THE DEVELOPMENT OF AN IMPROVED VOR/TVOR MONITOR

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SUMMARY

This report describes an improved VOR (or TVOR) monitor developed at the Technical Development and Evaluation Center of the Civil Aeronautics Administration, Indianapolis, Indiana Work on the monitor was initiated at the conclusion of the TVOR development with the primary objective of producing the companion monitor required for the TVOR to attain commissioned status However, since the design requirements for monitoring the VOR and TVOR are identical, the improved monitor described in this report is equally applicable to either type of facility

The monitor employs unique circuitry which is quite different from that used in previous VOR monitors and which is designed so that the monitor system would react to a VOR or TVOR signal in the same manner as an airline-type navigation receiver Alarms are provided whenever the facility transmissions vary by more than prescribed limits and when either the transmitter or the monitor fails

INTRODUCTION

Following the development of the terminal omnirange (TVOR), a companion development of an improved monitor was initiated The design objectives included

1 A monitor that would react to an omnirange signal in the same manner as a standard airline-type navigation receiver
2 Circuitry that is as simple as possible to assure maximum reliability
3 Such a degree of stability and accuracy that the monitor can be used for ground calibration of TVOR stations
4 Operation of external alarm circuits when the omnirange course, modulation levels, or transmitter power output vary beyond specific tolerances or when the monitor itself fails to function properly

GENERAL REQUIREMENTS

The following specific requirements were placed on the design of the monitor.

1 Stability--The monitor course indication shall be stable to within ±0 5° under conditions of temperature variations between -10° and +60° C, humidity up to 90 per cent, power-line voltage of 115 volts ±10 per cent, power-line frequency of 60 cps ±1 per cent
2 Reliability--The monitor shall provide continued operation over long periods of time with a minimum of maintenance The construction shall be such that the installation is simple and maintenance is relatively inexpensive Component tolerances shall be such that selection is not necessary when replacement of any component is needed The monitor shall provide an alarm whenever the monitor itself fails to function properly
3 Effects of Modulation or Hum--The monitor shall not be affected by 5 per cent of 60-cps or 120-cps ripple component on the carrier or by 10 per cent of 30-cps amplitude modulation on the 9 96-kc subcarrier
4 Indicated Course Shift--The monitor shall provide an alarm when the course shift is greater than ±1 0°
5 Modulation Levels--The monitor shall provide an alarm when either the 30-cps variable-phase signal or the 9 96-kc subcarrier signal varies ±15 per cent or more from normal level
6 R-F Level--The monitor shall provide an alarm whenever the transmitted r-f power is decreased more than 50 per cent below normal Any decrease less than 50 per cent in r-f level shall not affect the course or the modulation-level alarm limits
7 Self Calibration--Circuitry shall be provided for calibrating the monitor at zero-degree bearing
8 Bearing Accuracy and Resetability--The indicated bearing accuracy shall be such that its resetability is within ±0 1°

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CIRCUIT DESCRIPTION

The monitor circuitry employed is presented in the block diagram, Fig 1, and in the schematic diagram, Fig 2 It is similar to that of a Collins Radio Company Type 51R-3 airborne navigation receiver, and a large number of component parts used in the monitor are interchangeable with similar parts in the Collins receiver

Reference Channel

See blocks 9 through 14 and 17 through 20 of Figs 1 and 2 The detector output is connected to the reference channel by a 470-mmfd capacitor which effectively blocks the 30-cps component and offers a low impedance to the 9 96-kc signal The signal then passes through a 9 96-kc band-pass filter (block 9) and a 0 5-megohm potentiometer to the input of tube V-1A (block 10) The input level to tube V-1A is controlled by the 9 96-kc LEVEL potentiometer The output of tube V-1A is connected to the limiting stages (block 11), consisting of tubes V-2 and V-3, where all amplitude modulation is removed from the 9 96-kc frequency-modulated signal The output of the limiting stage, tube V-3, is fed to the discriminator amplifier, tube V-4A (block 12) The discriminator (block 13) used in the monitor is a ratio-detector type of discriminator using tube V-5 as the rectifier The 30-cps reference signal from the output of the discriminator is fed to the input of the reference 30-cps amplifier tube V-4B (block 14) The output of this tube is fed through a phase-adjusting network to a level control and thence to the input of the omnibearing selector (OBS) amplifier tube V-6A (block 17) The VOR PHASE-VERNIER potentiometer, in conjunction with the OBS, is used to set the VOR bearing to coincide with the bearing obtained during the commissioning flight check for that particular bearing where the detector head is located By use of this vernier and of an OBS with detents, the resetability of the OBS to a specified bearing is within ±0 1° The value of the asterisk-marked resistor is selected to set the control range of the VOR PHASE VERNIER to ±2° The REF 30-cps LEVEL control is used to adjust the reference-channel output to the desired level

