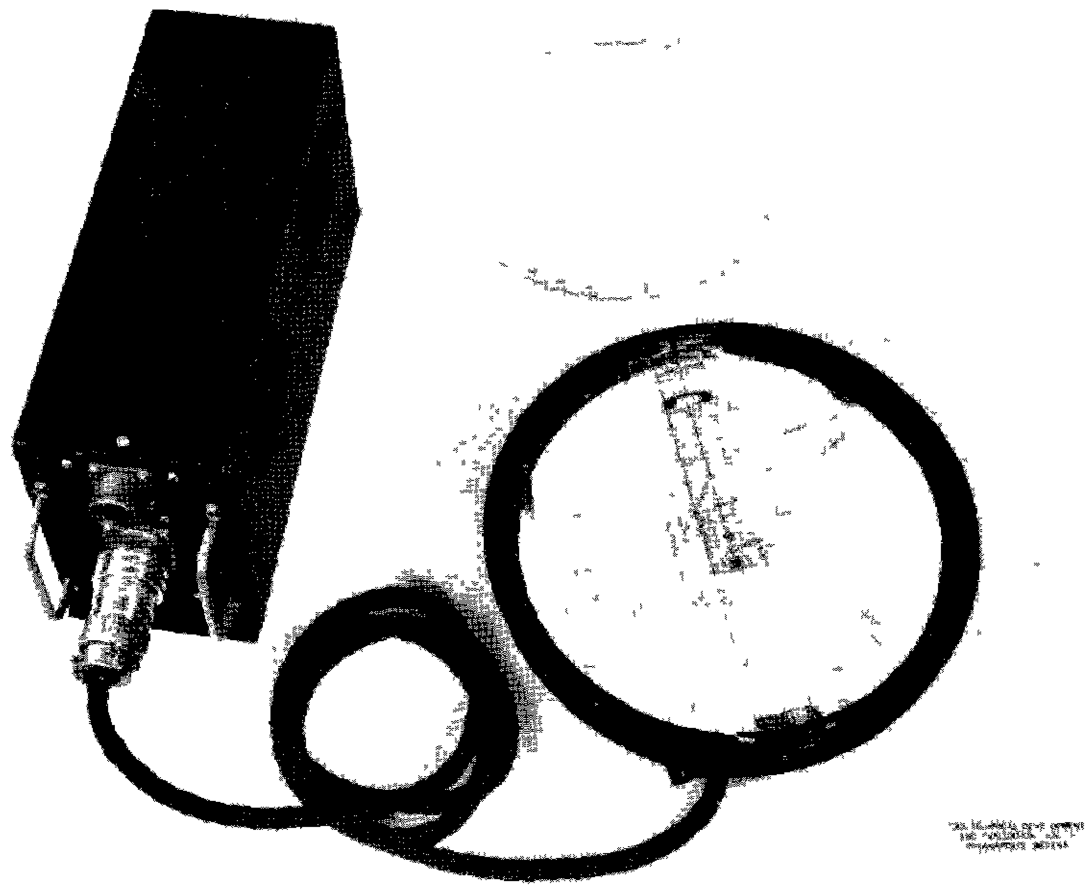

Fig. 1 Portable Pictorial Computer

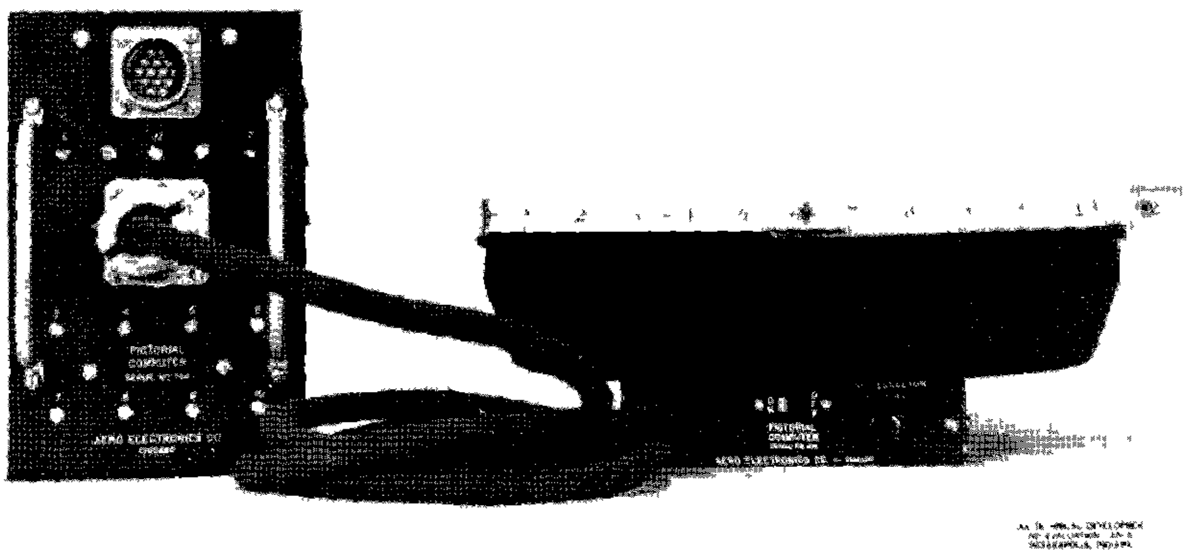

Fig 2 Portable Pictorial Computer

computer. The characteristics desired in such a display were discussed with personnel of the Aero Medical Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio, with personnel of the Special Devices Center, Department of the Navy, Port Washington, New York, and with other interested groups. In addition, the results of tests of pictorial and symbolic displays of OBD information conducted at the University of Illinois were given careful consideration [4] As a result, a list of features that could be incorporated was prepared, and a discussion of them is included in Appendix II Specifications were prepared for three types of pictorial computers which were designated

1 CAA Type III Portable
2. CAA Type IV Rotatable Panel
3. CAA Type V Panel with heading, automatic chart selection, and automatic receiver tuning

The distinction between course-line and pictorial computers will be clarified by the following brief description

A course-line computer is airborne equipment which accepts information from the distance measuring equipment (DME) and the omnirange receiving equipment and, after properly processing this information, presents the results on meter type of indicators which provide the pilot with "track guidance" and "distance-to-go" information for any selected course and destination which are within the range of the DME and omnirange. When using it as a navigational aid, the pilot or navigator is required to set (1) the distance of the destination or way point from the OBD station, (2) the bearing of the destination from the OBD station, and (3) the intended course on the corresponding controls of the course-line computer.

A pictorial computer is airborne equipment which utilizes information from the DME and from the omnirange receiving equipment to move a symbolic representation of the airplane automatically and continuously on a chart of the area over which the plane is being flown.

Early in the program it was recognized that the sectional aeronautical charts contain much more information than is required for instrument flights and that the excess information clutters the charts and reduces their value. Therefore, the Coast and Geodetic Survey was requested to prepare special charts for use in the pictorial computer. Fifty-six charts covering the routes from Chicago to New York, from Boston to Richmond, and from Washington to St Louis were prepared. A discussion of the features of the charts and samples that were prepared is included in Appendix III.

On April 18 and 19, 1951, a symposium on airborne computers was held at TDEC. This meeting was sponsored by the ANDB and was attended by representatives of various agencies interested in the problems of air traffic control and navigation. A digest of the minutes of this meeting is included in Appendix IV.

A critical operational evaluation of the Type III computer is under way and will be described in a subsequent report.

DESCRIPTION

The portable pictorial computer shown in Figs. 1 and 2 is an automatic, electromechanical airborne instrument for indicating continuously on a chart the position of an airplane with respect to an OBD station. The computer receives the position data from an omnirange receiver and DME. The instrument consists of two principal units, the display unit and the amplifier unit. The size and weight of the display unit have been kept small so that it may be held in the pilot's or co-pilot's lap or may be mounted on the instrument panel or on a bulkhead of the airplane.

The display unit consists of a fixed circular chart holder, the airplane position indicator assembly, a control panel, and two servomechanisms. The chart holder accommodates specially prepared aeronautical charts each of which has a 10-inch diameter. The OBD station is represented at the center of these charts. The airplane position indicator assembly consists of a scale which slides in a guide extending diametrically across the chart holder. The guide can rotate over the surface of the chart holder. A small hole at one end of the scale indicates the location of the airplane A lead pencil point may be inserted into this hole to mark the position of the airplane at any time or to trace the airplane's course. Graduations extending from the center of this hole along the scale indicate the distance between the airplane and the OBD station. The bearings TO or FROM the ground station are indicated by a 360° azimuth scale engraved on the chart holder and by hairlines at the two ends of the rotatable guide.

Two controls are located on the display unit panel. See Fig. 2. One is the power

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

TABLE I

CALIBRATION ADJUSTMENTS ON FRONT PANEL OF AMPLIFIER UNIT

Control No	Description	Nominal Setting
1	Flag-alarm bias for bearing error	Operate flag-alarm relay for ± 3° error
2	Flag-alarm bias for distance error	Operate flag-alarm relay for ± 2-mile error
3	15-mile maximum range calibration	To calibrate the 15-mile range
4	30-mile maximum range calibration	To calibrate the 30-mile range
5	60-mile maximum range calibration	To calibrate the 60-mile range
6	Bearing-servo rate control	For critical damping
7	15-mile range zero adjustment	
8	30-mile range zero adjustment	
9	60-mile range zero adjustment	
10	Distance-servo rate control	For critical damping
11	Range limit control	To disable distance servo at maximum range

switch, and the other is the three-position chart scale selector switch which must be set to correspond to the scale of the chart being used.

The servomechanisms contained in the case below the chart holder operate the airplane position indicator assembly Two mechanical drives are provided, one for the bearing indication and one for the distance indication. The bearing servomechanism includes a motor and gearing which rotate the airplane position indicator guide and the shaft of an Autosyn The distance servomechanism includes a motor, gearing, spring belt, cord drum, potentiometer, cord, distance scale, and airplane position indicator. The motors are driven by two servoamplifiers contained in the amplifier unit.

The amplifier unit contains a bearing servoamplifier for driving the bearing servomechanism, a distance servoamplifier for driving the airplane position indicator and distance scale, a power supply which is common to the two amplifiers, a flag-alarm circuit for indicating malfunctioning of the computer, and a range limit circuit which prevents the airplane position marker scale from being driven beyond the chart edge and possibly jamming the distance servomechanism when the airplane flies beyond the area included on the chart This limit system automatically re-establishes normal operation of the computer when the airplane returns to the area of the chart

As shown in Fig. 2, the amplifier panel has two cable connector sockets and eleven screwdriver controls for adjusting the above circuits. The purpose of each of these controls is set forth in Table I.

The portable pictorial computer incorporates the following circuits

a. Bearing servo.
b. Distance servo.
c. Range limit.
d. Flag alarm.
e. Power supply.

