Report No. NA-69-23
(DS-69-5)

FINAL REPORT

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Project No. 520-004-06X

AIRCRAFT PROPELLER VIBRATION MEASUREMENT SYSTEM

SEPTEMBER 1969

Prepared for

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
NATIONAL AVIATION FACILITIES EXPERIMENTAL CENTER
Atlantic City, New Jersey 08405

by

HAMILTON STANDARD DIVISION
UNITED AIRCRAFT CORPORATION
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September 1969

Prepared by
Richard C. Dorshimer

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HAMILTON STANDARD DIVISION
UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT

FOREWORD

The report was prepared by Hamilton Standard Division of United Aircraft Corporation for the Federal Aviation Administration. The work was part of a program of the Engineering and Safety Division, Aircraft Development Service, Washington, D. C. Engineering technical direction and review for the project were furnished by the Instruments and Flight Test Section, Aircraft Branch, Test and Evaluation Division, National Aviation Facilities Experimental Center, Atlantic City, New Jersey.

ABSTRACT

A slip ringless propeller-mounted data system has been designed, fabricated and tested for the measurement of propeller blade strain during flight and ground operation of an instrumented aircraft. This data system is self-powered through the rotary motion of the test propeller, employs a 16 channel constant bandwidth Frequency Modulated (FM) Multiplex and signals are capacitively coupled from the propeller to the aircraft. The FM Multiplex consists of 17 channels of information including propeller rpm and 16 strain gage channels containing information from dc to 1 kHz. An environmentally protected strain gage installation has also been a consideration of this program.

The FM Multiplex is split into four groups of signals with a frequency translation process in order to conserve bandwidth and/or recording time on an airborne tape recorder. Seven additional data channels are provided on board the aircraft for inclusion of parameters needed to define the aircraft operating conditions.

The data system was demonstrated for a period of 50 hours on an engine test stand during which the demodulated signals were observed and additional data was obtained relative to the system stability.

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INTRODUCTION

The need for in-flight propeller vibratory strain measurements has been evident for approximately thirty years. With the advent of metal bladed propellers an increased number of unexplained blade fractures occurred. Investigation revealed that these fractures were the result of material fatigue rather than excessive tensile strain. Analysis indicated that each propeller installation was probably excited by a vibratory phenomenon peculiar to that particular propeller engine installation.

As a result, techniques were developed in the 1930's and 1940's to determine the vibration response of propeller installations under actual operating conditions. Initial efforts in this area resulted in the development of the carbon block strain gage, slip rings to transfer the strain signals from the propeller to the aircraft, and the use of two-channel oscillographs which recorded strain signal images on reels of 35 mm film.

Since these early efforts, continuing improvements have been achieved. The strain gage has evolved from the "ground-down" radio resistor to modern foil and wire-wound self-temperature compensated gages. Slip ring assemblies have been designed which generally provide low-noise and long life operation with proper maintenance and exposure to good environments. Recording techniques have progressed from the 35 mm recorder, through multi-channel airborne oscillographs, to present day magnetic tape recorders which permit the use of automatic data reduction.

In order to provide propeller vibration measurement systems capable of long term operation with a minimum of maintenance on operational aircraft, it was evident that improvements were required in two principal areas. These areas are the strain gage installation and the method of signal transmission.

Propeller strain gage installations in the past have been capable of operation only in the best of weather conditions. A long standing requirement for conducting successful propeller vibration surveys has been the necessity of avoiding exposure of the strain gage and wiring assembly to moisture. This has required that the instrumented propeller not be exposed to overnight condensation and that the aircraft be operated only in good weather. Even flying through clouds can destroy contemporary propeller strain gage installations. However, in recent years materials and techniques have been developed that will successfully handle normal operational environments. In addition, further effort promises to result in strain gage installations that will tolerate many erosive environments to which the propeller can be exposed.

The use of slip ring assemblies for the transmission of strain gage signals has also caused numerous operational problems in propeller applications. This has been due primarily to the fact that a sliding mechanical contact is used to transfer low level data signals from the rotating propeller with the attendant problems of brush wear, brush bounce, brush breakage, and electrical noise. Although successful short term installations are practical, the slip ring is not compatible with long term unattended installations. Like the strain gage, the slip ring must also be protected from the adverse effects of oil and moisture.

Recognizing the difficulty of employing slip rings in conjunction with propeller measurements, Hamilton Standard, a Division of United Aircraft Corporation, has conceived and demonstrated the feasibility of a system of measurement which eliminates the need for slip rings and permits accurate long term measurements on rotating structures. This concept is a multi-channel, solid-state electronic measuring system eliminating the need for slip rings for the measurement of strains, pressures, and similar parameters in airplane propeller, helicopter rotor, and other rotating machinery systems. The system is self-powered and provides measurement accuracy consistent with both quasi-steady state and vibratory requirements. In addition, the electronic system fits within a compact envelope, is entirely solid state, and is packaged to provide maximum versatility and ease of installation.

The idea of a self-powered rotating measurement system capable of transmitting strain gage signals without slip rings or a radio frequency link was conceived by Hamilton Standard in 1963. Since that time the evaluation of electronic components and circuits has indicated that reliable electronic modules can be constructed to operate in a propeller environment. In addition, feasibility testing has proved the overall system concept to be sound.

DISCUSSION

A long term propeller measurement system, which does not employ a mechanical contact for signal transmission and is capable of operation in adverse environments must include the following functions:

(A) Strain Gage Installation - Strain gages and lead wires must be installed on the test blades to meet the combined requirements of long life when exposed to normal operational environments, high electrical leakage resistance consistent with steady-strain measurements, high stability for steady-state measurements, temperature compensation, and long fatigue life in a vibratory-strain environment.

(B) Signal Conditioning - The strain gage signals must be converted to a form amenable to data transmission and recording requirements. The signal conditioning package must be adaptable to various propeller configurations.

(C) Power Source - A source of electrical energy, which is mechanically adaptable to many different installations, must be provided to excite the strain gages and power the associated electronics.

(D) Signal Coupling - A suitable technique must be provided to couple the modified data signals from the rotating test member. This component must also be readily adaptable to existing propeller installations.

(E) Recording System - An on-board recording system, which is consistent with the measurement problem and capable of operation in an uncontrolled thermal environment must be employed.

The general requirements listed above have been implemented into an operational system as illustrated in the block diagram, Figure 1. This sixteen-channel data system provides for the modulation of constant bandwidth Voltage-Controlled-Oscillators (VCO) by low-level strain gage signals. Each VCO operates about a specific center frequency and the resultant frequency-modulated outputs are linearly combined in a Mixer Amplifier. The Mixer output, consisting of the 16 FM carriers from 16 to 136 kHz, is then connected to an air gap capacitor composed of an engine-mounted stator and a propeller-mounted rotor. The electrical power for the propeller-mounted system is generated by the rotary motion of the propeller in conjunction with a stationary magnet assembly and a rotating winding. The ac output of the alternator is rectified, filtered and regulated to provide both the 12.8 vdc strain gage excitation and the 28 vdc for the electronics. In addition, a signal with frequency proportional to propeller speed is obtained from the power supply and included at the Mixer.

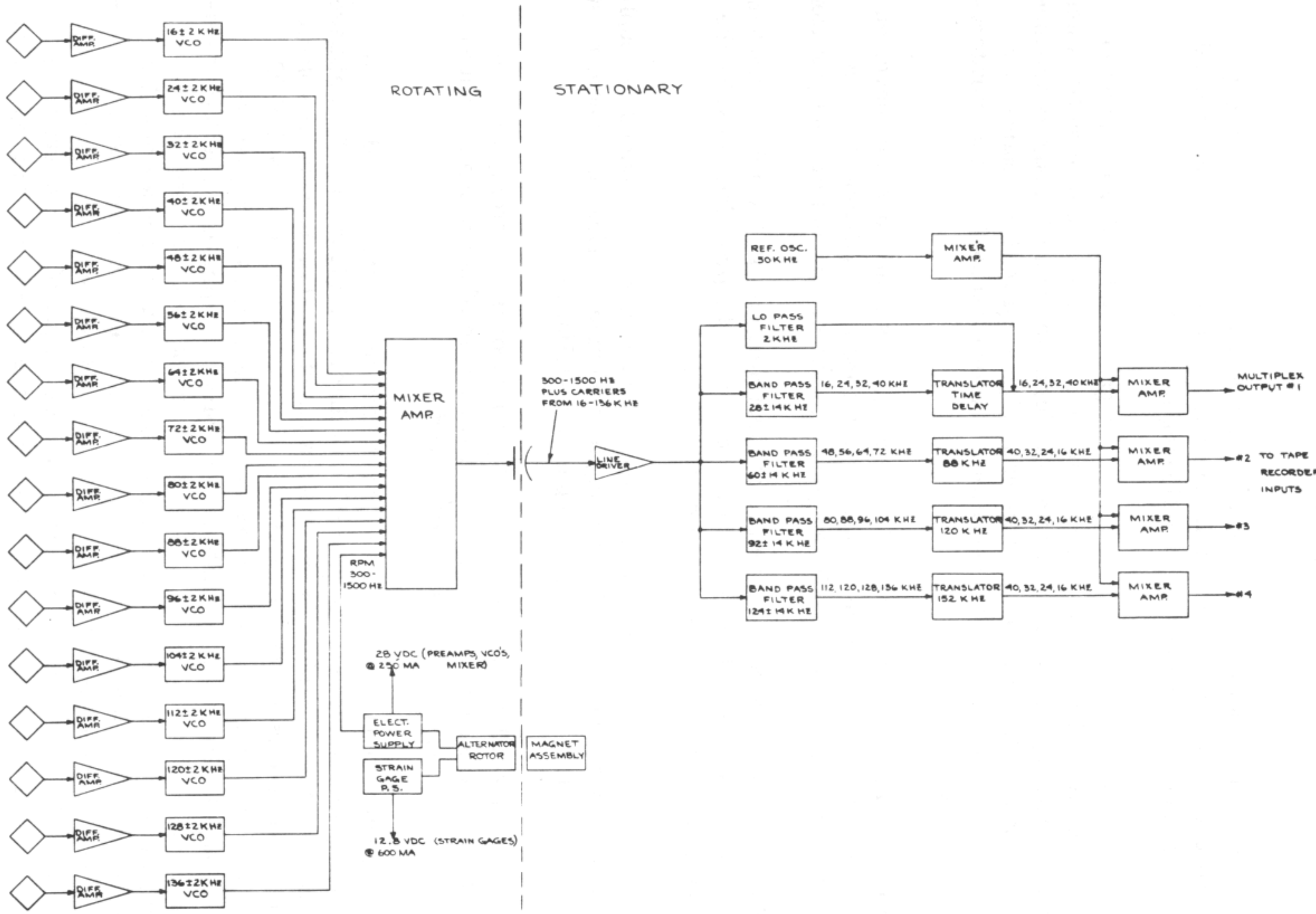


FIGURE 1. PROPELLER MEASUREMENT SYSTEM BLOCK DIAGRAM

The stationary (on-board) equipment prepares the frequency modulated data for recording on an airborne tape recorder. The input to the engine-mounted Line Driver is obtained from the capacitor stator. The Line Driver output then drives a group of five filters. The 2 kHz low pass removes the rpm signal from the spectrum and the four bandpass filters divide the 16 VCO bands into four groups of four carriers. The bandpass filter outputs are heterodyned in the Translators to produce four groups of carriers from 16 to 40 kHz. The output from a 50 kHz reference oscillator is then combined with each group of carriers and are then recorded with a 50 kHz bandwidth tape recorder.

The following discussion will expand upon the above general information and provide the basic design background and specific comments concerning selection of the system components.

Strain Gage Installation

This aircraft propeller strain gage installation was designed for relatively long term steady and dynamic strain measurements in an outdoor environment such as encountered in normal aircraft usage. Design criteria included maximum fatigue life, minimum gage creep under centrifugal and thrust loads, minimum electrical leakage, blade surface temperature from -65° F to +180° F, and erosion protection from rain and foreign object damage. Ease of installation was considered in each phase of design and was implemented within the overall performance requirements.

The blade locations selected for strain measurements were chosen to cover the normal flatwise, edgewise and torsional modes of propeller vibration deemed significant. These locations also served to define the steady strain distribution on the blade.

A systems approach was necessary in the selection of materials for the strain gage installation. Each material was selected for its own qualities as well as its compatibility with the other materials in the system.

(A) Strain Gages - A study of strain gage specifications and direct contacts with three leading strain gage manufacturers indicated that the Micro Measurements (Division of Vishay Intertechnology, Romulus, Michigan) Type WK-13-250BG-350-R1 gages best satisfied the design requirements. These were fiberglass-backed, encapsulated, temperature-compensated foil gages with a nominal resistance of 350 ohms ±0.1%. The active gage length was 0.250 inch and the gage factor was 2.12 ±1%. Dual lead wires were factory-installed at the gage tabs; therefore, no critical soldering was required. All gages were from the same lot, insuring maximum standardization.

Fiberglass-backed gage solder terminals, Types T-50 and T-75, were also provided by Micro Measurements.

(B) Strain Gage Adhesive - Micro Measurements adhesive, Type BR-600 was selected based on extensive Hamilton Standard experience with these materials. This was a solvent-thinned, elevated temperature epoxy adhesive curable at low enough temperatures to avoid heat aging of the blade. Previous test data indicated that this adhesive had good stability and creep resistance.

Contact and room temperature-curing adhesives were considered from the convenience standpoint, but were rejected as marginal for the design requirements.

(C) Strain Gage Wire - Electrical leakage tolerances specified for this installation dictated the use of wire with very high quality insulation. Small size, low mass, bond ability and damage resistance were also desirable qualities. Solid copper AWG No. 32 wire with Durad (Haveg Industries, Winooski, Vermont) insulation was selected based on Hamilton Standard's experience with this wire in other strain gage applications. The thin-walled Teflon insulation is coated with a very thin polyimide coating, which is bondable with no further preparation.

Previous experience with this wire in high "g" fields indicated the possibility of wire slippage inside the insulation. To assure its adequacy for this application, a dural disc was instrumented and wired with the Durad wire and a spin test was conducted to "g" levels in excess of those anticipated in the subject installation. No slippage occurred.

(D) Wire Tacking Adhesive - A contact-type adhesive was desired for tacking the wires in place on the blade in order that the final blade coating might be applied in a single operation. Bostik (USM Chemical Co., Middleton, Massachusetts) Type 7070 adhesive was selected, based on recent test data. This solvent-thinned urethane adhesive had good tacking qualities and was compatible with other system materials.

(E) Moisture and Erosion-Resistant Coating - A review of Hamilton Standard experience with strain gage coatings for aircraft and marine propellers resulted in the selection of several groups of materials for further testing for this installation. Various combinations of metal surface treatment, primers, coatings and adhesives were applied to strain gaged aluminum test panels. These panels were than exposed to accelerated humidity tank tests where loss of strain sensitivity (strain gage bond deterioration) and electrical leakage were observed. These tests led to the selection of a protective coating system consisting of (a) surface treatment of the dural with Alodine 1200 (Amchem Products, Inc., Ambler, Pennsylvania), (b) MIL Spec. P-23377B Primer (Andrew Brown Co.,

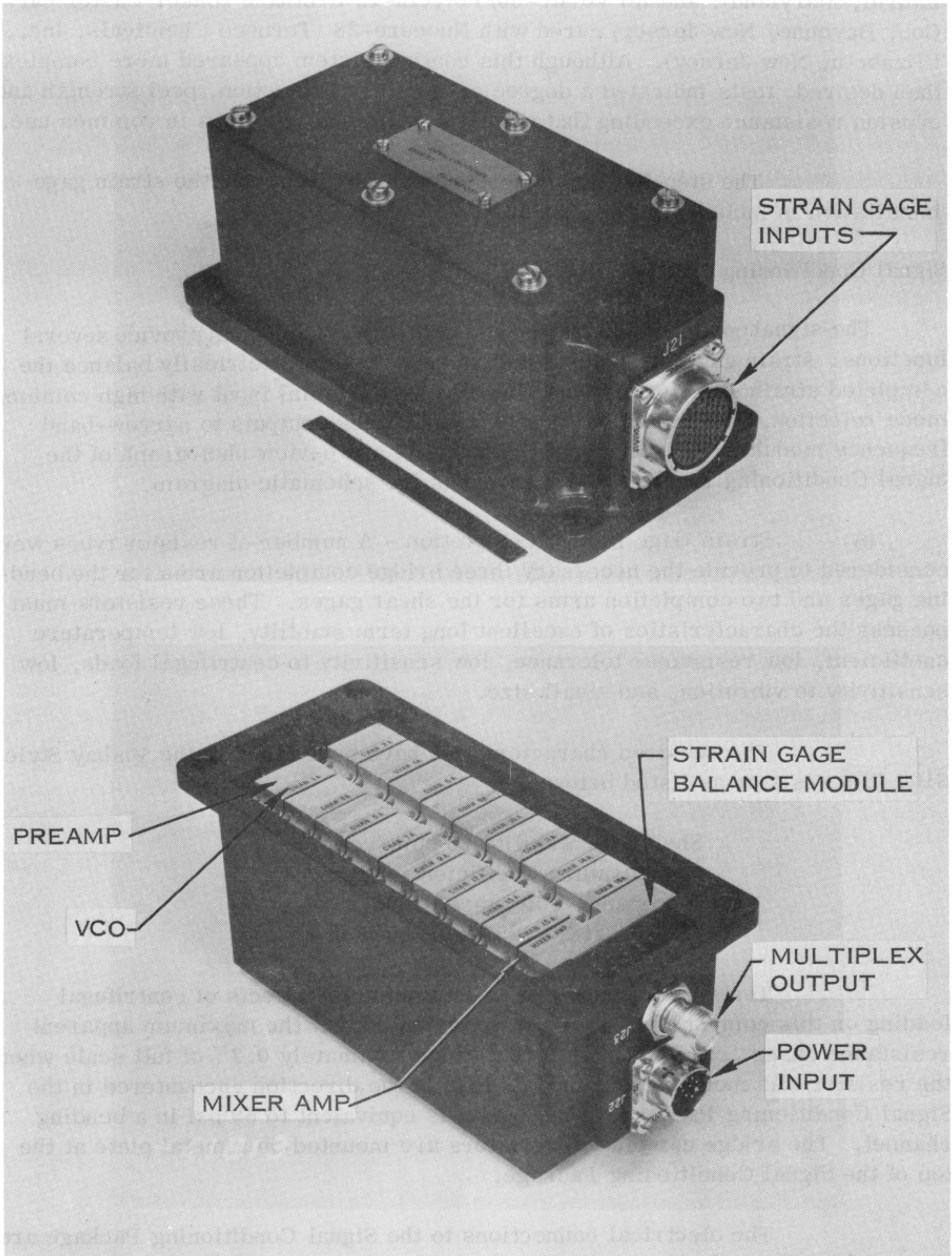


FIGURE 2. SIGNAL CONDITIONING PACKAGE

Laurel, Maryland), and (c) Vorite-63/Polycin-12 Urethane (Baker Caster Oil Co., Bayonne, New Jersey) cured with Nuocure-28 (Terneco Chemicals, Inc., Elizabeth, New Jersey). Although this coating system appeared more complex than desired, tests indicated a degree of moisture protection, peel strength and erosion resistance exceeding that available with other coatings in common use.

The step-by-step procedure used in preparing the strain gage installation is included in the Appendix.

Signal Conditioning

The signal conditioning equipment in this data system must provide several functions: strain gage bridge completion, a method to electrically balance the completed strain gage installation, low level differential input with high common-mode rejection, conversion of the strain gage bridge outputs to narrow-band frequency modulated subcarriers. Figure 2 is a two-view photograph of the Signal Conditioning Package and Figure 3 is the schematic diagram.

(A) Strain Gage Bridge Completion - A number of resistor types were considered to provide the necessary three bridge completion arms for the bending gages and two completion arms for the shear gages. These resistors must possess the characteristics of excellent long term stability, low temperature coefficient, low resistance tolerance, low sensitivity to centrifugal loads, low sensitivity to vibration, and small size.

The required characteristics have been found in the Vishay Style S102 film resistor as listed below:

Shelf Life Stability 25 ppm/year
Temperature Coefficient ±1 ppm/°C
Resistance Tolerance 0.005%
Size 0.320 x 0.295 x 0.100 inch

Tests were conducted to determine the effects of centrifugal loading on this component. These tests indicated that the maximum apparent resistance change resulted in an output of approximately 0.2% of full scale when the resistor was mounted with the "g" load in the direction encountered in the Signal Conditioning Package. This output is equivalent to 60 psi in a bending channel. The bridge completion resistors are mounted on a metal plate at the top of the Signal Conditioning Package.

The electrical connections to the Signal Conditioning Package are arranged so that a three-wire lead system must be used with the strain gages. That is, three separate wires are run to each propeller mounted strain gage. Two of the three wires are used to provide the strain gage excitation current and the third wire provides the signal input to the VCO preamplifier. This technique is used to provide temperature compensation of the lead wires.

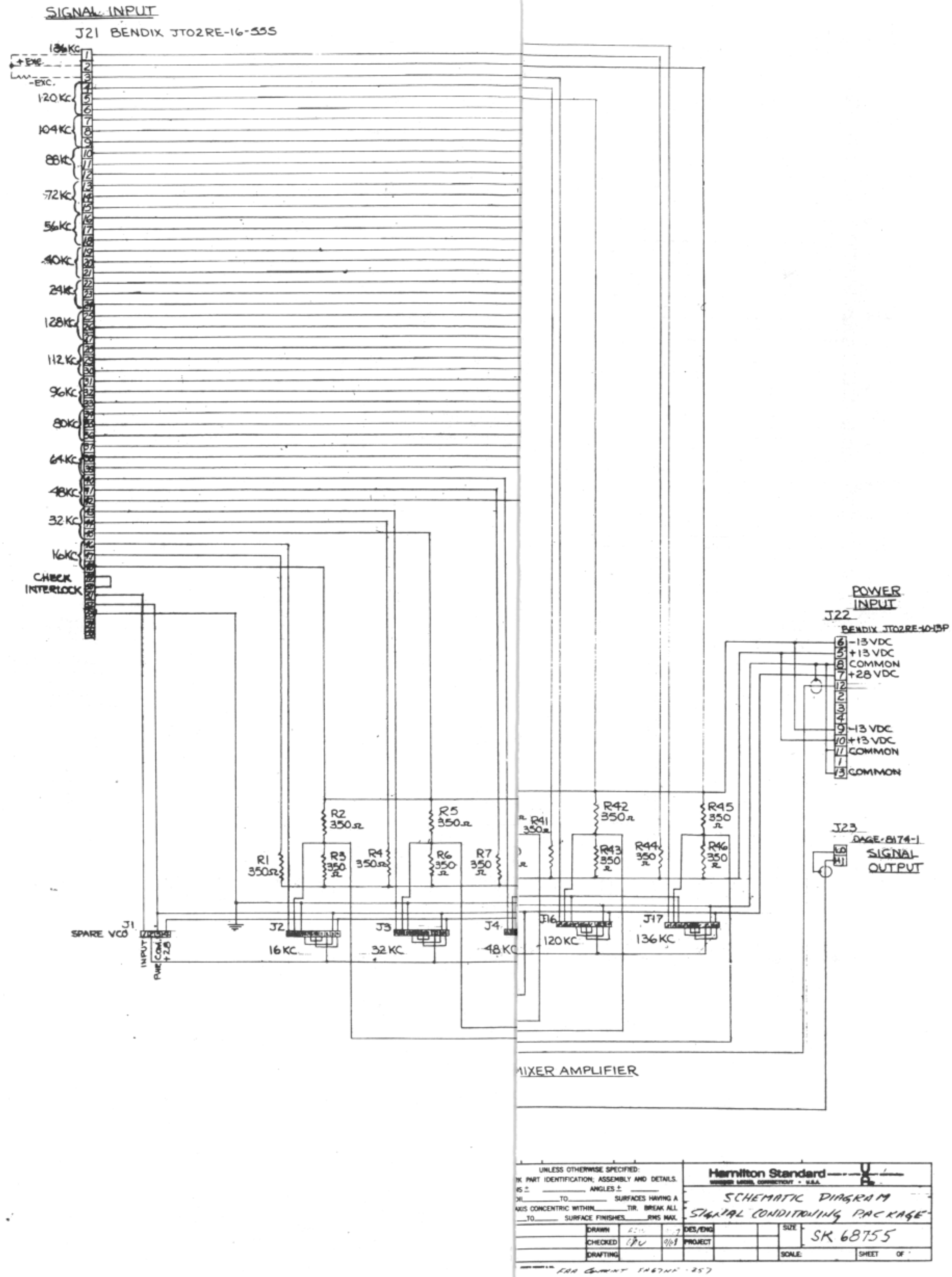
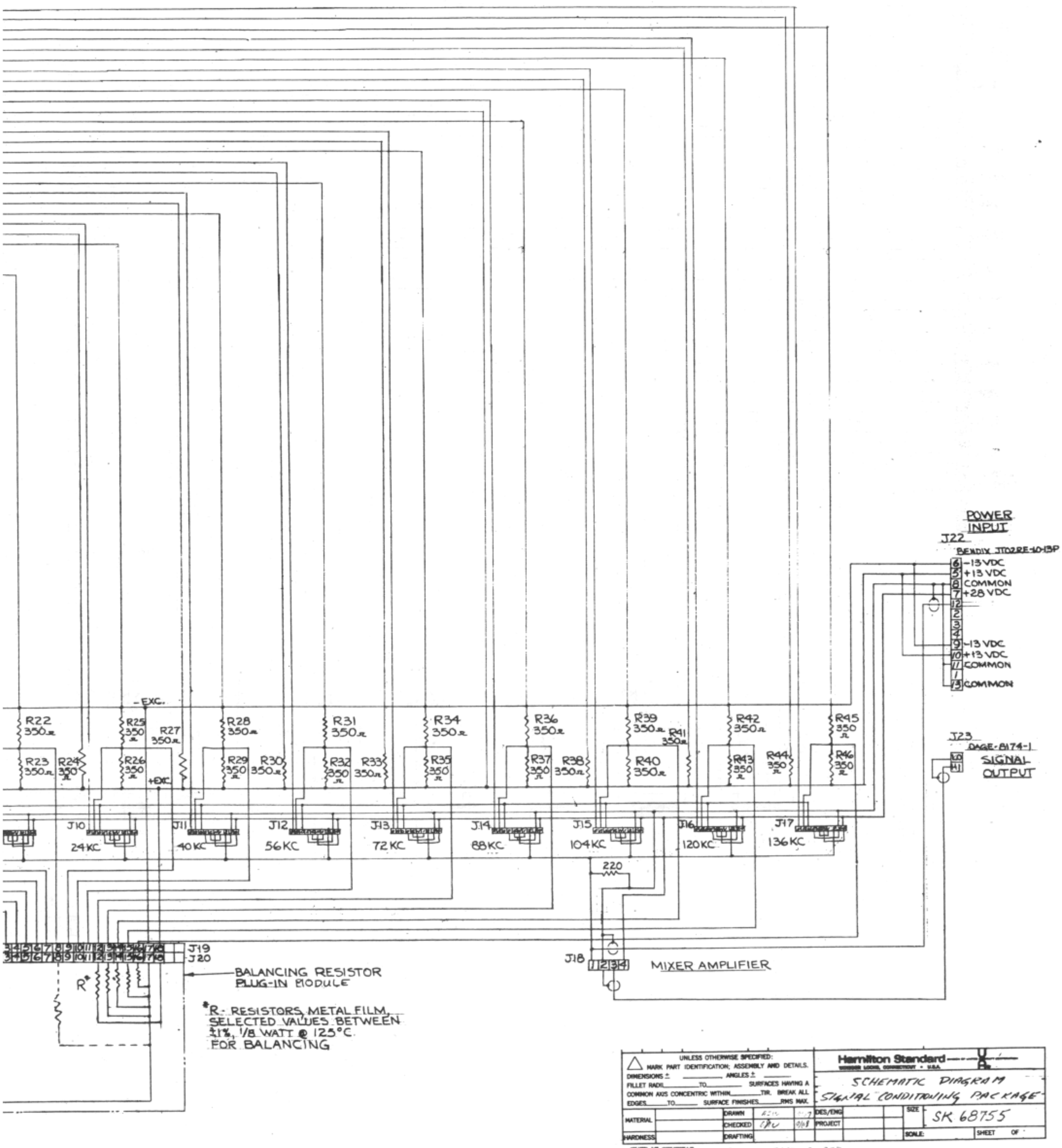

SIGNAL INPUT
J21 BENDIX JT02RE-16-55S
136KC
+EXC.
-EXC.
120KC
104KC
88KC
72KC
56KC
40KC
24KC
128KC
112KC
96KC
80KC
64KC
48KC
32KC
16KC
CHECK INTERLOCK
POWER INPUT
J22
BENDIX JT02RE-10-13P
-13 VDC
+13 VDC
COMMON
+28 VDC
-13 VDC
+13 VDC
COMMON
COMMON
J23
DAGE-8174-1
SIGNAL OUTPUT
R1 350Ω
R2 350Ω
R3 350 Ω
R4 350Ω
R5 350Ω
R6 350 Ω
R7 350 Ω
R41 350Ω
R42 350Ω
R43 350 Ω
R44 350 Ω
R45 350 Ω
R46 350 Ω
J1 SPARE VCO
INPUT
PWR COM
+28
J2
16KC
J3
32KC
J4
48KC
J16
120KC
J17
136KC
MIXER AMPLIFIER
UNLESS OTHERWISE SPECIFIED:
PART IDENTIFICATION; ASSEMBLY AND DETAILS.
ANGLES ±
TO
SURFACES HAVING A
AXIS CONCENTRIC WITHIN
TIR. BREAK ALL
TO
SURFACE FINISHES
RMS MAX.
Hamilton Standard
SCHEMATIC DIAGRAM
SIGNAL CONDITIONING PACKAGE
DRAWN
CHECKED
DRAFTING
DES/ENG
PROJECT
SIZE
SK 68755
SCALE
SHEET
OF

FIGURE 3.