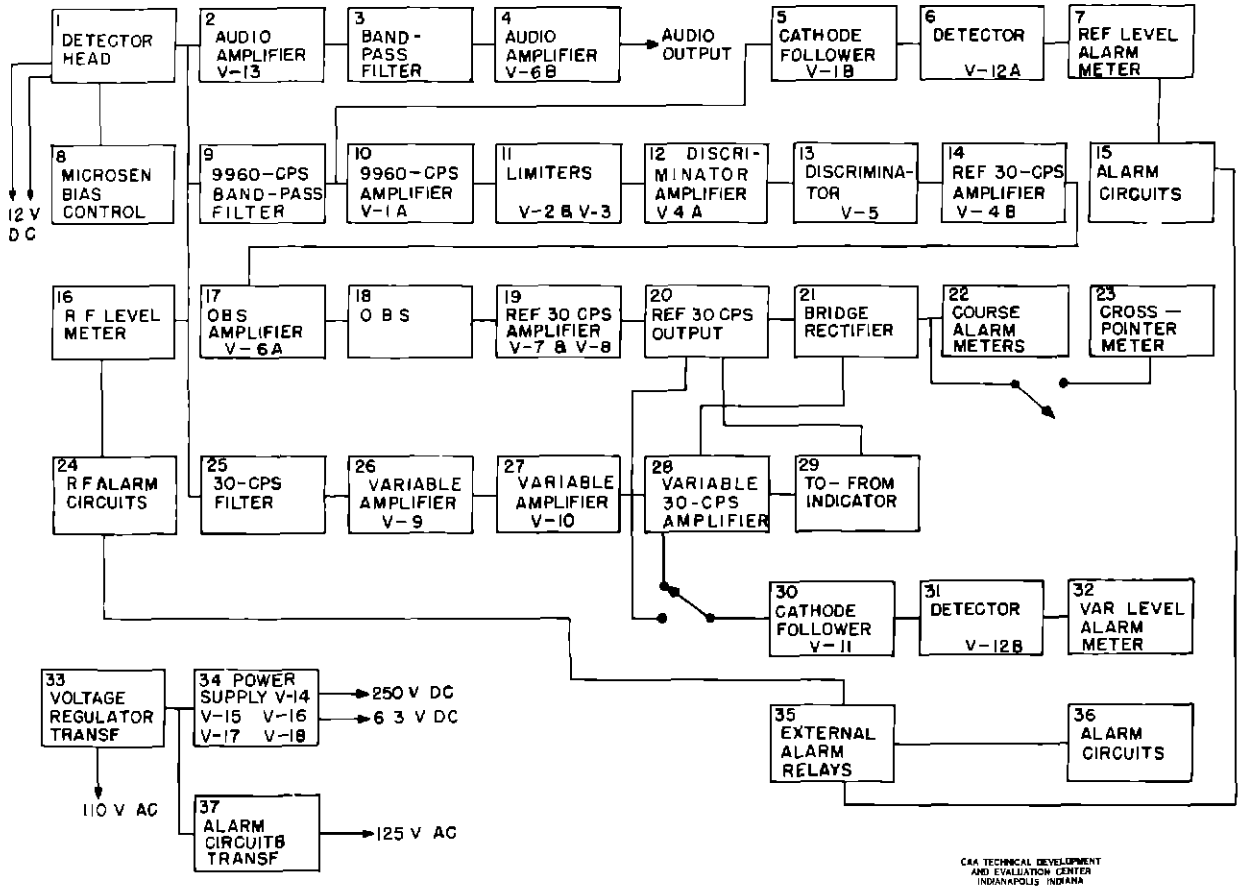

Fig 1 Block Diagram of TVOR Monitor

The rotor of the OBS (block 18) is connected in series with a 1500-ohm resistor between the cathode of tube V-6A and ground The stators of the OBS are connected to a resistance-capacitor (RC) network in which the resistance is equal to the reactance of the capacitor at 30 cps The OBS CAL TRACKING control is adjusted to an OBS bearing of 60° whenever the OBS is replaced A Type CA-1430 audio generator should be used for this adjustment The output of the RC network is fed through a low-pass RC filter to the input of tube V-7 (block 19) The output of tube V-7 is fed to the input of tube V-8 through the secondary winding of a push-pull transformer The secondary of this transformer is connected to an autotransformer to provide push-pull excitation for the grids of tube V-8 The 0 01-mfd capacitor tunes the autotransformer to parallel resonance at or very near 30 cps The 470,000-ohm resistor provides a constant transformer load Tube V-8 serves as a straight amplifier to provide the power necessary to drive the reference portion of the course-deviation-indicator (CDI) circuits The primary of the output transformer (block 20) is tuned to resonance at 30 cps in order that variations in the plate resistance due to tube interchange will not cause variations in phase angle

Variable Channel

This variable channel is shown in blocks 25 through 28, Fig 1 The 30-cps output from the detector passes through the VAR LEVEL control, a blocking capacitor, through the VOR-CAL switch and the 30-cps filter (block 25) to the input of tube V-9 (block 26) The VAR LEVEL control is used to adjust the 30-cps output to the desired level The tuned circuit, in conjunction with 0 0448-mfd and 0 05-mfd mica capacitors to ground, forms a resonant circuit tuned to approximately 25 cps By this combination there is established between 30 cps and frequencies slightly higher a steep attenuation characteristic which minimizes the effects of 60-cps hum The CAL PHASE control, used during monitor calibration, serves as an adjustment of the amount of phase shift through the filter so that the course-deviation indicator can be centered during monitor calibration The variable-phase amplifier tube V-9 (block 26) is a phase-inverter stage obtaining excitation from the voltage divider comprising the 470,000-ohm and the 6500-ohm resistors The push-pull output of this tube is coupled to the input of tube V-10 (block 27) Tube V-10 serves as the meter-circuit amplifier and raises the power to a suitable level for excitation of the meter circuit The primary winding of the output transformer (block 28) is tuned to 30 cps in order that variations resulting from tube interchange will not produce phase shift

Course-Deviation-Indicator Circuit

It will be noted in Fig 2 that part of the reference-channel output is added to a similar portion of the variable-channel output by the transformer secondary connections and that the vector sum of these two voltages is applied to one section of the double-bridge rectifier It will also be noted that the other half of the double-bridge rectifier is driven in a similar manner except that the polarity of one winding has been reversed Thus the condition is established wherein the two a-c voltages are rectified (block 21) and appear across the load resistor as a differential d-c voltage

This results in a deflection of the CDI meter (block 23) when a difference in the two d-c voltages exists The BALANCE potentiometer provides a differential adjustment of one bridge output with respect to the other when measured across the double-bridge load and thus serves as a balance adjustment to eliminate the unbalanced currents which may result from slight differences in the two bridges as well as from tolerance variations in the load resistors

TO-FROM Meter Circuit

The TO-FROM meter circuits (block 29) are composed of the center-tapped secondaries of the reference- and variable-channel output transformers and the phase-splitting components (the 1 0-mfd capacitor and the 5600-ohm resistor) A TO-FROM indicator housed within the omnibearing selector indicates whether the bearing being received is the desired bearing or one displaced 180° from it To provide this ambiguity indication, the phase detector operates in such a fashion that a condition of balance exists displaced 90° from the condition of balance on the course-deviation indicator Thus, when the desired bearing is selected, a d-c output of one polarity will exist across the outer terminals of the 5600-ohm load resistors and the TO-FROM indicator will indicate FROM If the reciprocal of the desired bearing is selected, the indicator will indicate TO

30-Cps Level-Meter Circuit

The VARIABLE LEVEL meter (block 32) is used to measure the voltage levels of the reference and variable channels The signal to be measured is selected by the spring-return toggle switch (normally in the variable channel) and is fed to the input of the cathode-follower tube V-11 (block 30) The output of this tube is detected by tube V-12B (block 31) The detected signal is then fed to the VARIABLE LEVEL meter The VARIABLE LEVEL potentiometer is used to adjust the sensitivity of the meter for operation as the variable-level alarm

Self-Calibration Circuits

The calibrating circuits consist of the VOR-CAL switch, the CAL VAR LEVEL potentiometer, and a resistor When the switch is in the CAL position, the 30-cps reference signal is fed to both the variable and reference channels When the OBS is set to a bearing of zero degrees, the CAL phase control is used to adjust the phase shift of the 30-cps filter (block 25) until the CDI reads zero deviation The CAL VAR LEVEL control is used to adjust the level of the variable channel The REF 30-cps LEVEL control is used to adjust the level of the reference channel to the same level as that of the variable-channel output

Modulation-Level Alarm

The modulation-level alarms for both the reference and variable signals use the same type of circuitry The reference-signal alarm operates from the detected 9 96-kc signal (blocks 5,6, 7, 15), whereas the variable-signal alarm operates from the detected variable 30-cps output (blocks 30, 31, 32, 36) The signal from the reference channel is taken from the output of tube V-1A (before limiting) and is detected by V-12A (block 6), and its level is indicated by the reference-alarm meter (block 7) This meter has two vanes on its pointer, and, when the detected signal level varies by more than ±15 per cent from its adjusted value, one of the vanes will cover the dial hole, cut off the light to the photocell, and thus cause the relay to produce an alarm The photocell is a barrier-layer type and has a very long life, evidenced by its use in photographic exposure meters

Operation of the photocell-alarm circuits (blocks 15, 24, 36) is as follows When the photocell is not conducting (the alarm-meter vanes are over the dial hole), the generated current in the photocell is zero and the alarm relay is in the de-energized (alarm) position When the