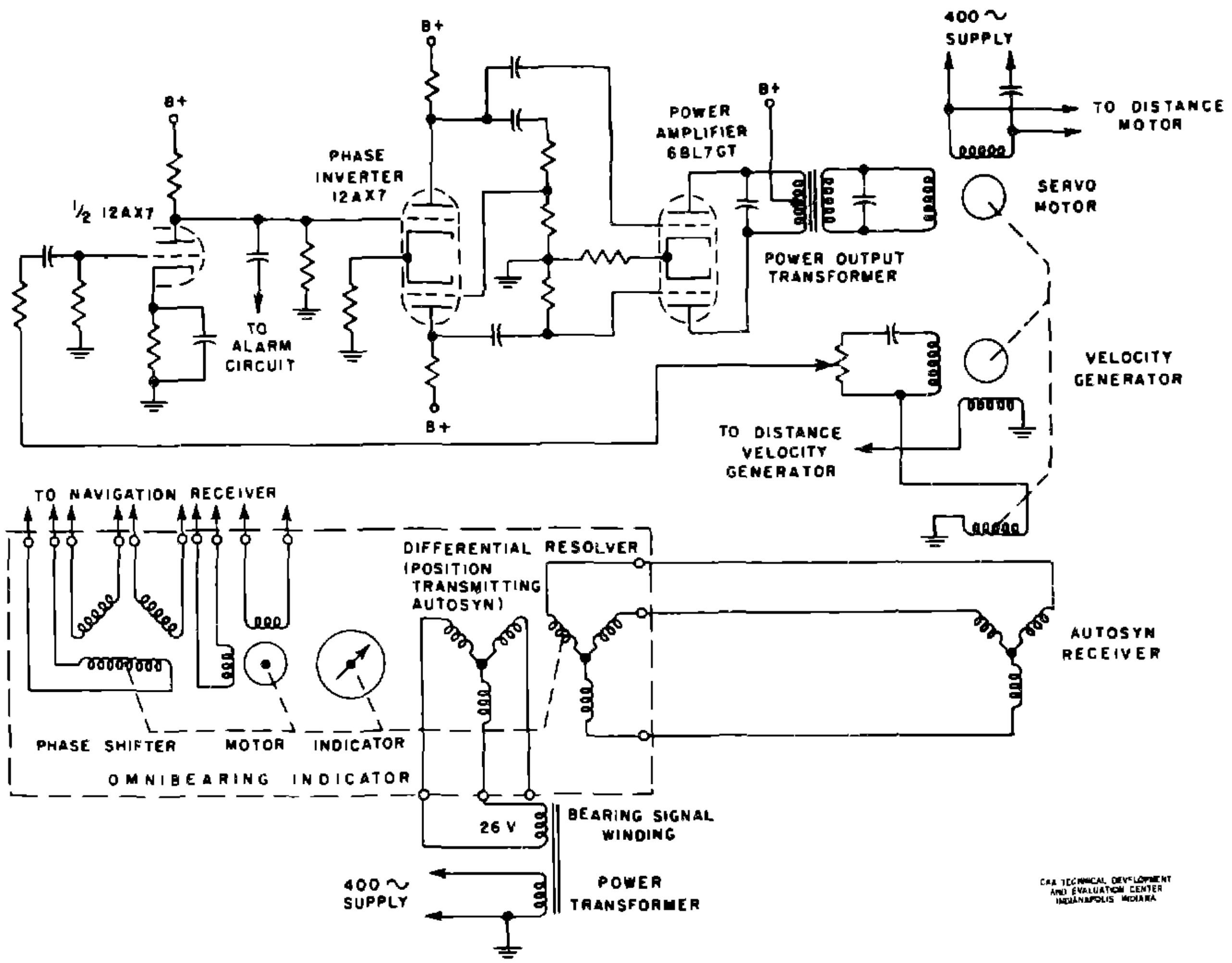

Fig. 3 Schematic Wiring Diagram of Bearing Servocircuits of CAA Type III Portable Pictorial Computer

The bearing servo (Fig. 3) consists of an Autosyn transmitter, an amplifier, a bearing servomotor with rate generator, and an Autosyn receiver.

The Autosyn transmitter is contained in the omnibearing indicator (OBI) and is a differential Autosyn which is normally used in conjunction with the radio magnetic indicator. When used with the pictorial computer, a voltage from the power supply transformer is applied to two of the stator windings. The amplitudes of the voltages induced in the three rotor windings are determined by the position of the rotor with respect to the stator. The rotor is positioned by a servo controlled by the omnirange receiver so that the rotor position is a measure of the bearing to the OBD station. The voltages induced in the rotor windings of the Autosyn transmitter are applied to the three stator windings of the Autosyn receiver in the display unit.

The shafts of the two Autosyns are said to be in electrical alignment when the voltage induced in the rotor of the Autosyn receiver is zero and when a small displacement of the rotor of the Autosyn receiver causes a voltage to be induced in the rotor winding of a phase. This would be such a phase that when applied to the amplifier and bearing servomotor the rotor would be driven in the direction that would reduce the voltage to zero.

The voltage induced in the rotor winding of the Autosyn receiver is the bearing-servo error signal. A velocity signal is added, and the resultant signal is fed through a filter to the first amplifier stage of the bearing servoamplifier. The output of the first amplifier stage is divided into two parts One part is fed to the flag-alarm circuits as described later, and the other is fed to a phase-inverter amplifier stage. The two outputs of the phase inverter are applied to the grids of a push-pull power amplifier stage, and the output of the amplifier stage drives the signal phase of the bearing servomotor The motor is two-phase and has an induction generator built in the same motor frame with it. The reference phases of the bearing servomotor and of the distance servomotor are excited in parallel through a phase-shifting condenser by 110 volts at 400 cycles per second (cps). This condenser is selected so that the output of the amplifier will either lead or lag the voltage applied to the reference phase by approximately 90°, depending upon the phase of the voltage from the rotor of the Autosyn receiver.

The bearing induction generator is a two-phase asynchronous machine on the same shaft as the servomotor. The reference phase of this generator is connected in series with the reference phase of the distance induction generator, and the two are excited directly by 110 volts at 400 cps. The output of the bearing induction generator is fed through a condenser to a trimmer potentiometer.

When voltage is induced in the rotor winding of the Autosyn receiver, it is filtered and applied to the first amplifier stage. The amplified signal is applied to the input of a phase inverter where it is further amplified, and a phase-inverted signal is produced. These signals are applied to a push-pull power stage the output of which is applied to the signal phase of the bearing servomotor so that the motor is caused to run in the direction that reduces the voltage in the rotor winding of the Autosyn receiver. For the motor to run when the error voltage is quite small, the gain of the amplifier must be large, but when the gain is large the momentum of the motor will cause the motor to run beyond the zero error position, and the amplifier will apply a voltage to the motor to make it run again toward the balance point. If the gain of the amplifier is sufficiently high for good servo performance, an oscillation will build up and the servo will hunt about the balance point. The induction generator has been provided to eliminate the hunting. The output of the induction generator is proportional in amplitude to the rotational velocity of the generator and is connected to the amplifier so that, when the motor is driving the Autosyn receiver rotor toward the balance point, the output of the induction generator reduces the error signal and causes the motor to slow down as it approaches the balance point. A trimmer potentiometer provides an adjustment of the amount of the velocity signal which is added to the error signal from the receiving Autosyn.

The distance sensing and calibration circuits are shown in a simplified schematic diagram in Fig. 4. Except for the sensing elements and calibration provisions, the distance servocircuits are similar to the bearing servocircuits. The signal for the distance servo is obtained from the distance sensing potentiometer contained in the DME The distance repeat-back potentiometer is in the display unit. Basically, the two potentiometers make up a Wheatstone bridge. The ends of the windings are connected together through the calibrating potentiometer and are excited by the power transformer. The signal for balancing the bridge is taken from the wipers of the potentiometers. The wiper of the DME one is grounded, and that of the repeat-back is connected to the input of the distance servoamplifier. Thus, if the calibrating potentiometers are properly adjusted, no voltage will be fed to the amplifier when the wiper of the repeat-back is in a position corresponding to that of the DME. Under this condition the bridge is said to be balanced. Both of the wipers are connected mechanically to the distance indicators which should show the same distance when the bridge is balanced.

The calibrating resistors and range switch provide a means for using charts of different scales. The range of the DME for which this equipment was designed is 100 nm (one nm equals 6,080 feet). The radii of the area represented on the various charts to be used in the computer are approximately 17.1 nm for the 1 250,000 scale, 34.2 nm for the 1 500,000 scale, and 68.4 nm for the 1 1,000,000 scale. Each chart has a radius of five inches. The construction of the computer is such that the wiper of the repeat-back potentiometer travels over a large part of the potentiometer resistance winding while the distance indicator travels the distance represented by the radius of the chart. To produce an indication of a distance equal to the distance represented by the radius of a chart having a scale of 1 250,000, the wiper of the DME potentiometer travels approximately one-sixth the length of the DME potentiometer resistance winding. Similarly, when using a chart having a scale of 1 500,000, the wiper travels approximately one-third the length of the winding, and with the scale of 1 1,000,000, it travels two-thirds the length. To cause the computer distance indicator to track properly, additional resistance was added in series with both ends of the repeat-back potentiometer

The cord drum was made large so that the airplane position marker would travel the radius of the chart before the wiper of the repeat-back potentiometer travels the