POWER INPUT
J22
BENDIX JT02RE-10-13P
-13 VDC
+13 VDC
COMMON
+28 VDC
-13 VDC
+13 VDC
COMMON
COMMON
J23
DAGE-8174-1
SIGNAL OUTPUT
-EXC.
+EXC
R22 350Ω
R23 350Ω
R24 350Ω
R25 350Ω
R26 350Ω
R27 350Ω
R28 350Ω
R29 350Ω
R30 350Ω
R31 350Ω
R32 350Ω
R33 350Ω
R34 350Ω
R35 350Ω
R36 350Ω
R37 350Ω
R38 350Ω
R39 350Ω
R40 350Ω
R41 350Ω
R42 350Ω
R43 350Ω
R44 350Ω
R45 350Ω
R46 350Ω
J10 24KC
J11 40KC
J12 56KC
J13 72KC
J14 88KC
J15 104KC
J16 120KC
J17 136KC
220
J19
J20
J18
MIXER AMPLIFIER
BALANCING RESISTOR PLUG-IN MODULE
R*
*R- RESISTORS, METAL FILM, SELECTED VALUES BETWEEN ±1%, 1/8 WATT @ 125°C. FOR BALANCING
UNLESS OTHERWISE SPECIFIED:
MARK PART IDENTIFICATION; ASSEMBLY AND DETAILS.
DIMENSIONS ± ANGLES ±
FILLET RADII TO SURFACES HAVING A
COMMON AXIS CONCENTRIC WITHIN TIR. BREAK ALL
EDGES TO SURFACE FINISHES RMS MAX.
MATERIAL
HARDNESS
DRAWN
CHECKED
DRAFTING
DES/ENG
PROJECT
Hamilton Standard
WINDSOR LOCKS, CONNECTICUT • U.S.A.
SCHEMATIC DIAGRAM
SIGNAL CONDITIONING PACKAGE
SIZE
SK 68755
SCALE:
SHEET OF

(B) Electrical Balance of Completed Strain Gage Installation - In order to avoid the introduction of a questionable component in the high "g" loads encountered by the rotating electronics it was decided not to use the conventional strain gage resistance balancing technique employing potentiometers. Therefore, electrical balance is provided by the plug-in, repairable module illustrated in Figure 4. This module plugs into the Signal Conditioning Package and uses miniature metal film resistors to shunt the appropriate bridge arm. The resistors are potted in Sylgard 184 (Dow Corning, Midland, Michigan), which can be cut away to change the resistance value in a future installation.

Before the proper values of shunt resistance can be incorporated in the balance modules, an assessment must be made of the approximate maximum values of steady and vibratory strain to be encountered in each data channel. Then a zero (no strain) level is selected to allow the data channel to remain within its designated bandwidth when the maximum strain levels are realized. For example, estimated maximum strain levels for the propeller instrumented in the test program are as follows:

Blade Station	Steady-State Stress (Tension) (psi)	Vibratory Stress (±psi)
Shank Leading edge	8,000	3,500
Shank 90° from Leading Edge	8,000	3,500
35% Radius	10,000	3,000
50% Radius	10,000	3,000
70% Radius	8,000	5,000
80% Radius	6,000	5,000
88% Radius	3,000	5,000
70% Radius (Shear)	1,000	1,000

The equivalent full scale of the bending data channels can be calculated with the equation:

$$\frac{e_o}{E_{exc}} = \frac{1}{4} \times GF \times \frac{S}{E}$$

where: e_o = Strain gage bridge output volts
E_{exc} = Strain gage bridge excitation volts
GF = Gage Factor
S = Stress
E = Young's Modulus for propeller material

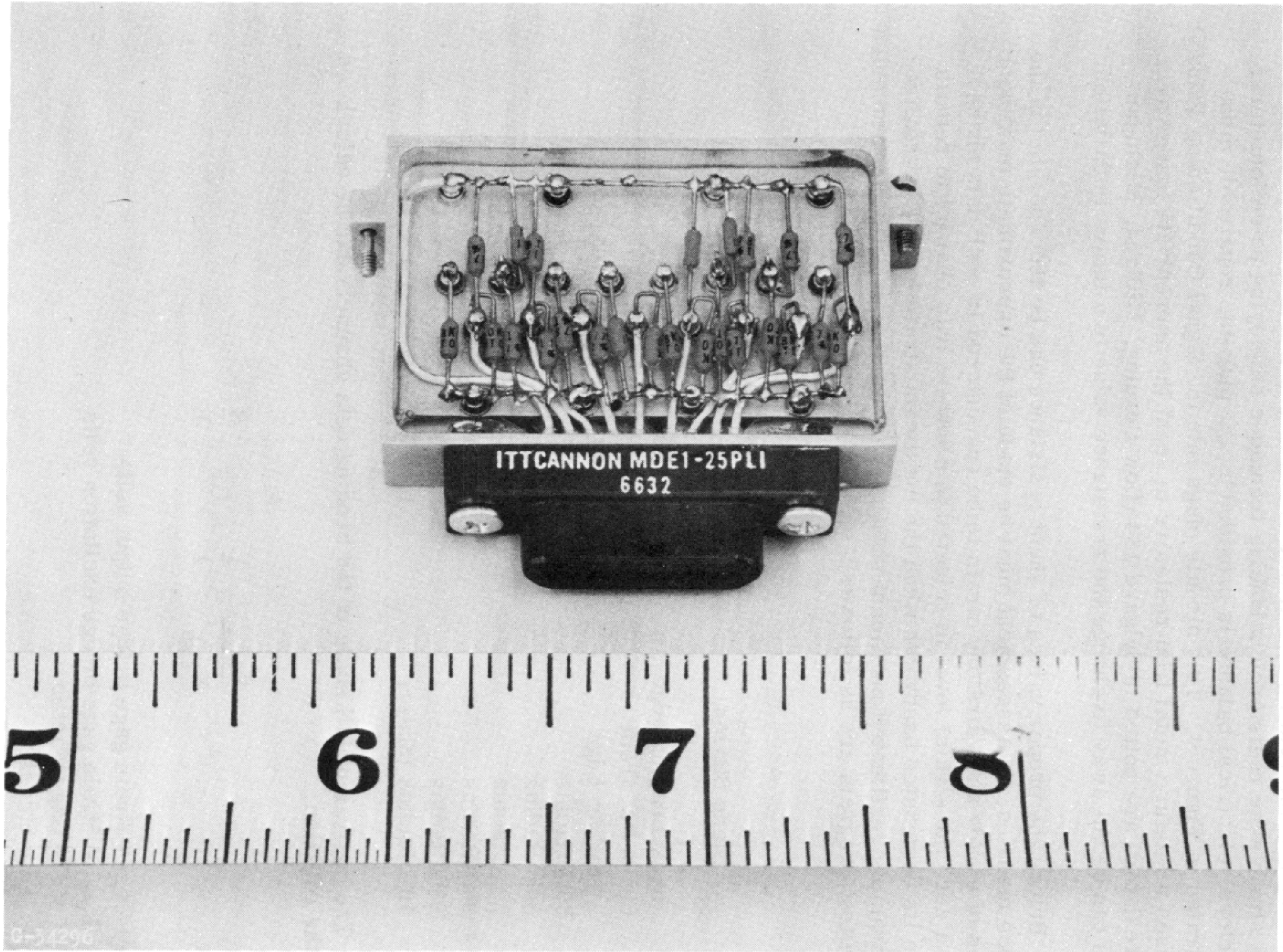


FIGURE 4. STRAIN GAGE BRIDGE BALANCING MODULE

Substituting the full-scale input to the differential amplifier for each data channel of 20 mv, the strain gage bridge excitation voltage of 12.8 Vdc, the gage factor of 2.12 and Young's Modulus of 10,000,000 into the above equation:

$$\frac{20 \times 10^{-3}}{12.8} = \frac{1}{4} \times 2.12 \times \frac{S}{10^{7}}$$

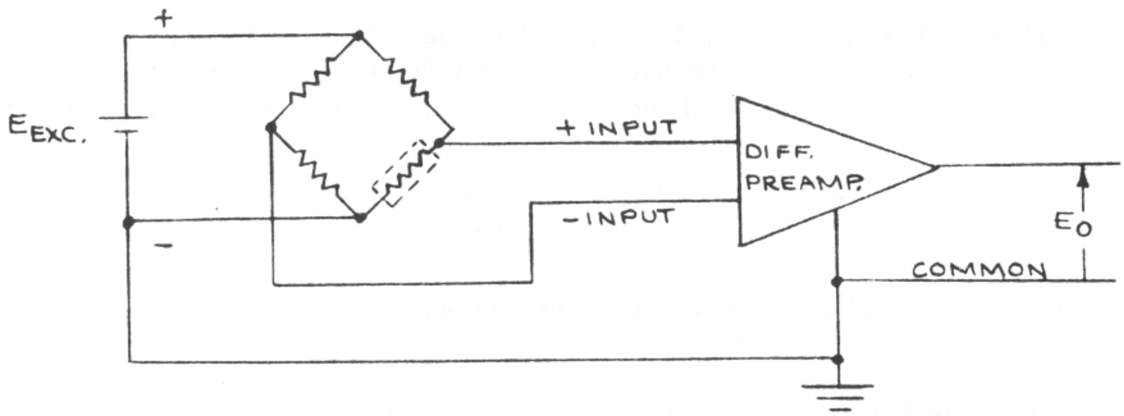
and solving for $S = \frac{20 \times 10^{-3}}{12.8} \times \frac{4}{2.12} \times 10^{7} = 29,500$ psi

Therefore, full-scale span for the data channels with bending gages is approximately 30,000 psi. In order to provide a zero strain point, which will not allow the total strain excursion to exceed full-scale or negative vibratory peaks to be less than zero input (for channels where peak vibratory signal exceeds the level of the steady component), each data channel was placed between ten percent and thirty percent of full scale.

The actual balancing was accomplished with the final strain gaged propeller connected to the data system. Power was applied to the system with the calibration setup used for checkout of the system. The frequency of each VCO was measured with a counter and appropriate shunt resistors were included in the balance module, Figure 4.

(C) Strain Gage Amplifier - Since the output from the strain gages is a low-level signal (millivolts), voltage gain is required to raise the signal level to a value sufficient to drive the Voltage-Controlled Oscillators. The preamplifiers used in this data system are paired with the Voltage-Controlled Oscillators. These preamplifiers provide a differential input impedance of 100 kilohms and a gain of 250. The preamplifier input range is 0 to 20 mv which produces an output of 0 to 5 volts.

A further requirement of a low-level data system is high common-mode rejection. That is, the preamplifier must respond to the difference in potential between the input leads but at the same time reject the common potential at the input leads. In the illustration below of a typical strain gage bridge circuit, for example, one half of the excitation voltage appears at the preamplifier input as a common-mode signal. That is, both sides of the preamplifier input are above ground by one-half of the excitation voltage. Likewise, any noise power, which is coupled into the strain gage circuit through electromagnetic and electrostatic pickup, will also appear at both inputs as a common-mode voltage.



The common-mode rejection ratio of the preamplifier used in the data system is specified as a minimum of 80 dB at dc. That is, a common-mode signal at the preamplifier input leads is attenuated by a factor of 10,000 before being amplified. Therefore, the preamplifier output will contain 25 millivolts of apparent signal for each volt of common-mode signal at the input.

$$\frac{1 \text{ volt}}{10,000} \times 250 = 0.025 \text{ V}$$

A further technique has been used in this data system to help eliminate the effects of common-mode voltage. The power supply circuits are designed so that the strain gage bridge outputs are effectively held at the system common potential instead of one-half the bridge excitation voltage. This technique is illustrated below.

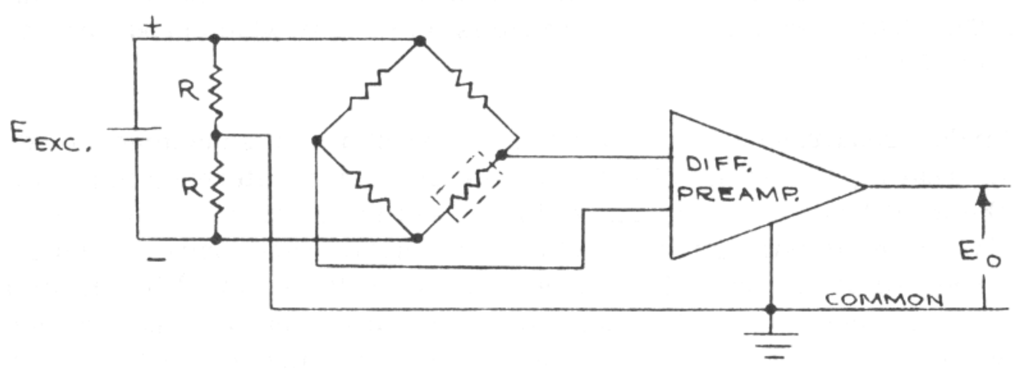


Figure 5 is a photograph of the combination Preamplifier and VCO units which plug into the Signal Conditioning Package.

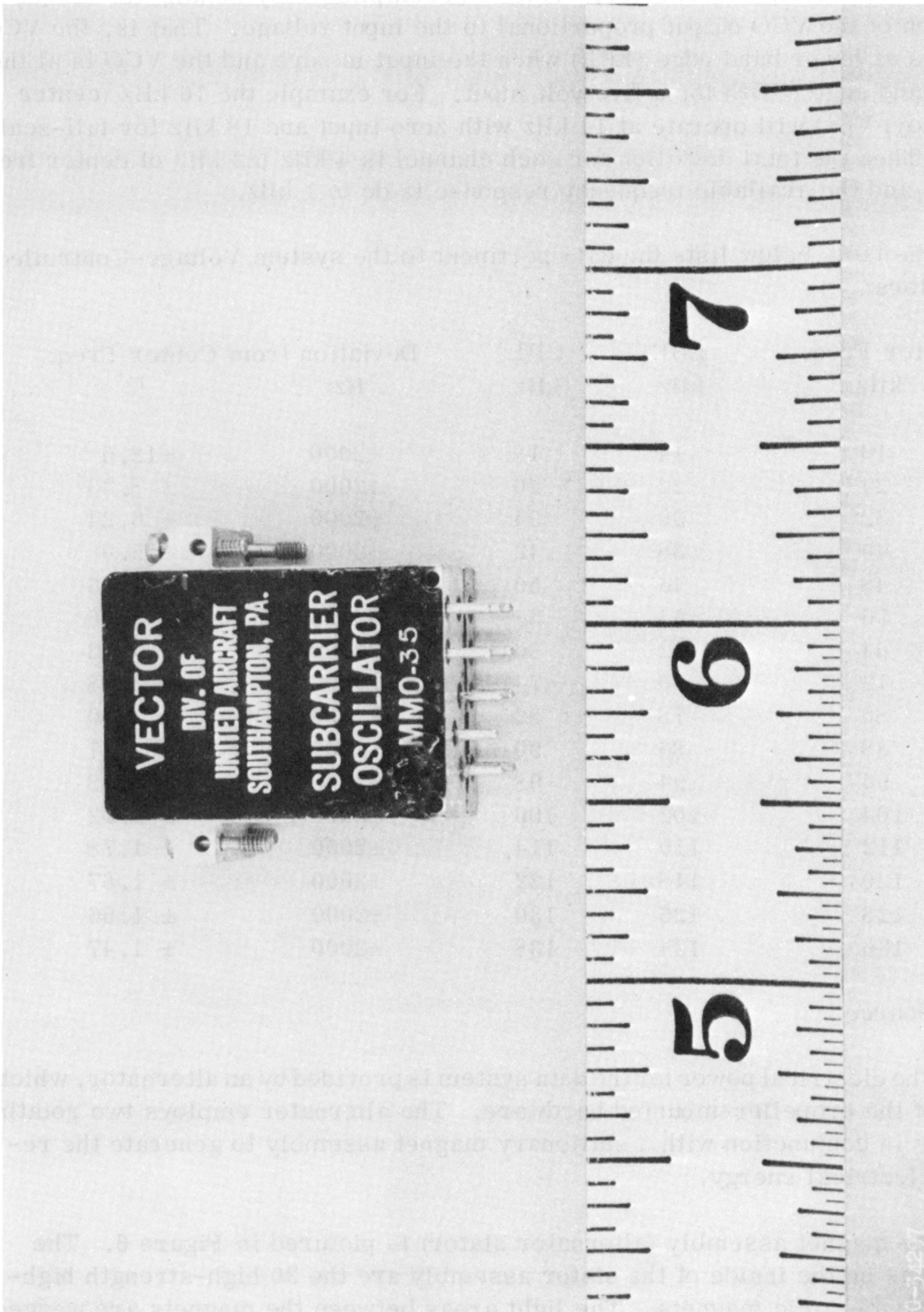


FIGURE 5. VOLTAGE–CONTROLLED OSCILLATOR AND PREAMPLIFIER

(D) Voltage-Controlled Oscillators - The function of the VCO is to convert the voltage output of the preamplifier, which represents strain to a frequency modulated subcarrier. This is accomplished by making the frequency deviation of the VCO output proportional to the input voltage. That is, the VCO operates at lower band edge (LBE) when the input is zero and the VCO is at the upper band edge (UBE) for a five volt input. For example the 16 kHz (center frequency) VCO will operate at 14 kHz with zero input and 18 kHz for full-scale input. Then the total deviation for each channel is 4 kHz (±2 kHz of center frequency) and the available frequency response is dc to 1 kHz.

The table below lists the data pertinent to the system Voltage-Controlled Oscillators:

Center Freq. kHz	LBE kHz	UBE kHz	Deviation from Center Freq. Hz	%
16	14	18	±2000	±12.5
24	22	26	±2000	± 8.33
32	30	34	±2000	± 6.24
40	38	42	±2000	± 5.0
48	46	50	±2000	± 4.16
56	54	58	±2000	± 3.56
64	62	66	±2000	± 3.12
72	70	74	±2000	± 2.78
80	78	82	±2000	± 2.50
88	86	90	±2000	± 2.27
96	94	98	±2000	± 2.08
104	102	106	±2000	± 1.92
112	110	114	±2000	± 1.78
120	118	122	±2000	± 1.67
128	126	130	±2000	± 1.56
136	134	138	±2000	± 1.47

Power Source

The electrical power for the data system is provided by an alternator, which is a part of the propeller-mounted hardware. The alternator employs two rotating windings in conjunction with a stationary magnet assembly to generate the required electrical energy.

The magnet assembly (alternator stator) is pictured in Figure 6. The dark areas on the inside of the stator assembly are the 30 high-strength high-retentivity ceramic magnets. The light areas between the magnets are wedge-shaped spacers, which are fastened to a ferrous backing ring. The stator is split into two sections to facilitate assembly and removal without disassembly of the test propeller.

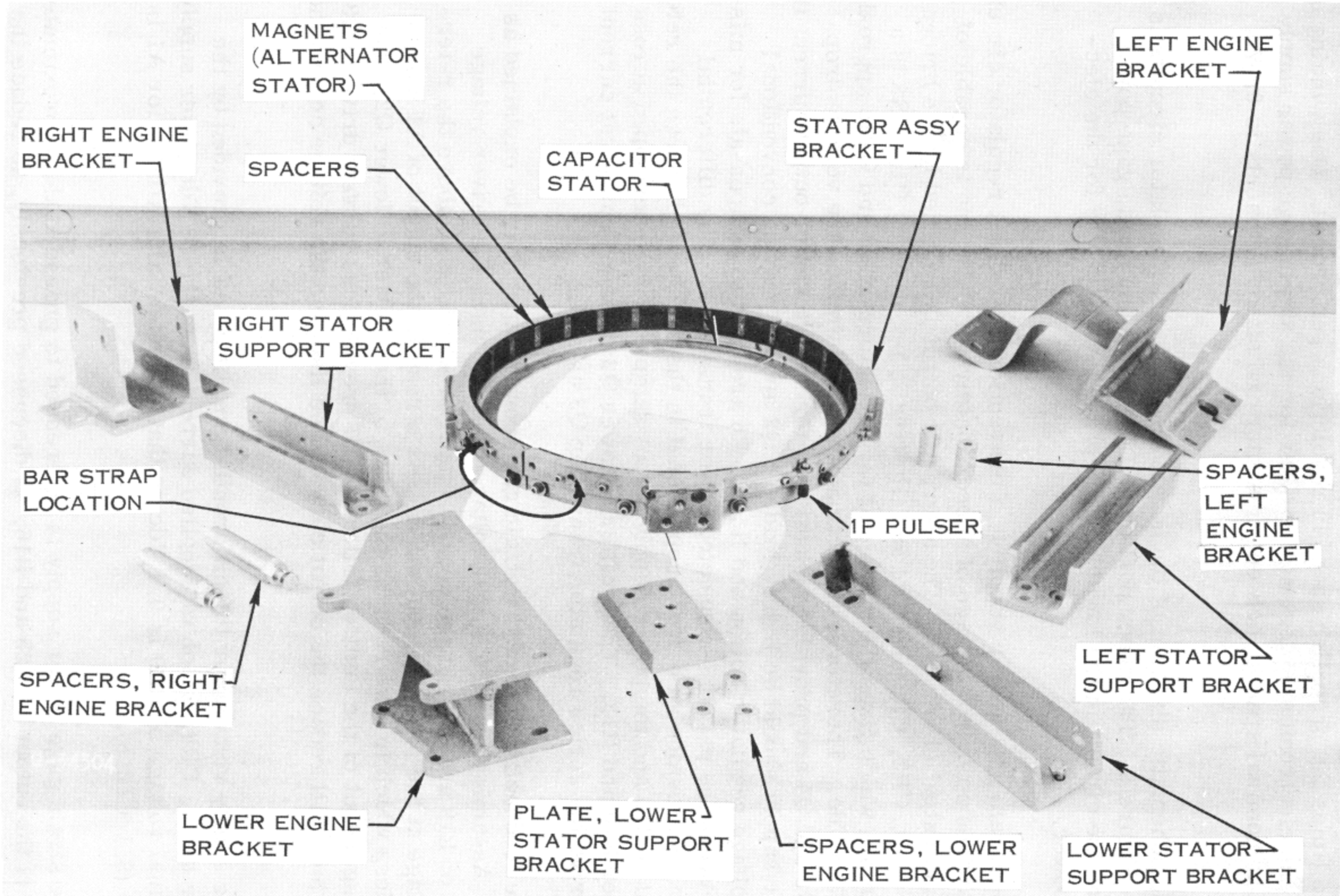


FIGURE 6. ALTERNATOR STATOR AND ENGINE MOUNTING BRACKETS

The rotor section of the alternator is visible in Figure 7 between the two electronics mounting plates. The rotor consists of two windings on separate segments both of which provide essentially constant current output at a frequency 15 times the propeller speed in revolutions per second. One winding is used for the electronics power and the other for the strain gage power supply input. The nominal spacing between the rotor and stator segments is 0.070 inch.

The schematic diagram of the dc power supply and regulator circuits is shown on Figure 8. The upper portion of Figure 8 is the strain gage power supply and the circuit in the lower portion provides the 28 Vdc for the electronics power.

The strain gage power supply is a conventional feedback regulator circuit, which provides an output voltage of approximately 12.8 Vdc and is capable of a maximum output of 650 mA. The alternator output is rectified by the bridge rectifier CR1, CR2, CR3 and CR4 and filtering is provided by C1. CR8 is a preregulator, which fixes the voltage at the collectors of Q3 and Q4 to approximately 15.5 Vdc. Therefore, the action of CR8 minimizes the voltage drop across Q3 and Q4 and provides a shunt path for the alternator output current if the power supply should be lightly loaded. Q3 and Q4 provide conventional series voltage regulator action and R5 and R6 are used to compensate for mismatch between the parallel-connected power transistors. The differential amplifier A1 provides an output proportional to the difference between the reference diode CR10 and the power supply output sample voltage developed across the divider R10 and R13. The emitter follower Q2 provides sufficient current gain to drive the series regulator transistor Q3 and Q4.

The feedback action of the strain gage power supply can be explained as follows. Assuming that the output voltage tends to rise, the driver voltage (junction of R10 and R13) at the negative input of A1 will rise above the reference voltage at the positive input of A1. As a result, the output of A1 will become less which in turn reduces the drive to the emitter follower Q2. The decreasing output of the emitter follower will provide less current drive to Q3 and Q4 which will reduce the output current and likewise the voltage across the load.

The supply voltage for the differential amplifier A1 is provided by the reference diode, CR9, which is supplied current from the 28 Vdc power supply. The nominal voltage of CR9 is 9.1 Vdc so that the potential available for A1 is 21.9 Vdc (9.1 + 12.8).