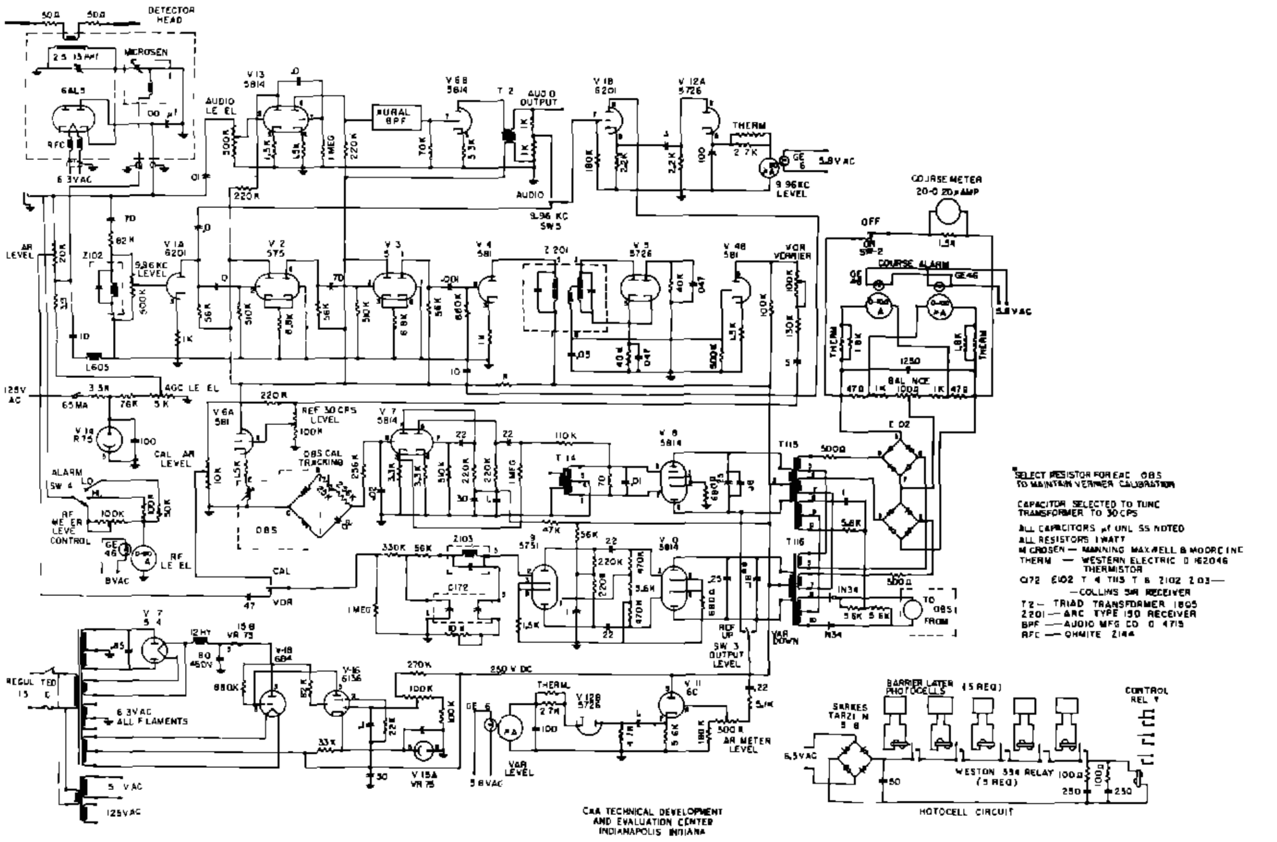

Fig 2 Omnirange Monitor With Photocell Motors

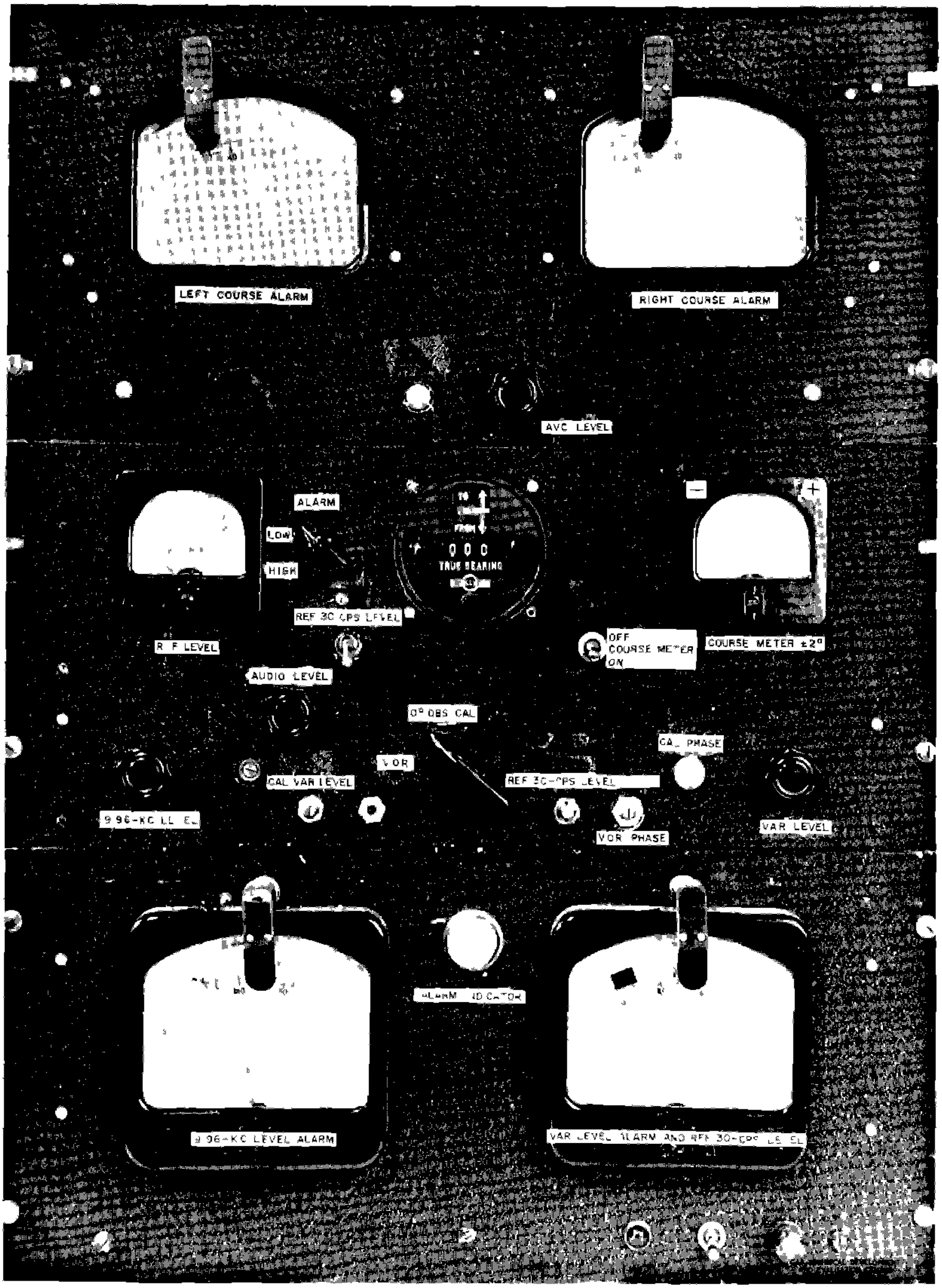

Fig 3 Front View of Monitor

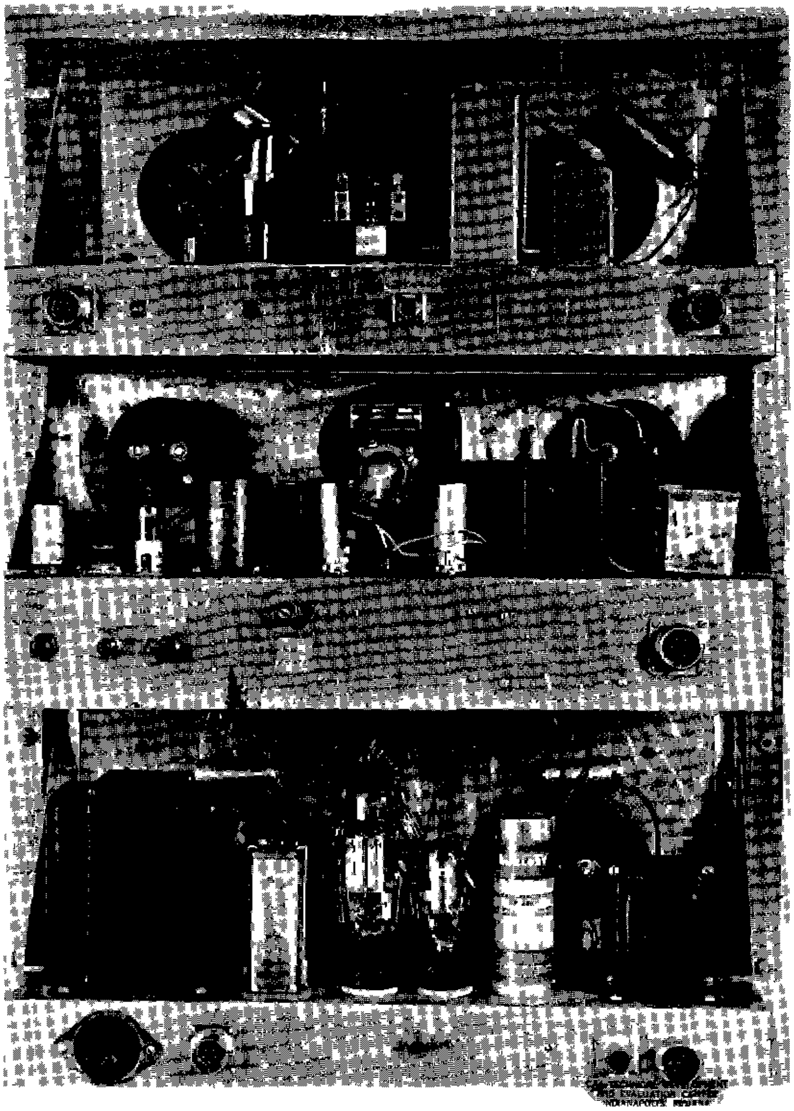

Fig 4 Rear View of Monitor

photocell is conducting (the meter vanes are not over dial holes), the photocell generates current, thus energizing the relay (nonalarm position) This type of alarm circuit has proven to be satisfactory during a test period of a year

In the early stages of development of the monitor, sensitive zero-center-type contact-making relays which operated as tolerance-alarm controls were tried and were found to be unreliable The unreliable condition was caused by the occasional failure of the relay contacts to maintain continuity when they were operated near the tolerance limits Vibration also caused erratic operation of the relays The sensitive relays that are used in the monitor under discussion are not used as tolerance-control relays The normal relay current is over 60 microamperes, and the contacts are open at 25 microamperes

Course-Deviation Alarm

Each of the course-deviation alarm meters (block 22), Fig 1, are connected at opposite ends of the bridge rectifier (block 21) through two 47-ohm resistors With an on-course signal, the voltage across the 47-ohm and 1000-ohm resistors and the balance potentiometer is equal for both sections of the resistance network and both meters read the same When the course deviates, the voltage across each 47-ohm section of the resistance network is different and the meter pointers move in opposite directions The value of the 47-ohm resistor was selected so that, with an off-course bearing of 1° or more, the vane on the meter pointer will cover the dial hole and will cause the alarm circuits to be actuated

R-F Level Alarm

The r-f level meter (block 16) measures the d-c output level from the field detector When the r-f power indicated by the field strength at the detector pickup is reduced by 50 per cent or more, the vane on the pointer of the r-f level meter covers the dial hole and thus energizes the alarm circuit (block 24)

Audio Channel

The input to the audio channel is connected from the detector output through an audio-level potentiometer to the input of the two-stage audio amplifier, tubes V-19A and V-19B (block 2) The output of V-19B is connected to a band-pass filter (block 3) which removes the 9 96-kc subcarrier and the 30-cps variable signal, allowing only the desired audio signal to pass through to the next stage The filter is constructed as a single unit with all circuit components sealed within The output of the band-pass filter is fed to the input of amplifier tube V-6B (block 4) through an output transformer

Field Detector

