PERFORMANCE TESTS OF THE NARCO VHF OMNIRECEIVER

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SUMMARY

This report presents the results of tests conducted at the Technical Development and Evaluation Center on the National Aeronautical Corp VHF omnireceivers developed under Civil Aeronautics Administration contract These receivers provide visual left-right indications of omnirange and phase comparison localizer courses and aural reception of modulated signals No attempt is made to present performance data for all equipments delivered under the contract, and the data presented are typical of those obtained from measurements of the performance of several equipments The equipment was tested to determine compliance with the requirements of CAA Specification ES-63C

INTRODUCTION

In order to promote commercial interest in the development and production of a low-cost private flyer's omnireceiver, approximately 12 manufacturers were contacted to determine the possibility of producing a low-cost omnireceiver suitable for the private flyer As a result of these contacts, CAA Specification ES-63C (see Appendix I) containing minimum essential performance requirements of an omnireceiver was prepared Negotiations with several radio manufacturers were continued in an effort to obtain a quantity of these receivers through a development contract intended to establish facilities for production at low cost

A contract was awarded to the National Aeronautical Corp of Wings Field, Ambler, Pa , for the development and delivery of ten complete omnireceivers, together with complete sets of manufacturing drawings, meeting the requirements of the specification Five vibrator and five dynamotor type power supplies were furnished with the receivers The test results in this report were obtained from equipments having vibrator power supplies In general, the performance of the equipments having dynamotor power supplies was slightly better than that of equipments having vibrator power supplies

NARCO also has developed a small filter-amplifier unit which, when connected to the receiver and modulator-power unit, provides visual indications of tone localizer courses The characteristics of the filter-amplifier unit are not included in this report

DESCRIPTION OF EQUIPMENT

One complete omnireceiver as furnished on the development contract consisted of the following components All components, except the interconnecting cables and transmission line, are shown in Fig 1

VHF receiver, NARCO Type VRA-1
Omnirange converter, NARCO Type VOA-1
Course selector assembly, NARCO Type CS-1
Modulator power unit, NARCO Type V12MP-1 (vibrator)
Course deviation indicator, NARCO Type MA-1
Interconnecting cables
Antenna transmission line

The over-all weight of the equipment, excluding antenna, is approximately 15 pounds The over-all dimensions of the various components are as follows

Component	Height (in)	Width (in)	Length (in)
Receiver	3 1/4	2 3/4	6 1/2*
Omnirange converter	6 9/16	5 5/16	9
Modulator power unit	6 9/16	5 5/16	9
Course selector assembly	3 1/4	5 1/2	2* *

* Excluding control knobs which protrude 1 3/16 in

* * Excluding course selector knob which protrudes 1 1/8 in

The course deviation indicator is designed for mounting in a 3 1/8-inch diameter instrument panel cut-out

Fig 2 is the schematic diagram of the receiver The receiver is of the superheterodyne type and is tunable over the frequency range of 108 to 122 Mc The oscillator fre-

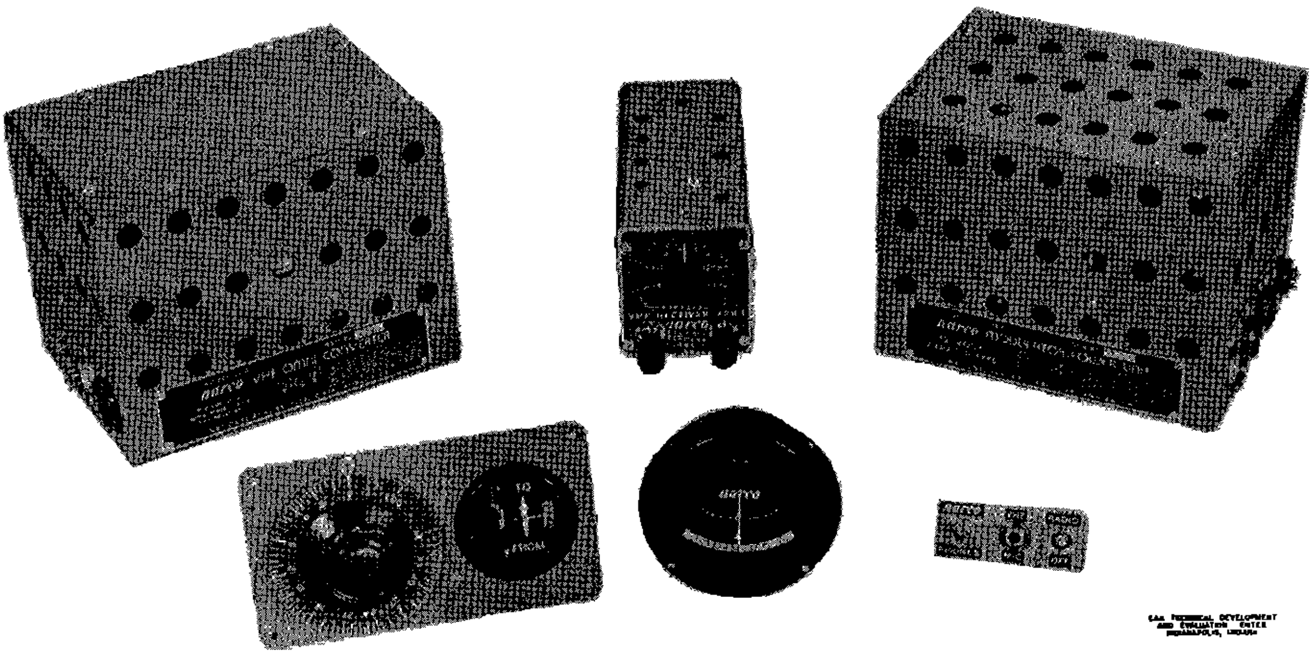

Fig 1 NARCO VHF Omnireceiver

quency is 8 5 Mc above the frequency of the received signal This was done to prevent image responses from FM broadcast stations The antenna input circuit is unbalanced to permit the use of coaxial transmission line which is smaller and more reliable than twin conductor or balanced transmission line A radio-frequency amplifier stage is used to improve the rejection of undesired signals The grid and plate circuits of the radio-frequency amplifier, converter injection grid circuit and the oscillator are tuned by a combination iron core and slug assembly which provides linear relationship between resonant frequency and movement of the tuning assembly Three conventional intermediate-frequency amplifiers are used The second detector is operated at high level to provide linear detection characteristics A noise limiter circuit is used in the aural output circuits to improve aural reception under adverse radio-frequency noise conditions The aural output from the first audio amplifier is fed to the modulator-power unit for further amplification and the audio output from the omni-jack is fed to the omniconverter unit

The modulator-power unit is designed to supply high voltage to the receiver, a small VHF transmitter (with or without the receiver) and receiver and omnirange converter (with or without the transmitter) Fig 3 is the schematic diagram of this unit The unit contains a speech amplifier for microphone signal amplification and an audio stage which is used as a final amplifier of the receiver aural output or as the transmitter modulator The transmit-receive relays provide the switching facilities required to switch the high voltage supply from the omniconverter and receiver to the transmitter, and to convert the receiver audio amplifier circuit to a transmitter modulator High voltage power is provided by the vibrator, transformer and rectifiers connected as shown in the schematic diagram Modulator-power units having dynamotor high voltage power supplies also are available

The omnirange converter contains all the audio circuits required for operation of the omnibearing selector, TO-FROM meter and course deviation indicator Fig 4 is the schematic circuit diagram The frequency modulated 9,960-cps subcarrier component of the receiver second detector output is filtered to remove the 30 cps and voice components of the second detector output The remaining 9,960-cps signal is then limited to remove 30-cps AM which may have been introduced by the transmitting equipment, propeller modulation or cross modulation in the receiver detector circuit The 9,960-cps discriminator is a ratio detector which recovers