The strain gage power supply is referenced to ground at the approximate midpoint of the output by R25 and R16, as discussed previously, to reduce the effects of common-mode voltage on the VCO preamplifiers. R25 and R16 are unequal in order to provide the same voltage drop between the plus and minus

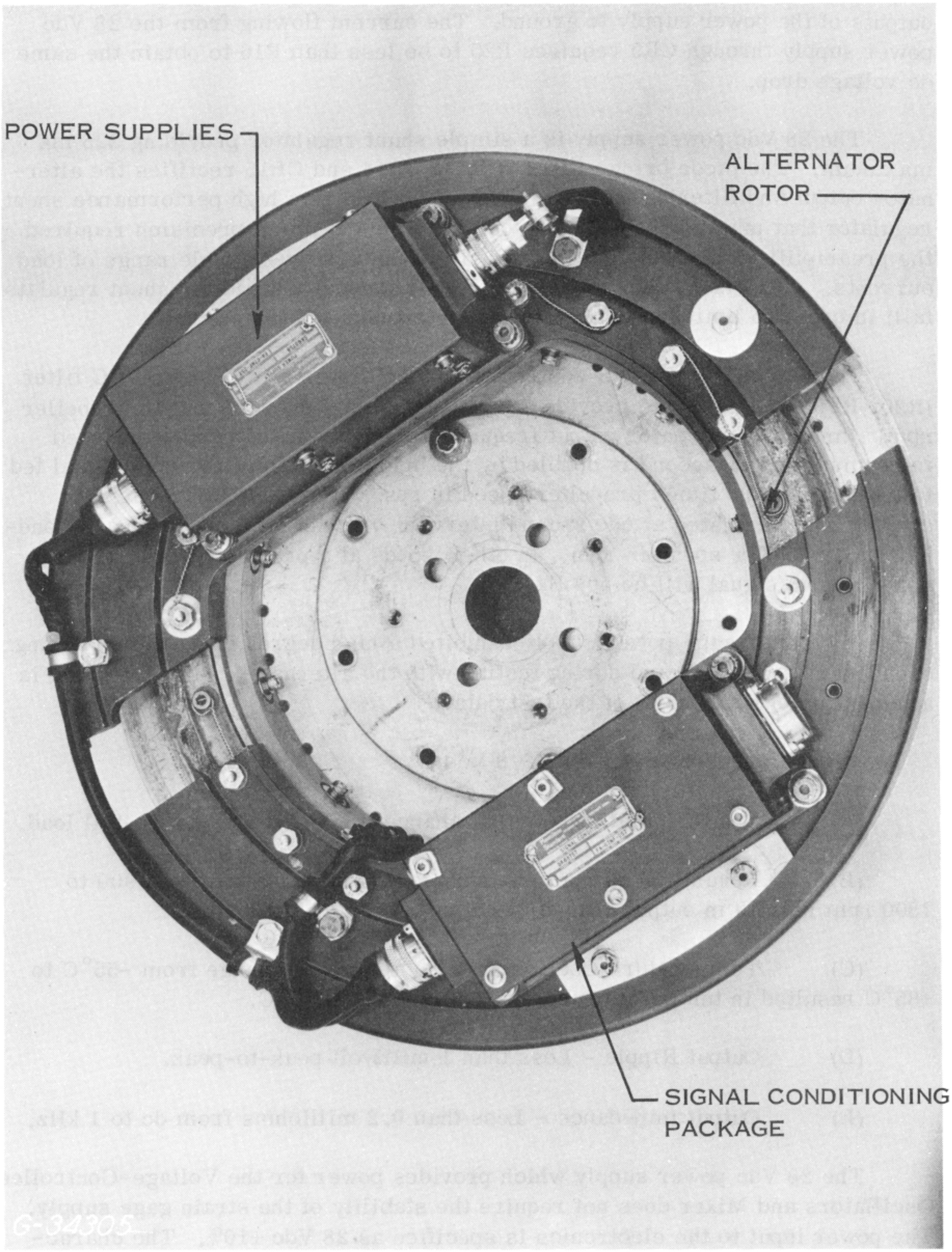


FIGURE 7. ALTERNATOR ROTOR AND ELECTRONICS PACKAGE MOUNTING

outputs of the power supply to ground. The current flowing from the 28 Vdc power supply through CR9 requires R25 to be less than R16 to obtain the same dc voltage drop.

The 28 Vdc power supply is a simple shunt regulator providing 225 mA maximum. The diode bridge CR12, CR13, CR14 and CR15 rectifies the alternator output and filtering is provided by C6. CR17 is a high performance shunt regulator that maintains the 28 Vdc output to the degree of precision required by the preamplifiers and Voltage-Controlled Oscillators over a wide range of load currents. CR18 is a zener diode, which will conduct (should the shunt regulator fail) in order to limit the voltage to the electronics to a safe level.

The output from the 28 Vdc rectifier also drives a two-section RC filter (R20, R21, C8 and C9) to provide a frequency signal proportional to propeller rpm. Since the alternator output frequency of 15 times the propeller speed in revolutions per second is doubled by the bridge rectifier, the rpm signal fed to the mixer is 30 times propeller speed in rps. Therefore, a frequency counter which is gated at one second intervals will exhibit a count equal to one-half the propeller speed in rpm. In other words at a propeller speed of 1000 rpm the rpm signal will be 500 Hz.

The strain gage power supply exhibited a high degree of precision during breadboard evaluation and during testing with the alternator. The following is a tabulation of the results of the test data.

Strain Gage Power Supply (12.8 Vdc)

(A) Load Regulation - Output change ± 1 millivolt zero-to-full load.

(B) Regulation vs rpm - Alternator speed variation from 900 to 2800 rpm results in output change of ± 2 millivolts at full load.

(C) Temperature Coefficient - Temperature change from -55°C to +85°C resulted in temperature coefficient of -0.0018%/°C.

(D) Output Ripple - Less than 1 millivolt peak-to-peak.

(E) Output Impedance - Less than 0.2 milliohms from dc to 1 kHz.

The 28 Vdc power supply which provides power for the Voltage-Controlled Oscillators and Mixer does not require the stability of the strain gage supply. The power input to the electronics is specified as 28 Vdc ±10%. The characteristics of the 28 Vdc power supply are summarized in the table below.

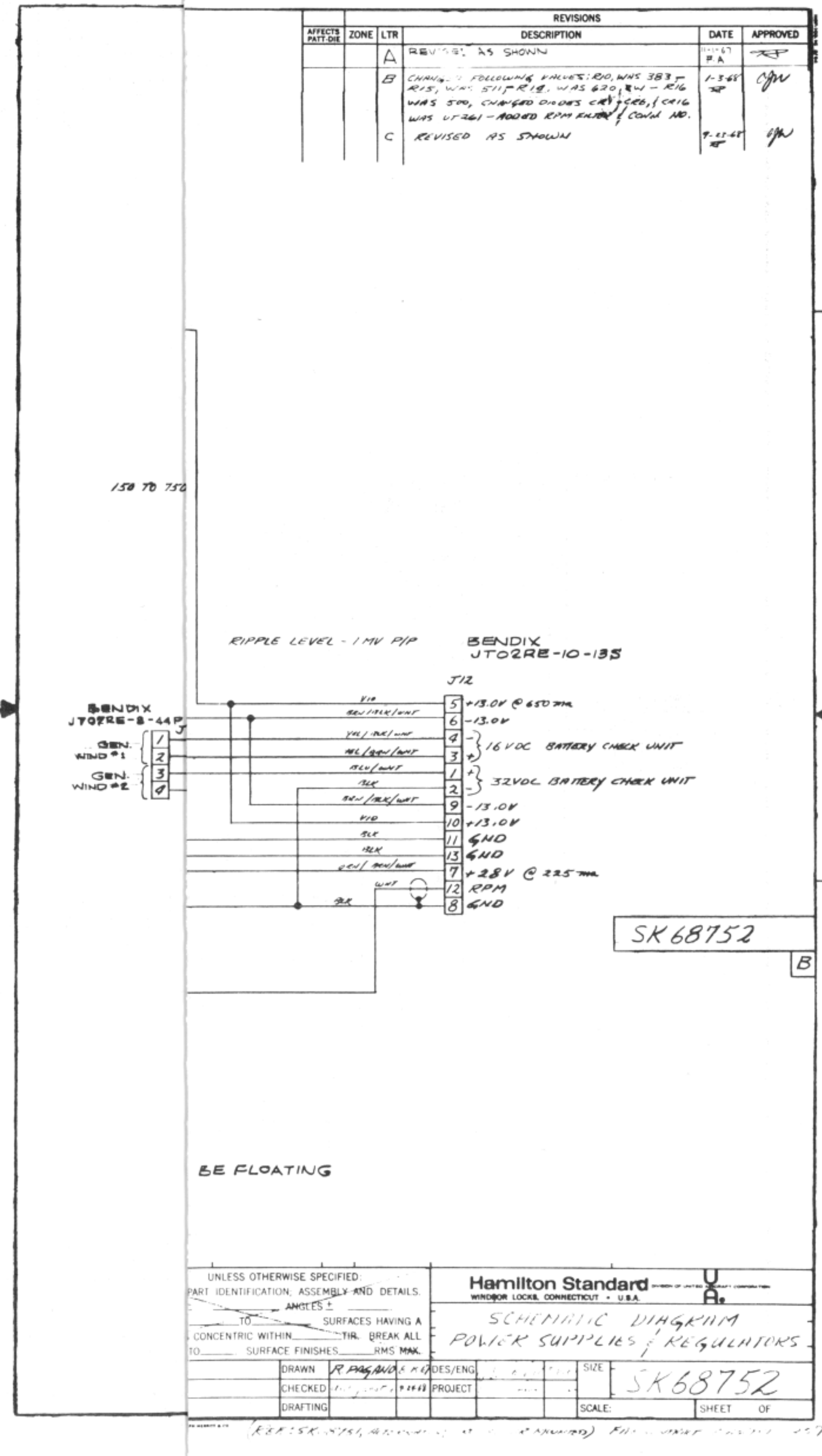
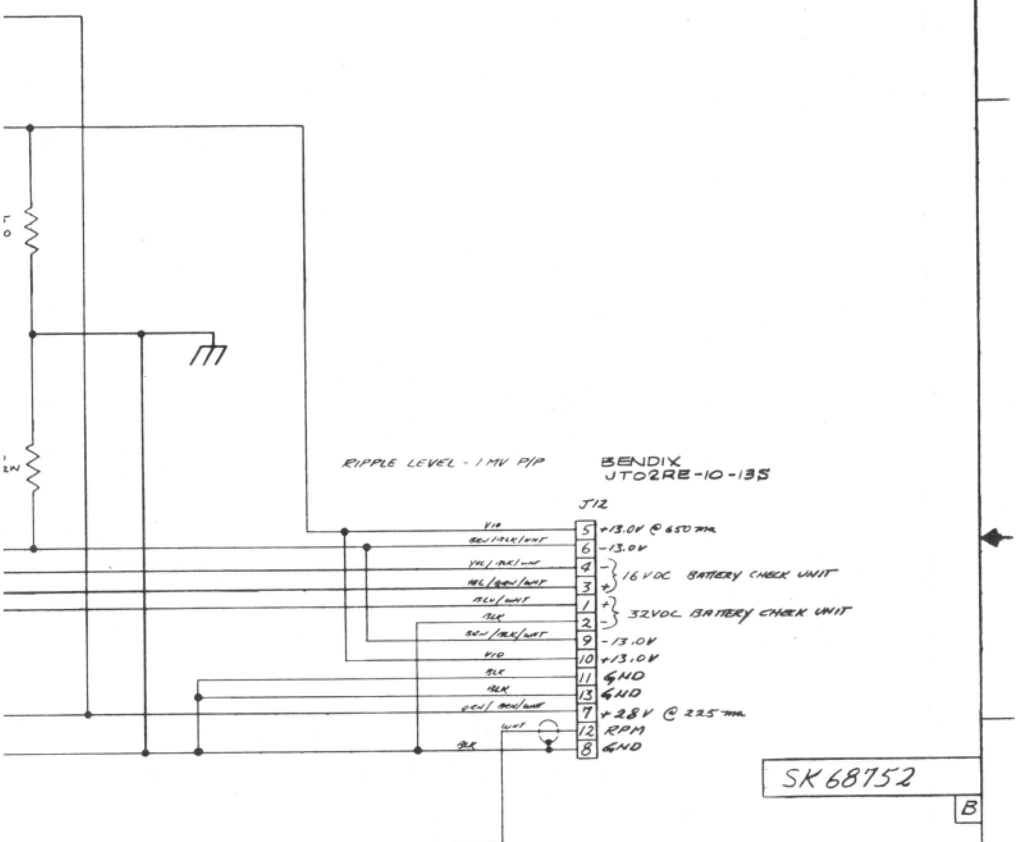

REVISIONS
AFFECTS PATT-DIE
ZONE
LTR
DESCRIPTION
DATE
APPROVED
A REVISED AS SHOWN
B CHANGED FOLLOWING VALUES
C REVISED AS SHOWN
150 TO 750
RIPPLE LEVEL - 1 MV P/P
BENDIX JT02RE-10-13S
J12
BENDIX JT02RE-8-44P
GEN. WIND #1
GEN. WIND #2
+13.0V @ 650 ma
-13.0V
16 VDC BATTERY CHECK UNIT
32VDC BATTERY CHECK UNIT
-13.0V
+13.0V
GND
GND
+28V @ 225 ma
RPM
GND
SK68752
B
BE FLOATING
UNLESS OTHERWISE SPECIFIED:
PART IDENTIFICATION, ASSEMBLY AND DETAILS.
ANGLES ±
TO SURFACES HAVING A
CONCENTRIC WITHIN TIR. BREAK ALL
TO SURFACE FINISHES RMS MAX.
Hamilton Standard
WINDSOR LOCKS, CONNECTICUT • U.S.A.
SCHEMATIC DIAGRAM
POWER SUPPLIES & REGULATORS
DRAWN R PAGANO
CHECKED
DRAFTING
DES/ENG
PROJECT
SIZE
SK68752
SCALE:
SHEET OF

FIGURE 8.

AFFECTS PATT-DIE	ZONE	LTR	DESCRIPTION	DATE	APPROVED
		A	REVISED AS SHOWN	11-1-67 F.A	
		B	CHANGED FOLLOWING VALUES: R10, WAS 383 — R15, WAS 511 — R19. WAS 620, 2W — R16 WAS 500, CHANGED DIODES CR1—CR6, & CR16 WAS UT261 — ADDED RPM FILTER & CONN NO.	1-3-68	
		C	REVISED AS SHOWN	9-23-68	



1. CASE TO BE FLOATING

NOTES:

UNLESS OTHERWISE SPECIFIED:
MARK PART IDENTIFICATION; ASSEMBLY AND DETAILS.
DIMENSIONS ± ____ ANGLES ± ____
FILLET RADII ____ TO ____ SURFACES HAVING A COMMON AXIS CONCENTRIC WITHIN ____ TIR. BREAK ALL EDGES ____ TO ____ SURFACE FINISHES ____ RMS MAX.

Hamilton Standard — DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT • U.S.A.

SCHEMATIC DIAGRAM
POWER SUPPLIES & REGULATORS

MATERIAL	DRAWN R. PAGANO 8-K-67	DES/ENG	SIZE SK68752
	CHECKED	PROJECT	
HARDNESS	DRAFTING	SCALE:	SHEET OF

(REF: SK68751, ALTERNATOR ... MOUNTED)

Electronics Power Supply (28 Vdc)

(A) Load Regulation - Does not normally apply because electronics load is fixed; but variation is nominally ±10 millivolts no load to full load.

(B) Regulation vs rpm - Alternator speed variation from 900 to 2800 rpm results in output change of ±20 millivolts.

(C) Temperature Coefficient - ±0.01%/°C from -55°C to +85°C.

(D) Output Ripple - Less than 100 millivolts peak-to-peak.

(E) Output Impedance - Less than 15 milliohms.

The Power Supply package is pictured in Figure 9. Conventionally wired circuit construction was used throughout consistent with a rugged mechanical environment. The assembly was potted with Sylgard 184 to provide a degree of mechanical isolation and allow for repairability.

Signal Coupling

Coupling of the FM Multiplex from the rotating propeller to the nonrotating Line Driver (block diagram, Figure 1) is accomplished with a passive element. This element is an air-dielectric capacitor composed of a stator plate sandwiched by two rotor plates. The capacitor rotor can be seen in Figure 10.

Measurements have shown that the capacitor coupling can be electrically represented as shown in Figure 11. As Figure 11 shows, the coupling is actually composed of three distinct capacitor elements. Where C2 represents the effective capacitance across the rotor to stator air gap, C1 and C3 are a measure of the shunt capacitance from the rotor and stator plates to ground.

The effect of the shunt capacitances C1 and C3 must be taken into account in the system design. C1, in addition to the cable capacitance from the Mixer output to the rotor plate, is a direct capacitive load on the Mixer output. C3 and C2 form a voltage divider for the signal being coupled. That is, the signal appearing at the input to the line driver is attenuated in the ratio of $\frac{C2}{C2 + C3}$ in the passband. Therefore, the FM carriers at the Line Driver input are approximately 65% of the amplitude appearing at the Mixer output.

The low frequency cutoff of the coupling capacitor is determined by the parallel combination of C2 and C3 and the input resistance of the Line Driver Amplifier. Since the Line Driver input resistance is approximately 200 kilohms, the low frequency cutoff of the coupling is 2.3 kHz. The frequency response of the coupling and Line Driver are illustrated in Figure 12.

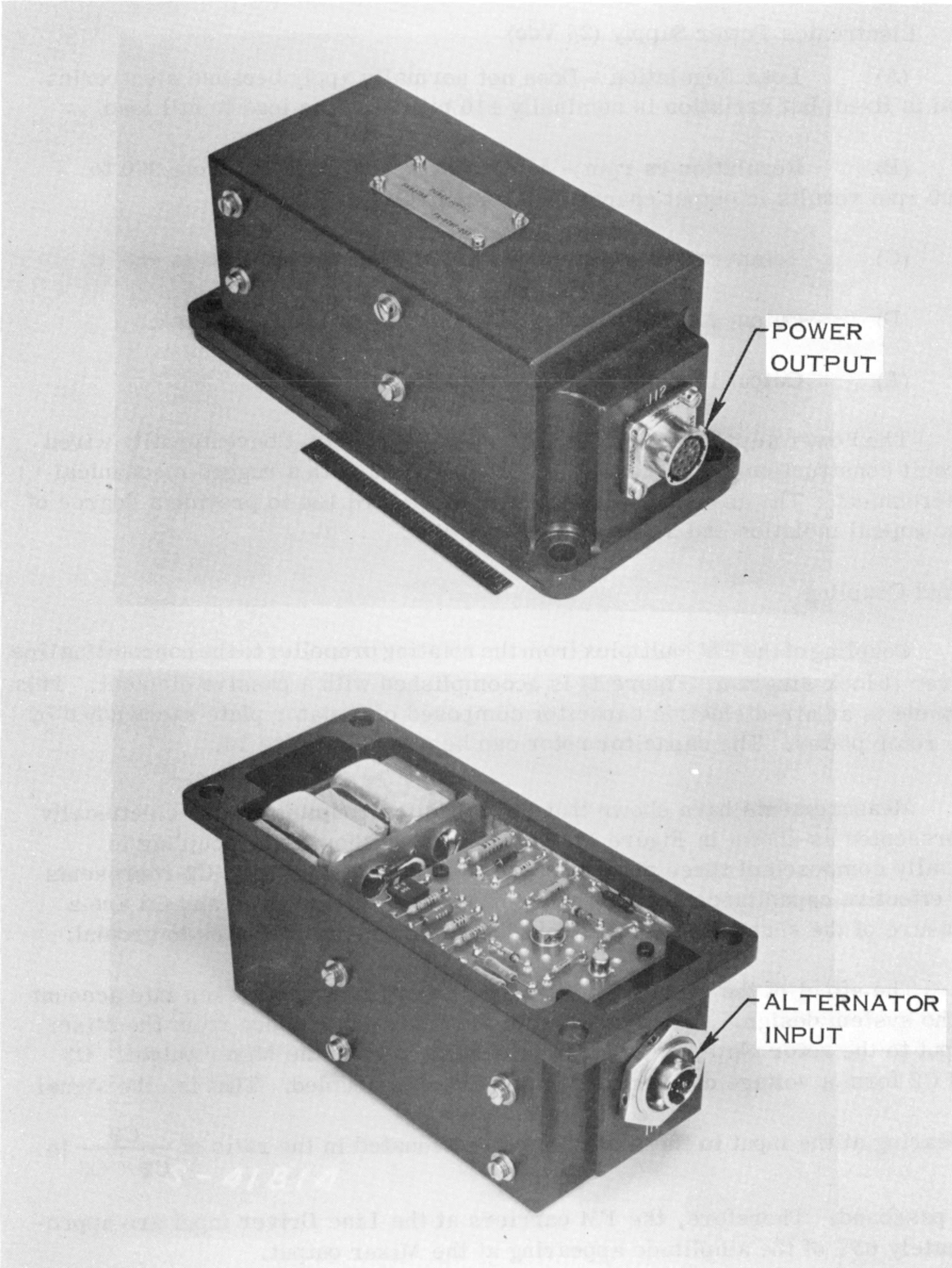


FIGURE 9. POWER SUPPLY PACKAGE

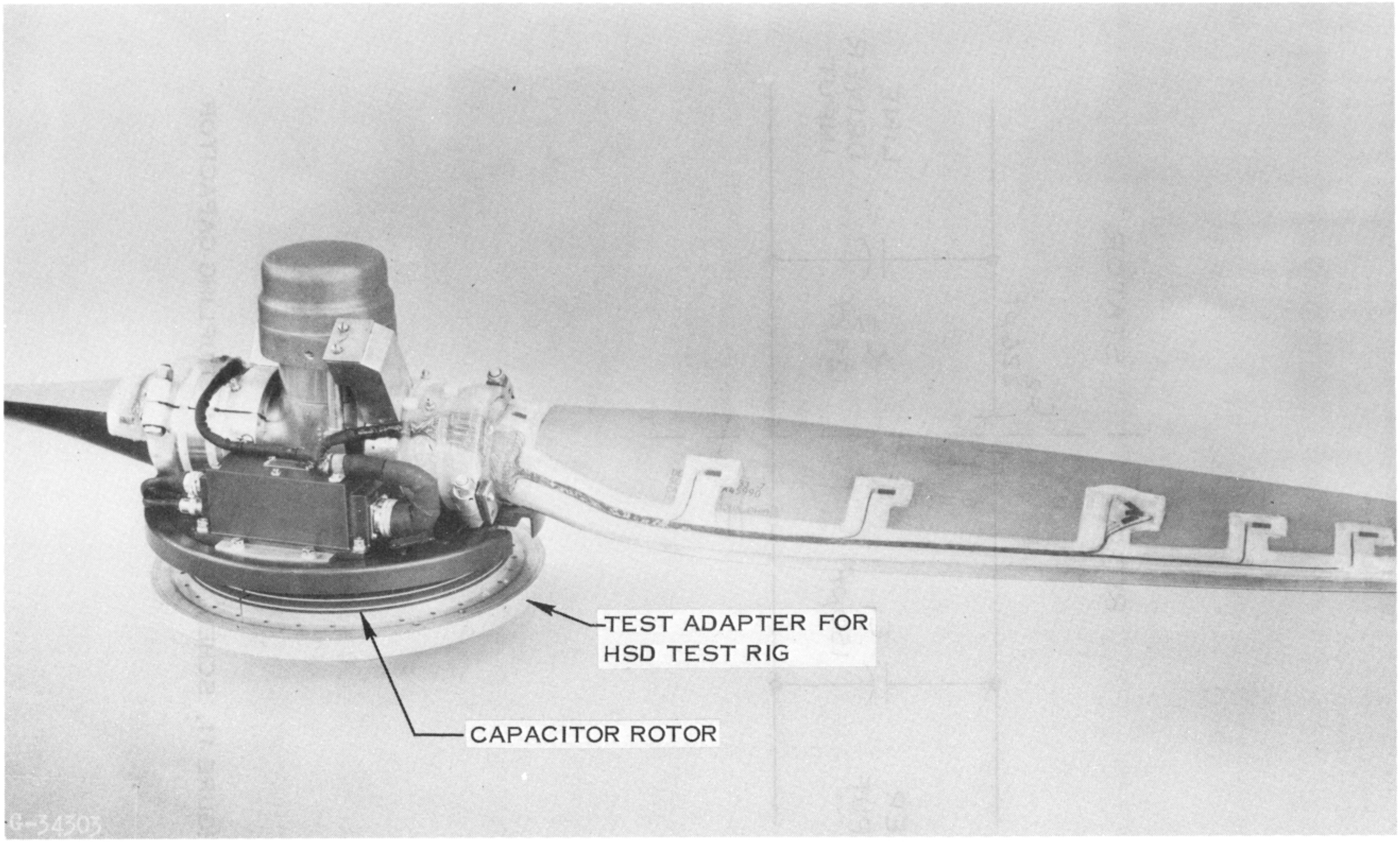


FIGURE 10. ASSEMBLY ILLUSTRATING CAPACITOR ROTOR

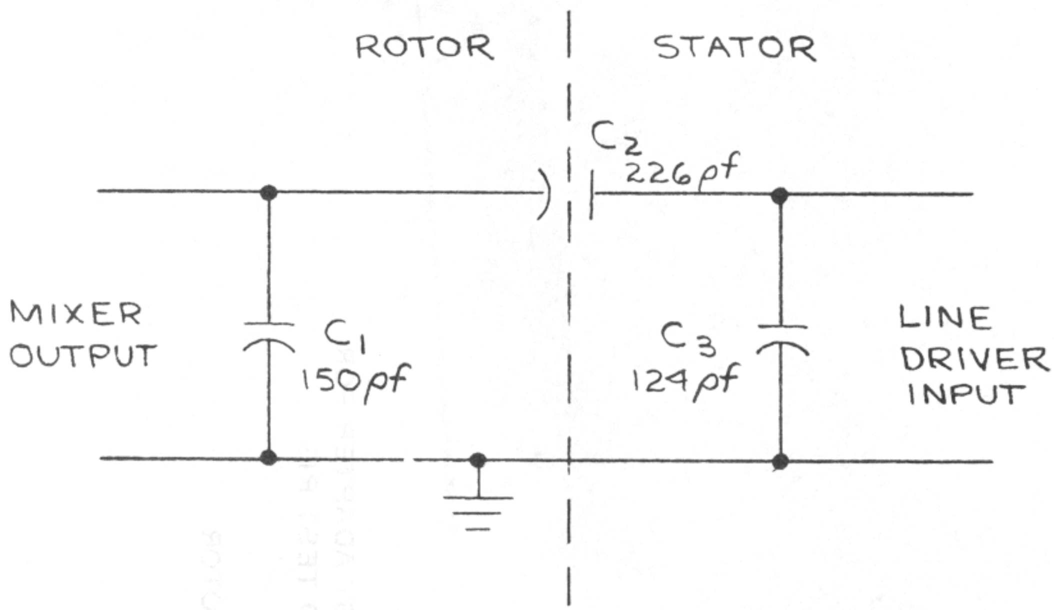


FIGURE 11. SCHEMATIC DIAGRAM, COUPLING CAPACITOR

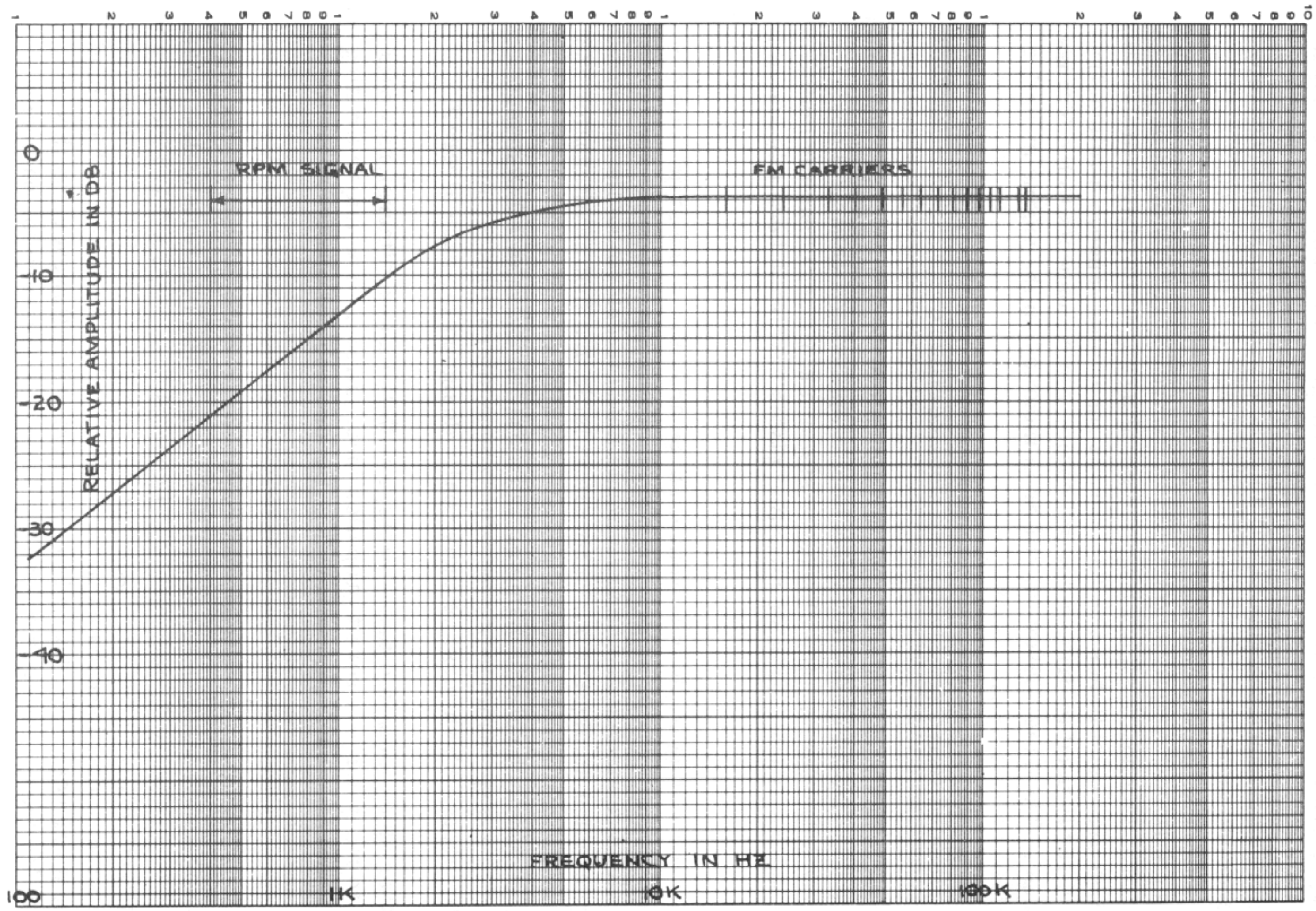


FIGURE 12. CAPACITOR COUPLING AND LINE DRIVER FREQUENCY RESPONSE

As Figure 12 indicates, all sixteen FM carriers occupy the frequency spectrum in the area of flat frequency response. On the other hand, the rpm signal is included below the cutoff of the coupling. However, the rpm signal output is approximately constant over the rpm range at the Line Driver output. This is due to the fact that the rpm filter R20, C8, R21 and C9 in the power supply (Figure 8) reduces the rpm signal amplitude with increasing frequency while the coupling increases the signal level as frequency increases.