The detector used with the monitor is a modified Type CA-1278 field detector and is shown in blocks 1 and 8 of Fig 1 and in the schematic diagram, Fig 2 The modification consisted of replacing the germanium crystal diode with a Type 12AL5 tube and adding a Microsen unit in the head A Type RG-22/U twin conductor cable with a polarized plug and a Type RG-8/U cable are used for interconnections between the detector head and the monitor One lead of the twin-conductor cable is used for the Microsen control, and the other is used for the filament supply, with the shield being used as a common ground return The RG-8/U cable is used to connect the detector output to the monitor input The output of the detector consists of three principle components namely, the 9 96-kc subcarrier, frequency modulated at 30 cps, the 30-cps signal, variable phase, and the audio signal, voice or 1020-cps keyed characters

SPECIAL COMPONENTS

The type of circuit components used in this equipment were selected for those characteristics which would enable the monitor to meet design objectives Figures 3 and 4 show the locations of the main components

R-F Level Meter

A Weston 0-50 microammeter is used as a voltmeter to measure the detector-head d-c output voltage and as an r-f alarm meter The modification required to provide the r-f-level alarm consisted of providing a hole in the dial face, moving the pointer stop, and adding a vane at the end of the pointer The relationship of the hole, the stop, and the vane is such that the vane covers the hole when the pointer is against the stop An external lamp is mounted over the hole so that its light shines on a photocell, which energizes the alarm relay When the power output from the transmitter falls 50 per cent or more below its normal value, the pointer vane cuts off the light, thereby de-energizing the alarm relay and actuating the alarm circuitry The r-f level meter shown in Fig 3 has not been modified as described above

Course Meter

A Weston Model 35CZ 20-0-20 microammeter is connected across the output of the varistor bridge and is used to indicate course deviation A 1500-ohm resistor across the meter is used as a shunt for calibration so that the meter reads directly in terths of a degree Full-scale deviation equals ±2 0°

9 96-Kc Level-Alarm Meter

Meters, Inc , Model 50 is a 0-500 microammeter incorporating a specially designed pointer and a dial calibrated from 0 to 100 The dial has a hole above the 50 mark through which an external light shines on a photocell, which in turn energizes the alarm relay when the monitor is operating normally Attached to the meter pointer are two arms with small vanes at the end of each arm Pointer stops are provided to prevent the movement of the vanes beyond the hole positions The spacing of the vanes is equal to 16 dial divisions When the monitor is in normal operation and the VOR carrier is modulated 30 per cent by the 9 96-kc signal, the center of the pointer is at 50 on the dial and is directly below the hole in the dial face When the 9 96-kc signal level is changed by more than ±15 per cent, the pointer will move in accordance with the change in level and either vane will cover the hole in the dial, thus interrupting the light to the photocell This de-energizes the relay and connects the alarm circuits