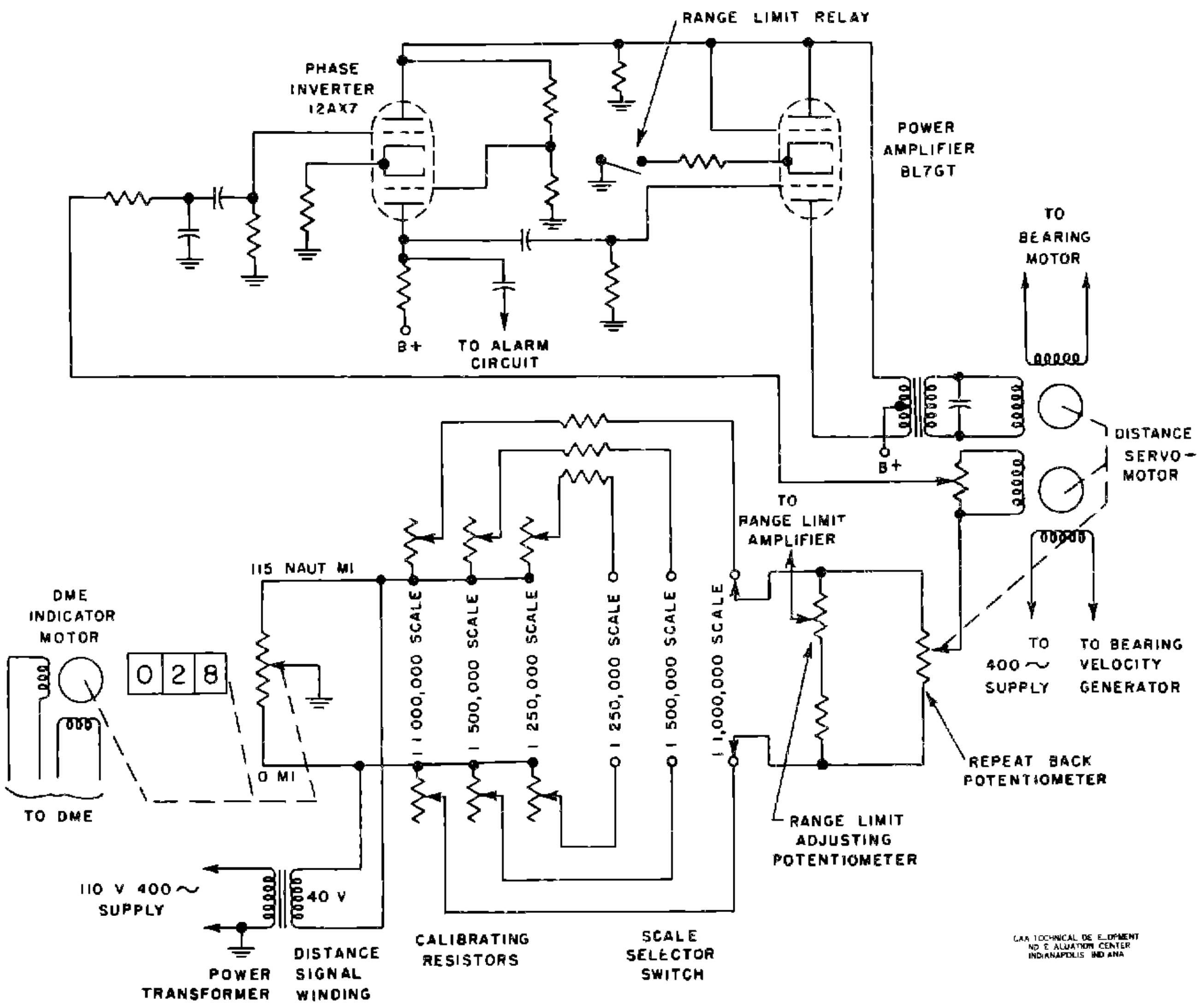

Fig 4 Schematic Wiring Diagram of Distance Servo and Calibration Circuits of CAA Type III Portable Pictorial Computer

entire length of the resistance winding This provides complete chart coverage but requires adjustable calibrating resistances at both ends of the repeat-back potentiometer. By adjusting these calibrating resistors, it is quite easy to calibrate the distance indicator over the entire range of each scale.

The error voltage is added to the voltage produced by the induction generator in the distance servomotor, and the resultant voltage is fed through a filter to the distance amplifier that consists of a phase inverter stage which drives a push-pull power output stage transformer-coupled to the distance servomotor.

A range limit has been provided to disable the distance servomotor when the airplane position indicator has reached the maximum range of the display A simplified schematic diagram of this circuit is shown in Fig 5. The range-limit-adjusting potentiometer is connected in parallel with the distance repeat-back one and, with the calibrating resistors and the distance sensing potentiometer, forms a secondary Wheatstone bridge. The output of this bridge is fed to a Class A amplifier stage, the output of which drives a relay stage. The plate circuit of the relay stage is supplied with 110 volts at 400 cps. When the DME distance indication is less than the radius of the chart, the voltage on the grid of the relay stage will be of opposite phase to that of the voltage on the plate and will bias the stage to cutoff. In

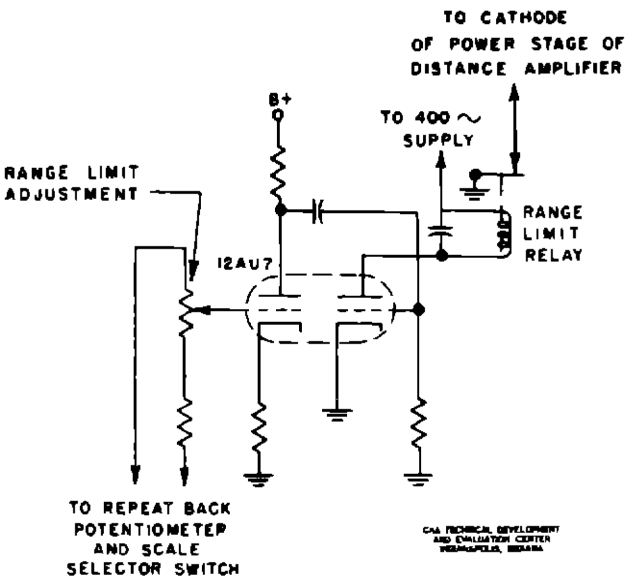

Fig. 5 Schematic Wiring Diagram of Range Limit Circuits of CAA Type III Portable Pictorial Computer

this condition the limit relay will be de-energized. The normally closed contacts of this relay are in the cathode circuit of the power stage of the distance amplifier. When these contacts are closed and the relay de-energized, the distance servo operates in its normal manner. When the DME distance is greater than the radius of the chart, the voltage on the grid of the relay stage will be in phase with that on the plate, under these conditions the tube will conduct, energizing the limit relay and opening the cathode circuit of the power amplifier stage of the distance servo. In this condition this servo is disabled, and its indication does not change until the distance again is within the range of the chart. When the distance is returned to a range within the radius of the chart, the plate and grid voltages again will be out of phase, the relay will be de-energized, and the operation of the distance servo will be restored.

The flag-alarm circuits open the contacts of the flag-alarm relay when any of the following malfunctions occur

a. Failure of the bearing servo to follow to within ± 3° of the OBI.

b. Failure of the distance servo to follow to within ± 2 miles of the distance indication.

c. Failure of the B^+ supply voltage.

d. Failure of the 110-volt, 400-cps supply.

The grid of the flag-alarm tube, Fig. 6, normally has a small negative bias permitting considerable plate current to flow, and the contacts of the flag-alarm relay are closed, completing the external flag-alarm circuit. If the error voltage in either the bearing or the distance servoamplifiers becomes excessively large a large negative bias is applied to the grid, the plate current is reduced, and the relay opens, interrupting the external flag-alarm circuit. Failure of the plate supply voltage (B^+) causes plate current to stop flowing in the relay coil and causes the alarm circuit to open. Failure of the 400-cps supply causes the B^+ supply to fail and also de-energizes the heater of the flag-alarm tube.

The power supply consists of a power transformer, a rectifier tube, and a resistance-capacitance filter. In addition to supplying filament and B^+ power to the amplifiers this power supply also furnishes 26 volts at 400 cps for energizing the OBI differential (the sensing circuit of the omnibearing servo) and 40 volts at 400 cps for energizing the distance bridge circuit.

Fig. 7 is a complete schematic diagram of the electronic circuits of the Type III computer.

INSTALLATION

In normal operation it is intended that the display unit should be held on the lap of the pilot or co-pilot as shown in Fig. 8. For this purpose, the cable which is an integral part of the display unit must reach to a suitable receptacle. Where practical, the display unit cable should plug directly into the amplifier unit, where this is not practical, an extension cable must be provided as part of the installation. Care should be exercised to keep any extension cable as short as practicable to avoid excessive noise pickup and capacitive loading in the signal circuits.

A rack should be provided for storing the computer when it is not in use. See Fig. 9. This rack should provide some protection against vibration and should be located in such a way that the display unit will not be subjected to excessive amounts of dirt or fluid of any kind. Protection from damage due to collision with baggage, cargo, or personnel should be provided.

The mounting base for the amplifier unit should be securely mounted to a suitable horizontal member of the airplane structure. The cables to the amplifier unit should be sufficiently long and suitably routed in order not to put a mechanical strain on the cable or mounting bases. Sufficient space should be provided to allow for vibration of the amplifier unit and to permit easy placement and removal of the amplifier unit on the mounting base which should be adequately

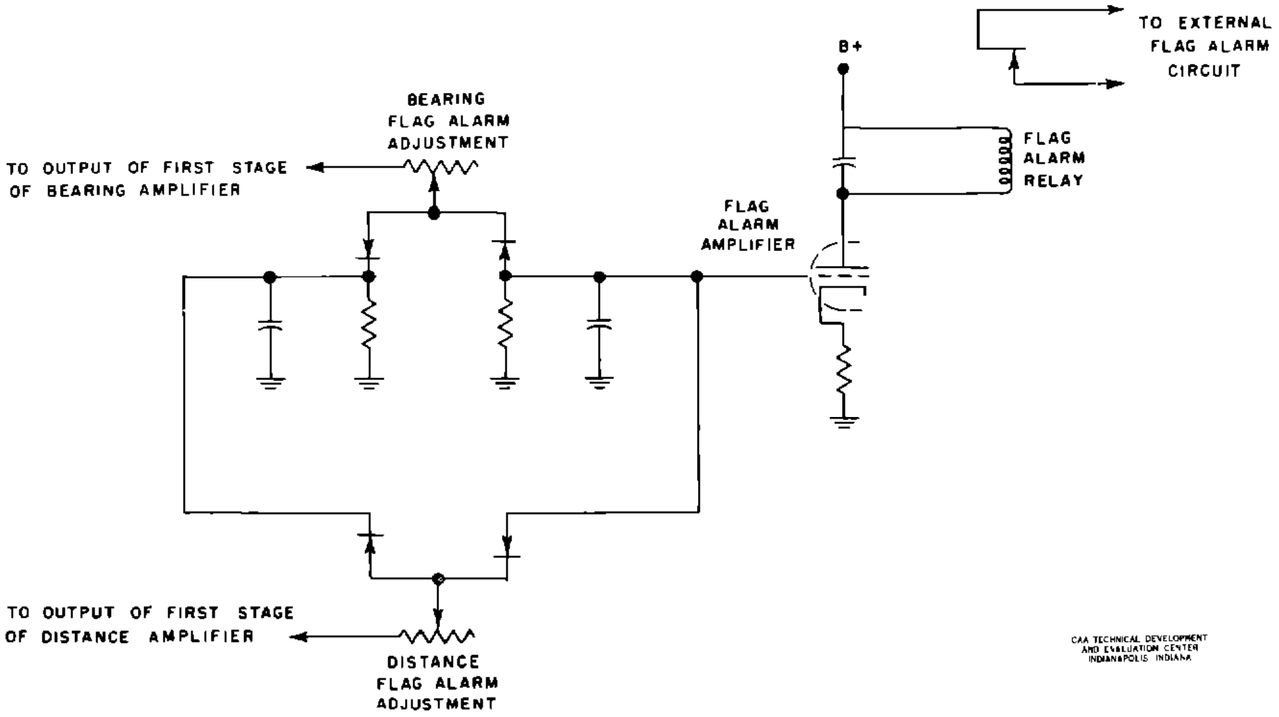

Fig. 6 Schematic Wiring Diagram of Flag-Alarm Circuits of CAA Type III Portable Pictorial Computer

grounded to the metal frame of the airplane. Ventilation to the amplifier unit should be provided In addition to the extension cable, a cable connecting the amplifier unit to the navigation receiver, DME, flag-alarm, and 400-cps power-supply circuits must be provided. A continuity switch must be added to short-circuit the series combination of the DME and the internal computer flag-alarm relay contacts, if normal operation of the receiver flag-alarm circuits is to be obtained when using the navigation receiver only This is necessary because the fail-safe operation depends on an energized closed circuit for normal flag-down indication

PREPARATION OF CHARTS

The portable pictorial computer requires charts cut to the proper size and shape. These charts may be readily cut from World Area Charts for the 1 1,000,000 scale, from Sectional Aeronautical Charts for the 1 500,000 scale, or from Local Area Charts for the 1 250,000 scale. This process is facilitated by use of the template supplied with the computer and shown in Fig. 1. The charts are prepared as follows

a. Locate on the chart the position of the OBD station.

b. Place the template on the chart with the center of the template coinciding with the location of the OBD station.

c. Orient the north-south line of the template with those on the chart. To facilitate this operation, additional lines are engraved on the template parallel with the central north-south line. One of these will be found to come very close to one of the north-south grid lines, and the template lines can be readily oriented by eye to be parallel to the grid line with an accuracy of 0.5°.

d. With a pencil, mark on the chart the location of the large notch on the north side of the template and the small V-notch on the south side of the template.

e From the chart, determine the magnetic declination at the location of the OBD station.

f. Being careful to keep its center exactly over the OBD station, rotate the template clockwise or counterclockwise (depending upon whether the declination is east or west) so that the north-south lines of the template are oriented in the direction of magnetic north. An azimuth scale is provided on the template to facilitate this rotation.

g. With a sharp pencil, circumscribe the template and mark the three notches with particular accuracy.