The Line Driver Amplifier (pictured in Figure 13) schematic is shown on Figure 14. The composite signal from the coupling capacitor drives an emitter follower stage that establishes the 200 kilohms input impedance. A telemetry mixer amplifier is used to drive a coaxial cable, which connects to the Translator Package. The Line Driver Amplifier is mounted on the engine mounting brackets close to the capacitor stator.

Propeller-Mounted Hardware Mechanical Considerations

In order to facilitate assembly and disassembly of the propeller-mounted data system without removal of the test propeller, a split ring mechanical design concept was used. That is, the alternator stator and rotor, capacitor stator and rotor, and the electronics package mounting plates have each been fabricated in two pieces.

Prior to deciding on the mechanical shape and size of the major components such as the alternator, capacitor and electronics packages, a variety of light aircraft were studied and measurements made to determine the most versatile packaging configuration. This effort indicated that an alternator and capacitor configuration fitting within a ring with approximately a 9-inch inside diameter, 11 1/2-inch outside diameter and axial thickness of 1 1/2 inches would adapt to a large number of aircraft. These dimensions do not include the mounting brackets, which must be individually designed for each aircraft.

Further study indicated that a package with the above dimensions would also adapt to many large aircraft propeller installations. The major limiting factor for application on larger aircraft is the presence of electrical de-icer slip rings.

The rotating electronics packages were configured to make efficient use of existing space and to allow for versatile mounting. The two rectangular packages, pictured in Figure 7, measure approximately 6 x 2 1/2 x 2 1/2 inches and can be operated in any orientation provided the center of gravity is at approximately the same radial location as in the present unit. On two- and four-bladed propellers, a balanced installation is easily achieved. However, on three-bladed installations a dummy third package may be necessary for balancing provisions.

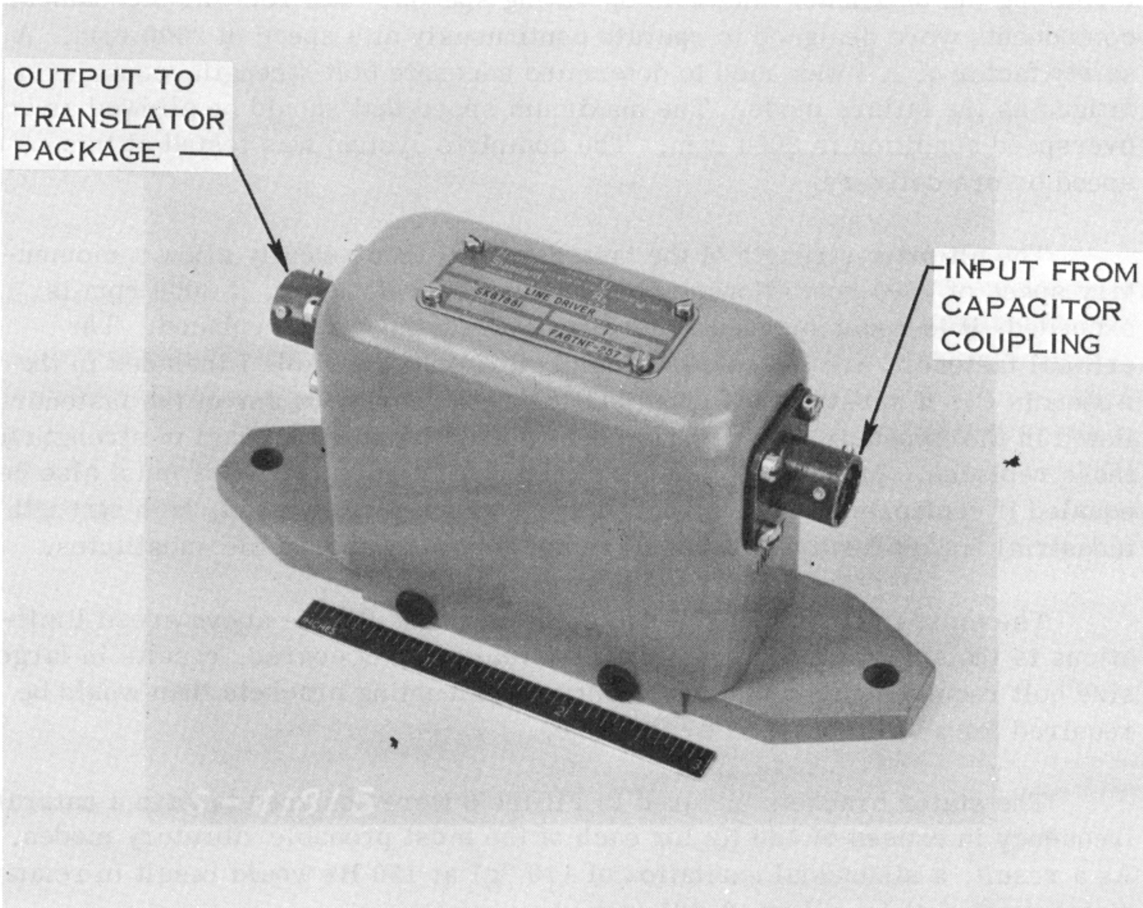


FIGURE 13. LINE DRIVER AMPLIFIER

Electrical connectors are provided on the electronics packages to provide for interconnection between the units, to the strain gage installation and to the alternator and capacitor coupling.

In general, size and weight were minimized through the use of small, high strength fasteners. These fasteners are one of the limiting factors in determining the maximum allowable operating speeds. The rotating mechanical components were designed to operate continuously at a speed of 2600 rpm. A safety factor of 1.4 was used to determine adequate bolt strength, considering fatigue as the failure mode. The maximum speed that should be allowed as an overspeed condition is 3000 rpm. The complete system was tested at this speed before delivery.

The ultimate strength of the fasteners will theoretically allow a momentary speed of 4000 rpm allowing no safety factor. However, if 3000 rpm is exceeded, it is recommended that all critical fasteners be replaced. The critical fasteners are indicated with an asterisk in the Table I included in the Appendix C. If substitutions should become necessary for any of the fasteners listed in the Appendix, the new fasteners should be at least equal in strength to those replaced. In addition, the corrosion and fatigue properties must also be equaled if replacements are made. Except where already used, high strength industrial socket-head cap screws are not generally acceptable substitutes.

The most important design factor responsible for the above speed limitations is the split ring concept. This convenience, of course, results in larger size bolt requirements and more substantial mounting brackets than would be required for a solid one-piece structure.

The stator brackets pictured in Figure 6 were designed to have a natural frequency in excess of 150 Hz for each of the most probable vibratory modes. As a result, a sinusoidal excitation of ±10 "g" at 150 Hz would result in relative stator motion of less than ±0.005 inch.

Number 10-32 bolts hold the generator rotor and the mounting plates onto the rotor bracket. These bolts engage threaded inserts in the rotor bracket. It was not possible to use helical coil inserts because a sufficient length of engagement was not available to develop a strength compatible with the high strength fasteners. Tap-Loc (Groov Pin Corporation) solid-wall inserts were selected for this application but laboratory tests showed that although adequate pullout strength was exhibited, the inserts showed a tendency to turn and strip out if the bolt was slightly overtorqued. This problem was solved by bonding the Tap-Loc inserts in place with Cycleweld C-14 (Chemical Division, Chrysler Corporation) epoxy adhesive.

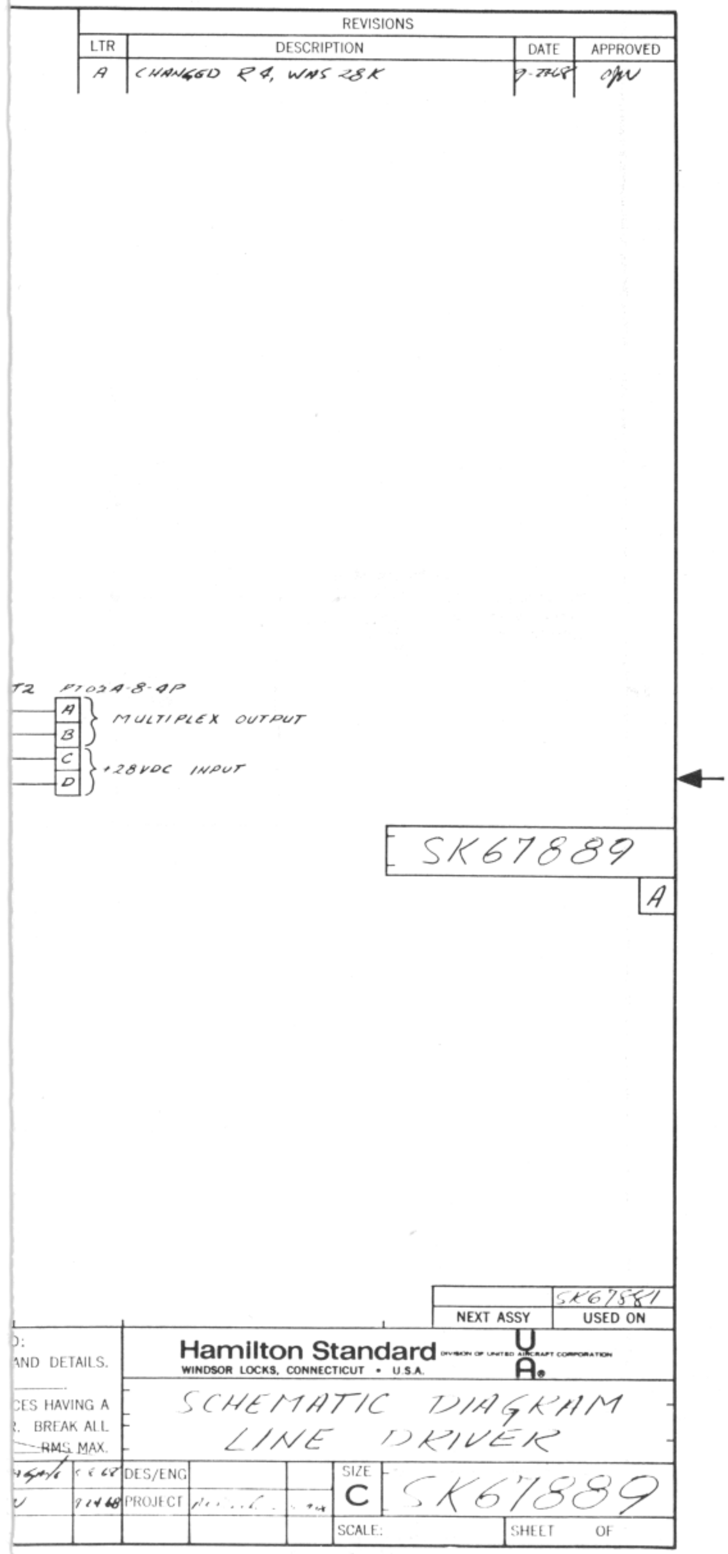

REVISIONS
LTR
DESCRIPTION
DATE
APPROVED
A
CHANGED R4, WAS 28K
T2 PT02A-8-4P
A
B
C
D
MULTIPLEX OUTPUT
+28VDC INPUT
SK67889
A
SK67881
NEXT ASSY
USED ON
AND DETAILS.
CES HAVING A
BREAK ALL
RMS MAX.
Hamilton Standard
WINDSOR LOCKS, CONNECTICUT • U.S.A.
SCHEMATIC DIAGRAM
LINE DRIVER
DES/ENG
PROJECT
SIZE
C
SK67889
SCALE:
SHEET
OF

FIGURE 14.

REVISIONS			
LTR	DESCRIPTION	DATE	APPROVED
A	CHANGED R4, WAS 28K	9-27-68	OJW

02A-8-4P

} MULTIPLEX OUTPUT

} +28VDC INPUT

SK67889

A

	SK67881
NEXT ASSY	USED ON

ILS.

NG A

ALL

MAX.

Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION

WINDSOR LOCKS, CONNECTICUT • U.S.A.

SCHEMATIC DIAGRAM
LINE DRIVER

-8-67	DES/ENG			SIZE C	SK67889
2-24-68	PROJECT		5-9-68		
				SCALE:	SHEET OF

A problem was encountered when the compact mounting/insulation bushings for the capacitor plates were being designed. That is, most engineering plastics exhibit large creep rates (cold flow) at relatively low loads. Since the plastic bushing is loaded by the mounting bolt, even a small amount of creep would result in a loss of preload. Some of this creep could be compensated for through the use of spring washers under the boltheads. However, with most plastics, the creep would exceed the capabilities of practical sized washers. Polyimide "Vespel", (DuPont Corp.) plastic was found to be a unique solution to this problem with its unusually low-creep rate. In order to realize these benefits, however, a carefully controlled preload must be used as tabulated in the Appendix C. If the spring washers are removed for any reason, they should be carefully counted to ensure that there are five spring washers under the head of each screw when reassembled.

The socket head screws and washers, which secure the capacitor plates, are at the same electrical potential as the Mixer Amplifier output. The stator plate attaching screws are lockwired and the lockwire is insulated with plastic tubing. The rotor screws are held in place with locking helical coil inserts so it is not necessary to lockwire them.

A step-by-step assembly procedure for the propeller-mounted components is included in the Appendix.

Translator Package

The output of the Line Driver Amplifier (ref. Fig. 1) contains the entire propeller measurement spectrum including the rpm signal and the 16 frequency modulated subcarriers. This complete signal could be recorded on a direct record tape track except for two important factors. First, the higher frequency carriers employ small percentage deviations (±1.47% for the 136 kHz carrier), which would present a problem in obtaining an adequate signal-to-noise ratio when the tape recorded data was demodulated during reproduce. That is, the tape record and playback machine wow and flutter would require compensation beyond the ability of currently available discriminator equipment. Also, recording of a relatively high frequency composite on one tape track would not utilize the tape in an efficient manner and, therefore, would significantly reduce the available recording time on any given transport.

In order to avoid the signal-to-noise ratio problem due to flutter and to obtain the maximum practical recording time, frequency translation is used prior to tape recording. Reference to the block diagram, Figure 1, shows that the Line Driver Amplifier drives five parallel filters. The 2 kHz low pass removes the rpm signal from the composite and does not enter into the translation process. The four bandpass filters split the 16 FM carriers into four groups of four channels each. The output of the 28 kHz filter includes the carriers from 16 to 40 kHz, the 60 kHz bandpass output includes the carriers from 48 to 72 kHz, the 92 kHz bandpass output includes the 80 to 104 kHz carriers, and the 124 kHz bandpass output includes the carriers from 112 to 136 kHz. In turn, each bandpass filter drives a frequency translator, which heterodynes the four subcarriers to a lower frequency spectrum. For example, the 112 kHz, 120 kHz, 128 kHz, and 136 kHz output from the 124 kHz bandpass filter is heterodyned with a 152 kHz note, which produces for each carrier the sum and difference frequency. Only the difference frequencies appear at the translator output so that the 136 kHz carrier is translated to 16 kHz, the 128 kHz carrier to 24 kHz, the 120 kHz carrier to 32 kHz, and the 112 kHz carrier to 40 kHz. Likewise, the 88 kHz and 120 kHz translators heterodyne the output from the 60 kHz and 92 kHz bandpass filters to form groups of carriers from 16 to 40 kHz. The time delay unit at the output of the 28 kHz filter is used to provide the same time delay to the original 16 to 40 kHz group as experienced by the other groups in the translation process. However, it should be noted that there is a 180° phase reversal between the original 16 to 40 kHz group and the three translated subcarrier groups although the group to group time delay is minimized.

The four subcarrier groups each containing carriers at 16 kHz, 24 kHz, 32 kHz and 40 kHz are combined with a 50 kHz reference oscillator, which can be used on data playback for tape speed compensation. The compensation available in the EMR Model 210 discriminators (used in the FAA Data Reduction Facility) will be compatible with the frequency deviation appearing on the translated channels.

Channel Center Frequency kHz	Percent Deviation %
16	±12.5
24	± 8.33
32	± 6.25
40	± 5.0

The filtered rpm signal is also mixed with one of the subcarrier groups, occupying the spectrum from approximately 400 Hz to 1500 Hz.

The system frequency translation equipment is housed together with the aircraft supporting parameter circuitry in a 1/2 ATR case as pictured in Figure 15. The front panel includes the four Multiplex Output connectors for tape recording and the parallel Monitor Outputs, which are used to observe the data on the Monitor Discriminators. Also available for observation at the front panel are the rpm and 1P pulser signals. Connection of the Translator Package to the Line Driver is accomplished at the Multiplex Input connector pictured in Figure 16. This connector provides power to the Line Driver as well as accepting the Line Driver output signal. Connections are also provided at the rear of the package for the 28 Vdc primary power and the 1P pulse input, and A/C parameter transducers.

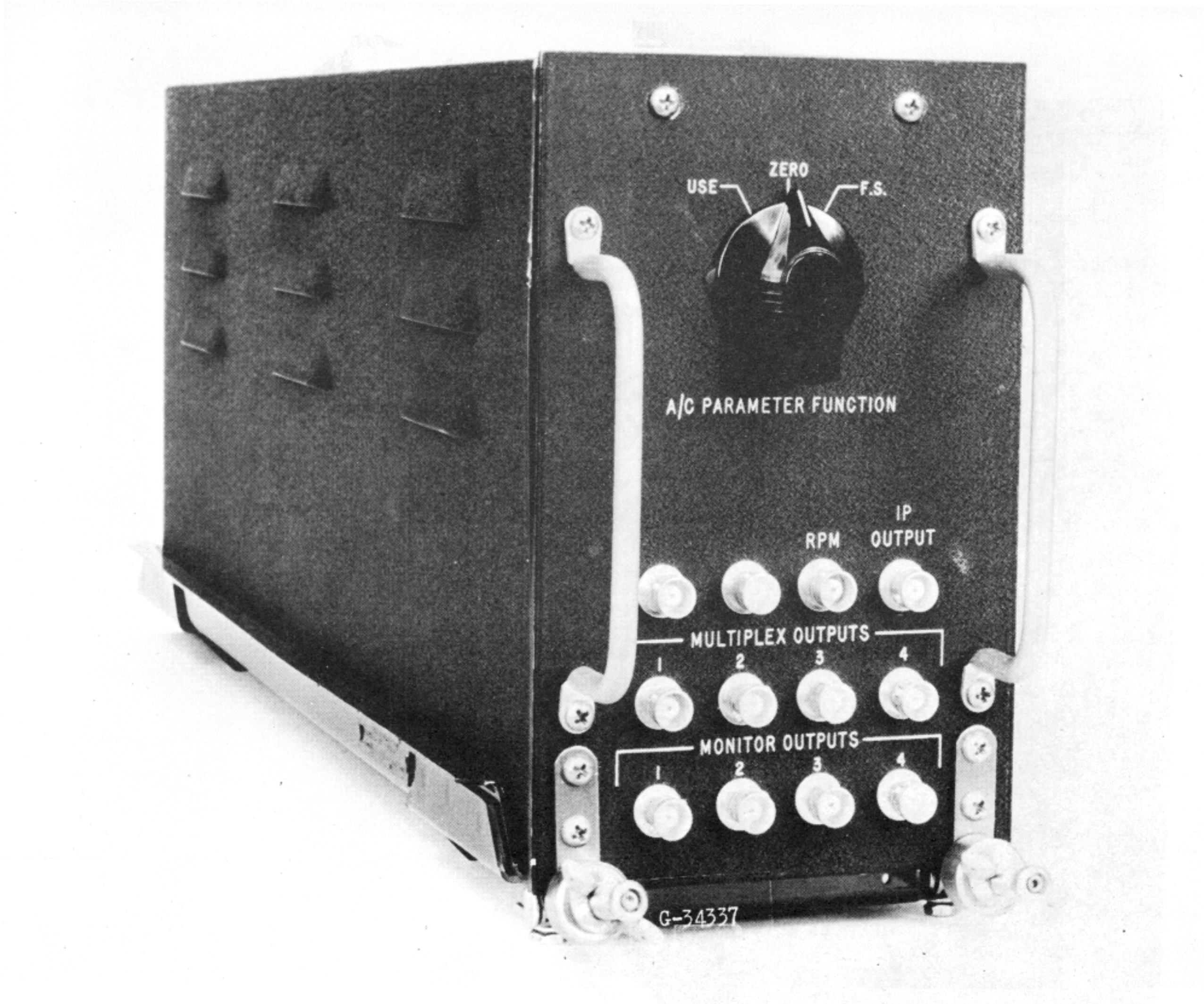


FIGURE 15. TRANSLATOR AND A/C PARAMETER PACKAGE FRONT VIEW

FIGURE 16. TRANSLATOR AND A/C PARAMETER PACKAGE REAR VIEW

Figure 17 shows the translator equipment and A/C supporting parameter VCO's. Each unit plugs into a mother board, which is wired according to the diagram in Figure 18.

Aircraft Supporting Parameters

Seven data channels are included in the Translator Package to provide for the measurement of several parameters, which are required to define the aircraft operating conditions. These data channels include transducers, calibration circuits, and Voltage-Controlled Oscillators for the recording of Deck Angle, Manifold Pressure, Landing Gear Position, Altitude, Vertical Acceleration, and Air Speed. In addition, a channel is included for recording a pulse once per propeller revolution. This pulse can be used to determine the angular relationship between 1P propeller strain and blade position.

The transducers used for the above measurements are connected to the data system at the rear of the Translator Package as shown in Figure 16. The block diagram, Figure 19, indicates the signal flow from the transducers to the Voltage-Controlled Oscillators and the subsequent mixing into the four groups of data channels containing the propeller blade strain information.

Figure 20 is a diagram that illustrates the wiring in the Translator Package pertaining to the aircraft supporting parameters. The A/C Parameter Function switch is mounted on the front panel of the Translator Package. This switch provides for direct connection of the transducers to the VCO's in the Use position, a zero input to each VCO in the Zero position and the full transducer excitation voltage representing full scale input is applied to each VCO in the "Full Scale" position.

The transducers supplied for measurement of the various aircraft parameters are all high output potentiometer types. The following information describes these transducers.

(A) Altitude - This potentiometer-type transducer is a Computer Instruments Corporation Model 7000. An output linear with altitude from zero to 30,000 feet is provided by a 1000 ohm film potentiometer. The transducer output is zero at sea level and 90% of the excitation voltage at 30,000 feet. Since this is a pressure transducer it must be mounted in an unpressurized area of the test aircraft.

(B) Airspeed - This is also a film potentiometer transducer Model 7100 by Computer Instruments Corporation. An output linear with airspeed from zero to 350 knots is provided by a 1000 ohm potentiometer. The theoretical output curve is drawn through zero output at zero knots and 95% of the excitation voltage at 350 knots. However, the threshold of operation is approximately 70 knots. This transducer requires a pitot and static pressure connection.