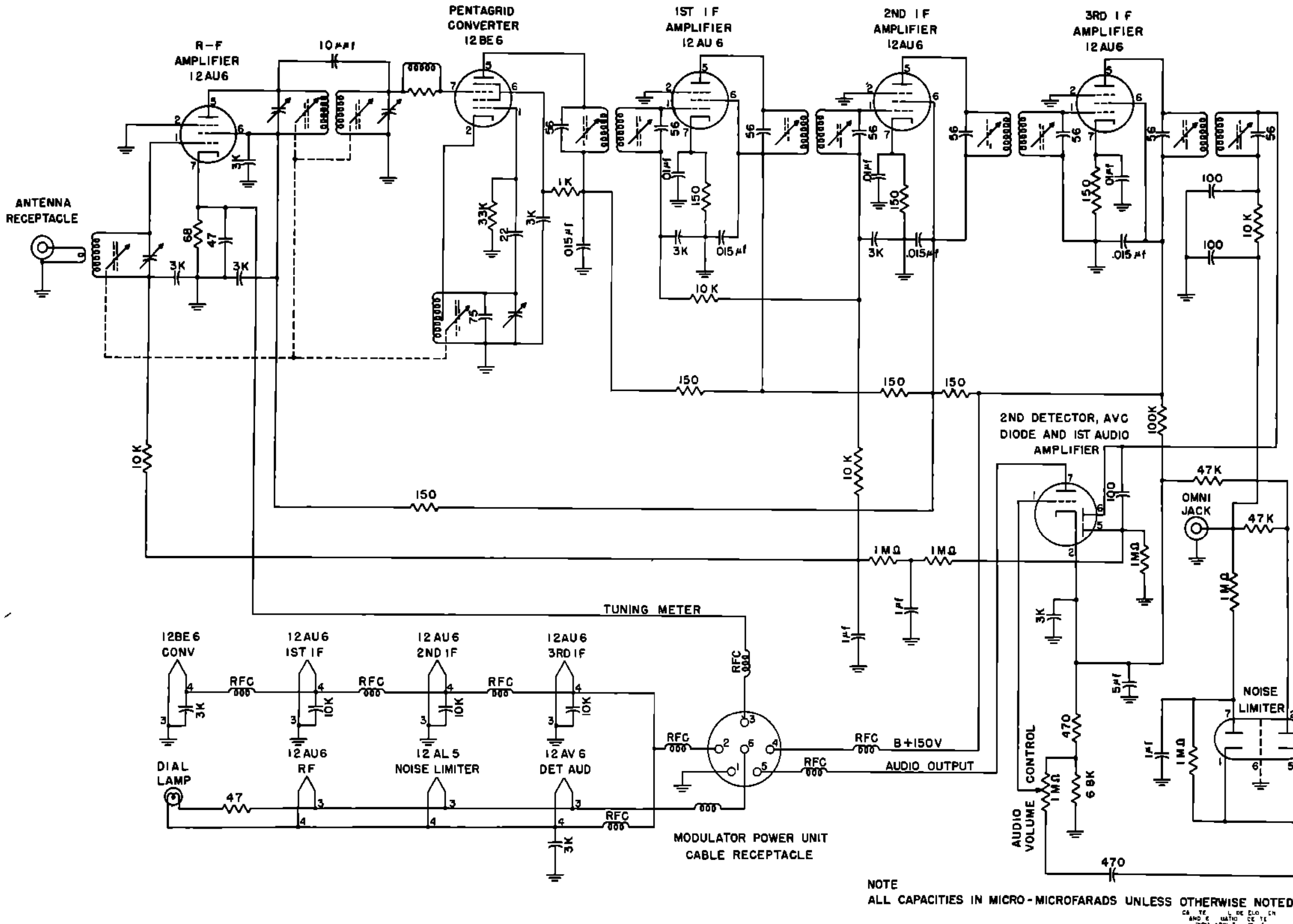

Fig 2 Receiver Schematic Diagram

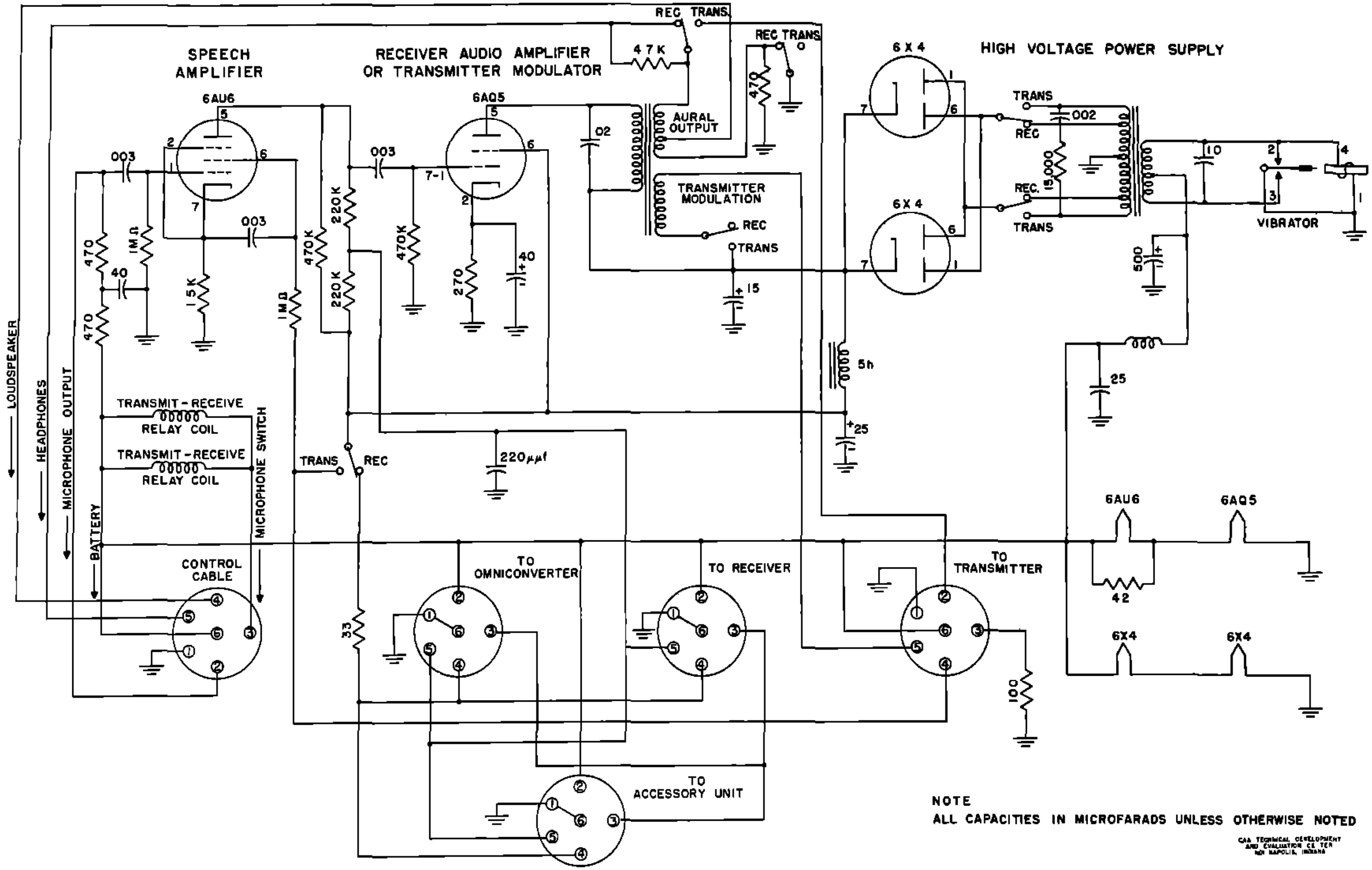

Fig 3 Modulator Power Unit Schematic Diagram

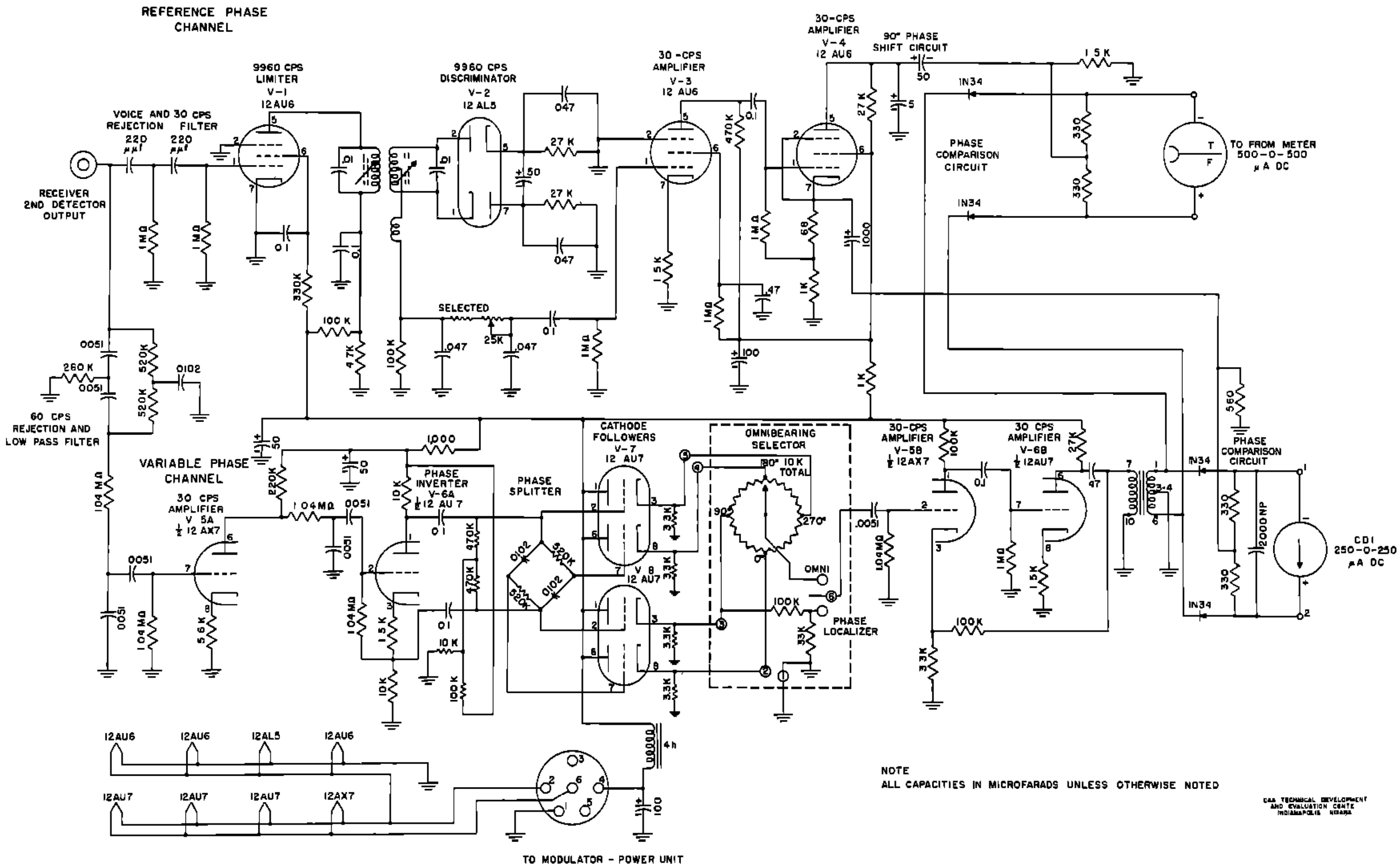

Fig 4 Omnirange Converter Unit Schematic Diagram

the 30-cps reference phase signal from the frequency modulated 9,960-cps subcarrier The 30-cps signal is then amplified and fed to the course deviation indicator and TO-FROM meter phase comparison circuits The phase of the signal fed to the TO-FROM meter is shifted 90° in the plate circuit of the final reference phase channel amplifier to provide proper TO or FROM indication when the course deviation indicator is centered