Variable-Level Alarm and Reference 30-cps Level Meter

This meter is the same type as just described It is modified and operated in the same manner except that it normally operates from the variable-channel 30-cps signal instead of from the reference-channel 30-cps signal When the SW-3 switch is operated, the meter reads the 30-cps voltage from the reference channel

Left and Right-Course Alarm Meters

These two meters are Meters, Inc , Model 50, 0-100 microammeters with specially modified dials and pointers The meters were modified to incorporate a hole in the dial above the 30-μa mark Through this hole, an external light shines on a photocell which in turn energizes the course-alarm relay when the monitor is operating normally A small vane is attached to the end of the pointer, and a stop is provided so that the pointer will not go below the 30-μa mark With the monitor operating normally and the CDI meter at zero deviation, the two course meters read approximately 47 on the dial When the course deviates from the zero bearing, the meter pointers will move in opposite directions When either pointer decreases to the 30-μa position, its vane will cover the hole in the dial and shut off the light to the photocell The photocell then stops generating current, de-energizes the alarm relay, and connects the alarm circuits

Microsen

The Microsen unit Type Y3-28-122, manufactured by Manning, Maxwell and Moore, Inc , is used as an automatic volume control A negative bias voltage is connected to the unit, and the desired bias level is set by the AVC level control When a specific value of bias is applied to the Microsen, it will not operate until the positive-rectified r-f voltage exceeds the bias voltage The Microsen will then operate and detune the secondary of the detector r-f-pickup transformer This will tend to hold the detector output constant with increased r-f voltage applied to the coil In case the r-f level decreases the Microsen will hold the detector output constant until the detuning action stops, at which time the detector output will decrease linearly until the R-F LEVEL meter gives an alarm

TESTS

The range of controls given in Table I is based on the variation of the input-signal level (as measured at monitor-signal input jack) that could be tolerated and still allow the monitor to operate normally after a readjustment of the level control

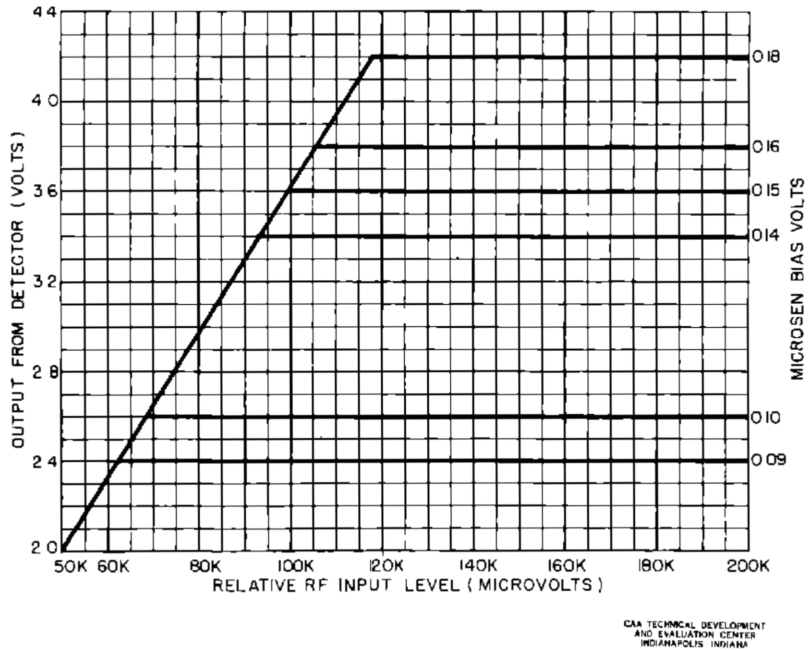

Fig 5 Detector-Head Microsen Characteristics

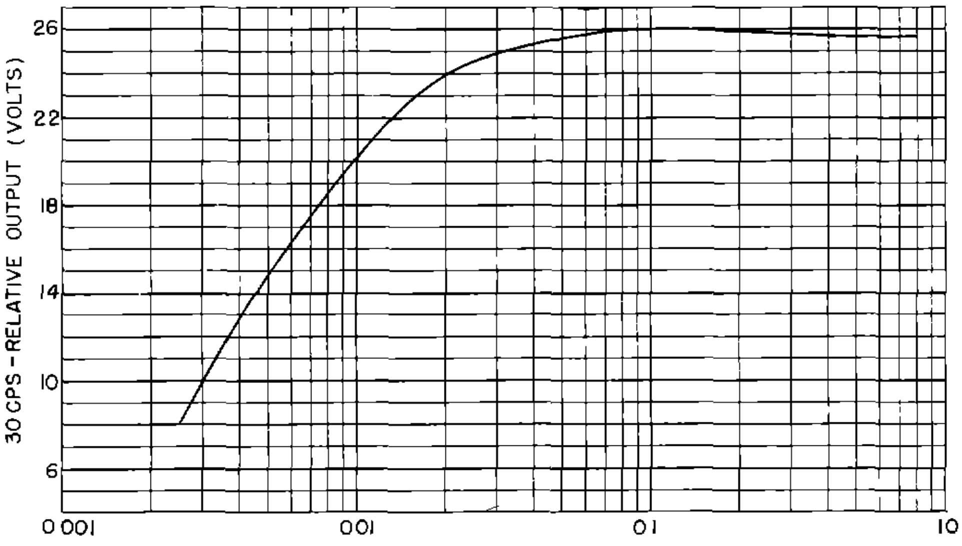

Fig 6 Limiter Characteristics With Change of 9 96-kc Input Level

TABLE I

RANGE OF LEVEL CONTROL

Input Signal	A C Input Voltage Maximum	Minimum
30 cps variable	10 0	0 19
9 96-kc reference	10 0	0 185

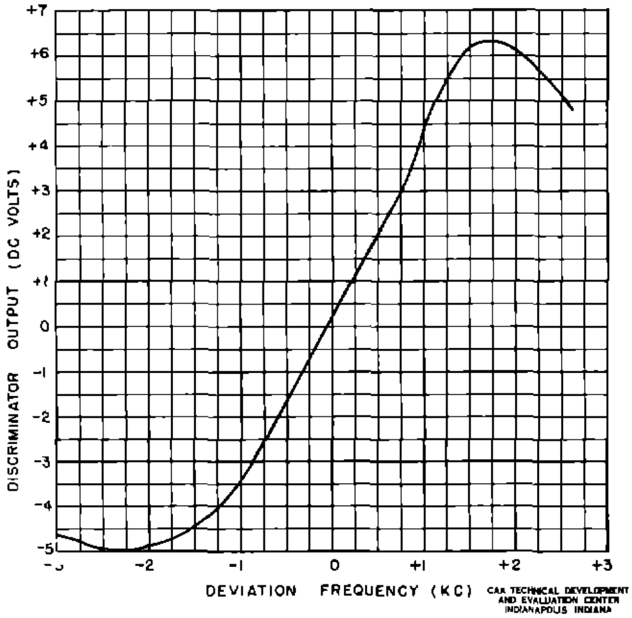

Fig 7 Linearity of Discriminator Output With Change of Deviation Frequency From 9 96-kc