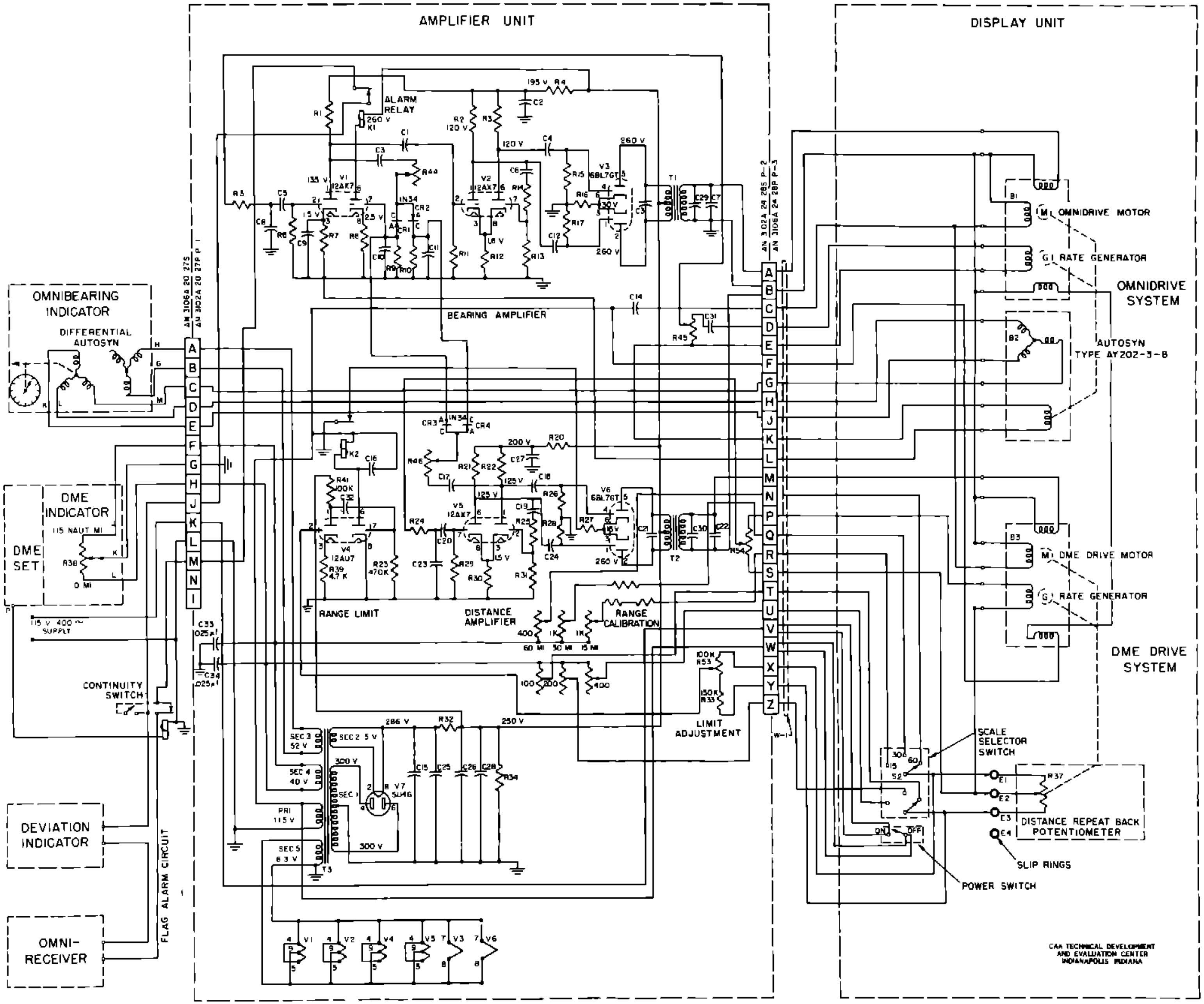

Fig. 7 Schematic Wiring Diagram of CAA Type III Portable Pictorial Computer

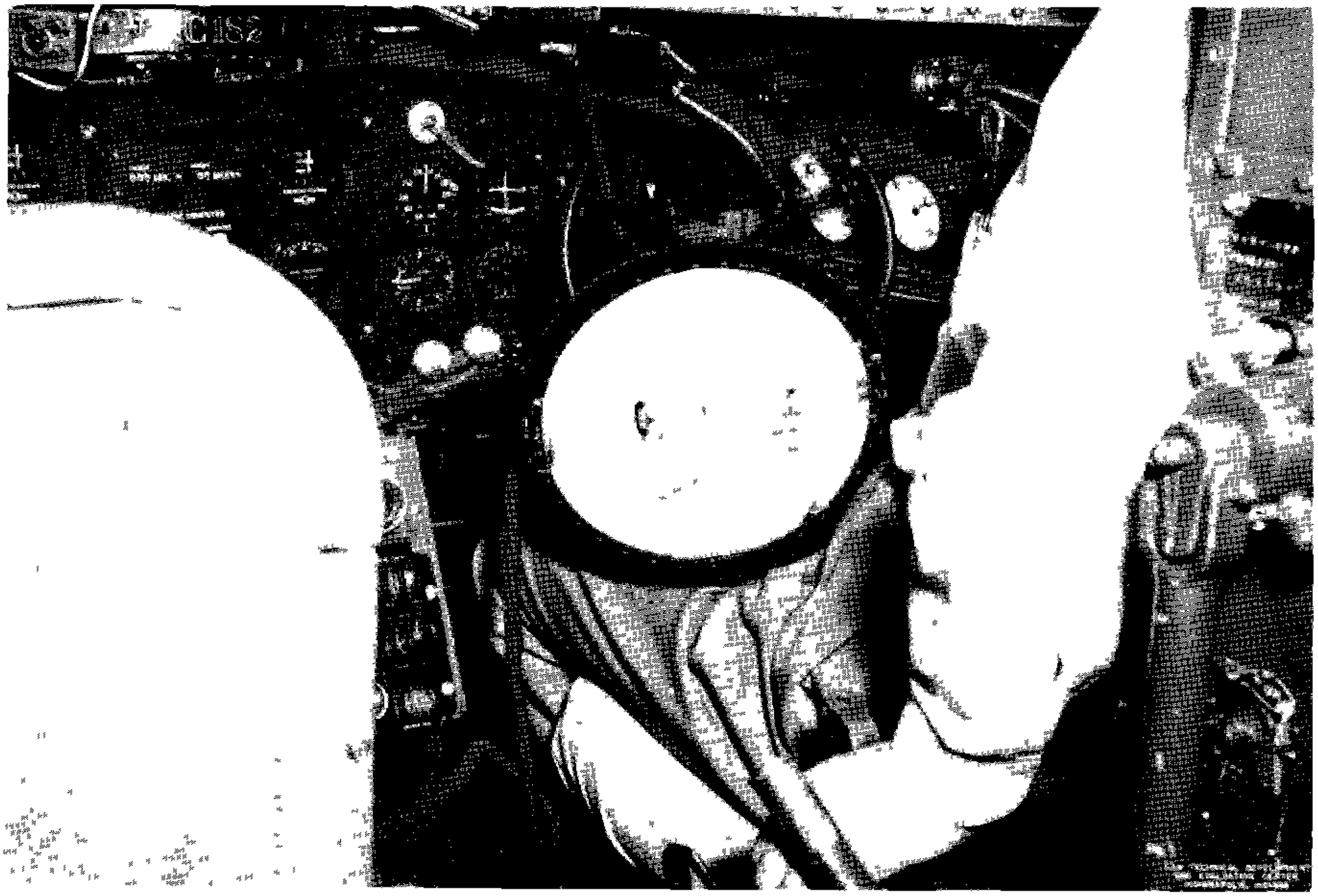

Fig 8 Display Unit in Operating Position

h With a pair of scissors cut out the chart, again paying attention particularly to the location of the three V-notches.

OPERATION

Navigation of an airplane equipped with a portable pictorial computer is similar to ordinary navigation using landmarks, except that it is no longer necessary to track manually the flight path on the map. To use the pictorial computer in normal flight, proceed as follows

a. Tune in the nearest OBD station on the navigation receiver and definitely identify the station by its call letters.

b. Turn on the computer and select the chart which has the location of that particular station at its center.

c. *Note the scale of the chart, and set the* scale selector switch of the display unit to correspond to that of the chart. The data tabulated in Table II may be of some assistance in this connection.

d. Lift up the airplane position indicator guide and place the chart on the map plate of the display unit being careful to have the three V-notches in the map fit into the corresponding locator studs under map clips.