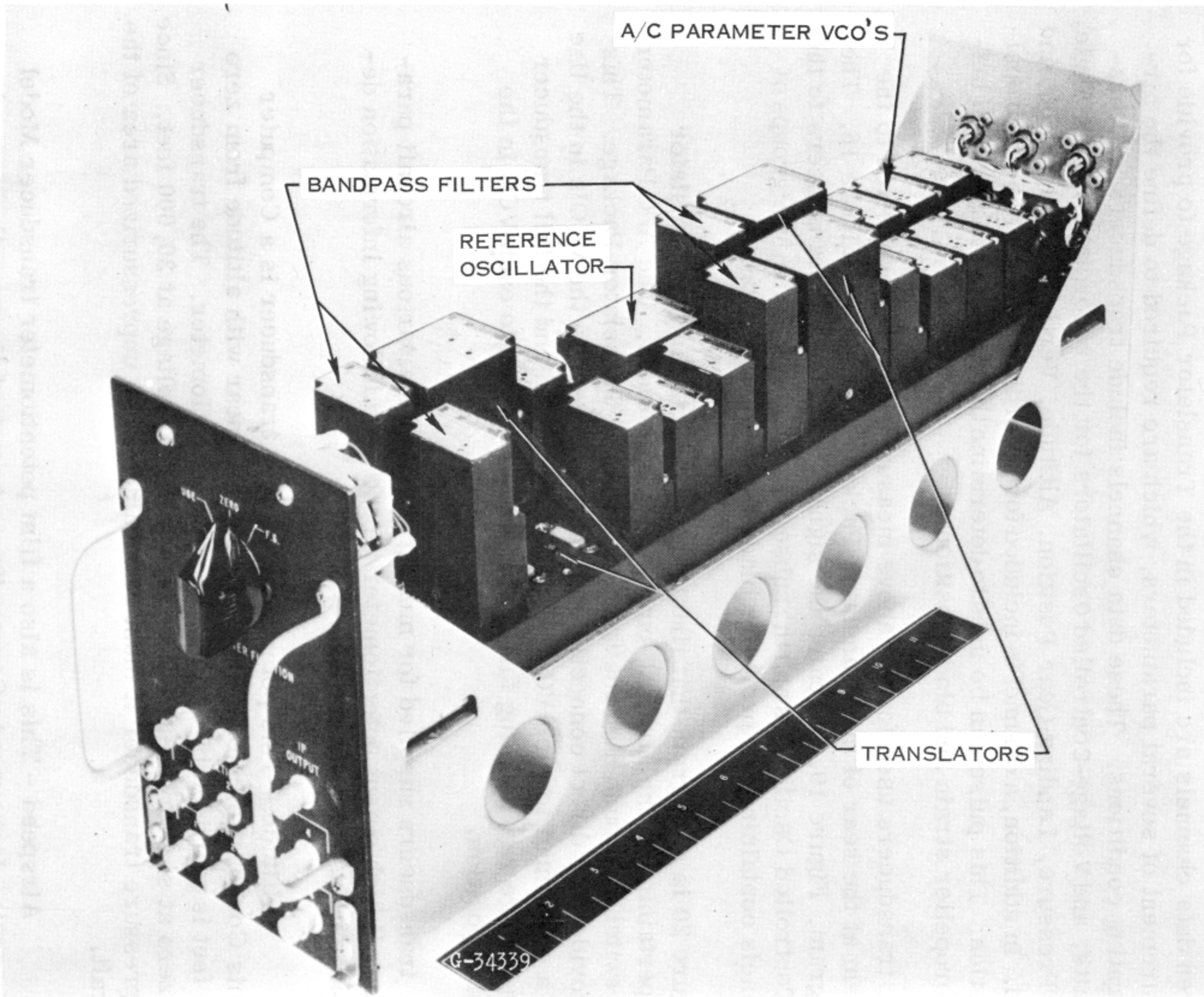


FIGURE 17. TRANSLATOR AND A/C PARAMETER PACKAGE INTERNAL VIEW

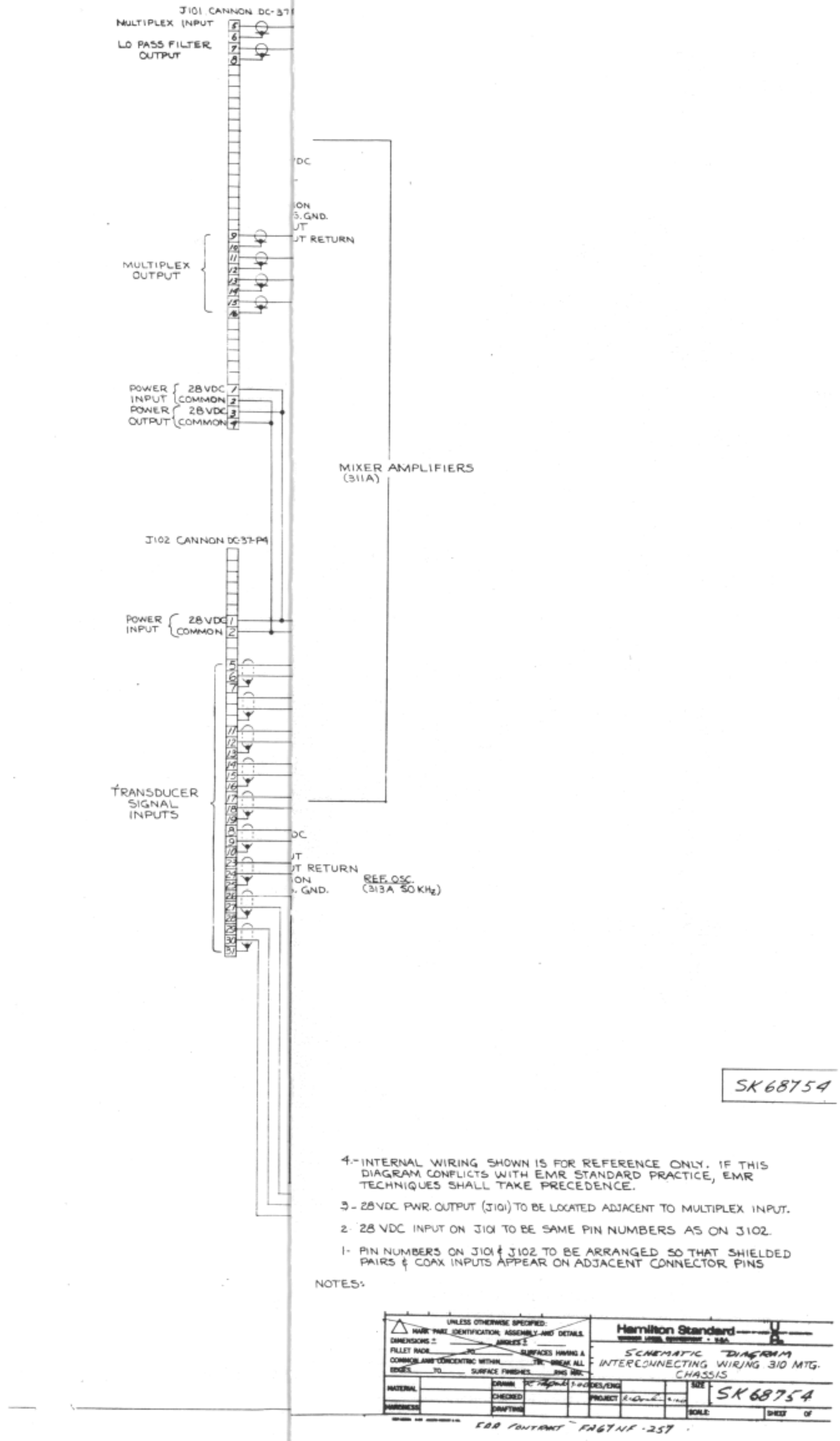
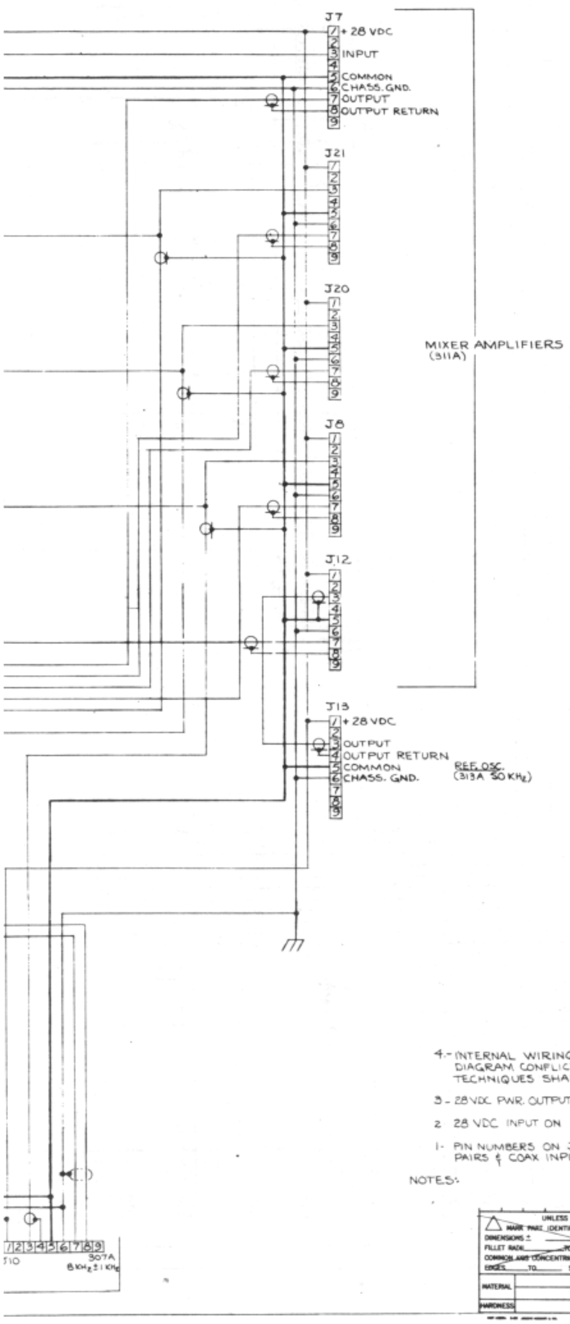

J101 CANNON DC-37
MULTIPLEX INPUT
LO PASS FILTER OUTPUT
MULTIPLEX OUTPUT
POWER INPUT 28 VDC COMMON
POWER OUTPUT 28 VDC COMMON
MIXER AMPLIFIERS (311A)
J102 CANNON DC-37-P4
POWER INPUT 28 VDC COMMON
TRANSDUCER SIGNAL INPUTS
REF. OSC. (313A 50 KHz)
SK 68754
4.- INTERNAL WIRING SHOWN IS FOR REFERENCE ONLY. IF THIS DIAGRAM CONFLICTS WITH EMR STANDARD PRACTICE, EMR TECHNIQUES SHALL TAKE PRECEDENCE.
3 - 28 VDC PWR. OUTPUT (J101) TO BE LOCATED ADJACENT TO MULTIPLEX INPUT.
2 28 VDC INPUT ON J101 TO BE SAME PIN NUMBERS AS ON J102.
1- PIN NUMBERS ON J101 & J102 TO BE ARRANGED SO THAT SHIELDED PAIRS & COAX INPUTS APPEAR ON ADJACENT CONNECTOR PINS
NOTES:
Hamilton Standard
SCHEMATIC DIAGRAM INTERCONNECTING WIRING 310 MTG. CHASSIS
SK 68754

FIGURE 18.



SK 68754

4.- INTERNAL WIRING SHOWN IS FOR REFERENCE ONLY. IF THIS DIAGRAM CONFLICTS WITH EMR STANDARD PRACTICE, EMR TECHNIQUES SHALL TAKE PRECEDENCE.

3 - 28VDC PWR. OUTPUT (J101) TO BE LOCATED ADJACENT TO MULTIPLEX INPUT.

2 28 VDC INPUT ON J101 TO BE SAME PIN NUMBERS AS ON J102.

1- PIN NUMBERS ON J101 & J102 TO BE ARRANGED SO THAT SHIELDED PAIRS & COAX INPUTS APPEAR ON ADJACENT CONNECTOR PINS

NOTES:-

UNLESS OTHERWISE SPECIFIED: MARK PART IDENTIFICATION; ASSEMBLY AND DETAILS. DIMENSIONS ± ANGLES ± FILLET RADII TO SURFACES HAVING A COMMON AND CONCENTRIC WITHIN TIR BREAK ALL EDGES TO SURFACE FINISHES RMS MAX			Hamilton Standard	
			SCHEMATIC DIAGRAM INTERCONNECTING WIRING 310 MTG. CHASSIS	
MATERIAL	DRAWN		DES/ENG	SIZE SK 68754
	CHECKED		PROJECT	
HARDNESS	DRAFTING			SCALE: SHEET OF

FOR CONTRACT FA6TNF-257

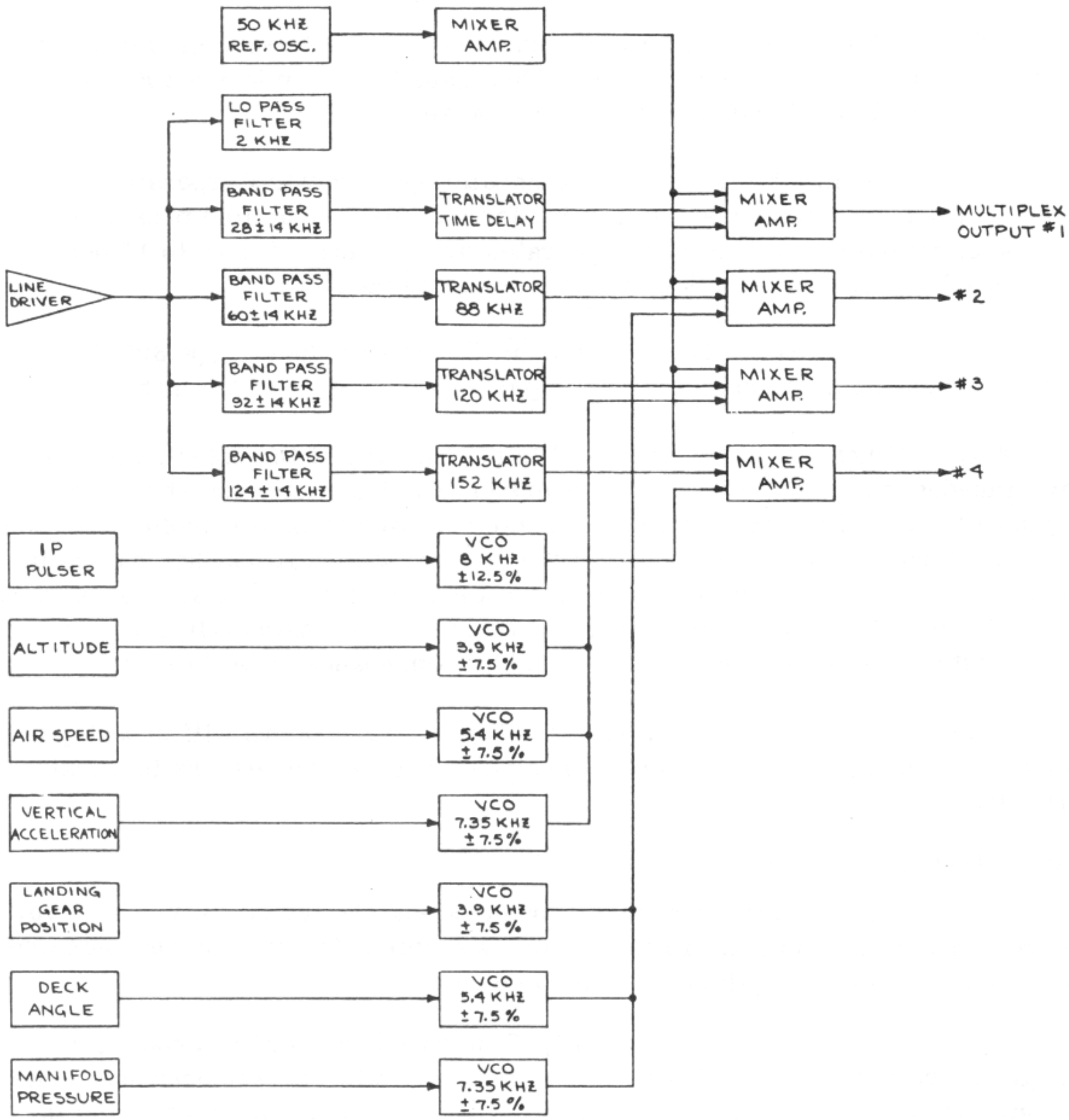


FIGURE 19. BLOCK DIAGRAM — A/C SUPPORTING PARAMETERS

(C) Vertical Acceleration - An Edcliff Instruments Model 7-114 potentiometer type accelerometer with a full-scale range of -1.0 to +2.5g is used for aircraft vertical acceleration. The potentiometer element is 1000 ohms.

(D) Deck Angle - An Edcliff Instruments Model 5-510 Inclinometer is provided for measuring deck angle. This transducer employs a 1000 ohm potentiometer element and operates over a range of ±45°.

(C) Manifold Pressure - A Computer Instruments Corporation differential pressure transducer is supplied for measuring manifold pressure. This potentiometer type transducer operates over a range of zero to 15 psi differential and employs a 1000 ohm resistance element.

(F) 1P Pulser - The pulser is an Electro Products Type 3055A pickup, which should be operated at a gap of approximately 0.020 inch.

A special note should be observed in the handling of the potentiometer-type transducers. Since these transducers employ film potentiometer elements they should never be checked with an ohmmeter. An ohmmeter applied between the wiper terminals and the low end of the element with zero mechanical input can result in destruction of the element. Therefore, these transducers must be checked and calibrated with the winding excited with approximately 5 Vdc and output voltage measurements made with a high-impedance dc voltmeter.

Also, long-term reliability and life of these transducers will probably be enhanced by using a vibration mount when mounting the transducers in a test aircraft.

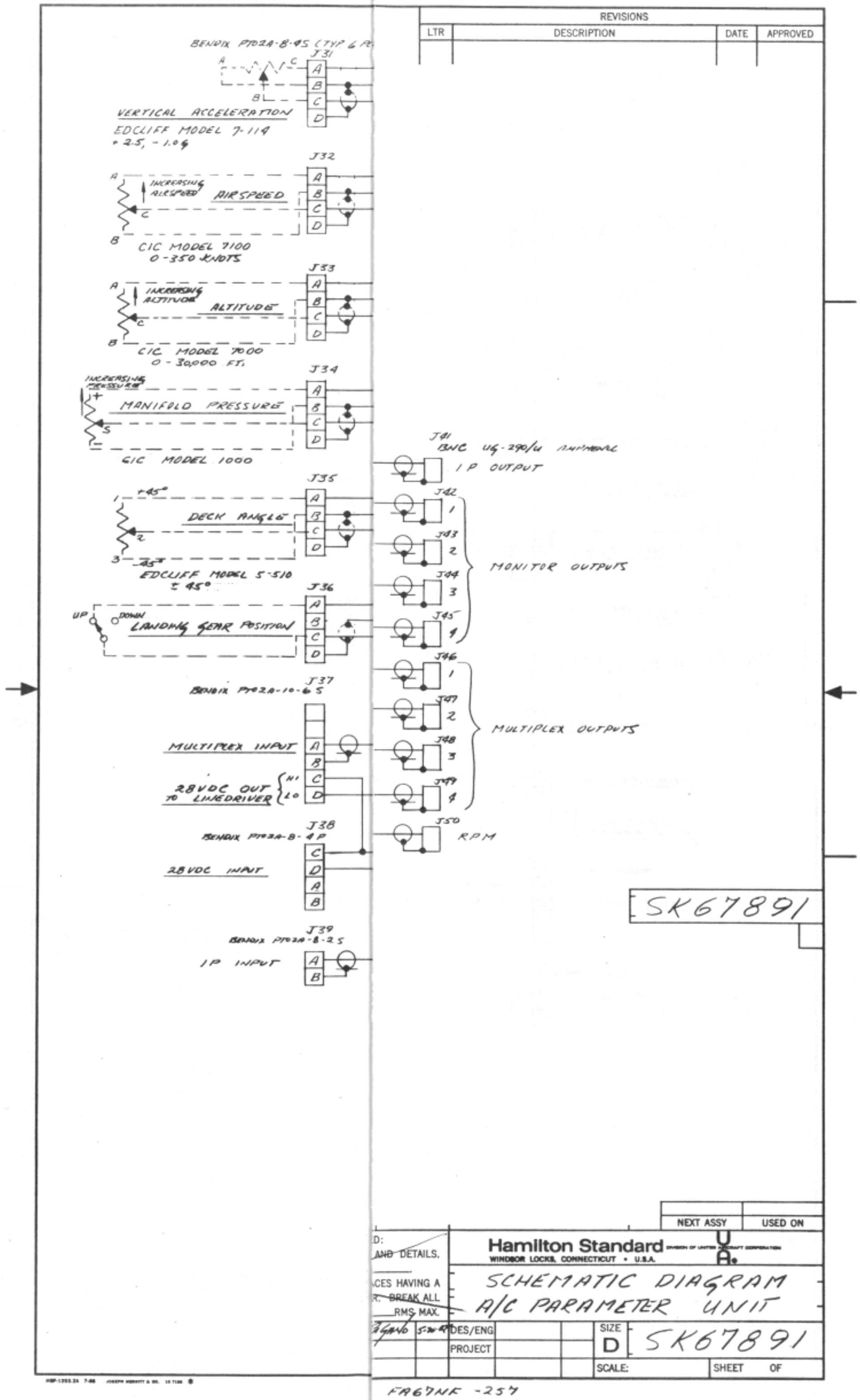
System Test Instruments

A number of instruments have been included with the system for use in setup, checkout, monitoring and calibration of the data system. The instruments supplied andthe intended function will be described below.

(A) Oscilloscope - Figure 21, Tektronix Model 321A portable, rechargeable battery operated instrument with a separately supplied manual. The manual should be consulted for operating instructions and battery charging information. This scope can be used to observe the FM signals at the Translator Package "Monitor Outputs", "RPM" output, and the Discriminator demodulated outputs.

(B) VTVM - Figure 21, Hewlett Packard Model 400E AC Voltmeter has been supplied for use in checkout of the data system and the tape recorder. A manual describing the operation of this instrument has been supplied.

(C) Oscillator - Figure 21, Hewlett Packard Model 204B portable, battery operated instrument with a separately supplied manual. This instrument


REVISIONS
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APPROVED
BENDIX PT02A-8-4S (TYP 6 PL)
J31
VERTICAL ACCELERATION
EDCLIFF MODEL 7-114
+2.5, -1.0 g
J32
INCREASING AIRSPEED
AIRSPEED
CIC MODEL 7100
0-350 KNOTS
J33
INCREASING ALTITUDE
ALTITUDE
CIC MODEL 7000
0-30,000 FT.
J34
INCREASING PRESSURE
MANIFOLD PRESSURE
CIC MODEL 1000
J35
DECK ANGLE
EDCLIFF MODEL 5-510
± 45°
J36
LANDING GEAR POSITION
UP
DOWN
J37
BENDIX PT02A-10-6S
MULTIPLEX INPUT
28VDC OUT TO LINEDRIVER
HI
LO
J38
BENDIX PT02A-8-4P
28VDC INPUT
J39
BENDIX PT02A-8-2S
IP INPUT
J41
BNC UG-290/U AMPHENOL
IP OUTPUT
J42
J43
J44
J45
MONITOR OUTPUTS
J46
J47
J48
J49
MULTIPLEX OUTPUTS
J50
RPM
SK67891
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Hamilton Standard
WINDSOR LOCKS, CONNECTICUT • U.S.A.
SCHEMATIC DIAGRAM
A/C PARAMETER UNIT
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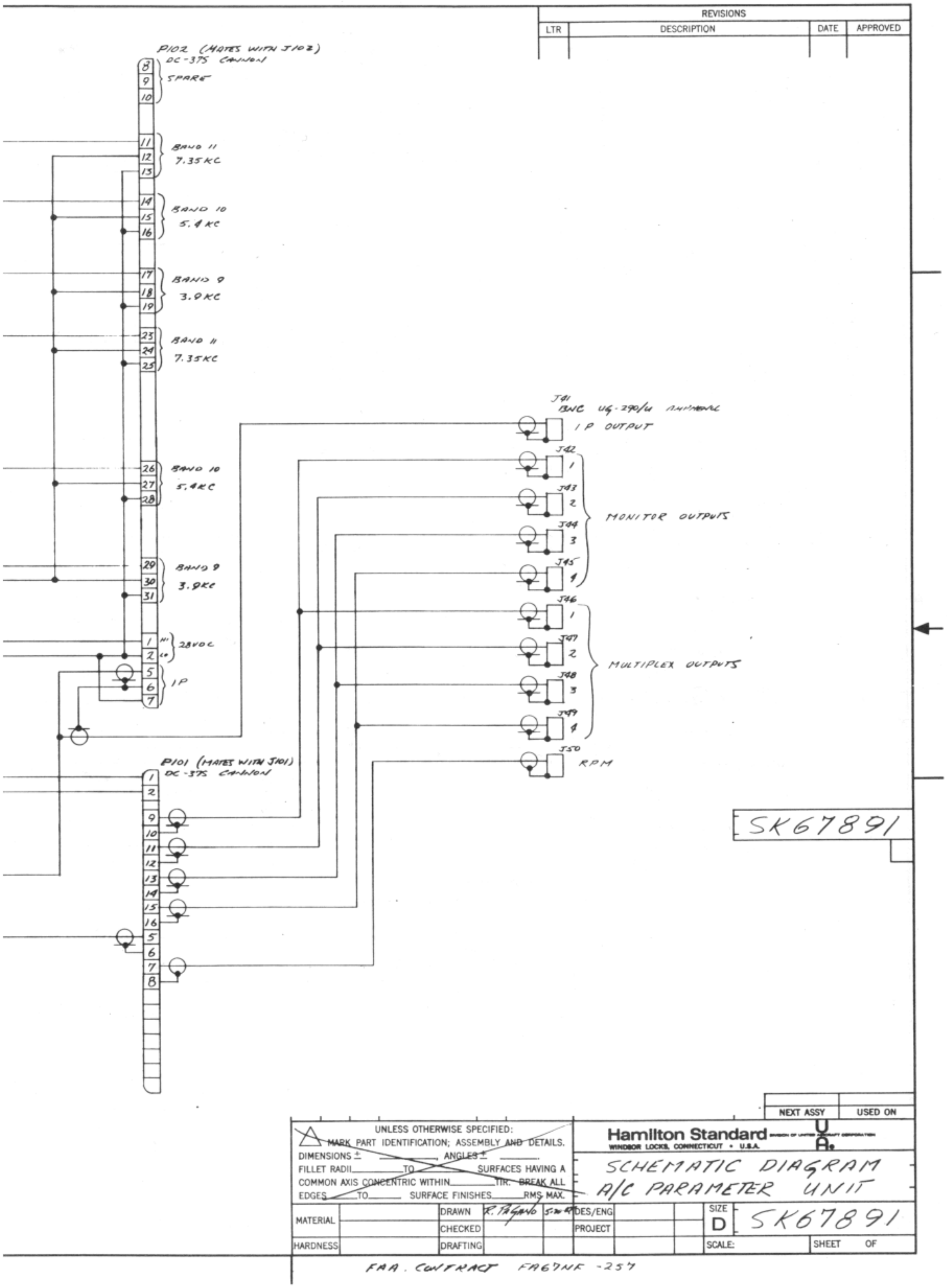
FA67NF-257

FIGURE 20.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P102 (MATES WITH J102)
DC-37S CANNON
SPARE
BAND 11
7.35KC
BAND 10
5.4KC
BAND 9
3.9KC
BAND 11
7.35KC
BAND 10
5.4KC
BAND 9
3.9KC
28VDC
IP
J41
IP OUTPUT
J42
J43
J44
J45
MONITOR OUTPUTS
J46
J47
J48
J49
MULTIPLEX OUTPUTS
J50
RPM
P101 (MATES WITH J101)
DC-37S CANNON
SK67891
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DIMENSIONS ±
ANGLES ±
FILLET RADII
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SURFACES HAVING A
COMMON AXIS CONCENTRIC WITHIN
TIR. BREAK ALL
EDGES
TO
SURFACE FINISHES
RMS MAX.
Hamilton Standard
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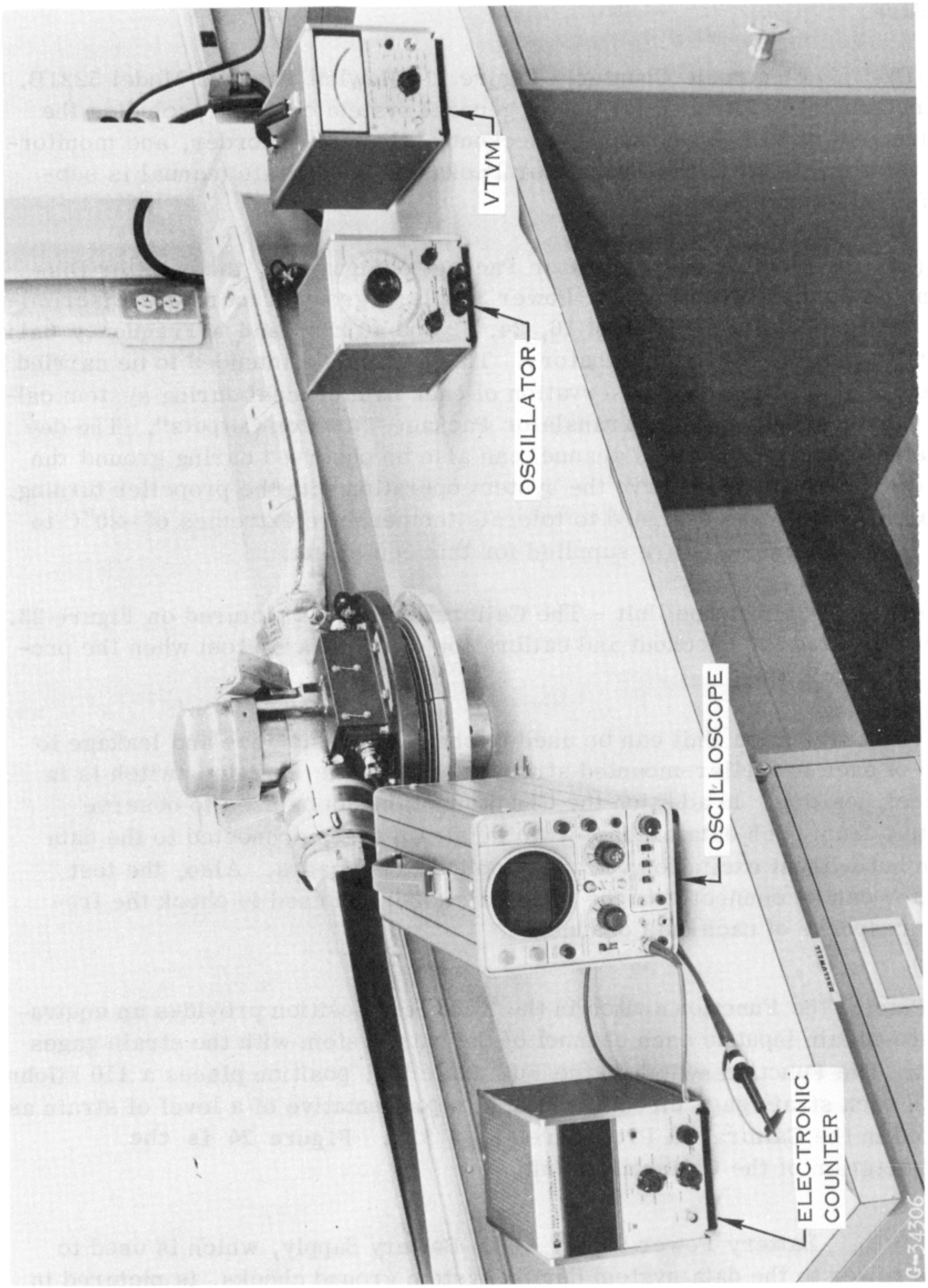

FIGURE 21. TEST INSTRUMENTS AND INSTRUMENTED PROP

can be used for checking various system components, setting tape record levels, and data system frequency response as discussed under the calibration procedure.