The signal fed to the variable phase channel is filtered to reject the 9,960-cps subcarrier, voice and 60-cps propeller modulation signals In some aircraft it is possible to select an engine speed such that the propellers cause the magnitude of the radio-frequency signal at the antenna to be varied at a 60-cps rate This modulation process produces a 60-cps signal in the output of the receiver second detector which must be attenuated to prevent oscillation of the course deviation indicator pointer

The output of the first 30-cps amplifier is fed to a phase inverter stage to obtain two signals which are equal in amplitude and which have a phase separation of 180° These signals are fed to the grids of two of the cathode followers and to the phase splitter circuit The phase splitter circuit output consists of two signals of equal amplitude having a phase separation of 180° and a phase shift of 90° and 270° with respect to either of the input signals The output of the phase splitter circuit is fed to the grids of the other two cathode followers The voltages developed across the cathode resistors of the four cathode followers are equal in amplitude and have relative phase relationships of 0°, 90°, 180° and 270°, as indicated on the schematic diagram These signals are fed to the tapped potentiometer or onmibearing selector, and the wiper of the potentiometer is connected to the 30-cps amplifier stages When the wiper of the potentiometer is set at the 0° tap, the signal fed to the amplifier is in-phase with the signal fed to this tap When the wiper is moved to the 90° tap, the phase of the signal fed to the amplifier is shifted 90° with respect to the phase of the signal fed to the 0° tap If the wiper position is between the 0° and 90° taps, the phase shift of the signal fed to the 30-cps amplifier will be between 0° and 90° A calibrated dial attached to the wiper shaft indicates phase shift in degrees It is possible to shift the phase of the signal any amount between 0° and 360°

The output of the 30-cps amplifier stages is transformer-coupled to the deviation indicator and TO-FROM meter phase comparison circuits The phase relationships of the reference and variable phase signals in the phase comparison circuits is such as to center the deviation indicator needle when the aircraft is on the course selected by means of the omnibearing selector and, to provide a TO or FROM indication depending upon whether the omnibearing selector setting is the bearing of the aircraft to or from the omnirange station

During operation as a phase comparison localizer receiver, the control grid of the 30-cps amplifier, V-5B, is switched from the omnibearing selector potentiometer wiper to a resistance voltage divider connected to the 90° tap of the potentiometer For phase localizer operation, the reference and variable phase signals in the phase comparison circuit are in-phase when the aircraft is to one side of the runway and 180° out-of-phase when the aircraft is on the other side of the runway When the aircraft is on-course, the variable phase signal component is zero and the deviation indicator needle is centered The TO-FROM indicator pointer is centered at all times since the phase relationship between the reference and variable phase signals in the TO-FROM meter phase comparison circuit is either 90° or 270° depending upon the position of the aircraft with respect to the runway

TESTS

The following equipments were used during the tests

Boonton Radio Corp Type 211A VHF Signal Generator with Boonton Radio Corp Type 505A 6-db Attenuator

Collins Radio Co 479S Audio Signal Generator

Daven Co Type OP-182 Power Output Meter

Hewlett Packard Co Type 200B Audio Oscillator

General Radio Wave Analyzer, Type 736A

The following conditions were maintained during all tests, unless otherwise stated

Battery voltage - 13 volts dc

Audio output load - 300 ohms

Signal generator setting - 1,000 microvolts with 53-ohm, 6-db attenuator connected between signal generator and receiver

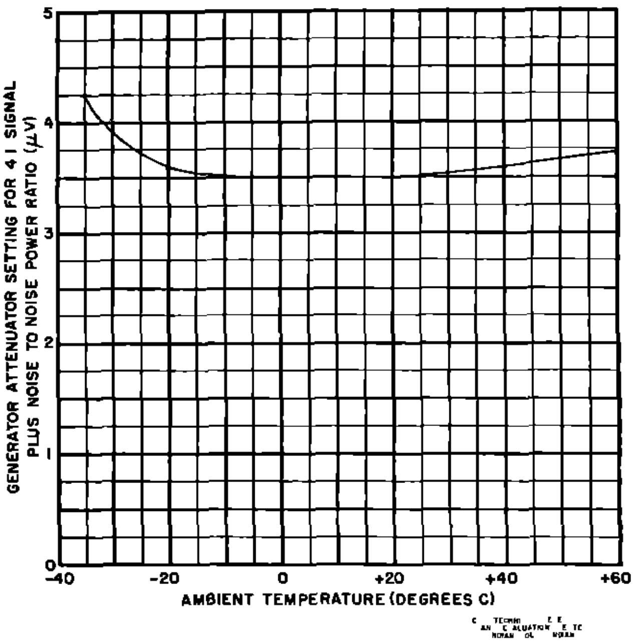

Fig 5 Sensitivity vs Ambient Temperature Variation

Modulation - 30 per cent of 1,000 cps for audio measurements, 30 per cent of 30 cps plus 30 per cent of frequency modulated 9,960 cps for omnirange measurements, and 13 per cent of 30 cps plus 30 per cent of frequency modulated 9,960 cps for phase comparison localizer measurements

Signal plus noise-to-noise ratio - 4 1 in power

Temperature - approximately 25°C

Warm-up period - not less than 20 minutes

For all measurements a 53-ohm, 6-db attenuator was connected between the signal generator and receiver All microvolt readings represent twice the microvolt level that exists at the receiver input, assuming that the input impedance is 53 ohms

The following test results were obtained

Sensitivity

Frequency Mc	Radio-Frequency Input for 4 1 Signal Plus Noise-to-Noise Power Ratio μ v
108	3 5
115	3 5
120	5 0

The receiver volume control and the signal generator attenuator were adjusted to provide 50 mw audio output, and 4 1 signal plus noise-to-noise ratio simultaneously

Receiver Dial Calibration Error

Receiver Dial Reading Mc	Boonton 211 Signal Generator Frequency Mc	Calibration Error Mc
110	109 777	-0 223
115	114 865	-0 135
122	122 067	+0 067

Effects of Temperature and Battery Voltage Variation (Receiver)

The variation of sensitivity with ambient temperature and battery voltage is shown in Figs 5 and 6 respectively For each sensitivity measurement the receiver volume control and the signal generator attenuator were adjusted to provide an audio output of 50 mw in a 300-ohm resistive load for 30 per cent 1,000-cps modulation, and an audio output of 12 5 mw for an unmodulated signal Fig 7 indicates resonant frequency drift due to temperature The receiver was tuned to a 114 9 Mc signal under room temperature conditions and the tuning knob position was not changed during the test Frequency variation was measured by varying the signal generator frequency to produce receiver resonance and by noting the variation of the signal generator frequency dial reading The signal generator attenuator setting was ap-

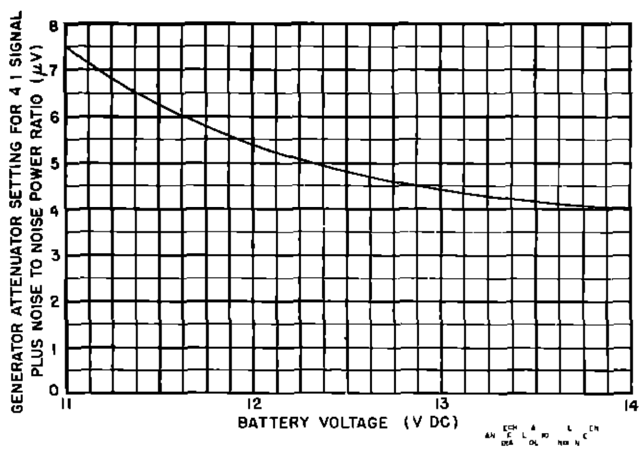

Fig 6 Sensitivity vs Battery Voltage Variation

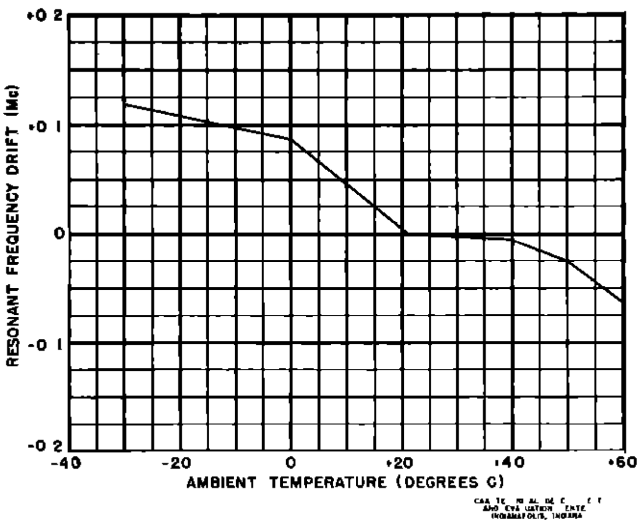

Fig 7 Resonant Frequency Drift from 114 9 Mc vs Ambient Temperature Variation

proximately four microvolts and the frequency dial was calibrated for each measurement

Selectivity

The selectivity of the receiver is shown in Fig 8 The receiver volume control and signal generator attenuator were adjusted for 50-mw audio output and 4 1 signal plus noise-to-noise ratio at the frequency of 122 Mc The generator frequency was varied above and below resonance to determine the deviation from resonant frequency required to reduce the audio output to 50 mw as the radio-frequency input level was increased in steps

Automatic Volume Control Action

Fig 9 shows the automatic volume control characteristics of the receiver The volume control was adjusted for an audio output of 300 mw in a 300-ohm resistive load when the radio-frequency input was 500 microvolts The radio frequency was 115 Mc The radio-frequency input level was increased in steps from 1 to 100,000 microvolts and the corresponding audio output levels were recorded and plotted The resonant frequency did not vary appreciably with change in radio-frequency input level

Harmonic Distortion

The results of harmonic distortion measurements are

Audio Frequency Distortion
Per Cent of Fundamental

Second Harmonic	Third Harmonic	Fourth Harmonic	Fifth Harmonic	Resultant Distortion
6 2	1 2	0 26	0 07	6 3

The radio-frequency input signal was modulated 30 per cent at 400 cps, and the volume control was adjusted to provide 300