TABLE II

CHARTS FOR COMPUTER USE

Display Unit Scale Selector Switch Position	Corresponding Chart Scale	Corresponding Chart Designation
60	1 1,000,000	World Aeronautical Charts
30	1 500,000	Sectional Charts
15	1 250,000	Local Charts

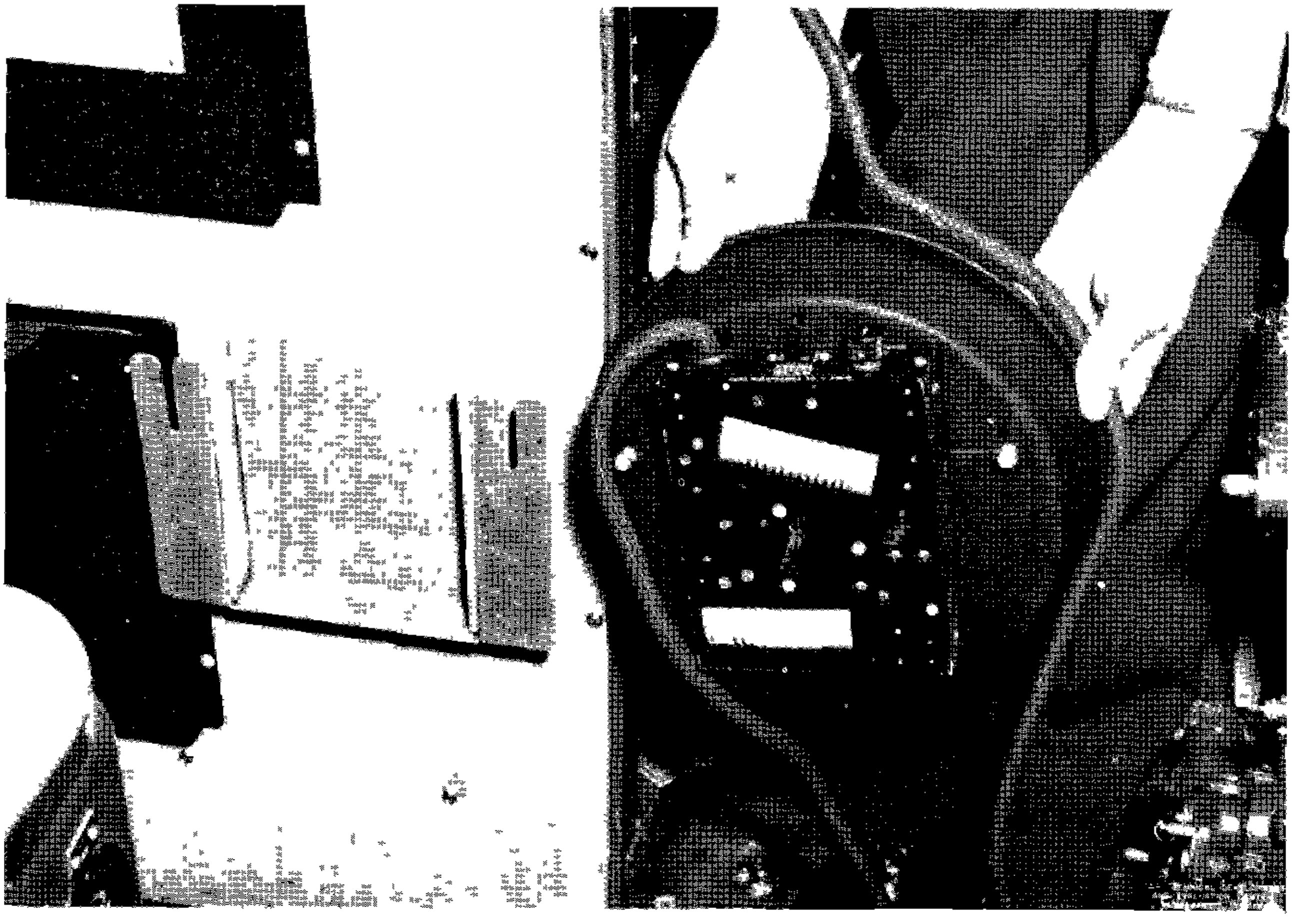

Fig. 9 Display Unit Storage Rack in N-182

e. Return the airplane position indicator guide to its normal position

f. In approximately 30 seconds from the time the computer is turned on, the flag of the deviation indicator will go out of sight indicating that the computer indication is accurate and may be used for navigation. If desired, the position of the airplane may be marked on the chart by inserting the sharp point of a pencil through the small hole located at the center of the airplane position indicator

g. As the airplane approaches the edge of the area represented by the chart, the OBD station corresponding to the next chart to be used should be tuned in and the above procedure repeated.

h. To turn off the computer, set the power switch to the OFF position Depending upon the particular airplane installation, it may also be necessary to turn off the navigation receiver and the DME.

During use, should the airplane fly beyond the reliable distance range of the OBD station concerned or should the computer error become excessive, the flag alarm of the course deviation indicator will immediately warn the observer that computer indication is not reliable Thus, there is little chance that the pilot will follow an incorrect path.

EARLY MODIFICATIONS

Prototype equipment was completed in March 1951. After examining this, seven changes were recommended to the contractor These were incorporated in the remaining equipment, and later the prototype was modified to include them. The changes were

a. Elimination of dropping resistors in the induction generator reference windings.

b. Elimination of the requirement for any 28-volt dc power. This was done by supplying all the heaters of the electron tubes from the 400-cps power transformer

c. Provision of separate transformer windings for the bearing-servo signal excitation and for the distance-servo signal excitation.

d. Provision of 100,000-ohm potentiometers for the induction generator loads instead of the 10,000-ohm potentiometers originally provided.

e. Addition of ventilation and inspection holes in the display unit cover

f. Revision of the flag-alarm circuit to provide flag indications when the alarm relay was de-energized, thereby making it fail-safe.

g. Redesign of the airplane position marker to use plastic instead of metal guides and to accentuate the airplane position.

The remaining equipment called for in the contract was received in August and September, 1951. After some bench and flight testing, these further modifications were made to all of the units

a. The zero adjusting resistors which were originally wired in the low end of the DME potentiometer were transferred to the low end of the repeat-back potentiometer.

b. The values of the maximum range calibration resistors were increased to provide a greater range of calibration adjustment.

c. The range limit circuits were rewired to prevent interaction with the range calibration adjustments and to reduce the distance between the cut-out and cut-in points This required a complete rewiring of the range limit tube and the substitution of a different type of tube.

In accomplishing those modifications which were necessary to achieve satisfactory operation of the computer, several conditions were encountered which (had they been considered in the design of the equipment) would have resulted in easier calibration and adjustment and probably in more dependable operation of the equipment. Some of these are listed, not to call attention to the shortcomings of the equipment but rather to point out the conditions so that they may be properly considered in the design of future equipment. The more important of these conditions are

a. Standardization of the characteristics of the output circuits of the OBD equipment available for computer use.

b. Method of signal summing.

c. Method of range limiting.

The need for the standardization of the output circuits of the OBD equipment available for computer use is important. The Type III computer was designed specifically to receive omnirange information from the differential Autosyn provided in the omnibearing indicator of Collins Radio Company, Types 51R-1 and 51R-2, and Bendix Aviation Corporation, Type NA-3 navigation equipment. Because it cannot be used with the Type III computer without elaborate converter units, the navigation equipment of the following is not satisfactory Aircraft Radio Corporation (Type ARC-15), National Aeronautical Corporation, Lear, Incorporated, and Mitchell Industries.

If a servomechanism is used to follow the OBI indication, in the case of the Collins and Bendix receivers, then two servomechanisms are cascaded with the addition of servo follow-up errors. This is because the OBI indication is produced by a servo. The power output of the OBI servoamplifier in the navigation receiver is not sufficient to drive the bearing servomotor in the computer, and the design of the amplifier is such that there is no practical way to extract a control signal from the omnibearing circuits except from the differential Autosyn which is provided for use in conjunction with the radio magnetic indicator A better design would be to have the computer indication produced by the primary servo

Likewise, in the case of the distance indication, there is a cascading of servomotors which is undesirable. However in the case of the DME, the derivation of the basic information is so complicated that it is very difficult to produce a satisfactory indication without a servomechanism At present the standard DME output provided for computer operation is simply to rotate the shaft of a Fairchild Camera & Instrument Corporation Type 747 potentiometer having 1,000 ohms resistance. In general, this choice is satisfactory. The low impedance helps to avoid capacitive loading of the potentiometer due to long cable runs. There has been some "wire hopping," or step increments in the output of the potentiometer as the wiper moves from turn to turn over the resistance winding of the potentiometer. The choice of a higher resistance potentiometer having more turns of finer wire (2,000 or even 5,000 ohms total resistance) would improve this condition, but it is doubtful that the resistance should exceed 5,000 ohms.

Assuming that linear potentiometers are to be used for the DME output and for the computer repeat-back and assuming that series signal summing is employed, then the relationship between the movement of the potentiometer wiper along its resistance winding and the change in distance indication is of importance because this relationship determines the values of calibrating resistances required. Since it is not practical to set the indicator to indicate zero miles when the potentiometer wiper is at the zero end of the resistance winding or to set the indicator to indicate a maximum number of miles when the potentiometer wiper is at that high resistance end of the potentiometer winding, either in the DME distance indicator or in the computer distance indicator, it is necessary to provide two trimmer resistances for each chart scale to be used. To obtain maximum resolution from the potentiometers, in the case of either indicator, it is desirable that the minimum and maximum values of resistance correspond as nearly as is practicable to minimum and maximum values of distance. In the case of either indicator, it is also necessary that the travel of the wiper along the resistance winding of the potentiometer be less than 100 per cent for full travel of the distance indication. This requirement is necessary to insure full range of indication A further requirement for the zero-trimmer resistance is that it be in series with the distance potentiometer which has zero miles set nearest to zero resistance. Thus, with the zero trimmer in series with the repeat-back potentiometer, the wiper of the repeat-back potentiometer should be at a position between zero and 2 1/2 per cent of the resistance of the winding, and the wiper of the DME potentiometer should be at a position between 2 1/2 and 5 per cent of the resistance of the winding for zero-mile indication. After some testing, it was decided to set zero miles on the computer at 20 to 25 ohms on the 1,000-ohm repeat-back potentiometer and to set zero miles on the DME potentiometer at 40 to 50 ohms. This permits adequate adjustment of the zero setting with comparatively small values of resistance.

In the case of the maximum range calibration, the trimmer resistance must be in series with that potentiometer which has the smaller full-scale distance indication. Thus, for the 1 250,000, 1 500,000, and 1 1,000,000 scales, the five-inch radius of each of the computer charts represents 17.1 nm, 34.3 nm, and 68.5 nm, respectively. Full scale on the distance indicator is 115 nm. If both the DME and the repeat-back potentiometer wipers were adjusted so that full-scale distance was indicated when the wipers were at 97 per cent of the resistance, then trimmer resistance would have to be added to the high end of the repeat-back potentiometer for all three scales. For the 1 250,000 scale, the active resistance (the resistance over which the potentiometer wiper travels) of the repeat-back potentiometer would be approximately 15 per cent of the total resistance in the repeat-back side of the bridge. For the 1 500,000 and 1 1,000,000 scales, the resistance would be approximately 30 and 60 per cent respectively. For a scale of 1 2,000,000, the chart radius represents 137.1 miles. To use this scale the trimmer resistance should be added to the distance indicator potentiometer. With this arrangement the active resistance of the DME potentiometer would be approximately 84 per cent of the total resistance in the DME side of the bridge. Actually, the computer was so constructed that only about 65 per cent of the resistance in the repeat-back potentiometer was active. This reduced the resolution of the repeat-back potentiometer and required reconsideration of the values of trimmer resistance. Had the 1 2,000,000 scale been used, a much larger value of trimmer resistance would have been necessary.

As has been indicated, series summing of signals was used in the Type III computer. There are some advantages to be gained by parallel summing Chief among these is that parallel summing permits the use of more than one computer or the use of a computer and a servo type distance indicator from one DME. It also reduces the effect of capacitive pickup in a sensing element, since the only impedance from the pickup element to ground is the impedance of the sensing device. One disadvantage is that at least two signal supply voltages are required With parallel summing, the DME and the repeat-back potentiometers would have to be supplied from separate voltage sources which are 180° out-of-phase.