(D) Electronic Counter - Figure 21, Hewlett Packard Model 5221B. This instrument is intended for use in general system checkout including the measurement of VCO frequencies, checkout of the tape recorder, and monitoring of the rpm signal at the Translator Package. A separate manual is supplied for this instrument.

(E) Monitor Discriminator Package - Figure 22, the Monitor Discriminator Package consists of a Power Supply; a group of four Data Discriminators with center frequencies of 16, 24, 32 and 40 kHz; and a Frequency Calibrator for setup of the Discriminators. This package is intended to be carried on board a test aircraft for observation of each data channel during system calibration by connecting to the Translator Package "Monitor Outputs". The demodulated output of each data channel can also be observed during ground run up of a test aircraft to observe the system operation with the propeller turning. This package has been designed to tolerate temperature extremes of -20°C to 50°C. Separate manuals are supplied for this equipment.

(F) Calibration Unit - The Calibration Unit is pictured on Figure 23. This unit is used for checkout and calibration of the data system when the propeller is not rotating.

The Calibration Unit can be used to check the resistance and leakage to ground of each propeller-mounted strain gage when the Function switch is in the Check position. In addition the Check function can be used to observe the output from each data channel with the strain gages connected to the data system but without excitation voltage supplied to the gages. Also, the test oscillator can be connected to the terminals (J36) and used to check the frequency response of each data channel.

Placing the Function switch in the Zero Std. position provides an equivalent zero-strain input to each channel of the data system with the strain gages excited. The Function switch in the Full Scale Std. position places a 110 kilohm shunt in each strain gage circuit, which is representative of a level of strain as indicated in the Calibration Procedure (page 52). Figure 24 is the circuit diagram of the Calibration Unit.

(G) Battery Power Supply - The Battery Supply, which is used to provide power to the data system during system ground checks, is pictured in Figure 25. This unit provides a nominal 30 Vdc output with a series connected Burgess Nickel Cadmium CD207 (6 volt) and CD211 (24 volt) battery and a nominal 18 volt output from a CD207 (6 volt) and CD208 (12 volt) battery.

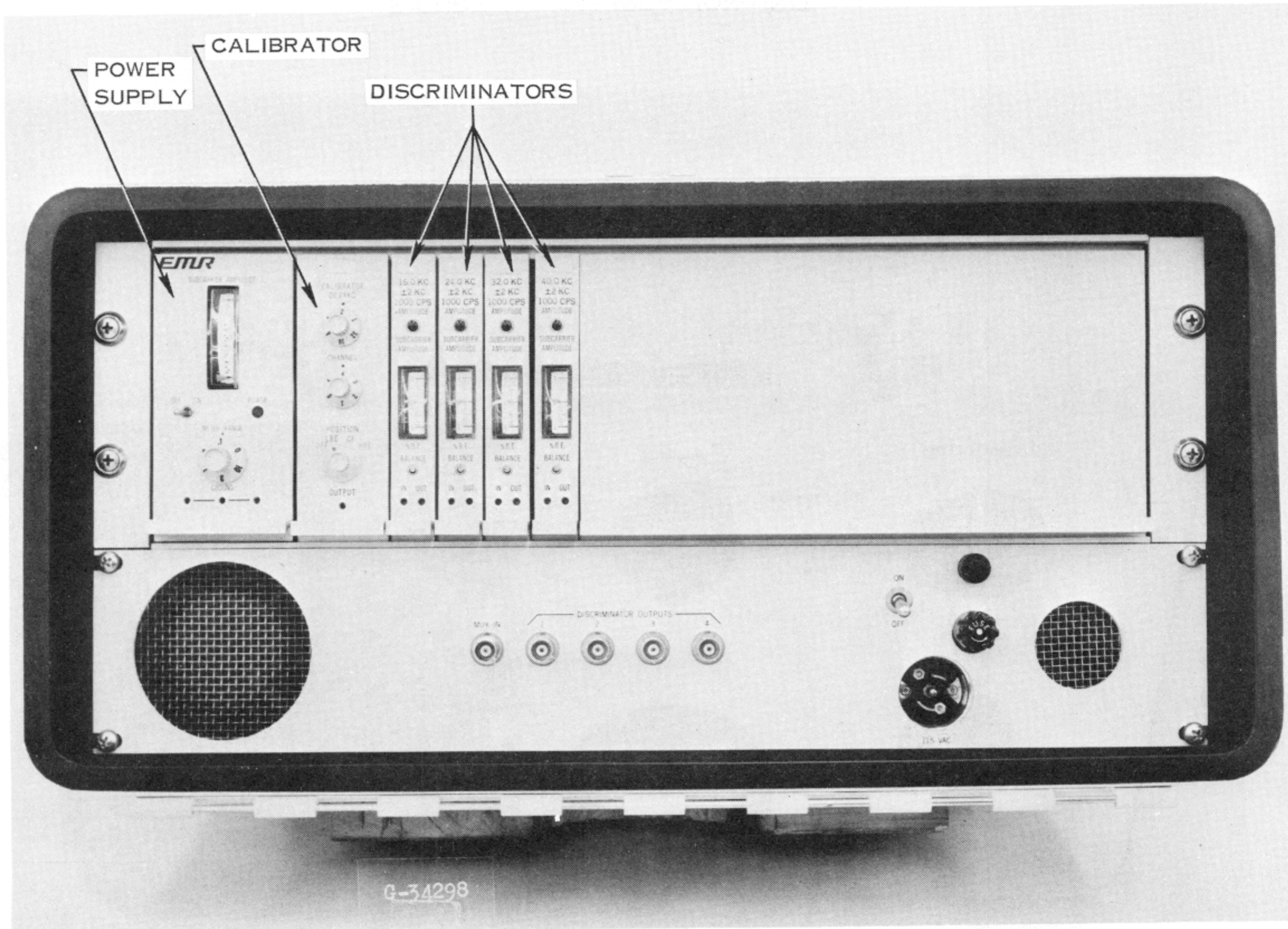

FIGURE 22. MONITOR DISCRIMINATOR PACKAGE

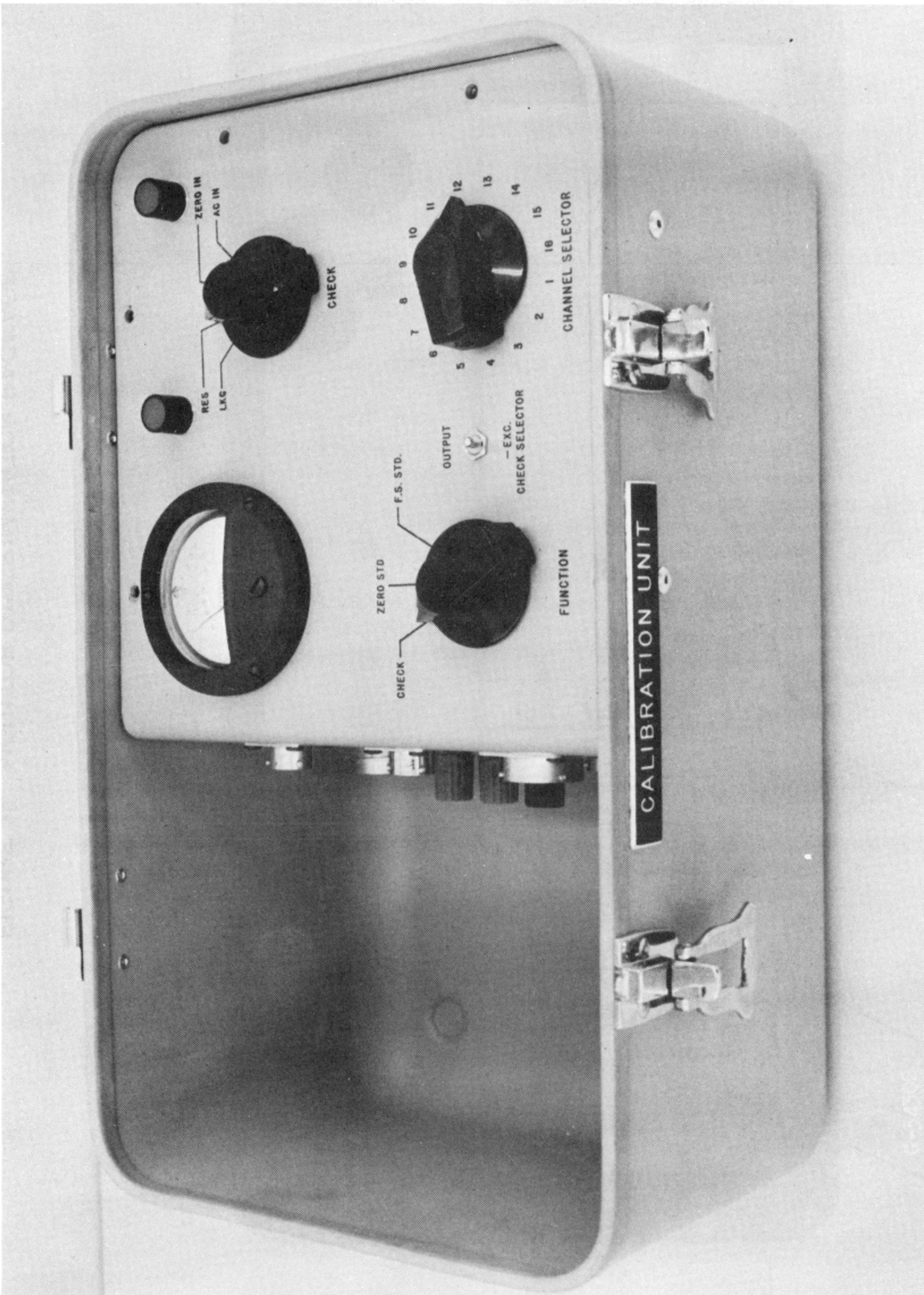

FIGURE 23. CALIBRATION UNIT

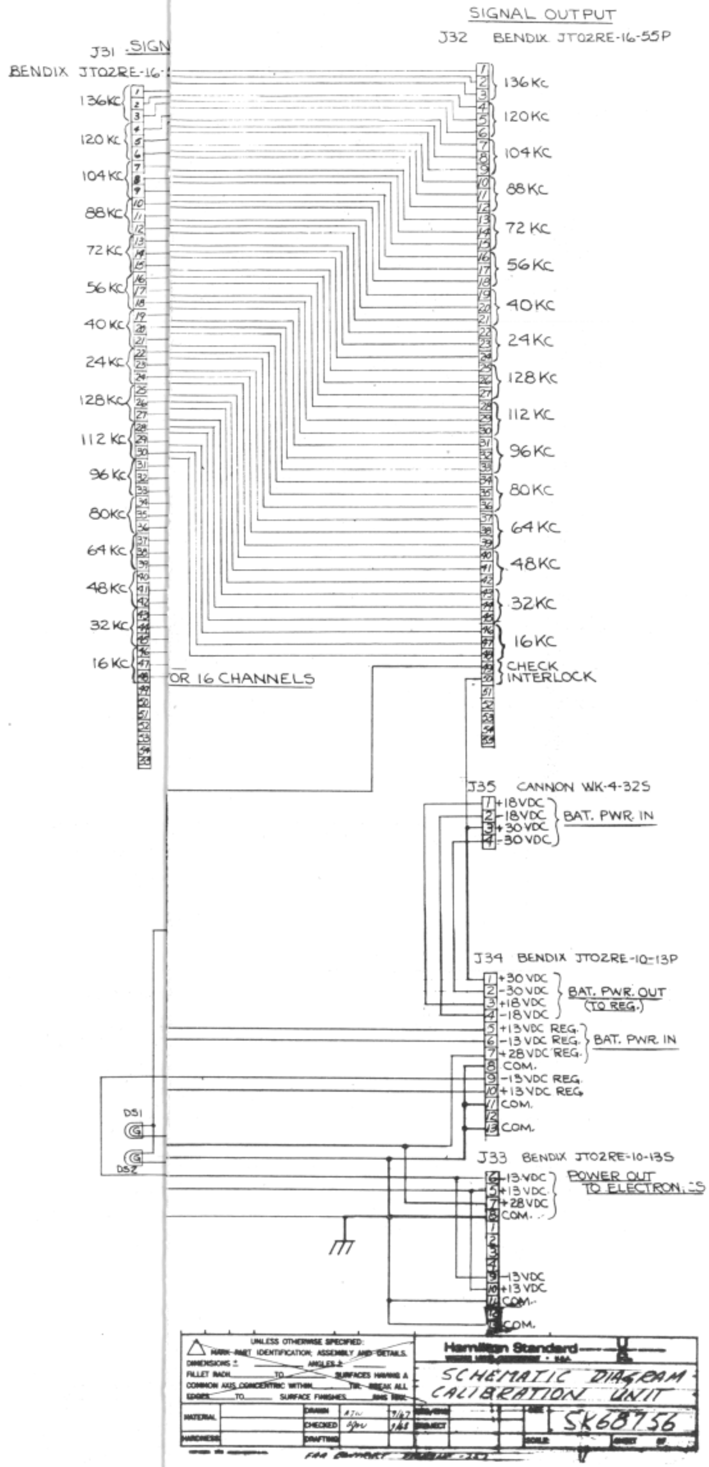
SIGNAL OUTPUT
J32 BENDIX JT02RE-16-55P
J31
BENDIX JT02RE-16-
136 Kc
120 Kc
104 Kc
88 Kc
72 Kc
56 Kc
40 Kc
24 Kc
128 Kc
112 Kc
96 Kc
80 Kc
64 Kc
48 Kc
32 Kc
16 Kc
CHECK INTERLOCK
OR 16 CHANNELS
J35 CANNON WK-4-32S
+18 VDC
-18 VDC
+30 VDC
-30 VDC
BAT. PWR. IN
J34 BENDIX JT02RE-10-13P
+30 VDC
-30 VDC
+18 VDC
-18 VDC
BAT. PWR. OUT (TO REG.)
+13 VDC REG.
-13 VDC REG.
+28 VDC REG.
BAT. PWR. IN
COM.
-13 VDC REG.
+13 VDC REG.
COM.
COM.
DS1
DS2
J33 BENDIX JT02RE-10-13S
-13 VDC
+13 VDC
+28 VDC
COM.
POWER OUT TO ELECTRONICS
-13 VDC
+13 VDC
COM.
COM.
UNLESS OTHERWISE SPECIFIED:
Hamilton Standard
SCHEMATIC DIAGRAM CALIBRATION UNIT
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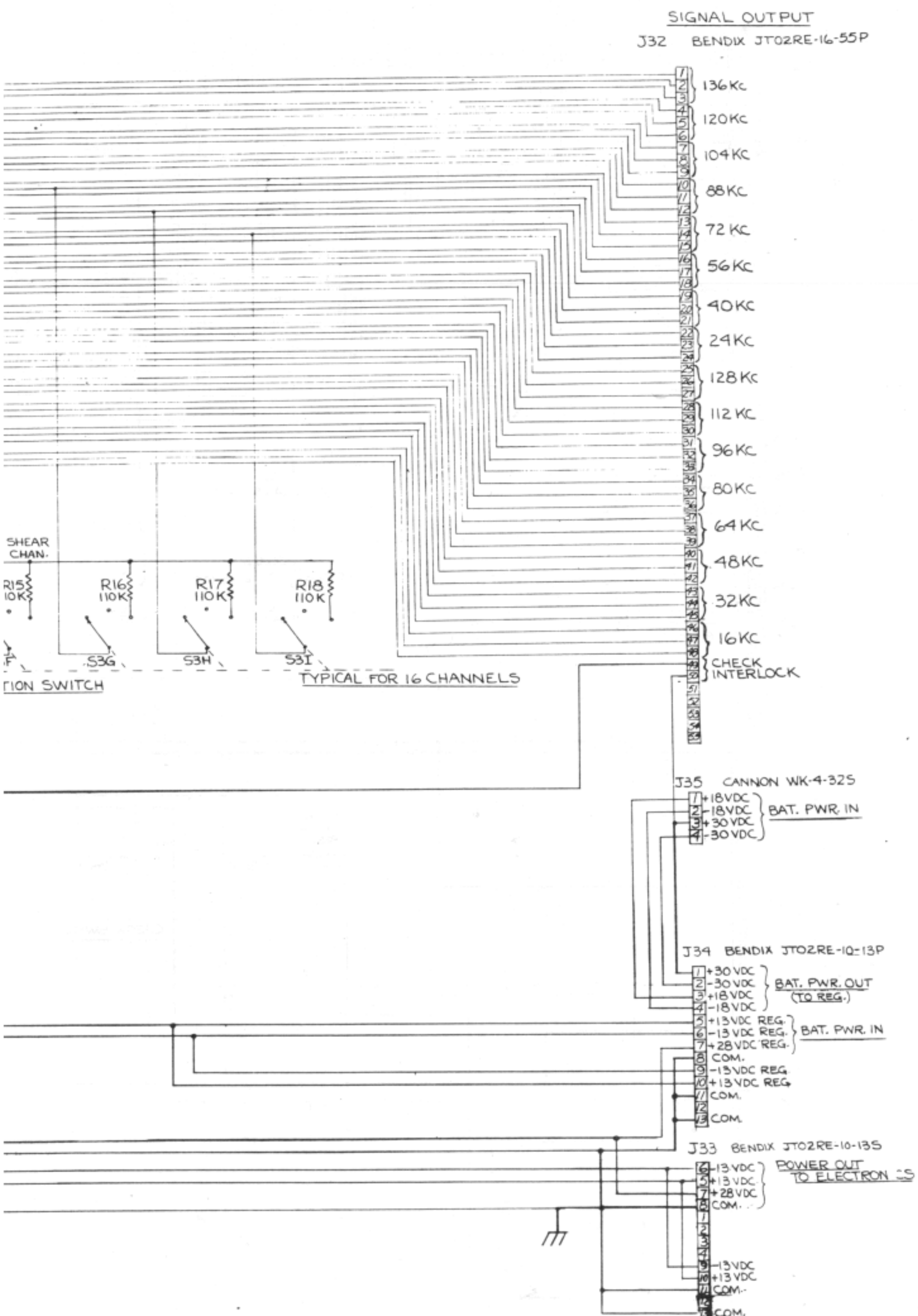
FIGURE 24.



UNLESS OTHERWISE SPECIFIED: MARK PART IDENTIFICATION; ASSEMBLY AND DETAILS. DIMENSIONS ± ANGLES ± FILLET RADII TO SURFACES HAVING A COMMON AXIS CONCENTRIC WITHIN TIR. BREAK ALL EDGES TO SURFACE FINISHES RMS MAX.	Hamilton Standard
	SCHEMATIC DIAGRAM CALIBRATION UNIT
MATERIAL / HARDNESS — DRAWN A.J.W. 9/67 — CHECKED 9/68 — DRAFTING	SK68756

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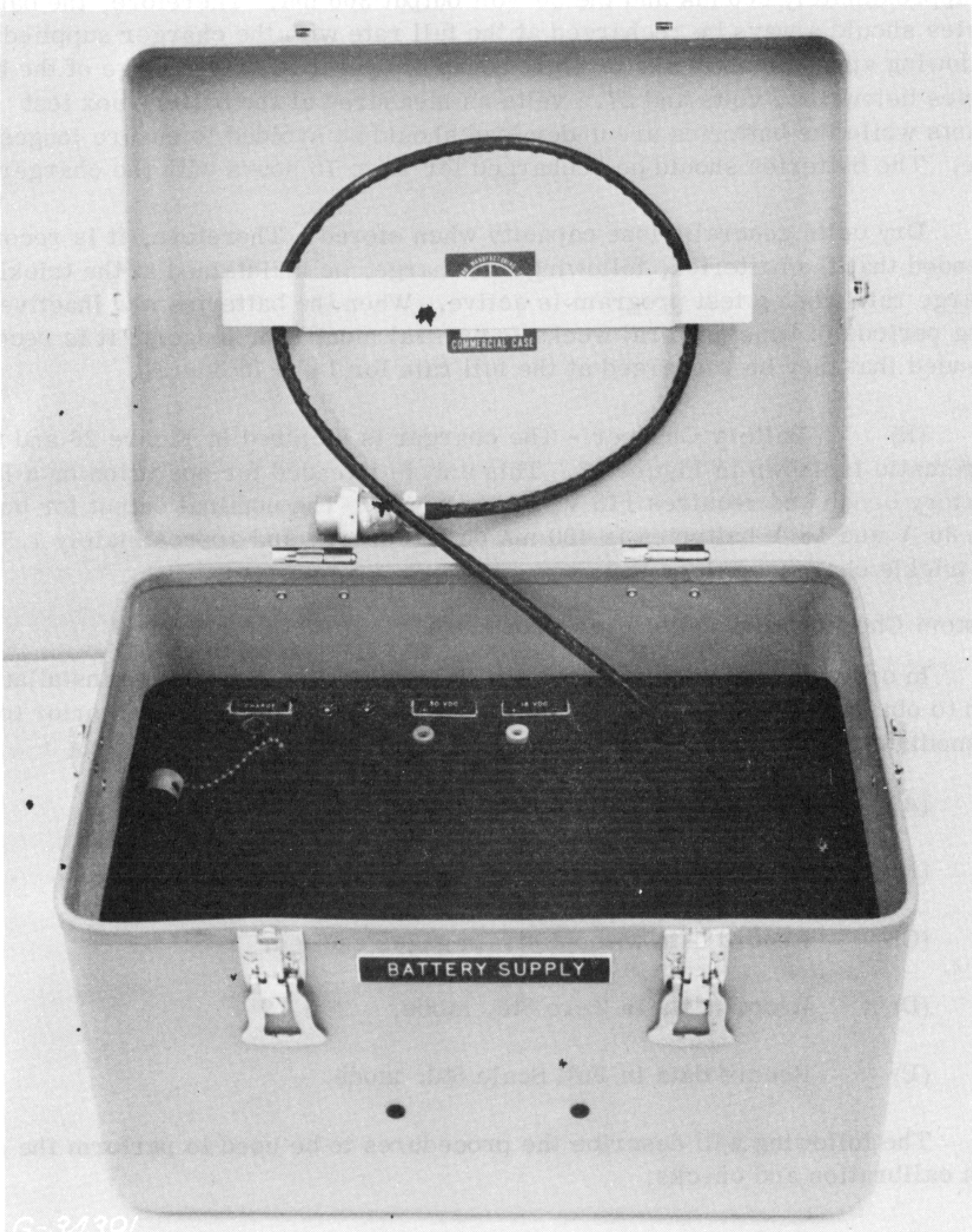

FIGURE 25. BATTERY SUPPLY

The batteries used provide a nominal four ampere-hour capacity per cell. However, for best life these cells are designed to operate at approximately a ten hour discharge rate (400 mA for 10 hours). The load on the 18 volt output is approximately 600 mA and the 30 volt output 300 mA. Therefore, the batteries should always be recharged at the full rate with the charger supplied following approximately six to eight hours of operation. Discharge of the batteries below 16.5 volts and 27.5 volts as measured at the battery box test points while the batteries are under load should be avoided to ensure longest life. The batteries should be recharged for 14 to 16 hours with the charger.

Dry cells generally lose capacity when stored. Therefore, it is recommended that the batteries, following full charge, be maintained at the trickle charge rate when a test program is active. When the batteries are inactive for long periods of time (several weeks to several months or longer), it is recommended that they be recharged at the full rate for 14 to 16 hours.

(H) Battery Charger - The charger is pictured in Figure 26.and the schematic is shown in Figure 27. This unit is intended for operation on a laboratory bench and requires 115 V, 60 Hz power. The nominal output for both the 30 V and 18 V batteries is 400 mA on full charge and approximately 1.5 mA on trickle charge.

System Checkout and Calibration Procedure

In order to periodically check the integrity of the strain gage installation and to obtain calibration data, the following should be accomplished prior to and immediately after each day's running:

(A) Check resistance of each strain gage.

(B) Check leakage resistance to ground of each strain gage.

(C) Record data without strain gages excited.

(D) Record data in Zero Std. mode.

(E) Record data in Full Scale Std. mode.

The following will describe the procedures to be used to perform the system calibration and checks.

(A) Cable Setup - Refer to Figure 28 for the normal system cable interconnections (solid lines) for the propeller instrumentation and the interconnections (dashed lines) for the calibration setup. Specifically, the following cable changes are to be made in order to perform the system checks:

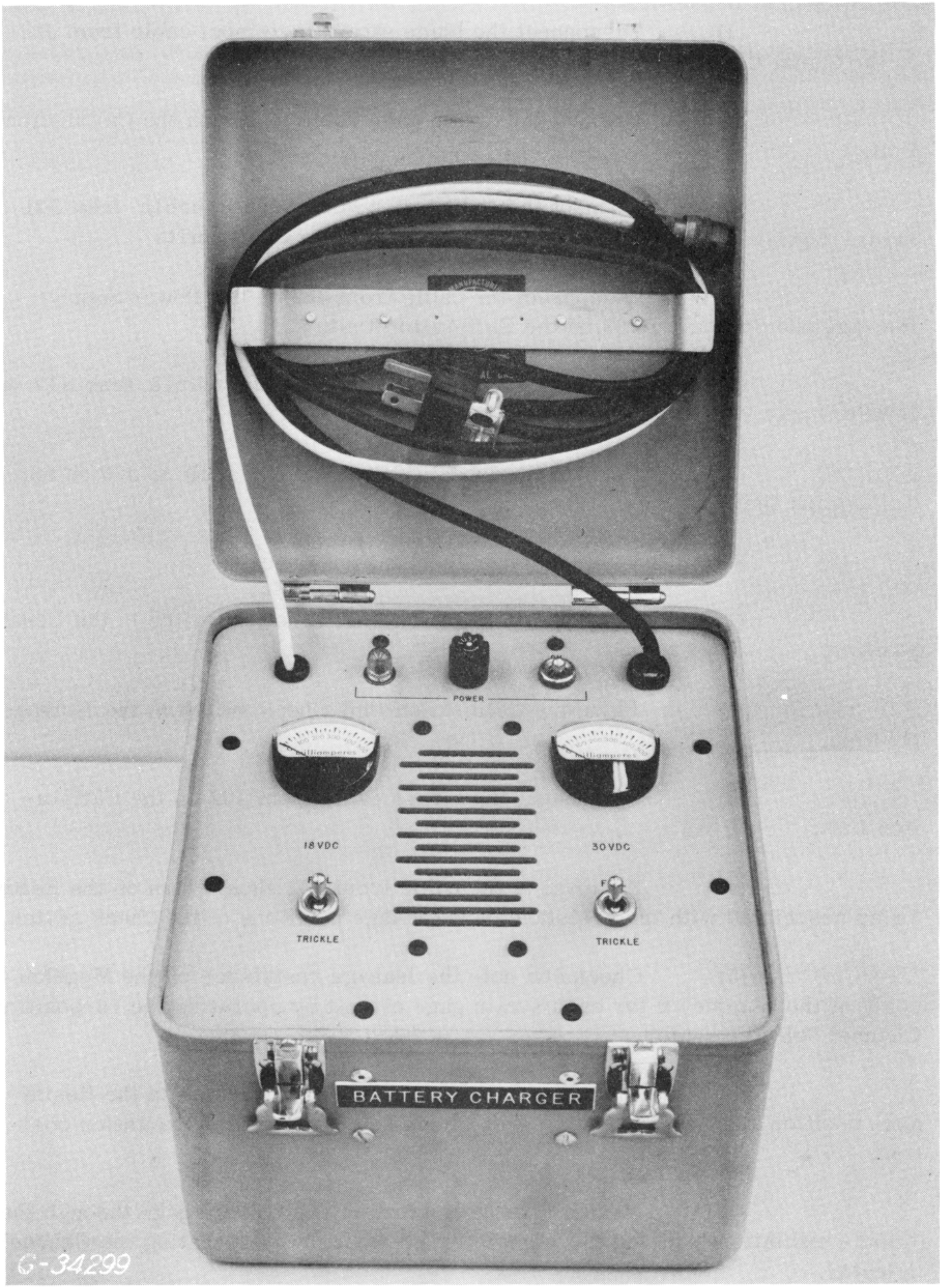

FIGURE 26. BATTERY CHARGER

(1) Disconnect the blade strain gage input cable from J21 on the Signal Conditioning Package.