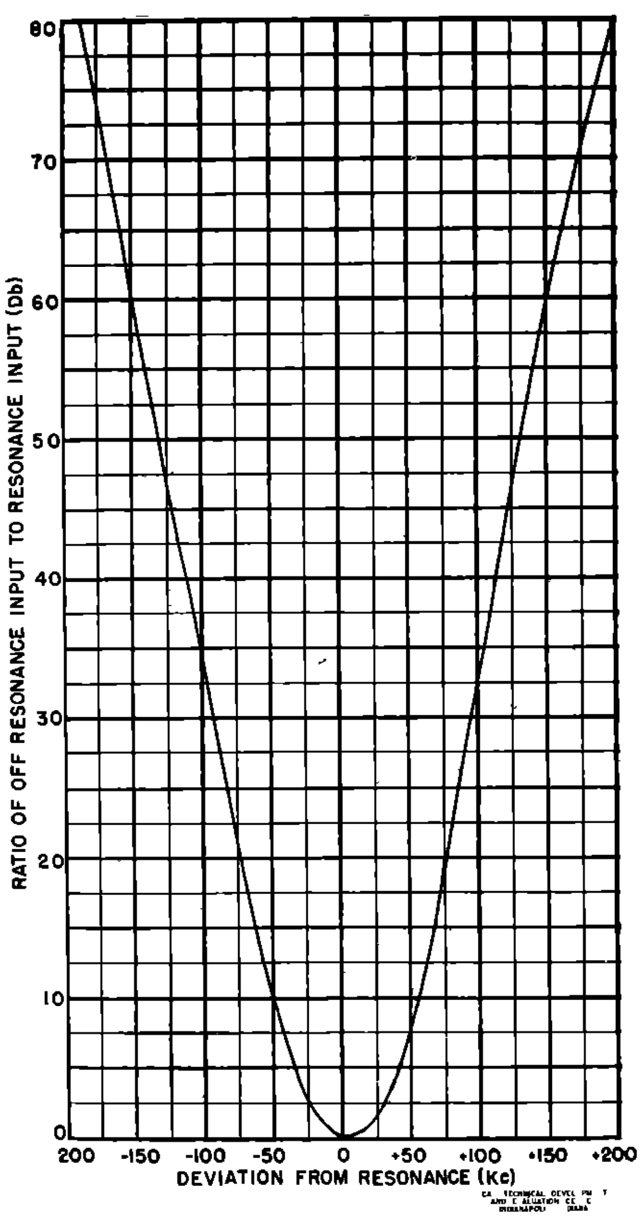

Fig 8 Selectivity

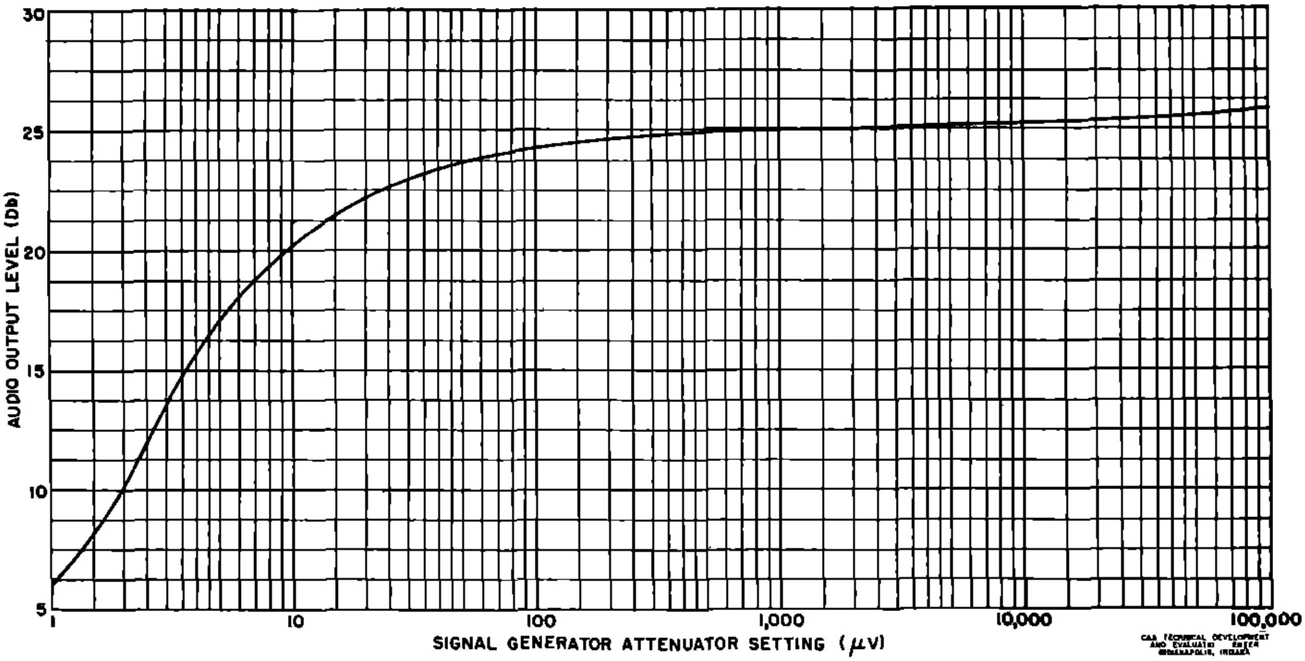

Fig 9 Automatic Volume Control Action

mw audio output The signal generator attenuator setting was 10,000 microvolts

Undesired Responses

The following table lists the undesired responses measured with the receiver tuned to 108 Mc

Frequency of Undesired Responses Mc	Microvolts Radio-Frequency Input for 50-mw Output	Rejection Ratio db
125 0	2,400	56 4 (image)
116 5	32,000	79 0
112 2	22,000	75 7
106 3	14,000	71 8
99 5	23,000	76 1

The radio-frequency input level required for 50-mw audio output at resonance was 3 6 microvolts The signal generator attenuator was set at approximately 0 2 volts and the frequency was varied from 88 to 140 Mc At each response frequency the attenuator setting was reduced to provide 50-mw output The rejection ratio was calculated from the attenuator settings for resonance and the undesired response frequency

Audio Fidelity

Audio fidelity characteristics are shown in Fig 10 The volume control was set for maximum audio output and the modulation was 30 per cent for all modulation frequencies The modulation frequency was varied from 30 to 10,000 cps and the corresponding audio outputs were recorded.

Bearing Accuracy and Stability

Figs 11 and 12 show bearing errors for omnibearing selector settings at each 45° point between 0° and 360° for equipment ambient temperatures of 0°, +23° and +60°C The ambiguity meter reading was FROM for the error curves shown in Fig 11 and TO for the curves shown in Fig 12 The errors were measured by adjusting the audio generator 30-cps phase control knob to center the course deviation indicator for each omnibearing selector setting The sign of the errors is positive when the omnibearing selector setting is greater numerically than the corresponding reading of the audio generator 30-cps phase dial

Figs 13 and 14 show variation of indicated bearings, for the omnibearing selector settings shown, due to radio-frequency input level and battery voltage changes The