The electronic apparatus required to achieve range limiting seems too elaborate for the results obtained. There was an objectionable amount of interaction between the limit adjustment and the range calibration of the computer when it was received. Readjustment of the limit required recalibration on all scales. There was also an objectionable amount of spread between the cut-in and cut-out points. When the limit was adjusted to cut out at 18 miles on the 1 250,000 scale, the cut-in point was about 14.5 miles.

SOME COMMENTS ON CONSTRUCTION AND GENERAL APPEARANCE

The design of the Type III computer incorporates some unique features. It was intended as experimental equipment, and as such the requirements were different from the requirements for production or preproduction equipment.

In the display unit, some shaft and bearing brackets were mounted on the flat base plate with roundheaded screws. The

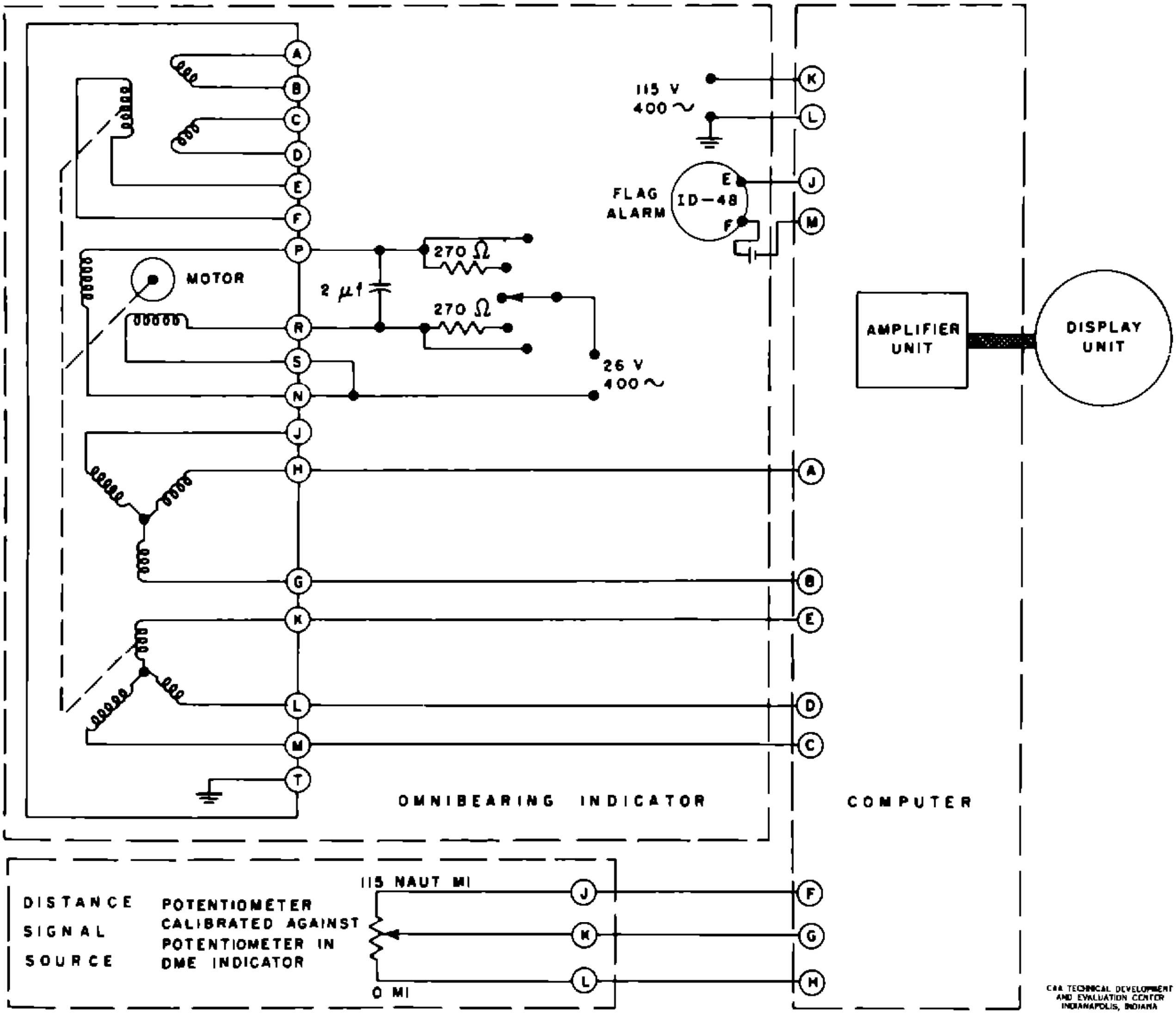

Fig. 10 Schematic Wiring Diagram of Laboratory Test Equipment of CAA Type III Portable Pictorial Computer

screws loosened under normal handling, and the shafts became misaligned. One end of the cord drum depended on the bearing in the repeat-back potentiometer for support. The stress on the cord drum due to tension in the cord resulted in binding of the potentiometer shaft. To adjust the value of resistance in the repeat-back potentiometer for zero indication, it was necessary to slip the cable drum on the shaft of the potentiometer which often resulted in its binding. The cord was made of a good grade of fishing line, but after some use it stretched, resulting in backlash in the position indication. The cord was originally attached by tying it to the cord drum and position indicator slide, but this method was abandoned in favor of pinning the cord in place in a hole in the same manner that the hairsprings of clocks are pinned. The case was difficult to remove from the display unit. It required the dismounting of the range selector switch and caused flexing of the wiring in the display unit so that some of the connections were soon broken and had to be replaced.

LABORATORY TESTS

To determine the performance that might be expected of the Type III computer, laboratory tests were performed. The omnibearing signals were obtained from an OBI, and the distance signals were obtained from a potentiometer which had been calibrated against an airborne DME currently in use. The flag-alarm circuits were connected to a dry cell and to the alarm indicator circuits of a Type ID-48 course deviation indicator. A schematic diagram of the circuits used for these tests is shown in Fig. 10 Computer

Serial No. 105 was used Power was applied to the equipment, and a 20-minute warm-up period was permitted before any measurements were made.

Range of Distance Calibration Adjustment.

The tests were made for each of the three distance ranges of 15, 30, and 60 miles

1. Range of zero adjustment

The zero adjustment was set to give a minimum distance indication. The distance signal was arbitrarily adjusted to cause the computer to indicate zero miles. The zero adjustment was reset to give a maximum distance indication, and this indication was considered to be the range of zero adjustment

2. Range of full-scale adjustment.

The full-scale adjustment was set to give maximum indication. The distance signal was arbitrarily adjusted to give 15, 30, and 60 miles on the corresponding scales. The full-scale adjustment was reset to give minimum indication. The difference between this indication and the corresponding 15-, 30-, or 60-mile ones was considered to be the range of full-scale adjustment. These results are shown in Table III.

TABLE III

RANGE OF
DISTANCE CALIBRATION ADJUSTMENT

Range (miles)	Zero Adjustment (miles)	Full-Scale Adjustment (miles)
15	8.75	2.9
30	8.2	10.2
60	8.2	18.4

Linearity of Distance Indication.

Each range was adjusted so that when zero distance signals were applied, the computer indicated zero distance from the OBD station, and when full-scale signals were applied, the computer indicated the corresponding distances of 15, 30, and 60 miles on the respective ranges Beginning at zero miles, distance indications were checked at each five-mile interval on each scale, as shown in Table IV.

TABLE IV

LINEARITY OF DISTANCE INDICATION

Distance Signal (miles)	Computer Indication: 15-Mile Range (miles)	30-Mile Range (miles)	60-Mile Range (miles)
0	0	0	0
5	5.0	5.0	5.1
10	10.0	10.0	10.3
15	15.0	14.9	15.3
20	-	19.9	20.2
25	-	24.9	25.2
30	-	30.0	30.1
35	-	-	35.1
40	-	-	40.0
45	-	-	45.0
50	-	-	49.9
55	-	-	54.9
60	-	-	60.0

Range of Distance Limit Adjustment

With the distance indicator calibrated, the distance signals were varied and the cut-in and cut-out points of the distance limit were observed on each distance range with the limit adjustment set to give cut-out at minimum range. The test was repeated with the limit adjustment reset to give cut-out at maximum range, and the results are shown in Table V

Change of Limit Adjustment
With Range Selected

With the limit adjustment set to operate at 17 miles on the 15-mile range, the limit operated at 32.5 miles on the 30-mile one and at 61.2 miles on the 60-mile.

TABLE V

RANGE OF DISTANCE LIMIT ADJUSTMENT

Range Limit Adjustment	15-Mile Range Min.	15-Mile Range Max.	30-Mile Range Min.	30-Mile Range Max.	60-Mile Range Min.	60-Mile Range Max.
Cut-out	15	24 1/4	28	47	54	90
Cut-in	15 1/4	24 1/2	28	47	54	90

TABLE VI

DISTANCE SERVO BACKLASH

15-Mile Range		30-Mile Range		60-Mile Range	
Indicated (miles)	Required (miles)	Indicated (miles)	Required (miles)	Indicated (miles)	Required (miles)
0	0.4	0	0.4	0	0.5
5	0.25	10	0.25	20	0.3
10	0.2	20	0.1	40	0.2
15	0.1	30	0.1	60	0.1

Distance Servo Backlash.

The change in distance signal required to give a visible change in distance indication was observed at four points on each distance range. The results are shown in Table VI.

Flag-Alarm Adjustments.

The adjustment of the flag-alarm circuits was extremely critical. A small change caused the flag either to stay in view or to be out of sight continuously. It was not possible to obtain reliable data concerning the limits of adjustment available.

Calibration of Bearing Indications.

The OBI (Collins Type 337-A2 OBI, Serial No. 376) was set at 10° intervals from 0 through 360°, and the computer indication was observed for each setting. The precision of reading the OBI was to the nearest one-fourth degree. These results are shown in Table VII.

Bearing-Servo Backlash.

One-tenth degree change in the OBI caused a noticeable change in the bearing indication. Backlash in the bearing-indicator drive gear permitted this indicator to be manually displaced one degree from the true indication. The sensitivity of the servo, however, was such that the indication would immediately return to within one-tenth degree of the original.

Flight Tests.

Fig. 11 shows the results of a flight made in the Indianapolis terminal area to test the accuracy of the computer. The airplane was flown over roads in the area under visual flight rule (VFR) conditions. The track is shown as a dotted line in Fig. 11. The indications of the computer were recorded on the chart in the computer by holding a pencil point in the hole provided for the purpose in the airplane position indicator. These indications are shown as a solid line in Fig. 11. During the flight, a calibration error of 0.6 mile in the computer was observed. This was corrected during the flight, as indicated on the chart. The dashed line of Fig. 11 was obtained by applying the proper corrections to the solid line from an error curve of the omnirange ground equipment.