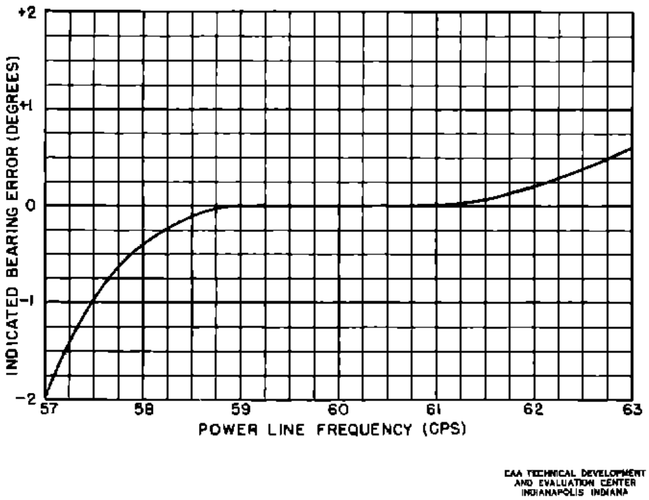

Fig 8 Change of Indicated Bearing With Change of Power-Line Frequency

The range of the phase controls, when the monitor is operated within these input-signal levels are given in Table II

TABLE II

RANGE OF PHASE CONTROL

Control	+ (degrees)	- (degrees)
Calibration phase	2 8	2 8
VOR phase vernier	2 0	2 0

The VOR phase vernier is calibrated at ±2 0° in 0 1° increments

Microsen Characteristics

Figure 5 shows the effects on the detector output when the Microsen is used as an automatic volume control The detector output increases almost linearly with increase in r-f signal level until the output reaches the value at which the Microsen takes control After this

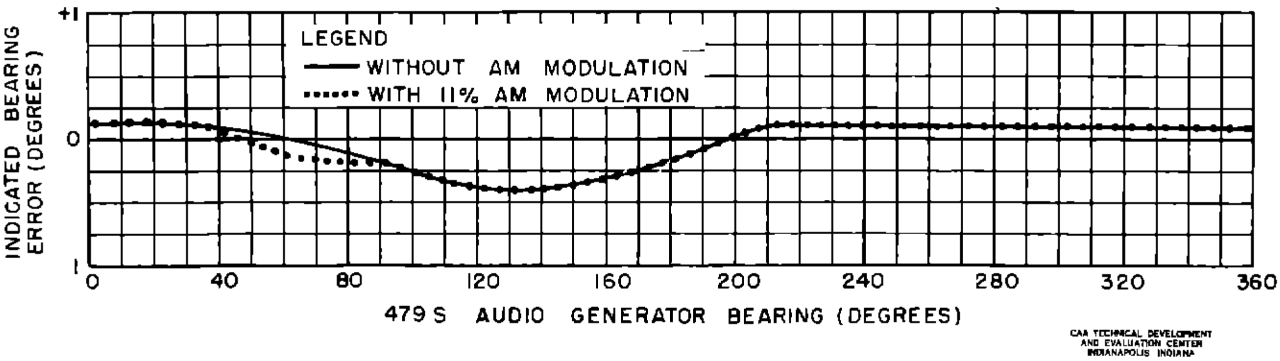

Fig 9 Change in Calibration-Error Curve Caused by Eleven Per Cent of AM Modulation on Tone-Wheel Output

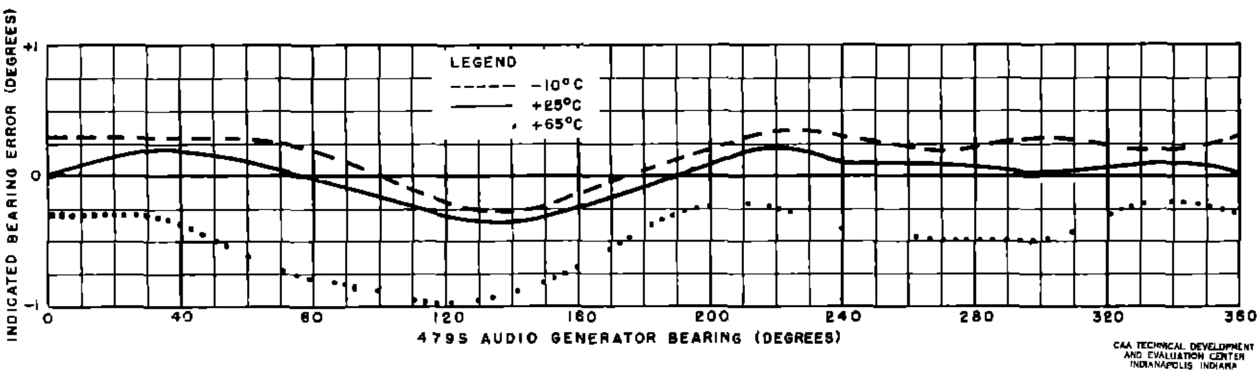

Fig 10 Indicated Change of Bearing With Change of Ambient Temperature

point has been reached, the detector output remains nearly constant with increased input levels Figure 5 graphically shows the level of control with the various bias voltages applied to the Microsen unit

Limiter Characteristics With Change of 9 96-kc Input Levels

The 9 96-kc FM signal was fed from a Collins 479S signal generator to the input jack of the monitor The signal level was varied from 0 001 to 1 0 volt, and the level of the 30-cps reference channel was recorded Figure 6 shows that the 30-cps reference voltage leveled off with an input of 0 08 volt and remained constant for inputs up to 1 0 volt

Discriminator-Output Linearity With Change of Deviation Frequency

The characteristic of the limiter is given in Fig 7 This characteristic was determined under static conditions by applying a signal of variable frequency in 0 2-kc steps and by measuring the d-c output of the discriminator at each step on a high-impedance d-c instrument This figure shows that the discriminator output is linear over the frequency-deviation range of ±1 kc from the 9 96-kc center frequency

Change of Indicated Bearing With Change of Power-Line Frequency

Figure 8 shows the error that would result with variation of the power-line frequency The errors resulting from a variation of ±1 cps in power-line frequency would be less than 0 1°, or ±0 4° for a 2-cps variation

Change in Calibration Error Caused by 11 Per Cent of 30-cps Amplitude Modulation on the 9 96-kc Subcarrier

The addition of 11 per cent of 30-cps amplitude modulation to the 9 96-kc subcarrier signal caused a change of 0 1° in the calibration-error curve, as shown in Fig 9 It will also