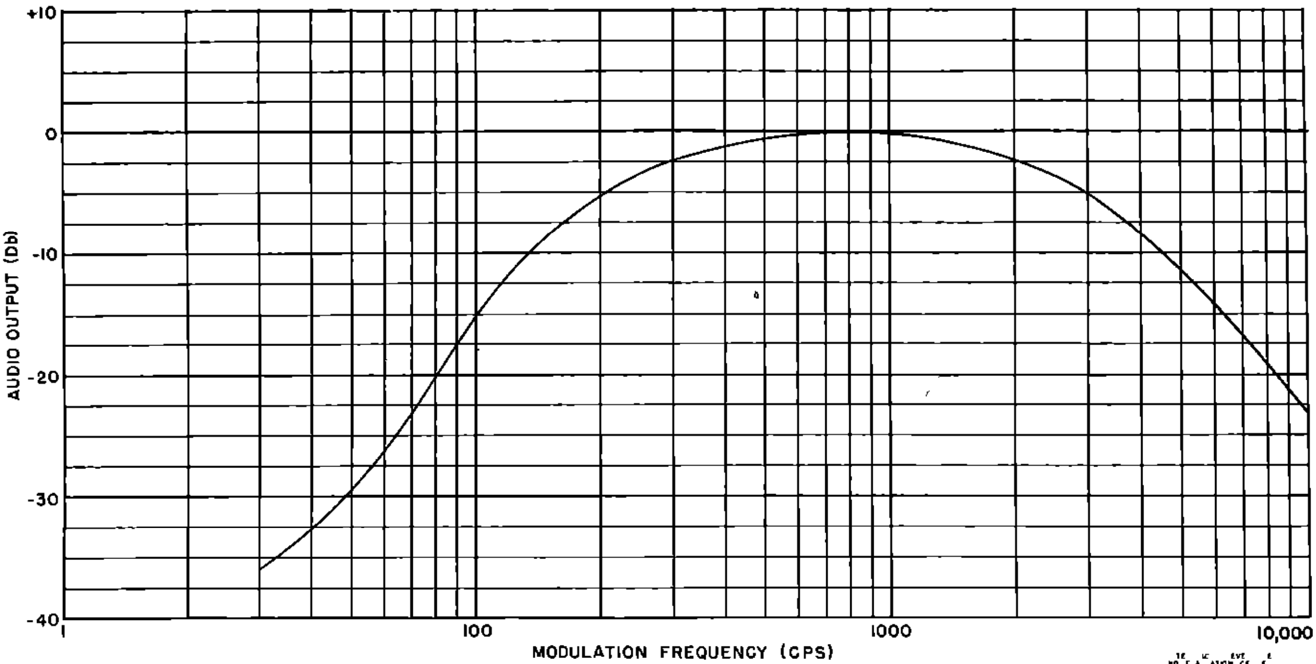

Fig 10 Audio Fidelity

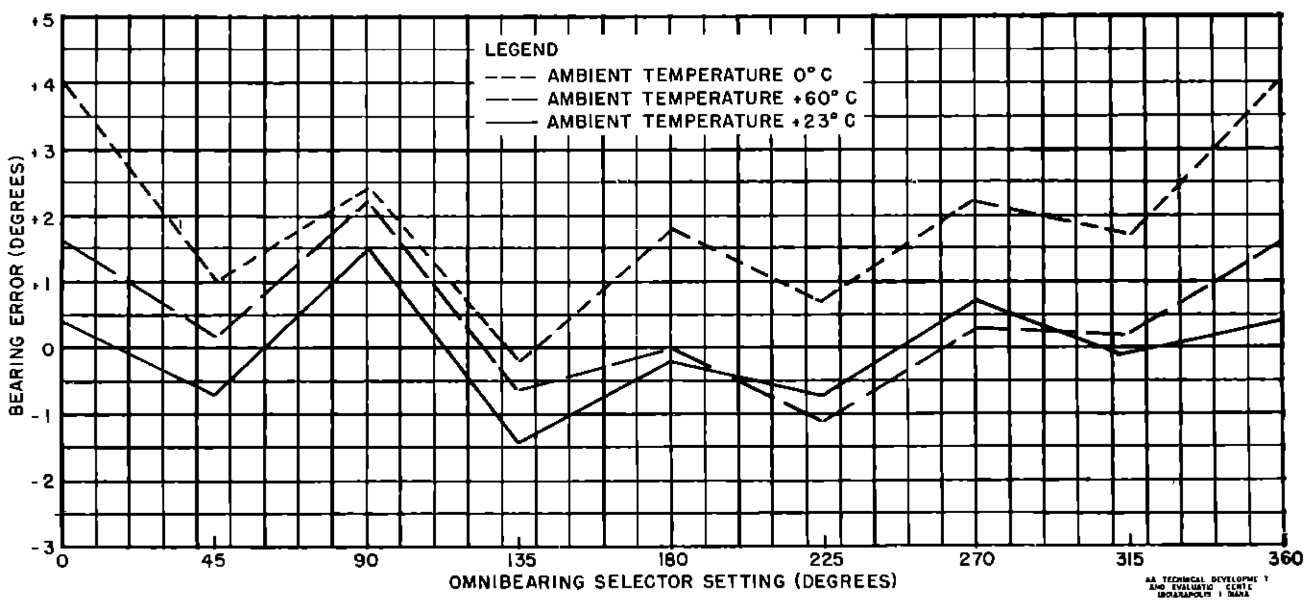

Fig 11 Bearing Accuracy ("FROM" Ambiguity Meter Reading)

variation is considered to be zero at the reference points of 500 microvolt radio-frequency input level and 13 volt, dc battery voltage The sign of the bearing variation is positive when the indicated bearing is greater numerically than that of reference conditions

Effect of Amplitude Modulation and Variation of Subcarrier Frequency Upon Bearing Accuracy

The addition of 10 per cent of 30-cps AM to the 9,960-cps subcarrier caused bearing changes of approximately ±0 5°

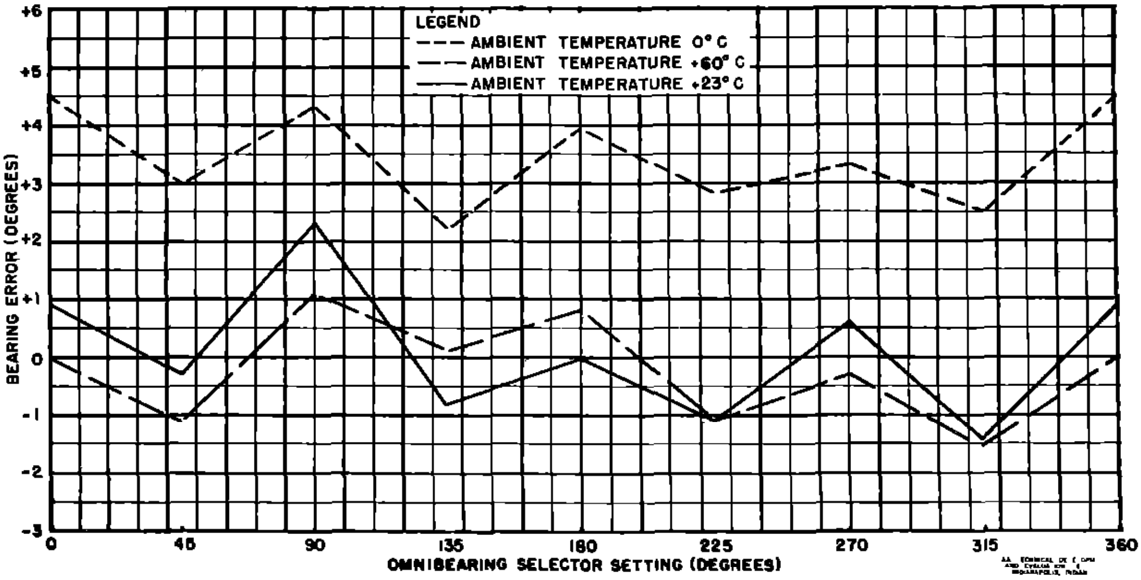

Fig 12 Bearing Accuracy ("TO" Ambiguity Meter Reading)

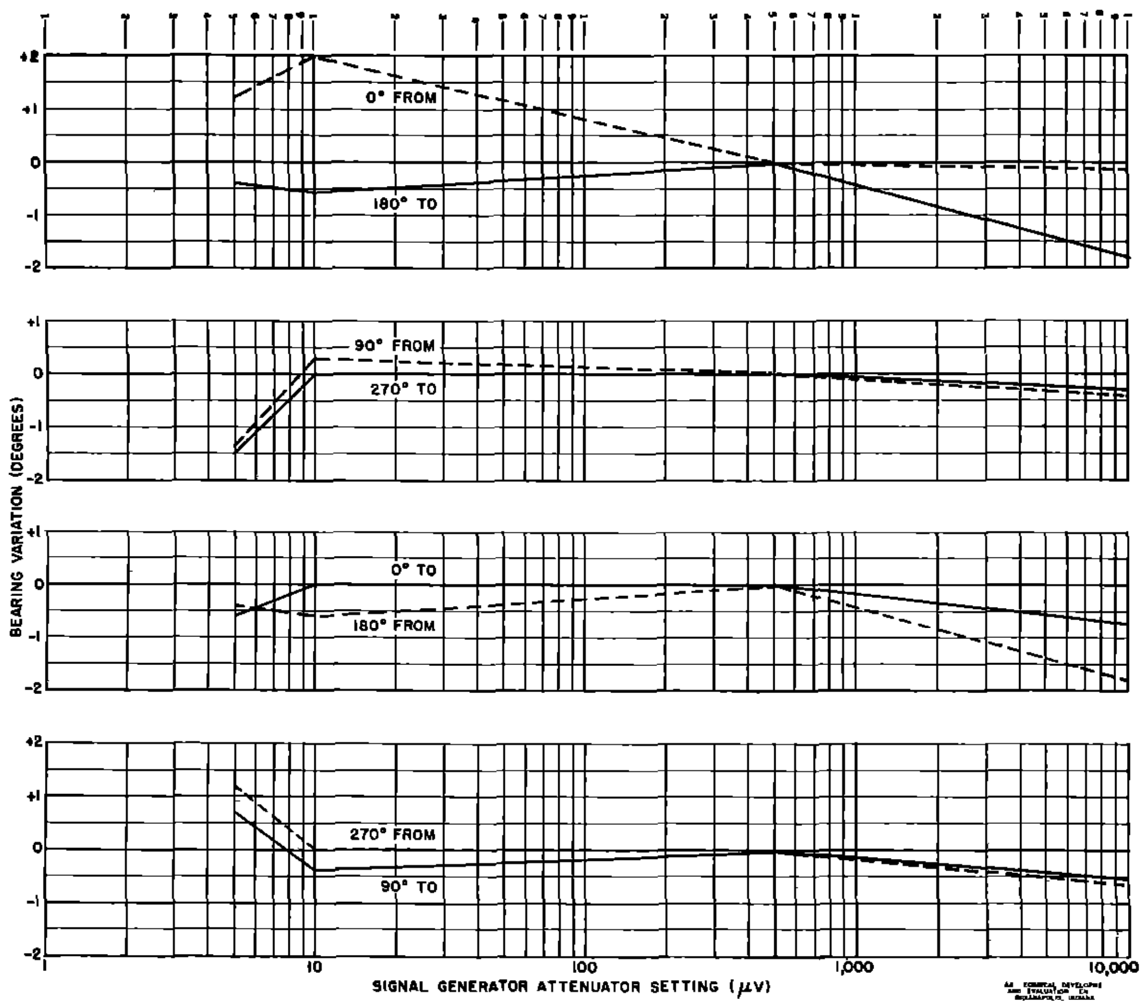

Fig 13 Bearing Variation (Omnirange) vs Radio-Frequency Input Level

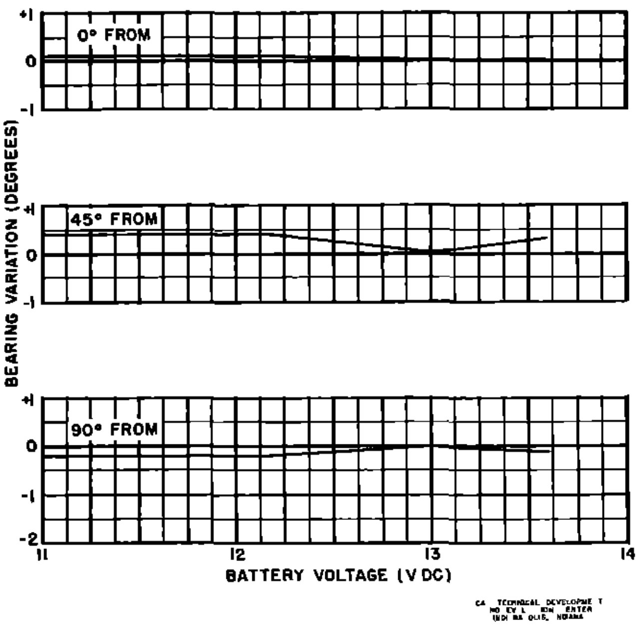

Fig 14 Bearing Variation (Omnirange) vs Battery Voltage

Variation of the subcarrier frequency from 9,760 to 10,160 cps with 10 per cent 30-cps AM applied to the carrier also caused indicated bearing changes of approximately 0 5° The variable phase modulation frequency and percentage were constant during these tests