TABLE VII

CALIBRATION OF BEARING INDICATIONS

OBI Setting (degrees)	Computer Indication (degrees)
0	1/4
10	10 1/4
20	20 1/4
30	30 1/4
40	40 1/4
50	50 1/4
60	60 1/4
70	70 1/4
80	80 1/4
90	90 1/4
100	100 1/4
110	110 1/4
120	120
130	130
140	140
150	150
160	160
170	170
180	180
190	189 3/4
200	200
210	210
220	220
230	230
240	239 3/4
250	249 3/4
260	259 3/4
270	269 3/4
280	280
290	290
300	300
310	310
320	320
330	330
340	340
350	350
360	360 1/4

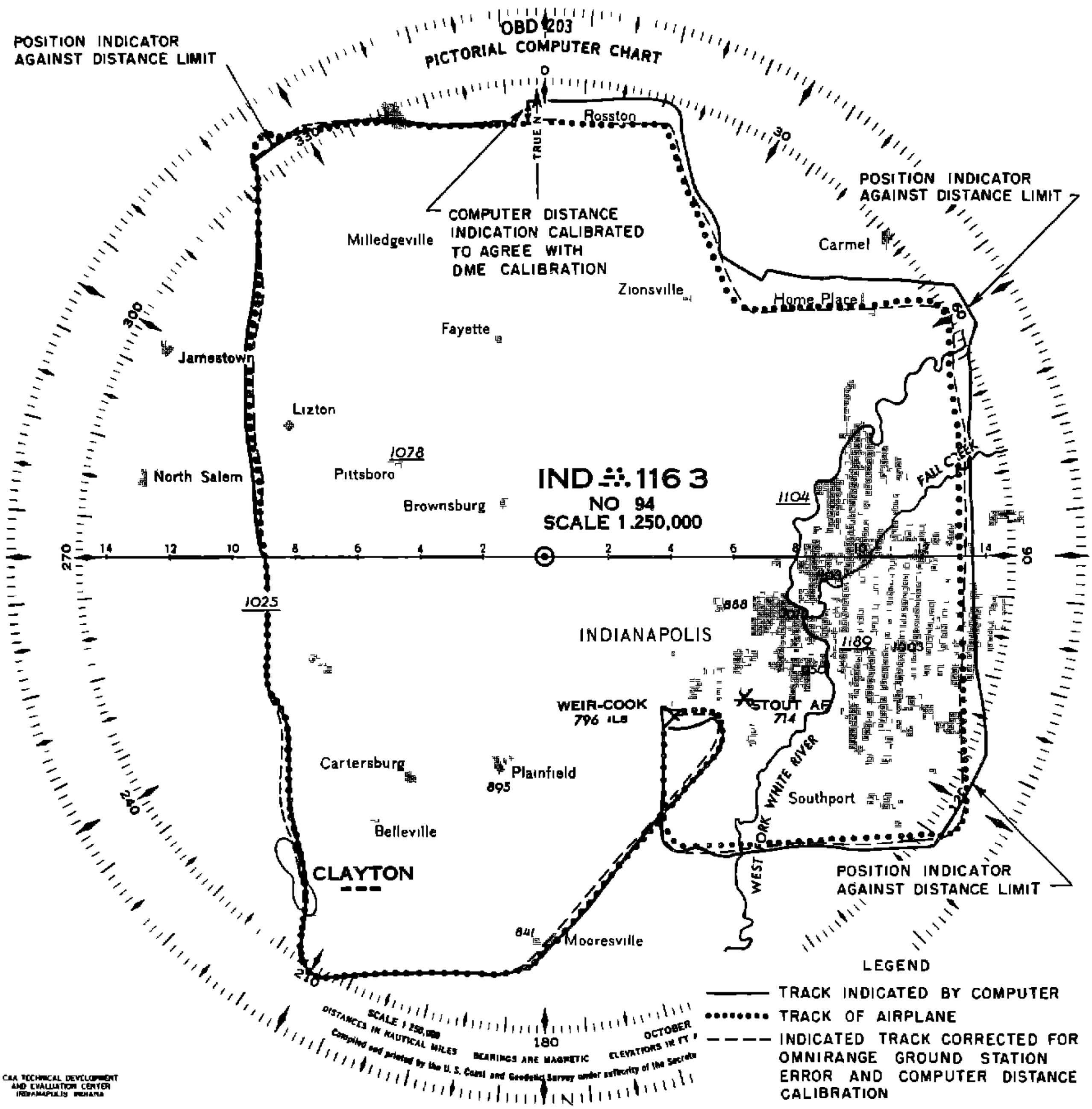

Fig 11 Chart for Pictorial Computer Use (Reduced Scale)

CONCLUSIONS

The CAA Type III portable pictorial computer, in its present form, provides the most easily used presentation of OBD information that has been made available to the pilot to date. Criticisms of the equipment have been made of the mechanical details rather than of the basic design. For example, the airplane position indicator is somewhat obscured by the mechanism of the bridge, and the changing of charts is unduly complicated by the bridge over the chart. After a few flights it also became obvious that some provision must be made to mount the computer in its operating position, because it is not practical to hold the display on the operator's lap during long flights.

The errors of position due to the computer are small compared to the errors in the OBD data. Therefore, until improvement of the OBD data is accomplished, gains in computer performance can be made much more rapidly by improving the features of the display rather than the accuracy of the computer mechanisms.

APPENDIX I

SUMMARY OF CHARACTERISTICS OF CAA TYPE III PORTABLE PICTORIAL COMPUTER

PHYSICAL

Display Unit.

Weight	10 pounds
Height	3 3/4 inches
Diameter	11 7/8 inches

Amplifier (With Mounting Base).

Weight	14 pounds
Height	9 inches
Width	5 inches
Length	13 1/4 inches

Charts.

Diameter	10 inches centered on OBD station
Scales	1 250,000, 1 500,000 and 1 1,000,000

SLEWING SPEEDS

Bearing Servo.	18° per second
DME Servo.	Approximately 0.3 inch per second (3600 nm per hour on the 1 250,000 scale)

ELECTRICAL

Power Source.	115 volts, 400 cps, single phase
Power.	125 watts with both servos balanced
	140 watts with both servos in operation
Power Factor.	0.93

ACCURACY (AS REQUIRED BY SPECIFICATION)

Range.	± 0.4 mile maximum error
Bearing.	± 1/2° or 1/32 inch, whichever is greater

VACUUM TUBE COMPLEMENT

3 each 12AX7
2 each 6BL7GT
1 each 5U4G
1 each 12AU7

APPENDIX II

SUMMARY OF CHARACTERISTICS CONSIDERED FOR A PICTORIAL DISPLAY BASED ON OBD INFORMATION

In planning the pictorial computer program, an effort was made to progress toward an ultimate computer design with a minimum of experimental work and yet not to overlook any worth-while characteristic. After some study of the problem and before any specifications were written, a list was prepared showing most of the characteristics that might be incorporated into a pictorial display of OBD information. An examination of the list showed that all of the characteristics could not be incorporated into two or even three types of computers.

Two principles were kept in mind when the specifications for the three pictorial computers were prepared

1. Each computer should include only those characteristics that are compatible in an over-all design.
2. Each listed characteristic should be included in at least one computer.

Orientation of the Chart.

Three methods of orienting the chart were considered (1) chart fixed, north up, (2) chart manually rotated with either the course or north up, and (3) chart rotated by a servomechanism to have the aircraft heading up. The charts were to be oriented north up in the Type V computer and were to be manually rotatable in the Type III and Type IV computers. The heading-up feature, with the chart rotated by a servomechanism, was not included in any of the three computers.

Mounting of the Display Unit.

The display unit of the Type III computer was designed to be held on the operator's lap while in use, however, the display could be placed in a rack on the control pedestal when in use and stored in a rack outside the cockpit when not in use. Although the display units of the Type IV and Type V computers were designed for instrument panel mounting, the displays may be mounted on the control pedestal in cases where there is insufficient space on the instrument panel.

Display of Heading.

Airplane heading was to be displayed at the airplane position indication in the Type IV and Type V computers. Consideration was given to a peripheral display of heading, but this was given up in the interest of mechanical simplicity. The heading indication was omitted from the Type III computer.

Airplane Position Indicator.

The airplane position indicator was to be nondirectional in character unless a heading indication was included. A nondirectional indication was used in Type III and in one model of the Type IV computers. One model of the Type V computer included distance circles and magnetic directional radials with the airplane position indicator. Another model of the Type V had both a small compass rose centered on the airplane's position and a heading arrow. One model of the Type IV computer had a small arrow at the airplane position indication.

Relative Motion.

The three pictorial computers to be developed as part of this program were to have the charts fixed and centered on the OBD station. Other configurations considered were (1) to have the airplane fixed at the center of the display while the chart is moved by servomechanisms, (2) to have the OBD station fixed at the center while the chart is rotated by servomechanisms to maintain the aircraft's heading toward the top of the display

Methods of Recording Track.

The methods of recording track which were considered included (1) the use of facsimile paper for charts, (2) the use of heat-sensitive paper for charts, Type IV computer, (3) marking of the position by the operator, Types III and V, and (4) marking of the track by pen and ink arrangements.

Preparation and Insertion of Charts.

The Type III and Type IV computers were to use charts which were cut from sectional aeronautical charts or others of the proper scales and were manually inserted into the computer. The Type V computer was to use charts photographed on film and projected on a screen. Several characteristics of projected charts were considered, for example, individual charts of each scale and each area could be moved each time a new omnistation was selected, or one large film could be moved about the airplane in the center of the display. Individual charts could be stored on a roll of film and the roll positioned by an electromagnetic device. This method was used in the Type V computer. In the case of individual charts, a mechanism could be used to select the charts from a storage magazine and return the last used chart to the magazine when the operator sets the station call letters on suitable dials.

Automatic Features.

Consideration was given to including, as a feature of the charts, information which would enable the computer to perform automatically some of the functions required to put the computer into operation. When the desired chart was selected and put on the display (in the case of the Type V computer) the scale mechanism of the computer was automatically set to agree with the scale of the chart, and the associated OBD equipment was tuned to the station represented on the chart.

Alarm Circuits.

It seemed desirable to have associated with the equipment a flag alarm which would monitor not only the operation of the associated OBD equipment but also the circuits of the computer.

Application of Computers.

The uses of the computers were to be evaluated as a part of the program. The various computers were to be used for navigational purposes, and if experience showed them to be acceptable, it was proposed to use them where possible as flight instruments.

Size of the Display.

It was desirable that the display be as large as is practical to get it into the cockpit. A chart diameter of ten inches seemed to be about the maximum for experimental units.

Auxiliary Functions.

Since the computer was to contain bearing and distance servomechanisms, the problem of providing a course-line computer function seemed relatively simple. A course-line computer indication was included as part of the Type IV computer.

APPENDIX III

FEATURES OF CHARTS PREPARED FOR PICTORIAL COMPUTER USE

From the beginning of this project it was obvious that the existing sectional aeronautical charts are not well-suited for pictorial computer operation. Therefore, the Coast and Geodetic Survey was requested to prepare special charts for this use.