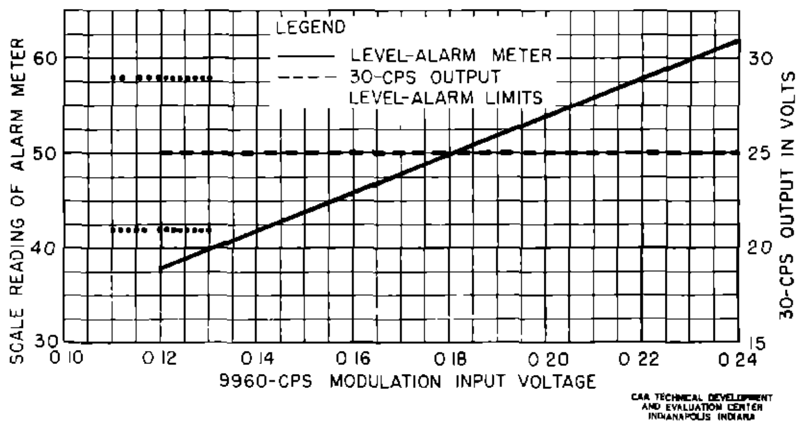

Fig 11 Reference-Level Alarm Characteristics and 30-cps Reference Output Level

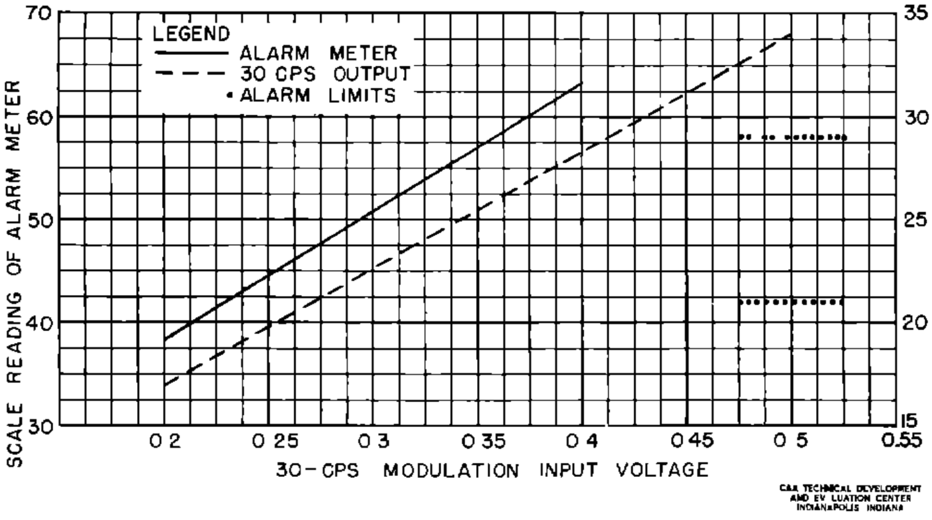

Fig 12 Variable-Level Alarm-Circuit Parameters

be noted that the calibration error of the monitor is ±0 25° In Table III, the change in alarm-meter readings is compared with the change in power-line voltage

Change of Indicated Bearing With Induced Hum

With equal voltages of 9 96-kc subcarrier, 30-cps variable signal, and 60- or 120-cps hum signal introduced directly into the input of the monitor, the maximum error in indicated bearing was less than ±0 01° With a normal omnisignal plus 5 per cent modulation of 60- or 120-cps hum from the 479S and 211 signal generators fed through an r-f amplifier to the antenna input of the field detector, the bearing error for variation in r-f level was as shown in Table IV Table V indicates how the course-alarm meter readings vary with the change in the 30-cps variable-signal level

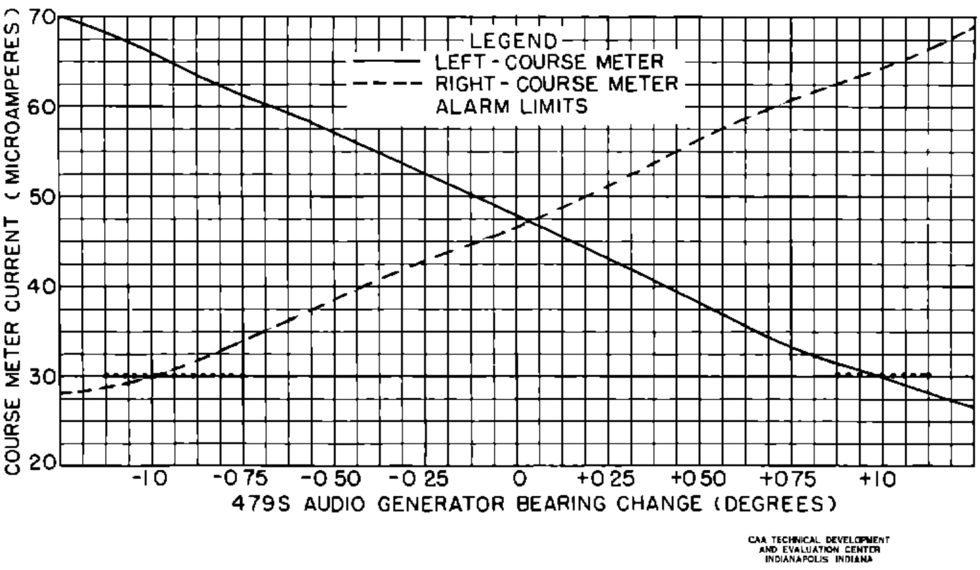

Fig 13 Course Alarm-Meter Characteristics With Change of Signal Bearing

TABLE III

ALARM METER READINGS VERSUS POWER-LINE VOLTAGE

Power Line (volts)	Course Meters Left	Course Meters Right	Meter Readings 9.96-kc Level-Alarm Meter	30-cps Level-Alarm Meter
108	47	47	49.5	50
120	49	49	50.0	50.2
132	50	50	50 3	50.3

TABLE IV

BEARING ERROR VERSUS INPUT LEVEL

211A Input to r-f Amplifier (microvolts)	Detector a-c (volts)	Detector d-c (volts)	Bearing Error 60-cps, 5 per cent Hum (degrees)	Bearing Error 120-cps, 5 per cent Hum (degrees)
200,000	3.75	16.0	±0.02	±0
100,000	1.95	8 2	±0.15	±0
50,000	0.92	4 0	±0.20	±0.01
20,000	0.37	1.6	±0.30	±0.02

TABLE V

COURSE-ALARM METER READINGS VERSUS 30-CPS VARIABLE-SIGNAL LEVEL

30-cps Variable Level	Course-Meter Readings Left	Course-Meter Readings Right	Bearing Error (degrees)
Normal	48	48	0
Reduced 15 per cent	43	43	-0 02
Measured 15 per cent	54	53	+0.08

Indicated Change of Bearing With Change of Ambient Temperature

The monitor was placed in the temperature chamber at a room ambient temperature of +25° C and a humidity of approximately 60 per cent The change in the indicated bearing was approximately 0 2° in the temperature range of -10° to +25° C and about 0 5° in the range of +25° to +65° C The indicated change of bearing averaged about 0 7° for the over-all temperature range, as shown in Fig 10

Reference-Level Alarm

The reference-level alarm meter reading is directly proportional to the input level of the 9 96-kc signal, as shown in Fig 11, and an alarm will be given when the input level varies by more than ±22 per cent The alarm limits are set by the physical spacing between the two vanes on the alarm-meter pointer, and, in the case of the prototype meters, this spacing allowed a variation of ±22 per cent instead of the design objective of ±15 per cent Figure 11 also shows the level of the 30-cps reference signal with change of level of the 9 96-kc signal

Variable-Level Alarm

Figure 12 shows the linearity of the 30-cps variable-signal voltage and the alarm-meter variation when the input level was varied from 0 2 to 0 5 volt The alarm meter will cause an alarm when the 30-cps input level changes by more than ±15 per cent from the adjusted value