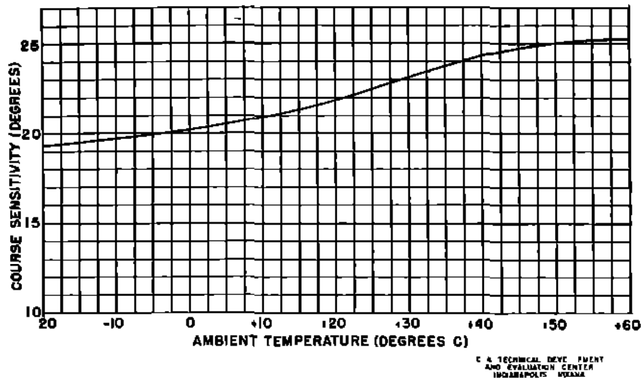

Fig 15 Course Sensitivity (Omnirange) vs Temperature

Omnirange Course Sensitivity

Figs 15, 16, 17 and 18 show the variation of omnirange course sensitivity with variations of ambient temperature, radio-frequency input level, battery voltage and omnibearing selector setting Course sensitivity was measured by adjusting the audio generator 30-cps phase control knob to produce full-scale left and full-scale right deflections of the course deviation indicator The deflection is full scale when the pointer deflection is at the outside end of the blue or yellow sectors of the dial The difference between the readings of the audio generator 30-cps phase dial was recorded

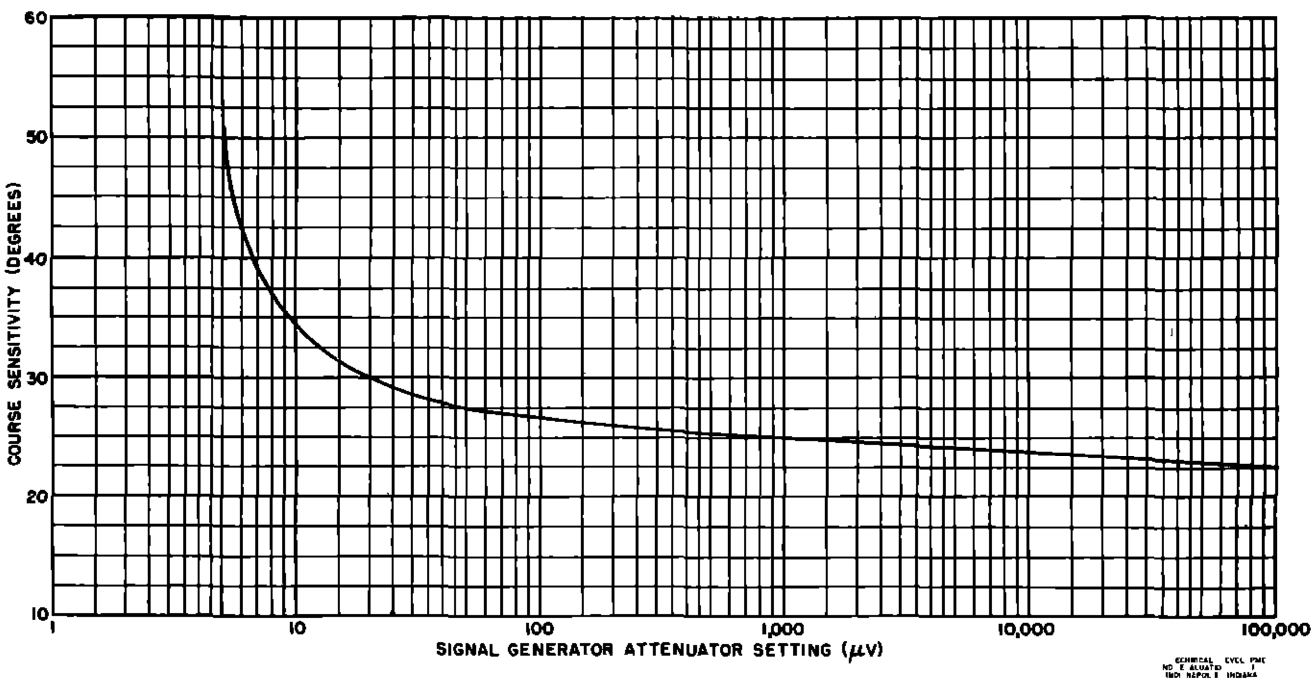

Fig 16 Course Sensitivity (Omnirange) vs Radio-Frequency Input Level

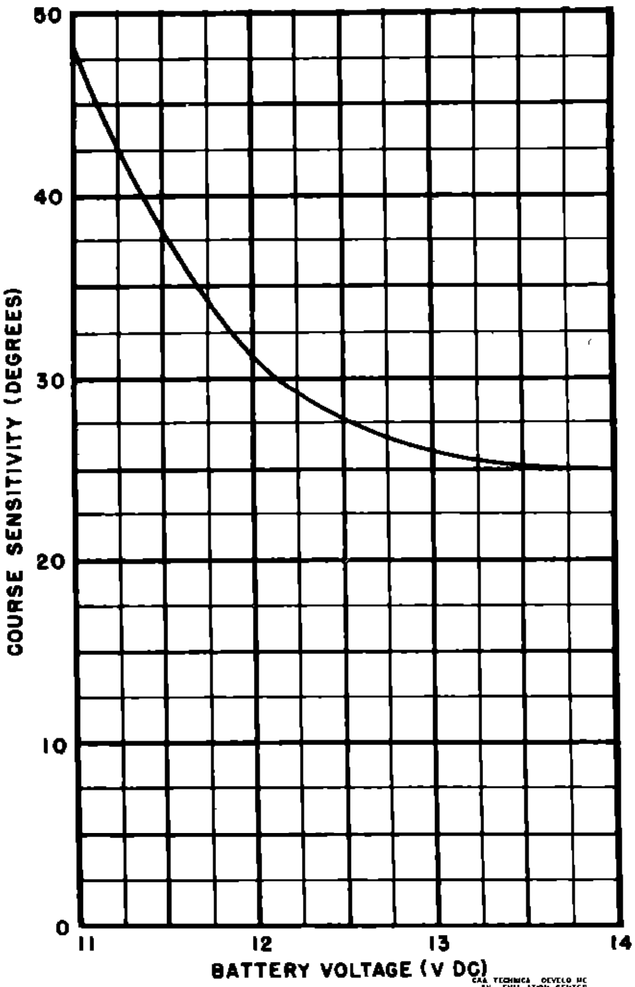

Fig 17 Course Sensitivity (Omnirange) vs Battery Voltage

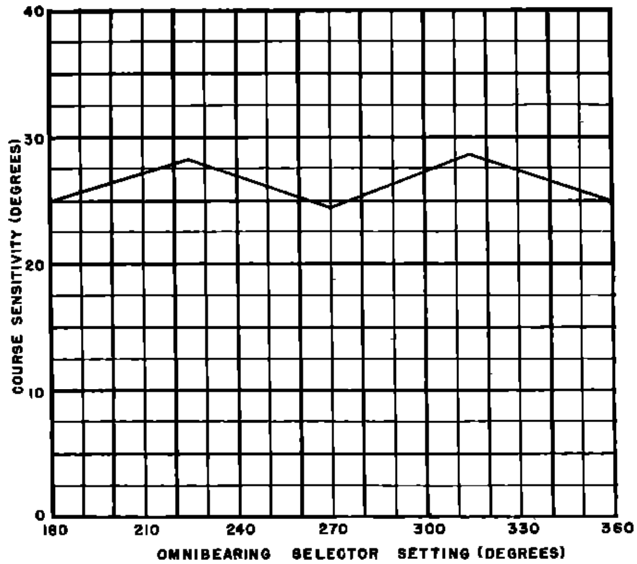

Fig 18 Course Sensitivity vs Omnibearing Selector Setting

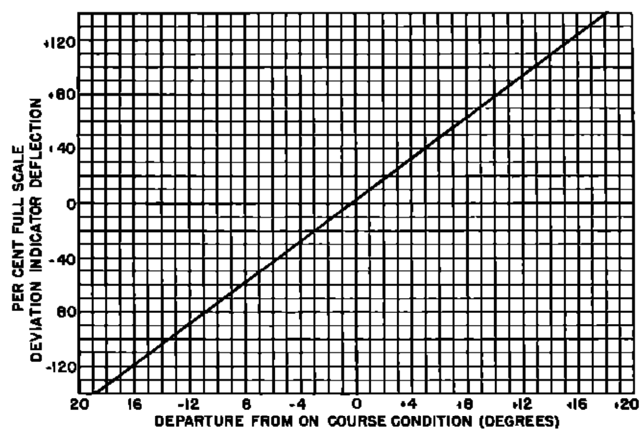

Fig 19 Course Deviation Indicator Circuit Linearity (Omnirange)

as course sensitivity The omnibearing selector setting was 0° except during measurements to determine course sensitivity at various omnibearing selector settings

Course Deviation Indicator Circuit Linearity (Omnirange)

The linearity of the course deviation indicator phase comparison circuit is shown in Fig 19 The phase of the 30-cps modulation was varied from that for on-course conditions to provide various deflections of the deviation indicator Deflection percentages greater than 100 per cent were calculated from measurements of voltage across the deviation indicator terminals The deflection is full scale when the pointer deflection is at the outside end of the blue or yellow sectors of the dial

Course Deviation Sensitivity and Centering (Phase Comparison Localizer)

The effects of radio-frequency input level and battery voltage upon course deviation sensitivity and centering are shown in Figs 20, 21 and 22 The 30-cps modulation was 13 per cent for sensitivity and 0 per cent for centering measurements Negative deflection percentages indicate per cent full-scale deflection to the left and positive deflection percentages indicate per cent full-