(2) Connect the strain gage cable to J31 on the Calibration Unit.

(3) Connect the Calibration Unit signal cable from J21 on the Signal Conditioning Package to J32 on the Calibration Unit.

(4) Disconnect the cable from J12 on the Power Supply Package and connect to J33 on the Calibration Unit.

(5) Connect the Calibration Unit power cable from J12 on the Power Supply Unit to J34 on the Calibration Unit.

(6) Connect the Battery Power Supply cable to J35 on the Calibration Unit.

(B) Strain Gage Resistance and Leakage Checks

(1) Place the Calibration Unit Function switch in the Check position.

(2) Place the Calibration Unit Check switch in the Leakage position.

(3) Disconnect the signal cable from J32 on the Calibration Unit.

(4) Removal of the cable from J32 should turn on the Ready Lamp associated with the Resistance and Leakage positions of the Check switch.

(5) Check and note the leakage resistance on the Megohm scale of the ohmmeter for each strain gage circuit by operating the 16-position Channel Selector switch.

(6) Place the Calibration Unit Check switch in the Resistance position and the Calibration Unit Check Selector in the - Excitation position.

(7) Measure the resistance of each strain gage through the + and - excitation leads on the ohmmeter ohms scale by operating the Channel Selector.

(8) Place the Check Selector in the Output position.

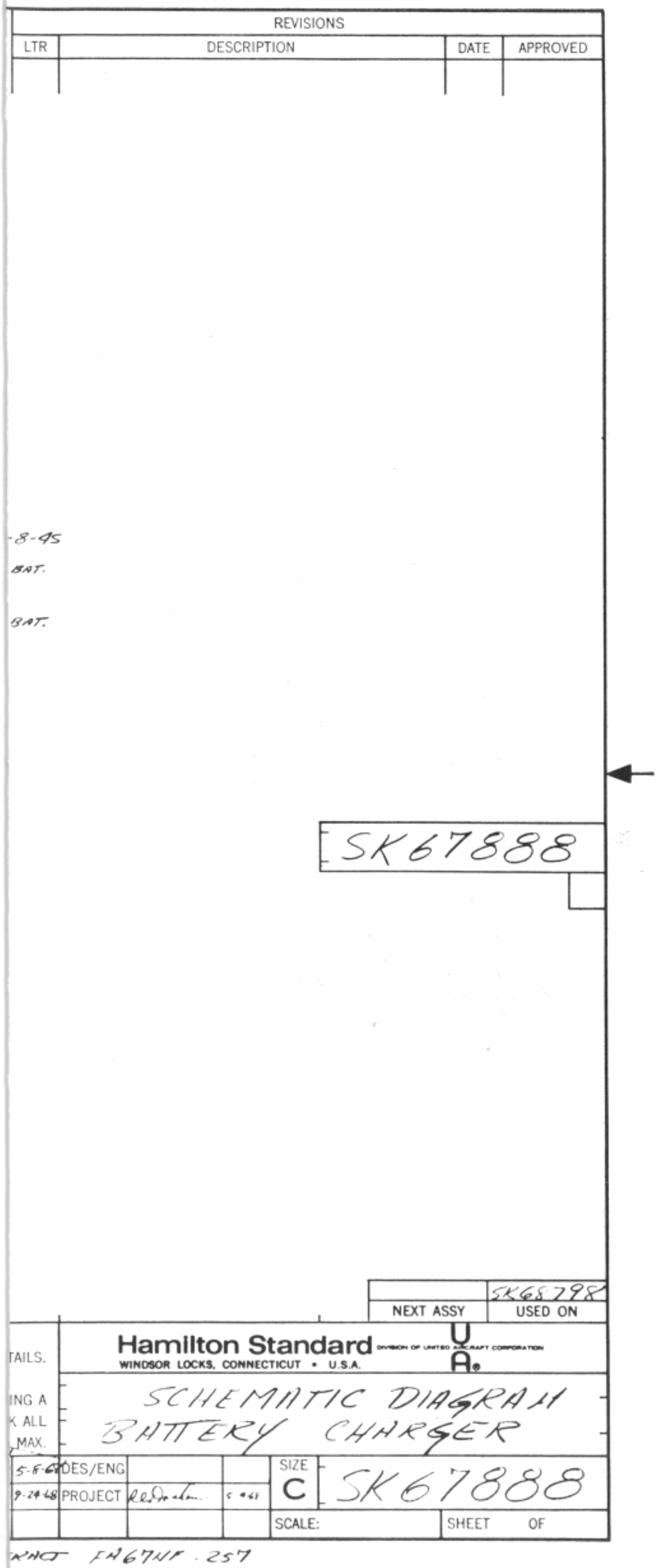
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FIGURE 27.

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SCHEMATIC DIAGRAM
BATTERY CHARGER

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CABLE INTERCONNECTIONS
FAA PROPELLER MEASUREMENT SYS.

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FIGURE 28.

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CABLE INTERCONNECTIONS
FAA PROPELLER MEASUREMENT SYS.

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(9) Measure the resistance of each strain gage through the + excitation and output leads by operating the Channel Selector.

NOTE: These checks are intended to determine the approximate leakage situation (good or bad) and to give an indication of the gross strain gage resistance so that an open or shorted gage or substantial gage resistance shift can be detected.

(C) VCO Stability Check

(1) Replace the cable disconnected from J32 on the Calibration Unit.

(2) With the Function switch in the Check position the Ready Lamp associated with the Zero In and AC In positions on the Check switch should be illuminated.

(3) Place the Check switch in the Zero In position. This provides for checking the VCO Zero stability with the VCO inputs connected to the unexcited strain gage bridges.

(4) Connect the Monitor Discriminators to one of the group of four outputs from the Translator Package.

(5) Using the Frequency Counter measure and note each of the four VCO frequencies (16 kHz, 24 kHz, 32 kHz and 40 kHz band) at the discriminator band pass filter output.

(6) Repeat (d) and (e) for each of the four Translator outputs to measure the frequency from all sixteen translated VCO's.

(7) Record data on Tape Recorder for approximately 30 seconds.

(8) This data will provide information relative to the long term VCO stability.

(D) AC or Frequency Response Checks

(a) The AC IN position of the Check switch provides for the insertion of ac signals from the test oscillator for system measurements (not required as a daily check).

(E) Zero Calibration

(1) Place the Function switch in the Zero Std. position.

(2) This data provides the VCO output frequency for zero strain input on each data channel.

(3) The dc output level from each channel can be observed at the Discriminator Outputs with the monitor oscilloscope. This signal should be a constant, noise-free dc level.

(4) Record this data for approximately 30 seconds.

(F) Full Scale Calibration

(1) Place the Function switch in the Full Scale Std. position.

(2) This data provides the VCO output frequencies with each channel shunted to provide an equivalent input strain level.

(3) The dc output level from each channel can be observed at the Discriminator Output with the monitor oscilloscope. This signal should be a constant, noise-free dc level.

(4) Record this data for approximately 30 seconds.

(G) Cable Setup - After completion of the above checks, reinstall cables to the normal operating condition.

(1) Remove the Calibration Unit cable from J21 on the Signal Conditioning Package.

(2) Remove the strain gage input cable from J31 on the Calibration Unit and connect to J21 on the Signal Conditioning Package.

(3) Remove the Calibration Unit power cable from J12 on the Power Supply Package.

(4) Remove the regulator power input cable from J32 on the Calibration Unit and connect to J12 on the Power Supply Package.

Evaluation of the Data System

The data system was assembled on a test rig at Hamilton Standard before delivery to the NAFEC facility. These tests were used to evaluate the power output capability of the alternator, regulation of the power supplies, capacitor coupling and the system signal-to-noise ratio. The system was operated satisfactorily over a range of 600 to 3000 rpm. Adequate power was available from the alternator at 800 rpm and the 12.8 and 28 Vdc power supplies regulated within specification from 800 to 3000 rpm. The capacitor coupling was evaluated and measurement of the series and shunt capacitances yielded the values shown in Figure 11.

The system signal-to-noise ratio was checked with the rotating data system output capacitively coupled to the Line Driver, which was connected to the Translator Package. The resultant Translator outputs were demodulated with the Monitor Discriminators. The peak-to-peak output noise ranged between one percent and five percent of full scale. However, the several channels which exhibited a peak-to-peak noise level approaching five percent were affected by electromagnetic coupling from the alternator. This was due to the fact that the dummy strain gages used to terminate the system inputs (the instrumented propeller was not included in this test rig) had to be located at a point susceptible to pickup from the alternator due to physical limitations of the test rig.

The data system and strain gaged propeller were delivered to NAFEC on July 12, 1968, and the system was assembled on a Lycoming 0-540-A1D5 engine on a test stand. Figure 29 is a photograph of the propeller and data system mounted on the test engine.

The engine was operated for a period of 50 hours while the signal outputs from the data system were observed. The engine was operated in a manner that exposed the propeller mounted data system to simulated flight cycles. During this period of time calibration checks were performed before and after each daily run and the quality of the data was observed throughout the test. In addition, the multiplexed data at the translator output was recorded on magnetic tape and later played back and demodulated. Frequency analysis was performed on demodulated tape recorded data and on real time data at the outputs of the Monitor Discriminators while the engine was operating. A block diagram of the instrumentation setup used on the engine test stand is shown in figure 30.

The demodulated data observed at the Monitor Discriminator outputs during the engine test stand operation exhibited an excellent signal-to-noise ratio. Noise components were found to be on the order of one to three percent peak-to-peak maximum. An rms measurement would indicate a signal-to-noise ratio of 34dB. Frequency analysis of this data indicated that maximum noise frequency components due to the alternator ranged between one-half and three percent of full scale. Frequency analysis of demodulated data played back from magnetic tape clearly indicated the fundamental propeller frequency orders.

The calibration data taken for 12 of the 16 data channels during the operation of the test stand for a two month period has been tabulated and plotted in figures 31 through 42. Data for the four highest frequency channels are not included since the highest frequency translator was not available until near the end of the two month test period. However, the limited amount of data avail-

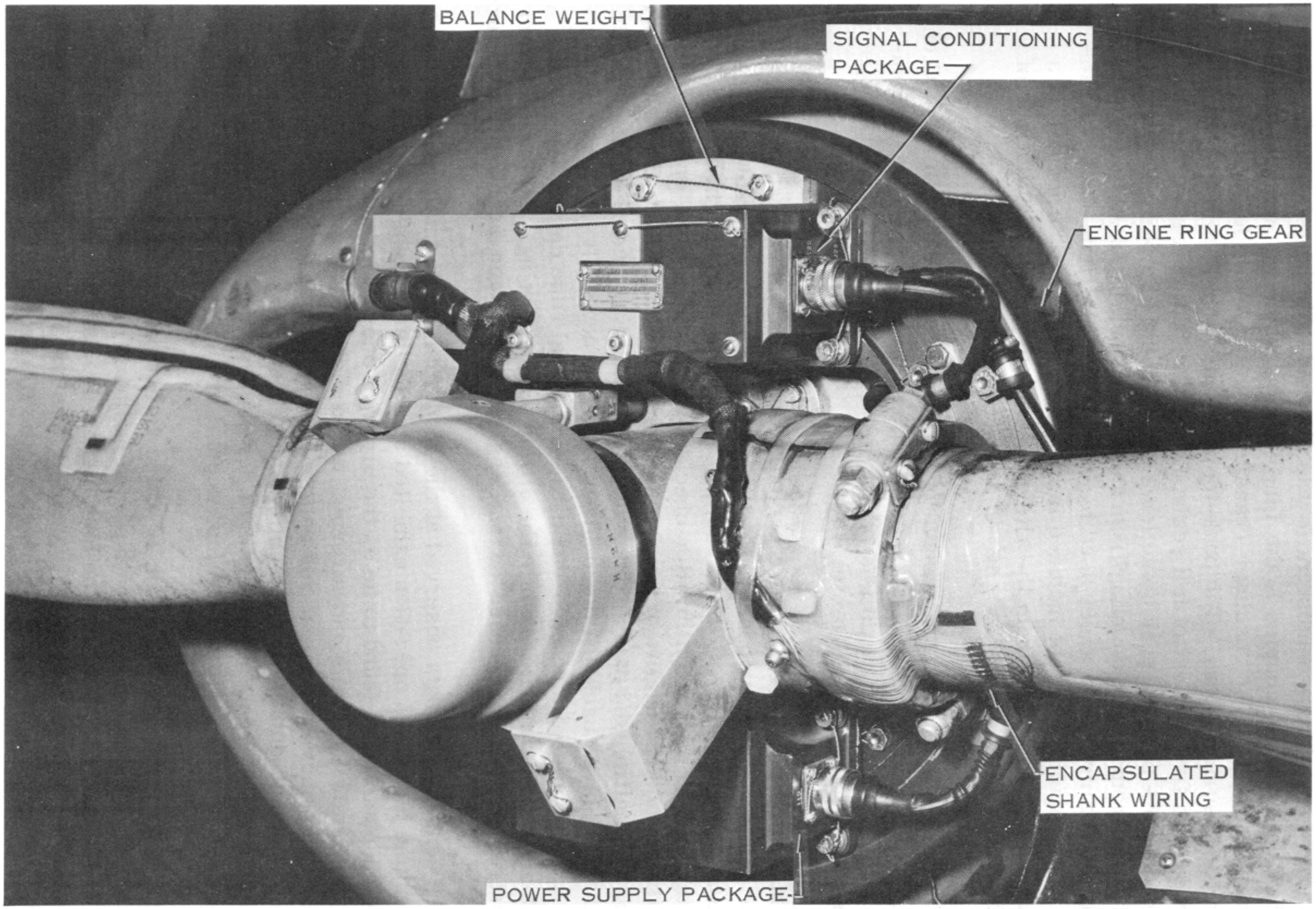

FIGURE 29. ENGINE TEST STAND INSTALLATION

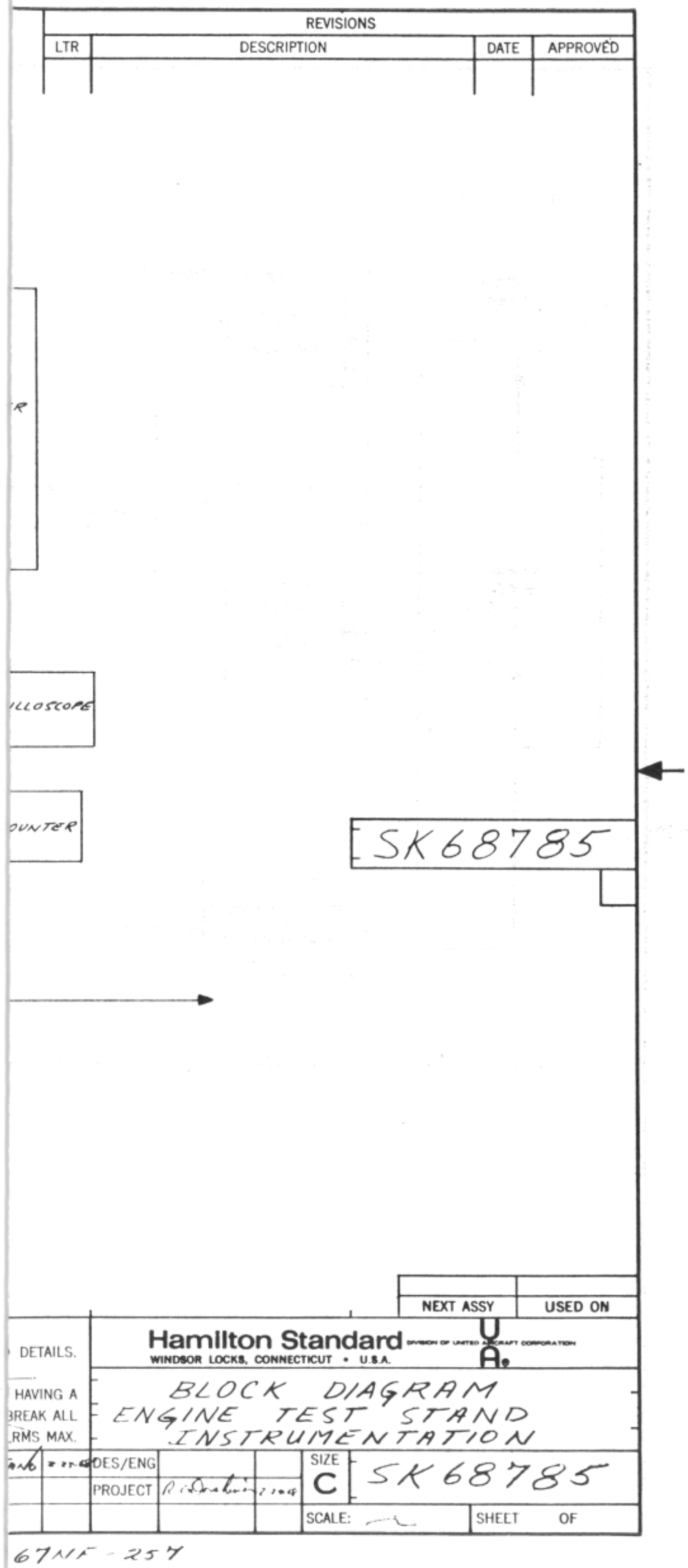
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FIGURE 30.

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ENGINE TEST STAND
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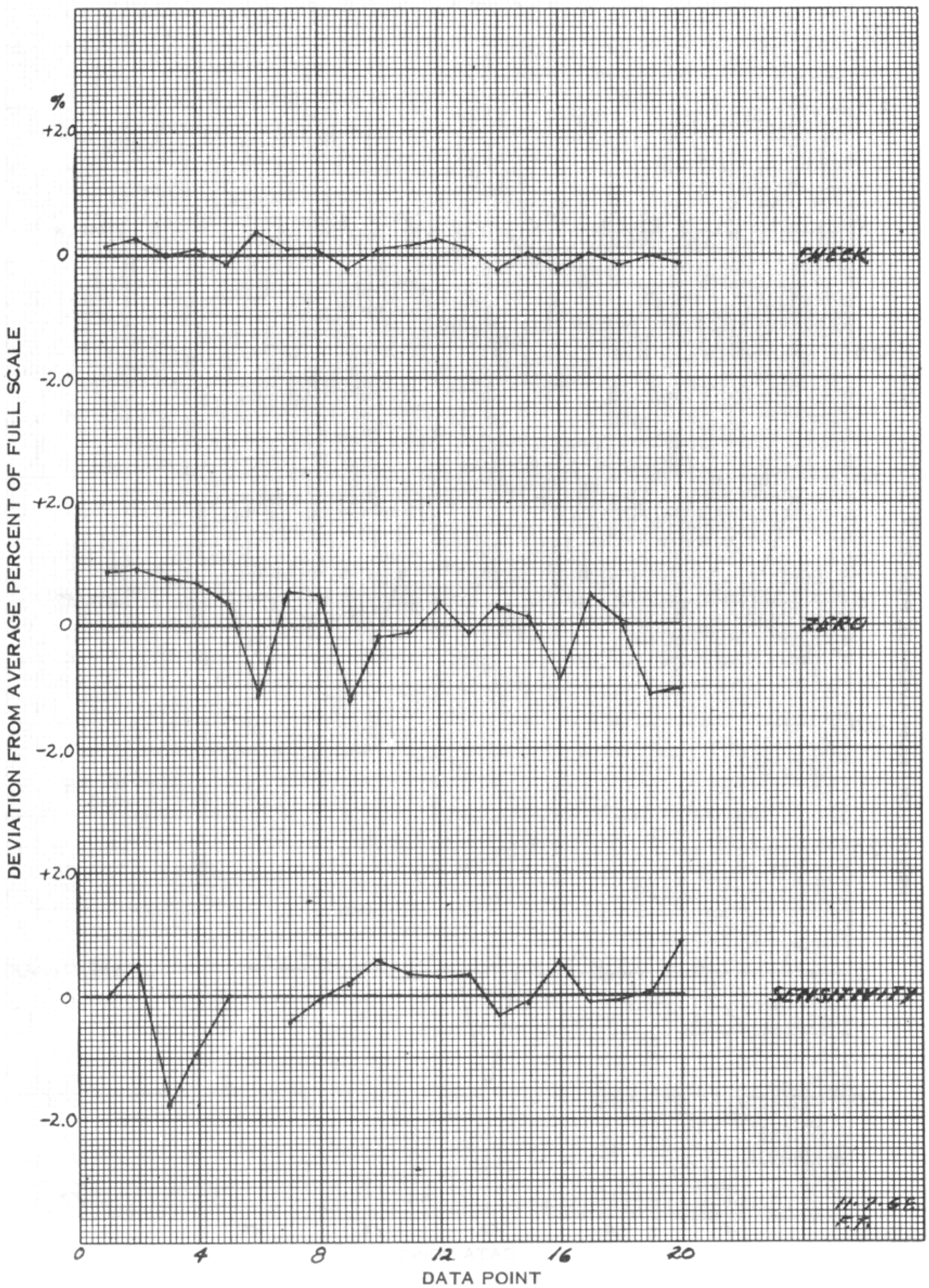