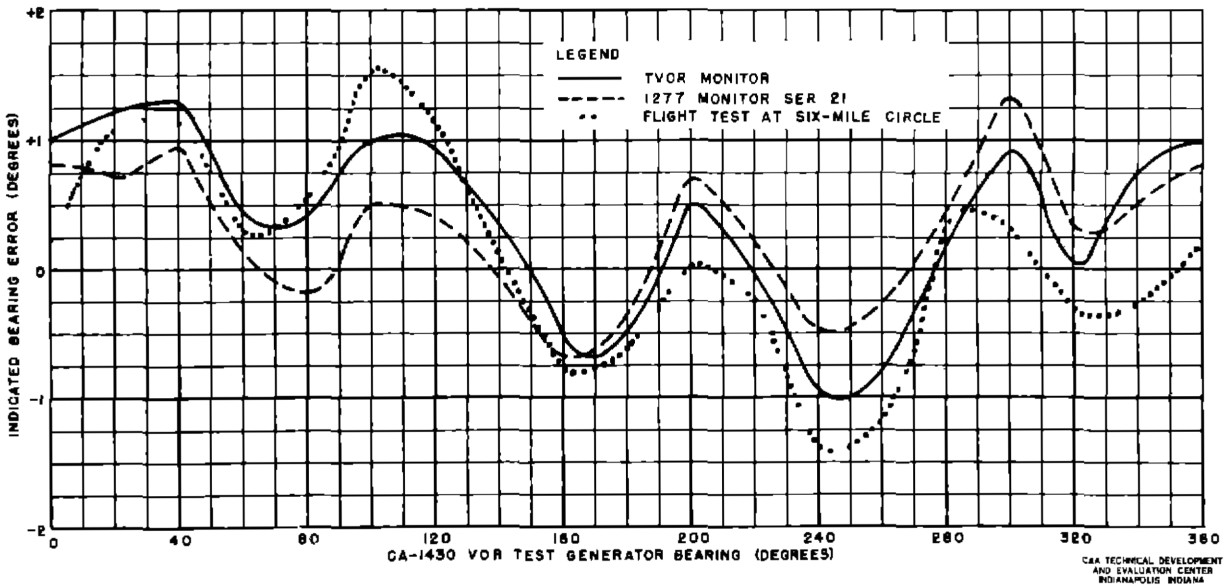

Fig 14 Calibration-Error Curve of Tilden VOR Station Using a Four-Loop Antenna

The variable-channel alarm meter is the same type as used in the reference channel, and the alarm limits are set by the distance between the two vanes on the pointer

Course-Alarm-Meter Characteristics With Change of Signal Bearing

The characteristics of the right- and left-course meters when the course shifts from the on-course bearing are shown in Fig 13 It should be noted that either meter will decrease in reading depending on whether the shifts are plus or minus, and it is this decrease which actuates the desired alarm These data indicate that the monitor will alarm when the course shifts approximately ±1° from its adjusted bearing

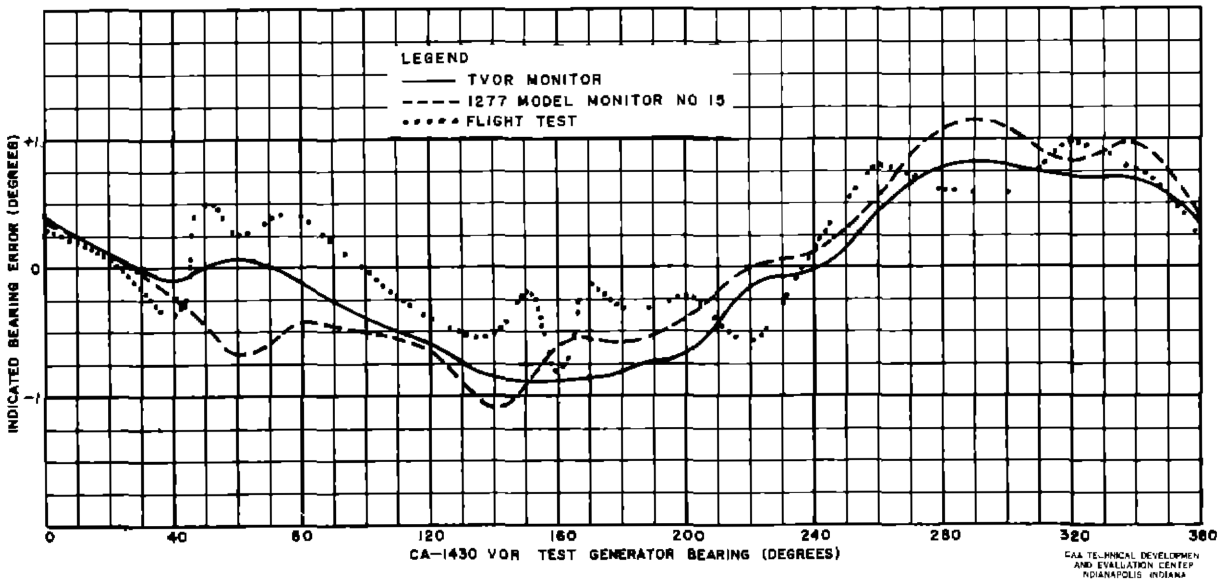

Fig 15 Calibration-Error Curve of North-Range VOR Station at TDEC Using Federal Spinning Antenna

Comparative Field-Calibration Tests

Figure 14 shows the calibration-error curves of the experimental Tilden VOR station when using the TVOR monitor, a modified Type CA-1277 monitor,[1] and data obtained on a six-mile-circle flight test Figure 15 shows the calibration-error curves when the same type of equipment and conditions are used with the exception that these data were obtained from the north experimental VOR station at TDEC

The flight-calibration data for both of these stations were taken from recordings made in the aircraft during flight on a six-mile theodolite-checked circle The flight-check on the Tilden VOR station had been made several weeks prior to the ground-checks The flight-check on the north VOR station was made during the same week as ground-checks The monitor-calibration data were obtained with a counterpoise detector mounted successively at 20° intervals about the counterpoise periphery and with the course being recorded at each position as indicated by the Type CA-1277 and the TVOR monitors

From the curves of Figs 14 and 15, it will be noted that

1 The flight and monitor checks show fairly good correlation
2 The two monitors agree within 0 5° at each station
3 The TVOR monitor-calibration curve lies between the flight-check and CA-1277 monitor curves at nearly all points and for each station calibration

CONCLUSIONS

A monitor has been developed which meets the requirements for monitoring TVOR or VOR stations On the basis of the tests conducted at this Center and on the basis of a comparison with the design of other monitors, it is concluded that

1 The monitor design incorporates many improved fail-safe features
2 The automatic gain control used is simpler and more stable than d-c amplifier types
3 The monitor can be used to calibrate a station to an accuracy of 0 1° without the use of external equipment such as oscilloscopes, mixers, and other equipments
4 A recorder may be used with this monitor to record course deviation over long periods of time
5 The monitor will alarm whenever the omnirange-course modulation levels or the transmitter-power output vary from the preset tolerances
6 The monitor is not affected by low levels of hum or ripple generated in the monitor or by less than 10 per cent amplitude modulation on the 9 96-kc subcarrier
7 The monitor reacts to a VOR signal in the same manner as an airborne navigation receiver
8 The dual use of meters to measure levels and to provide alarm control when tolerances are exceeded has proven to be satisfactory
9 The simplicity of design, the minimum number of special components, and the ease of maintenance are advantages of much economic importance, in regard to both original cost and to maintenance
10 The use of components which have proved reliable in receiver operation (namely, ruggedized tubes) and operation of components such as resistors, capacitors, and so forth at below-rated power increases the reliability of the monitor

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[1]R A Forcier and C G Lynch, "Improvements in the Type CA-1277 VOR Monitor," CAA Technical Development Report No 216, August 1954