After some discussion, it was decided that the charts should include the following features

1. Symbols for airports, except on the 1 250,000 scale where airports to be shown by exaggerated runway patterns if necessary.
2. Circles indicating distances from the OBD facility, at two-mile intervals on the 1 250,000 scale and at ten-mile intervals on scales smaller than 1 250,000, with identification of the distance circles to be on the north side.
3. Danger, warning, and prohibited areas.
4. The highest altitude in each geographic quadrant, except that in some cases it was desirable to indicate the minimum safe altitude.
5. Terrain features in relief only where there were hazards or obstructions.
6. Relief by spot elevations with the highest altitude shown in a box.
7. Fan markers not associated with an instrument landing system (ILS).
8. Double-line streams and very large lakes, however, where there was no other visual information, single-line streams to be marked.
9. A route sequence serial number assigned for each chart.
10. Longitude and latitude marks outside the azimuth circle of the chart.
11. The symbol used to indicate VOR facilities to be the center of the symbol developed by the U. S. mapping agencies.
12. The printing on the charts oriented to magnetic north, not true north.
13. Letters "ILS" and the frequency and identification of the ILS facility in a note adjacent to the airport symbol.

The charts should not include the following features

1. Low frequency radio information.
2. ILS localizer, back localizer, inner and outer markers, or compass stations.
3. State lines, roads, railroads, or drainage (except as indicated in the foregoing features under 8)
4. Airways.

Two charts prepared as part of this program are shown in Figs. 11 and 12.

APPENDIX IV

DIGEST OF MINUTES OF AIRBORNE COMPUTER SYMPOSIUM HELD AT TECHNICAL DEVELOPMENT AND EVALUATION CENTER, INDIANAPOLIS, INDIANA, APRIL 18 AND 19, 1951

The symposium was attended by 66 people representing 28 different organizations from industry and government.

The purpose was twofold (1) to acquaint the group with the ANDB development program in airborne computers, and (2) to obtain the opinions of both operational and technical people on the many problems involved in designing and using airborne computers.

Mr. Francis J. Gross of the TDEC described the Minneapolis-Honeywell offset course computer, the CAA Types I and IA course-line computers, and two models of course-line computers built by Collins Radio Company the AN/ARA-21 (XA-1) and the Collins Type 560A-1. Mr. Logan E. Setzer, TDEC, discussed the CAA Type II Automatic Flight and Navigation Equipment, the CAA Type III Portable Pictorial Computer, the CAA Type IV Rotatable Panel Pictorial Computer, and the CAA Type V Panel Pictorial Computer with heading and automatic chart changing. Lt. W. G. Muntean of All-Weather Flying Division described the chart display which is a part of a 5,000-megacycle (Mc) Rho Theta navigation system built for them by Sperry Gyroscope Company. Colonel John D. Kay of the Coast and Geodetic Survey discussed the charts which were prepared

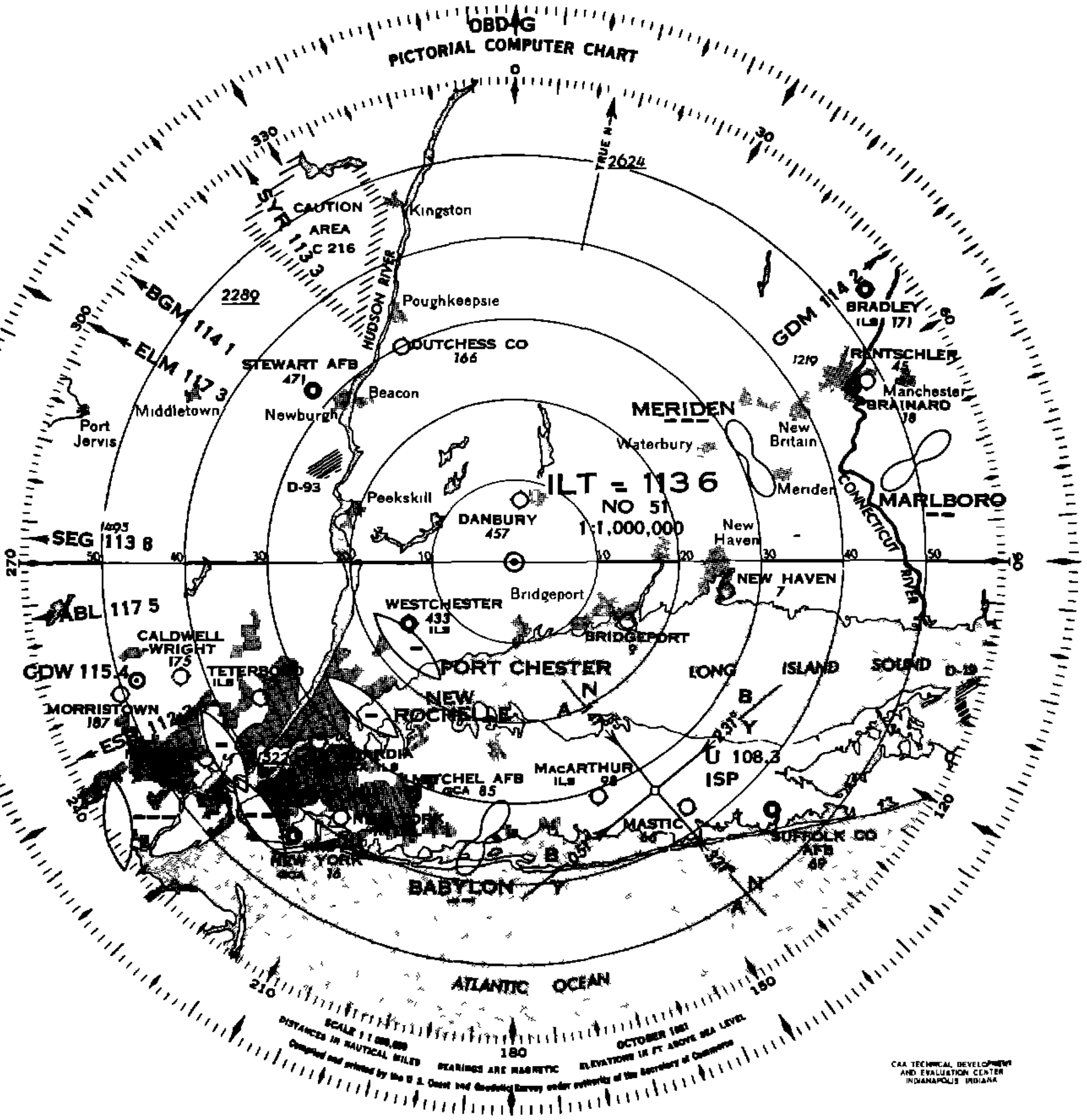

Fig 12 Chart for Pictorial Computer Use (Reduced Scale)

for use in the pictorial computers Dr. A C. Williams of the University of Illinois told of work that is being done there on the comparative evaluation of symbolic versus pictorial displays for the presentation of omnirange and distance information. Mr. V I. Weihe of the Air Transportation Association discussed the operational aspects of the use of airborne computers from the viewpoints of pilots and traffic control personnel.

After the formal presentation of papers was completed, Mr. J. W. Leas acted as chairman and moderator in a discussion of various aspects of airborne navigation computers. The following aspects of pictorial computers were discussed.

1. Orientation of Charts.

It was agreed that the charts should be oriented with north at the top if they are to be used by a navigator, however, for pilot usage there was no agreement on the orientation. Heading orientation did not seem to be desired. As a general conclusion, it appears that the charts should be capable of either north or course orientation by manual adjustment

2. The Airplane Position Indicator

For position reporting, the position indication should be such that the position can be read to essentially the same accuracy as with a symbolic display. The position marker should be omnidirectional unless heading is displayed.

3. Heading.

No definite trend was noted concerning the best kind of heading indicator. It was agreed that the addition of heading and of lines for indicating courses would convert the display to a flight instrument Extreme accuracy of heading indication did not seem to be required, since the directional gyro was to continue to be used. Should the heading indication replace the directional gyro, then an accurate heading indication would be required.

4. Use.

To justify its use, the pictorial computer should be considered a flight instrument rather than a navigational aid.

5. Relative Motion

Since the simplest presentation was to have the OBD facility at the center of the chart (and there was no definite indication of desire for change), it was agreed that this arrangement should be followed.

6. Mounting.

When employed as a flight instrument, the pictorial computer should be mounted on the instrument panel or control pedestal. Use of the portable display without provision for temporary cockpit mounting received very little encouragement, although it was recognized that further development of this display may alter this reaction.

7. Track Recording.

It was agreed that recording of the track would be desirable for test and training purposes but otherwise would have little value. The method of recording did not seem important.

8. Type of Display.

Electromechanical displays seem to be preferred. It was pointed out that a display of position without station, route, or runway was not enough.

9. Size of Display.

"The bigger, the better" seemed to be the feeling. The ten-inch diameter appeared a good compromise, except for the problem of mounting the instrument in the cockpit.

10 Chart Changing Methods.

Except for automatic chart changing, the problem seemed troublesome. Charts on film, roll charts, and single charts were discussed, but no particular decisions were made.

11. Charts.

It was agreed that special charts would be needed and that most cities, rivers, lakes, state boundaries, and the like could be omitted. It was believed that a chart in black, white, and halftones can supply the required information and simplify printing. Much discussion centered around the choice of chart material to be presented on the various scales. Halftone circles were favored to show distance from the omnistation, with halftone lines for radials shown every 30°.

12. Method of Scale Selection.

It was recommended that provision be made for alerting the pilot against selection of a chart of one scale and setting the mechanism of the computer to a different scale.

13. Automatic Frequency Selection.

This feature was considered desirable but not required. Its use should be evaluated in terms of its cost.

14. Automatic Flight

This feature was also considered desirable but not required.

15. Combined Course-Line and Pictorial Computer.

United States Department of the Air Force (USAF) representatives indicated a requirement for both indications. The Navy representatives wanted to evaluate both displays before selecting either.

One off-agenda item was considered. Mr. Robert B. Sleight of Johns Hopkins University told briefly of the work he was doing on the determination of numerical legibility and on the attention-getting value of geometrical figures which have application to charts.

During the second day of the symposium, the entire group inspected the installation of airborne 5,000-Mc equipment in an All-Weather Flying Division C-54 airplane.

Flight demonstrations of the CAA Type III portable pictorial computer were given to 50 observers in a TDEC DC-3 airplane. The summary of the comments made during and after these flight demonstrations does not purport to be complete, nor can any particular weight be attached to the order in which the following are presented.

The bridge carrying the aircraft indicator was too bulky, obscured too much of the chart, and gave the effect of indicating heading instead of omnibearing. It was suggested that the bridge be eliminated and that the position of the airplane be indicated by a spot of light projected through the chart from underneath The airplane position indicator was too obscure, and the three distance scales were confusing Some warning of the selection of the wrong chart scale should be provided. An indication of distance out to perhaps 50 per cent of the chart radius beyond the periphery of the chart seemed useful. An improved method of recording track would be of some value. A small amount of hunting by the position indicator seemed desirable, since it showed that the computer was functioning. Unless the weight and thickness of the display unit can be considerably reduced, some method of mounting it should be provided so that it will not have to be held on the co-pilot's lap. The size of the display was about the maximum that can be put into the cockpit. The 1 250,000 scale is sufficiently accurate for terminal area flying. Lines marking the course to be flown were considered very important

A review of the minutes shows that the symposium contributed considerably to the establishment of a common understanding of the importance of the pictorial computer in solving future air navigational problems.

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