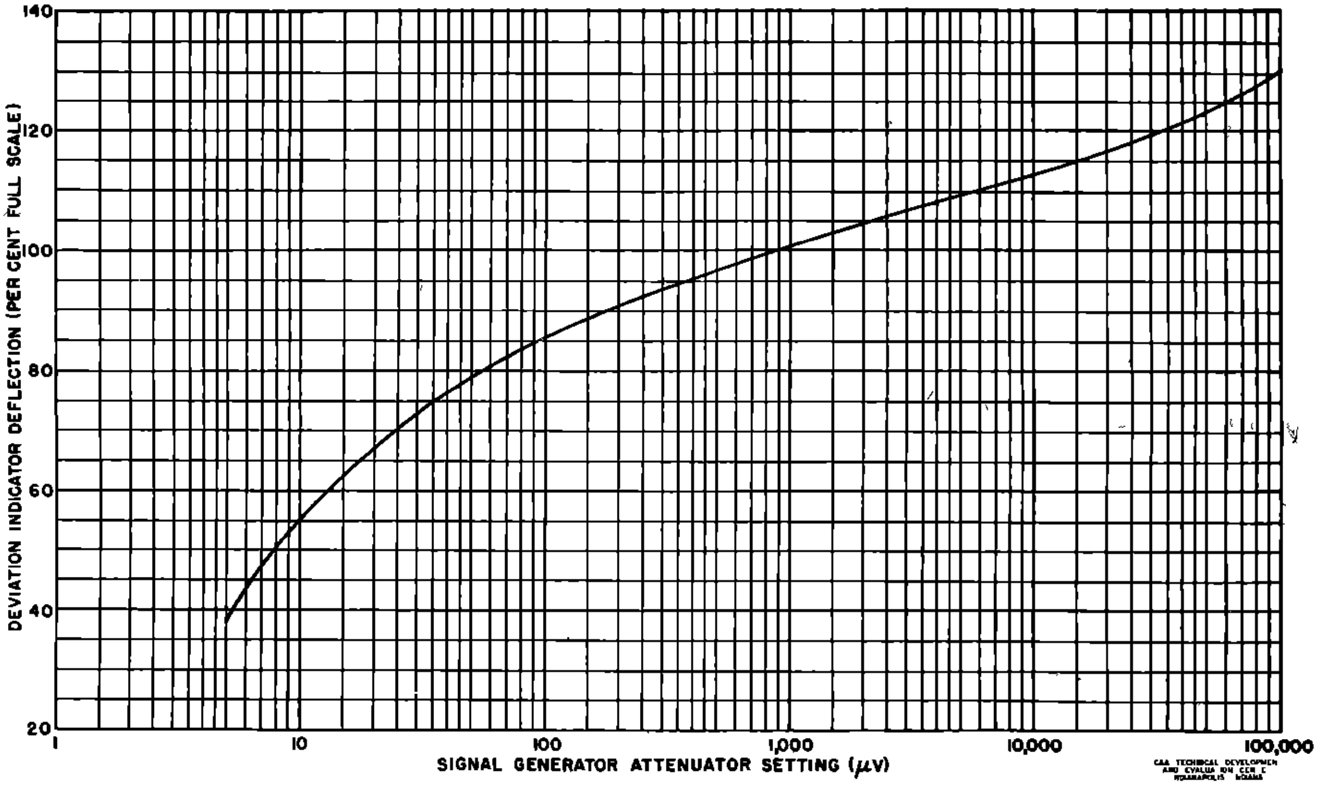

Fig 20 Course Deviation Sensitivity (Phase Localizer) vs Radio-Frequency Level

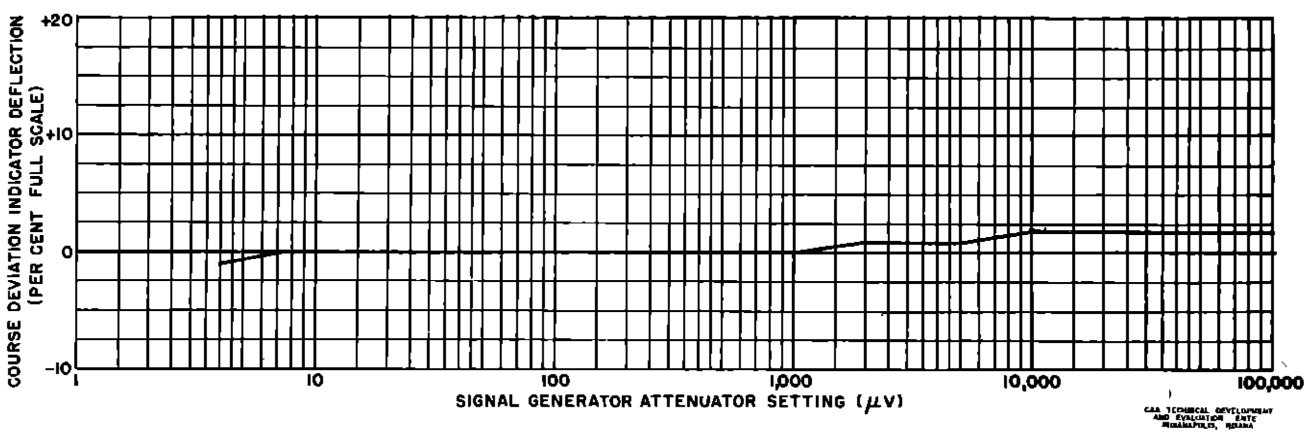

Fig 21 Course Deviation Indicator Centering (Phase Localizer) vs Radio-Frequency Level

scale deflection to the right The deflection is full scale when the pointer deflection is at the outside end of the blue or yellow sectors of the dial

Course Deviation Indicator Circuit Linearity (Phase Localizer)

The linearity of the deviation indicator phase comparison circuit for phase comparison localizer operation is shown in Fig 23 The deflection of the deviation indicator was recorded for variable phase modulation percentages from 0 to 18 per cent Negative deflection percentages indicate per cent full-scale deflection to the left and positive deflection percentages indicate per cent full-scale deflection to the right The deflection is full scale when the pointer deflection is at

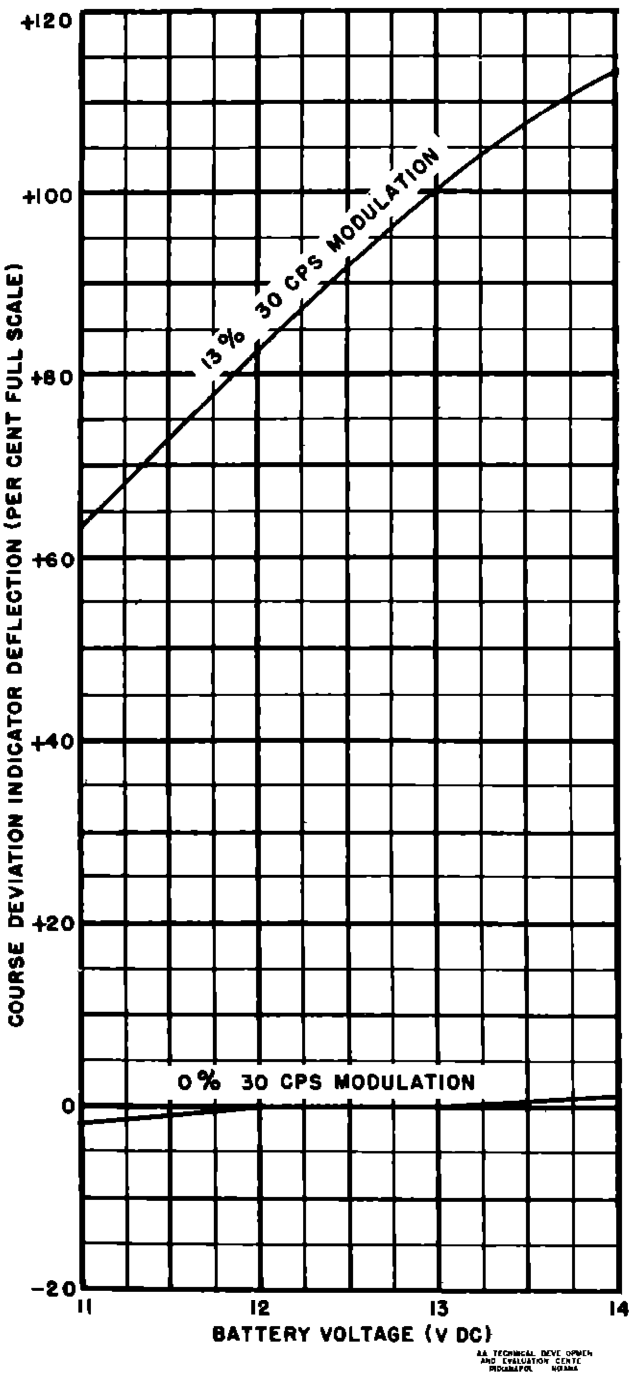

Fig 22 Course Deviation Indicator Sensitivity and Centering (Phase Localizer) vs Battery Voltage

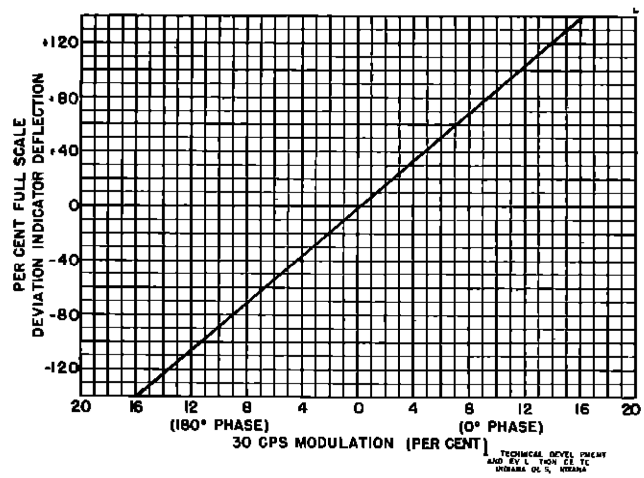

Fig 23 Course Deviation Indicator Circuit Linearity (Phase Localizer)

the outside end of the blue or yellow sectors of the dial The variable phase signal was 180° out-of-phase with the reference phase signal for left and in-phase for right deflection readings

CONCLUSIONS

The NARCO equipment described in this report meets the essential requirements of the specification and the performance is satisfactory for use in small aircraft An equipment of this type must represent a compromise between the performance characteristics desired and other factors including cost, weight and space requirements The performance is not as good as that of navigation receivers designed for use in commercial airline and military aircraft However, the weight and dimensions of such navigation receivers are somewhat greater and their cost is considerably higher The equipments furnished on the contract represent a satisfactory compromise with regard to the various technical and economical factors involved

APPENDIX I

Specification ES-63C
Rev May 5, 1949

Development Specifications for a Private-Flyer VHF Navigation Receiver

1
General

1 1
This specification covers the requirements for an airborne VHF receiver having appropriate controls and indicators to operate in the frequency band of 108 to 122 Mc for the reception, use and visual display of signals received from phase comparison localizer and omnirange stations which are operated by the Civil Aeronautics Administration

1 2
Because of the type of operation of this receiver, reliability of performance is of utmost importance in the design Furthermore, it is essential that there is no aging effects in any of the receiver components which would necessitate frequent readjustments The complete equipment will be expected to give at least 500 hours of service-free operation

1 3 Service Conditions
The receiver shall meet the performance requirements of this specification under any combination of the following service conditions

(a) Temperature 0°C to +60°C
(b) Relative humidity 10 to 90 per cent
(c) Continuous operation for 4 hours
(d) Battery voltage supply ±5 per cent from 13 or 26 volts
(e) Normal aircraft vibration (small aircraft)

1 4 Material to be furnished
One complete navigation receiver shall consist of the following

(a) One receiver unit complete with tubes and mounting base or shock mounts
(b) Control unit and all necessary connecting mechanical and electrical cables and plugs, if required
(c) Omnibearing selector, course deviation indicator and ambiguity TO-FROM indicator
(d) Instruction book

2 Electrical Requirements
The receiver shall use a superheterodyne circuit The intermediate frequency shall be chosen by the contractor

2 1 Frequency
The receiver shall be capable of being manually tuned to any frequency within the band 108 to 122 Mc The frequency channels are at 100 kc intervals beginning with 108 1 and ending with 121 9 Mc The dial shall be calibrated at least every 0 5 Mc starting at 108 0 Mc

2 2 Input
The antenna input circuit shall be inductively coupled, and shall be designed for connection to a 52-ohm coaxial line

2 3 Sensitivity
With a 5-microvolt signal modulated 30 per cent at 1,000 cycles fed through a dummy resistor to the input circuit, the audio power from the headphone circuit must be 50 mw into 300-ohm resistive load and the signal-to-noise ratio shall be greater than 6 db at all points in the radio-frequency range

2 4 Selectivity
At any resonant point in the frequency band the total bandwidth shall be as follows

Ratio	Total Bandwidth
6 db	More than 35 kc
60 db	Less than 360 kc

2 5 Undesired Responses

Image	40 db down
All others	40 db down

2 6 Stability
There shall be no evidence of parasitic radio-frequency or audio-frequency oscillations at any setting of any controls or under any service conditions listed under paragraph 1 3 Under any combination of these service conditions, the over-all sensitivity shall not change more than 10 db Tuning stability is essential

2 7 Automatic Gain Control
With all gain controls fixed, the automatic gain control shall maintain the unfiltered audio level constant for any degree of audio gain to

within a total of 5 db for radio-frequency input voltages from 10 to 10,000 microvolts

2 8 Power Supply
The power supply shall be either a separate unit or an integral part of the receiver It shall be possible to substitute power supplies in order for the complete equipment to operate on either 12 or 24 volts dc A 5 per cent ripple voltage in the battery supply at 100 to 10,000 cycles shall not decrease the receiver performance below the requirements specified herein

2 9 Aural Output
An aural output circuit shall be provided which will supply at least 300 mw of power to a 300-ohm resistive load from a radio-frequency signal modulated 30 per cent with 1,000 cycles The maximum permissible harmonic distortion shall not exceed 20 per cent at 10,000 microvolts radio-frequency input

The over-all audio response to the headphone circuit shall be such that the difference in response between any two frequencies between 400 and 2,500 cycles shall not be greater than 6 db The response of 30 and 10,000 cycles shall be 20 db or more below the response at 1,000 cycles

3 Electrical Requirements - Omnirange System
Omnibearing and course indications are obtained by comparing the phase of two 30-cycle voltages The phase of one voltage is a function of the azimuthal position of the receiver with respect to the range station and is referred to as the "variable" phase voltage The second voltage is one of constant phase at all azimuth angles and is referred to as the "reference" phase voltage and is transmitted on a subcarrier of 9,960 cycles which is frequency modulated with 30 cycles at a deviation ratio of 16

The range station radiates a carrier which is amplitude modulated 30 per cent by the 30-cycle variable phase signal, 30 per cent by the 9,960-cycle subcarrier and 40 per cent by voice The phase of the variable and reference 30-cycle voltages are in-phase at magnetic north from the range station

3 1 Phase Comparison Circuit
The reference and variable 30-cycle voltages shall be used in a phase comparison circuit to provide direct current for the operation of a sensitive zero-center type of course deviation meter which will be mounted on the instrument panel The meter shall be designed for aircraft use and shall not be less than 2 1/2 inches or more than 3 1/2 inches in diameter The meter shall be submitted for approval

The receiver shall provide a course width of an omnirange of full-scale left to full-scale right on the course deviation meter for a change in azimuth angle of 25° to 30° with a radio-frequency input of 500 microvolts The dc output of the phase comparison circuit shall be a linear function of phase shift up to full-scale deflection of the meter

3 2 Ambiguity Indicator
A zero-center, up-down type meter shall be provided to perform the following functions

(a) Meter shall be labeled "TO" and "FROM" to indicate the proper reading of the omnibearing selector
(b) The center section of the meter scale shall be painted red to indicate when the received signals are too weak for satisfactory reception or failure of the omnirange station
(c) The ambiguity indicator shall also be used as a tuning meter for omniranges

An omnirange signal of 10,000 microvolts shall not cause the pointer of the ambiguity meter to hit the stop The pointer indication shall be outside of the red sector for an input signal of ten microvolts

3 3 Omnibearing Selector
A phase shifting inductive or resistive device having a scale approximately 3 1/2 inches in diameter with a pointer shall be provided to select the omnibearing courses The scale shall be marked every 5° with slightly longer marks every 10° The scale shall be numbered every 10°

3 4 Stability
With the receiver operating with a radio-frequency input signal to provide normal reference and variable voltages as defined in paragraph 3 1 and the bearing selector set for an on-course indication, the course deviation meter shall not deflect more than the equivalent of 2 0° change in azimuth

angle at any bearing selector setting under any of the following conditions

(a) Radio-frequency input to receiver is varied from 5 to 10,000 microvolts
(b) When the 9,960-cycle frequency modulated subcarrier is amplitude modulated at 10 per cent with 30 cycles, and the mean subcarrier frequency is shifted ±166 cycles
(c) Battery voltage varies ±5 per cent of 13 or 26 volts
(d) When the radio-frequency input to the receiver is modulated 10 per cent with frequencies from 45 to 75 cycles per second (Simulated propeller modulation)

3 5 Over-all Omniaccuracy
When a simulated radio-frequency omnirange signal of 10 microvolts or 10,000 microvolts is applied to the input of the receiver and the variable phase voltage is varied in-phase through 360°, the omnibearing selector shall indicate the simulated course within ±3° Also, the reciprocal on-course indication at any course setting shall not be greater than ±2°

3 6
With a simulated radio-frequency omnirange signal of 10 microvolts or 10,000 microvolts and having 35 per cent voice modulation, the course deviation meter shall not vary more than the equivalent of 1° from on-course

4 Electrical Requirements - Phase Comparison Localizer
The phase comparison localizer course indications are obtained by comparing the phase of two 30-cycle voltages The reference phase voltage is one of constant phase at all azimuth angles The variable phase voltage is in-phase with the reference phase voltage on the left side of course and 180° out-of-phase on the right side of course, when approaching the localizer The reference phase voltage is transmitted on an FM subcarrier of 9,960 cycles which is modulated with 30 cycles at a deviation ratio of 16 The variable phase of 30 cycles amplitude modulates the carrier except on the on-course line

4 1 Phase Comparison Circuit
When on-course, only the 30-cycle reference voltage is received, and this voltage shall not cause a deflection of greater than 1/20 full-scale deflection from center of the course deviation meter Also, the ambiguity indicator shall indicate in the red sector

When off-course to the left approaching the station with 1,000 microvolts signal and 30 per cent reference phase modulation and 13 per cent variable phase modulation, the course-deviation meter shall indicate full scale ±10 per cent to the right and the ambiguity indicator shall read in the red sector Similarly, when off-course to the right approaching the station under the same conditions of signal modulation, the course deviation meter shall indicate full scale ±10 per cent to the left and the ambiguity meter indicator shall read in the red sector

A switch shall be provided to select either omnirange or localizer facilities When in the localizer position, the omnibearing selector shall be disconnected from the circuit.

5
Mechanical Requirements

5 1 Construction and Design
The receiver shall be designed for minimum size and minimum weight

5 2 Receiver Panel Facilities
Facilities shall be provided on the receiver panel for

(a) Tuning control with calibrated dial
(b) Audio gain control

5 3
The control unit shall contain an on-off switch and one phone jack

5 4 Plug Connections

(a) Satisfactory plug connectors and sockets shall be used throughout
(b) A low-loss antenna plug (coaxial line) shall be mounted on the rear

6 Tests
Tests will be made at the contractor's factory to determine if all the requirements of this specification have been provided All test equipment shall be furnished by the contractor