FIGURE 31. CHANNEL 1 — 16 KHZ

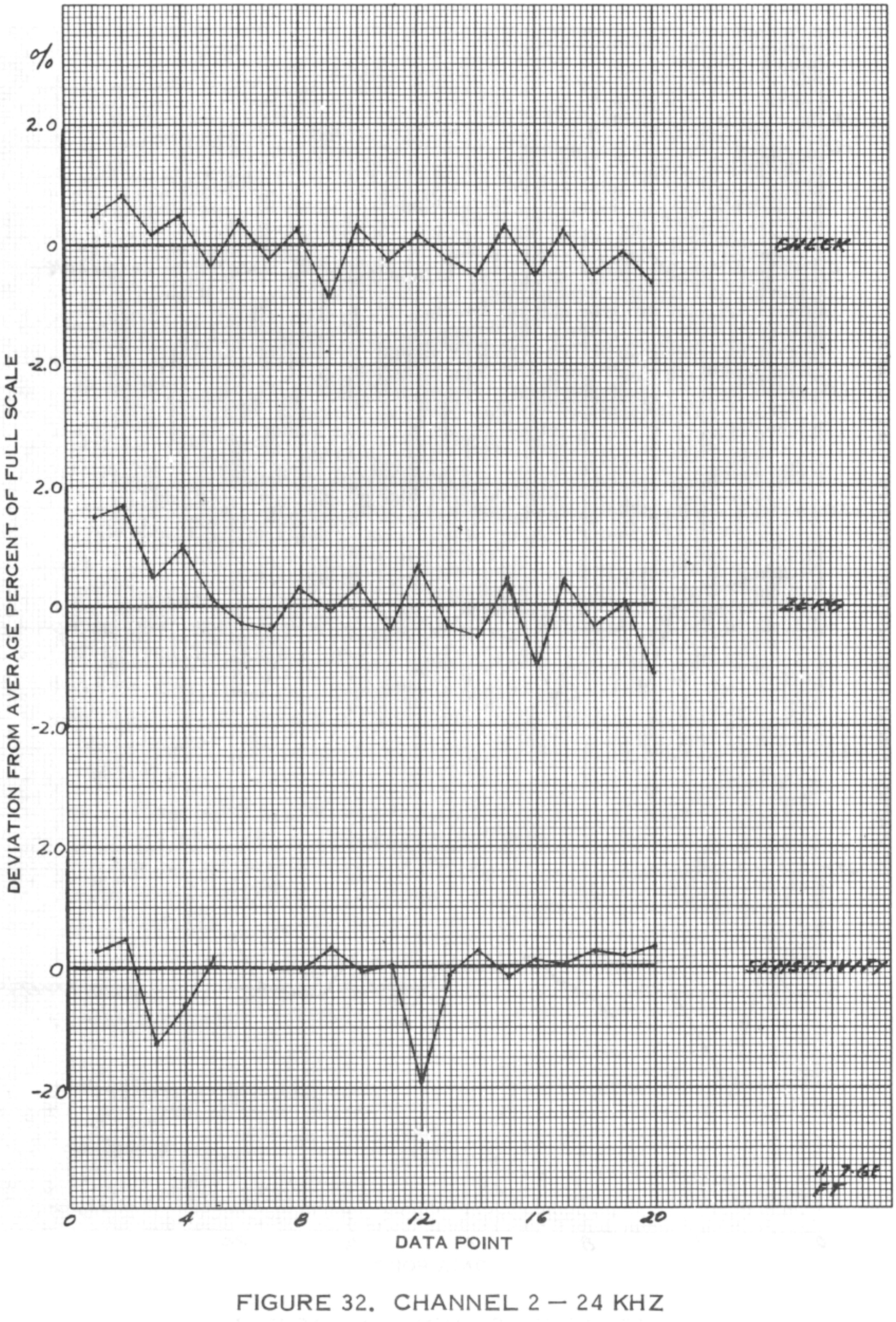


FIGURE 32. CHANNEL 2 — 24 KHZ

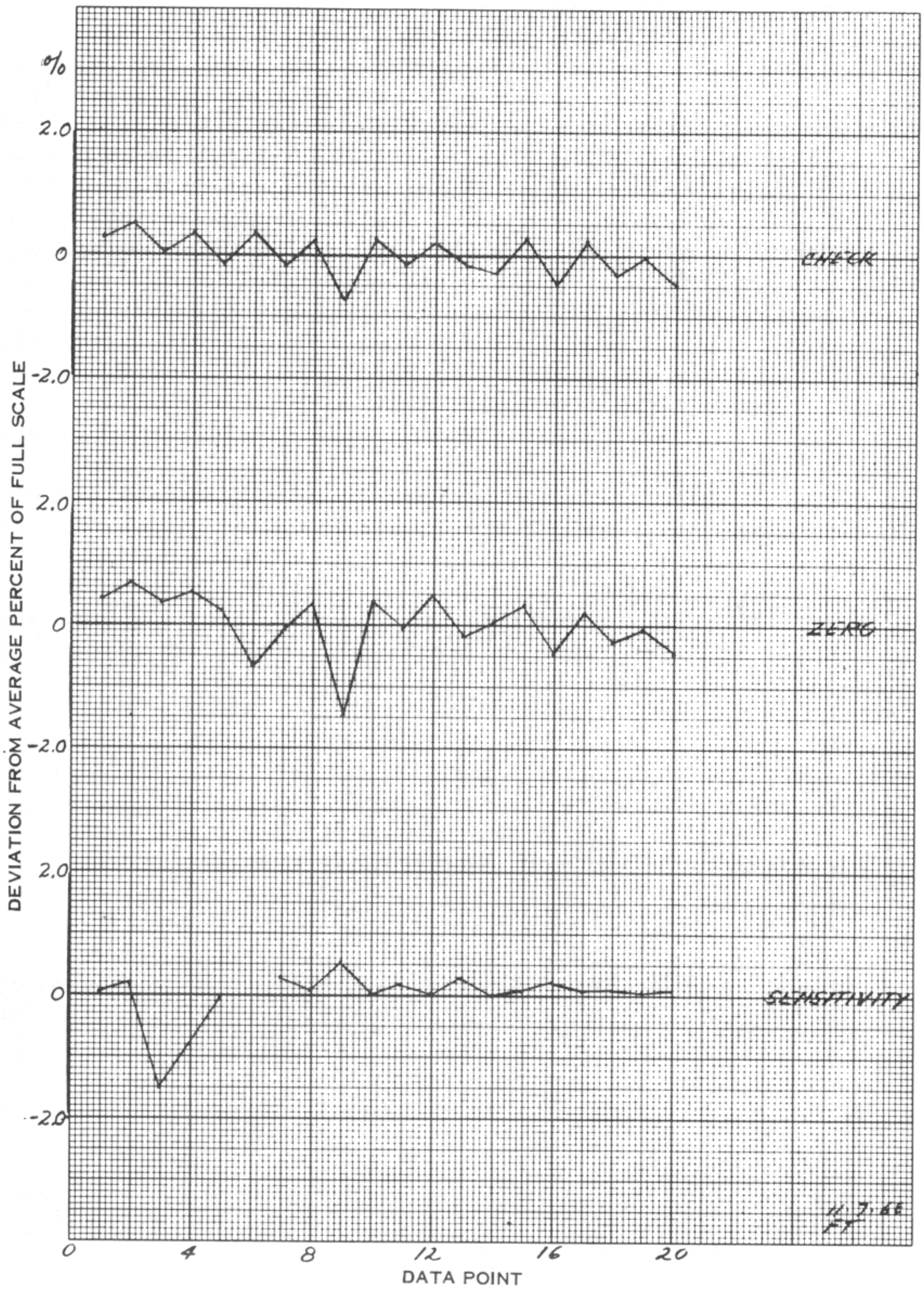


FIGURE 33. CHANNEL 3 — 32 KHZ

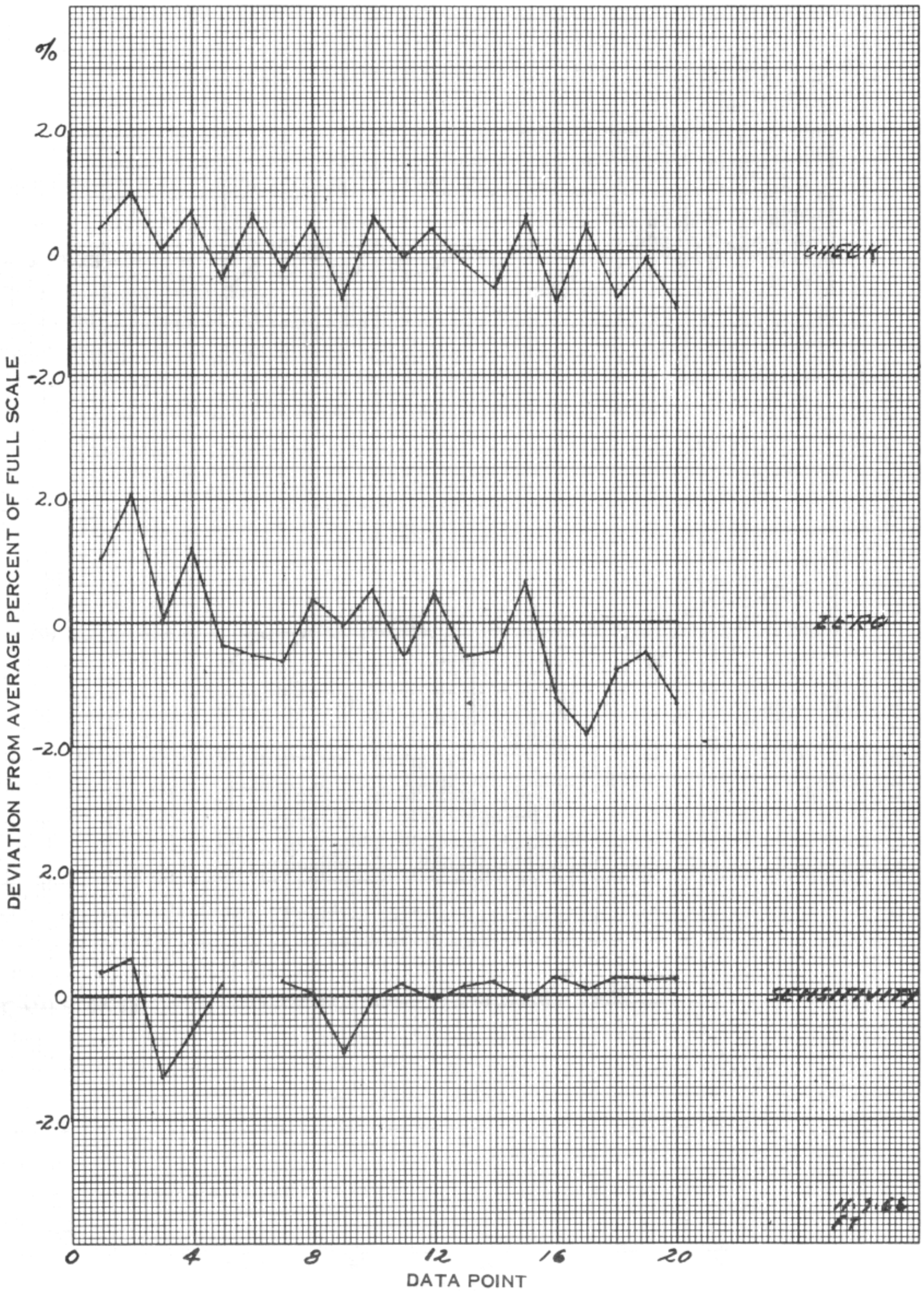


FIGURE 34. CHANNEL 4 — 40 KHZ

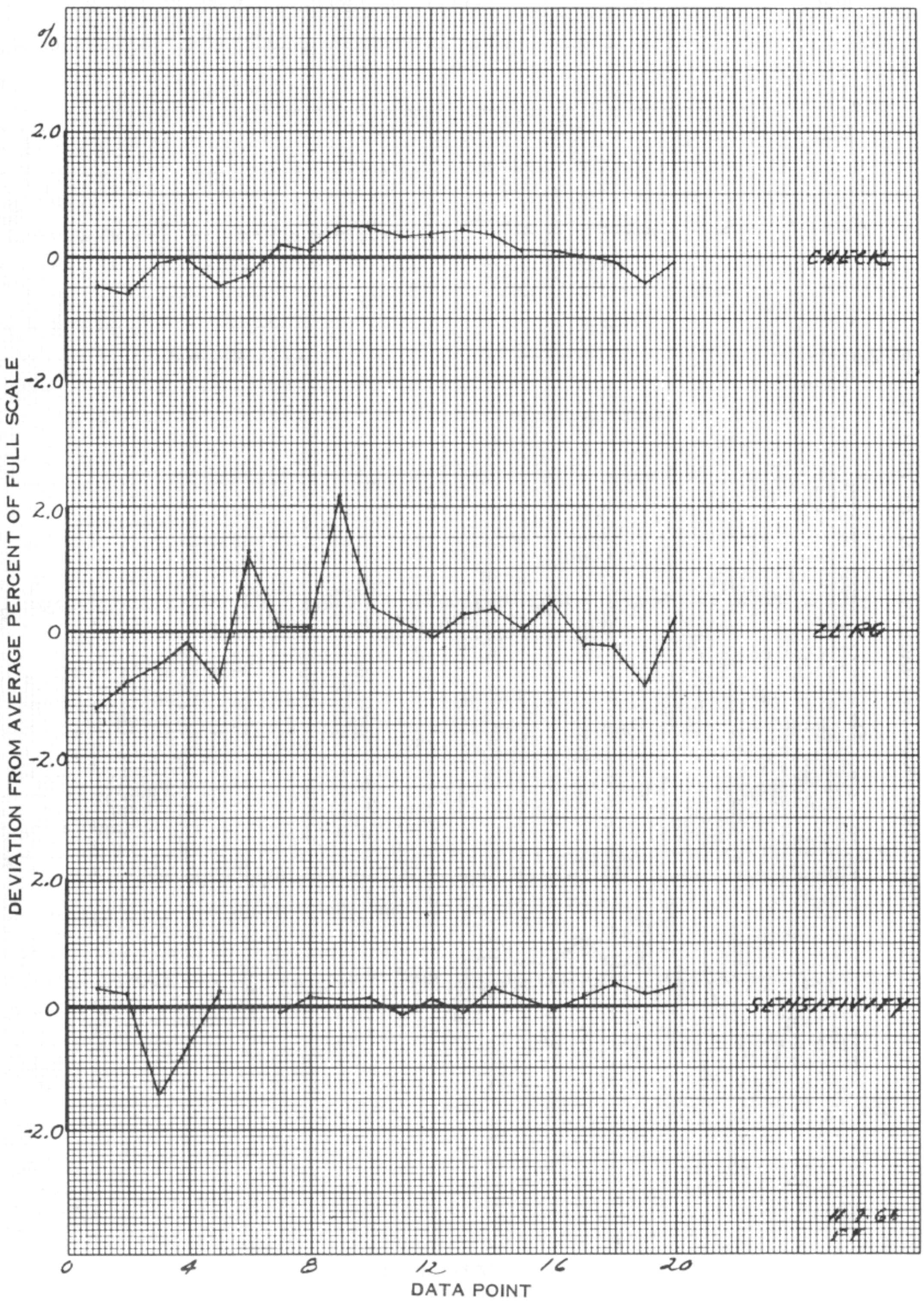


FIGURE 35. CHANNEL 5 — 48 KHZ

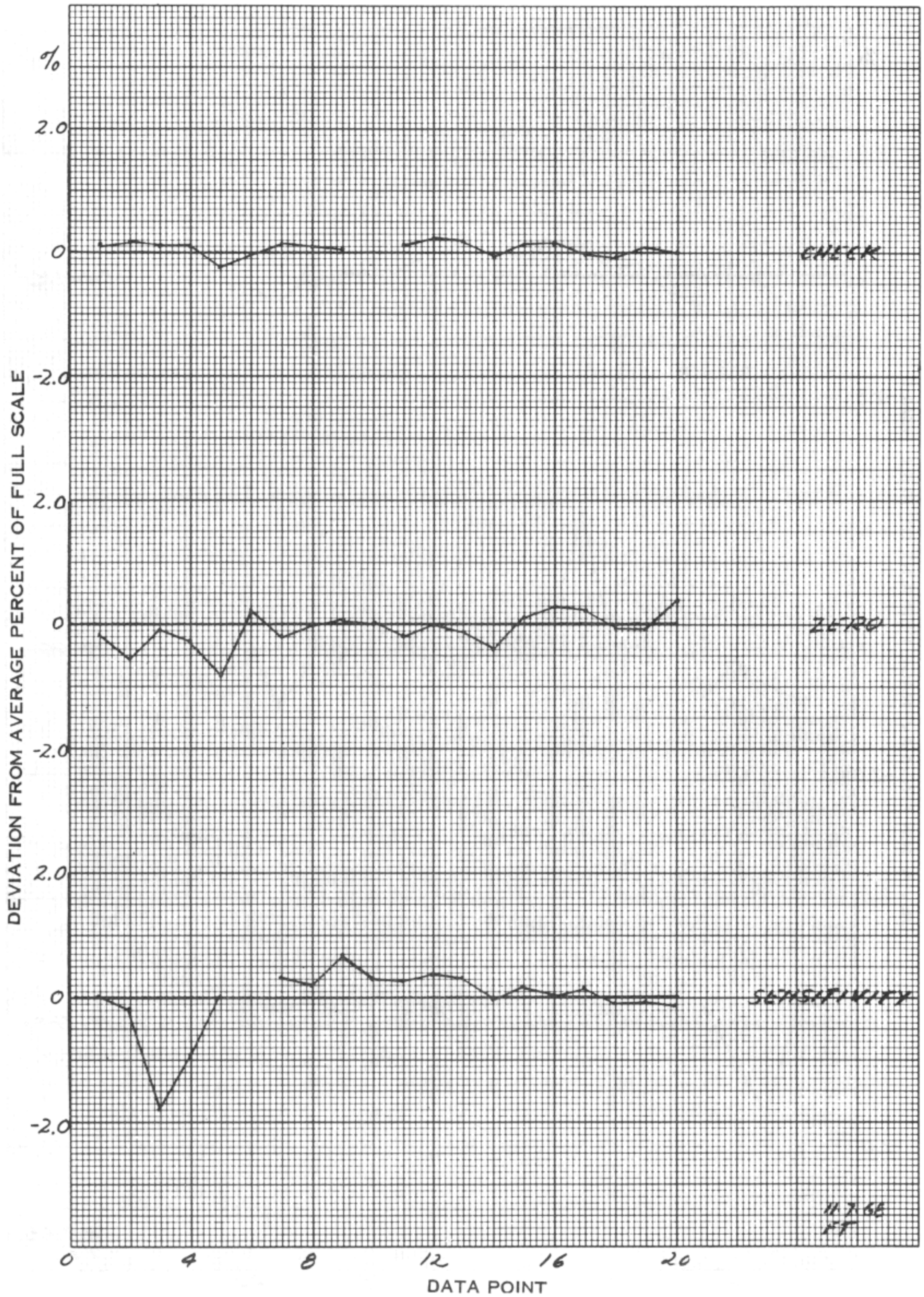


FIGURE 36. CHANNEL 6 — 56 KHZ

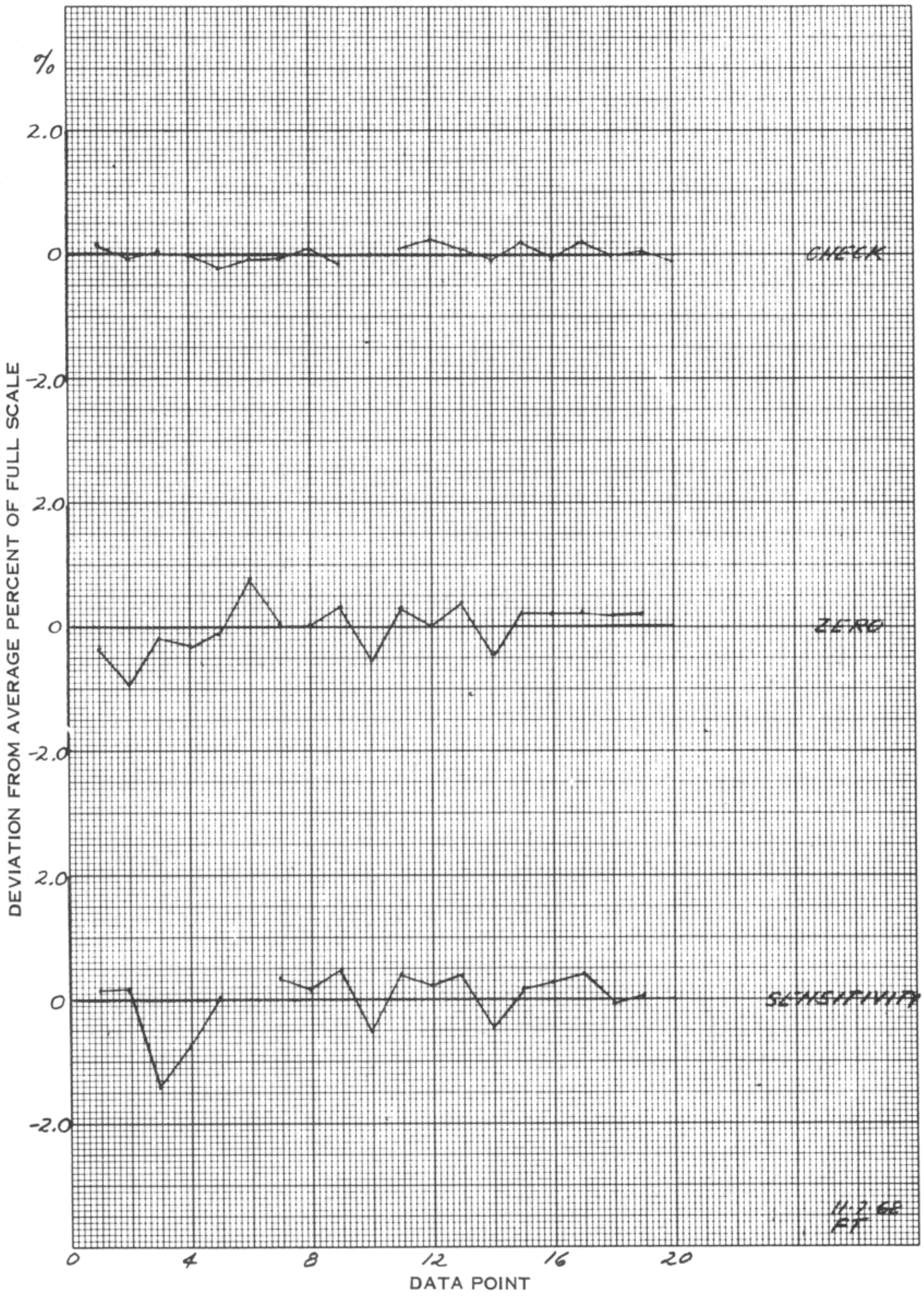


FIGURE 37. CHANNEL 7 — 64 KHZ

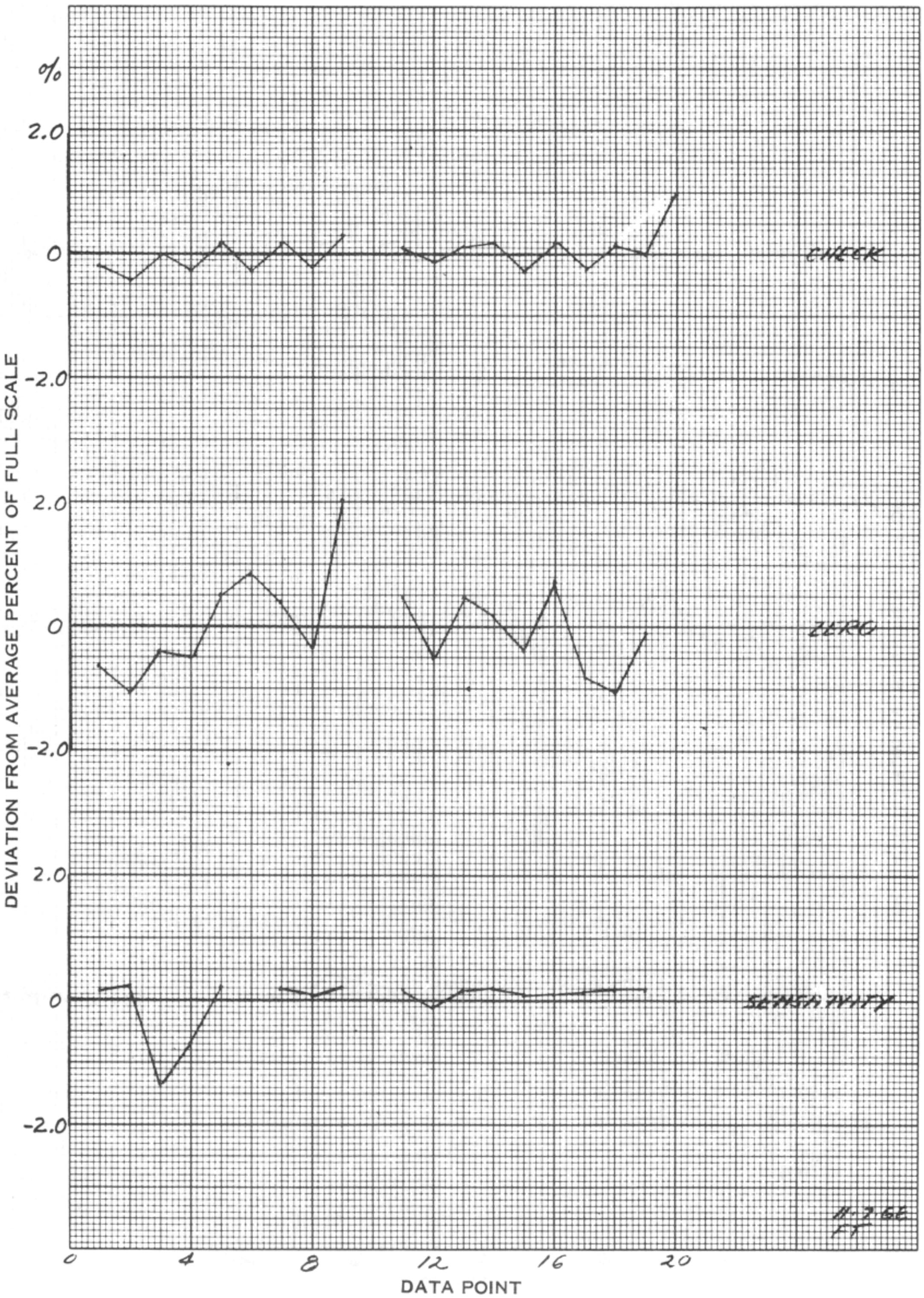


FIGURE 38. CHANNEL 8 — 72 KHZ

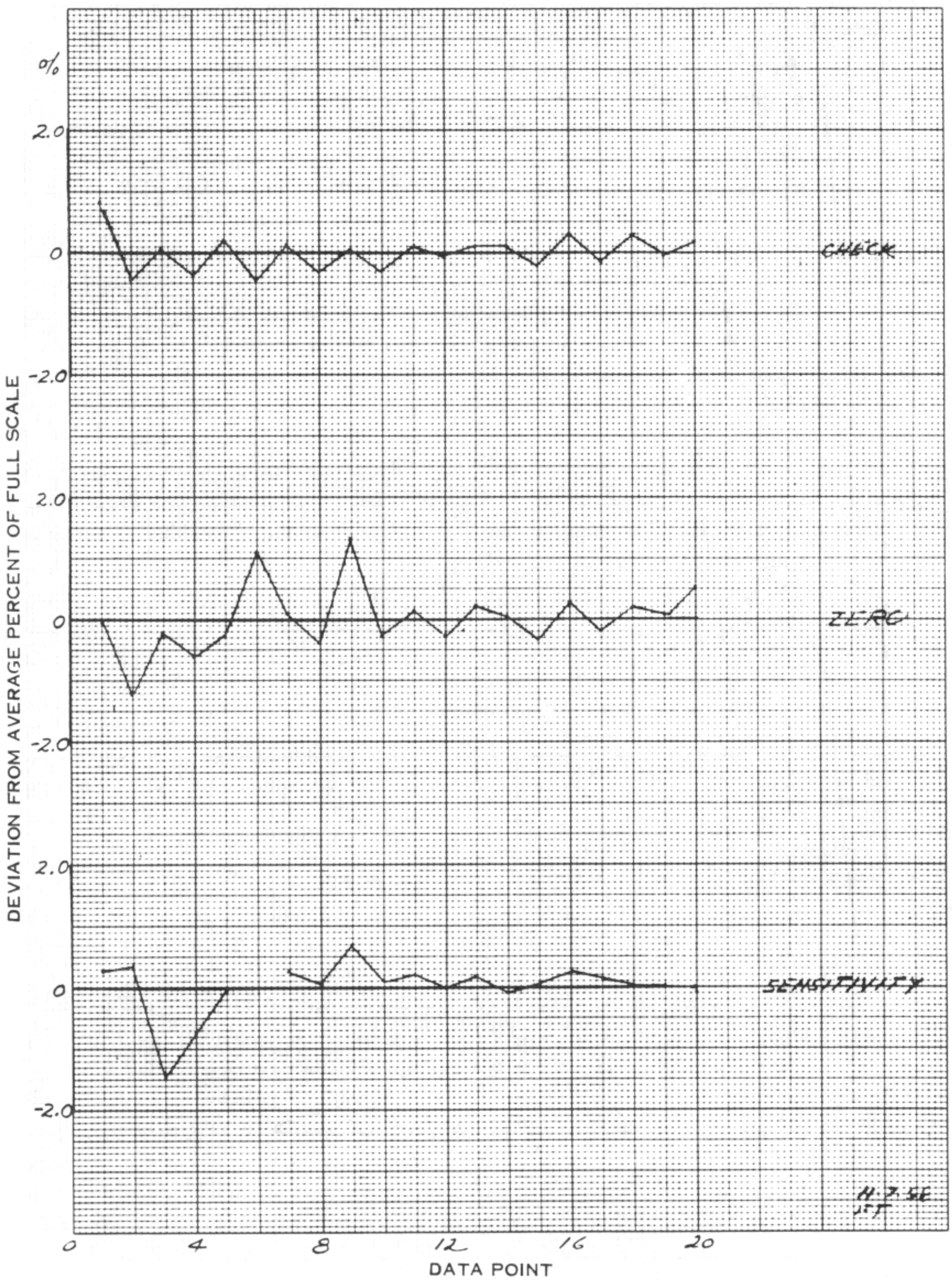


FIGURE 39. CHANNEL 9 — 80 KHZ

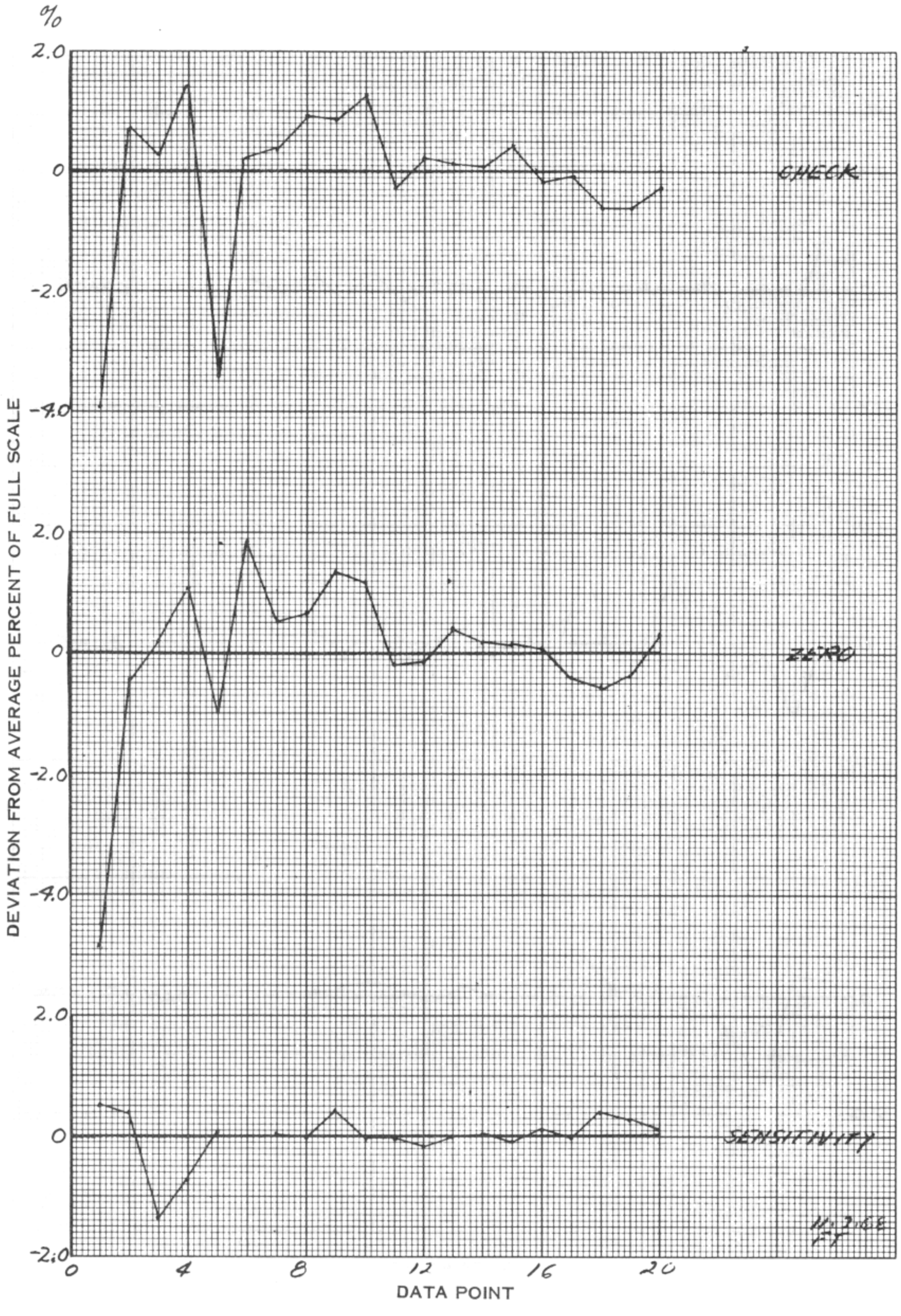


FIGURE 40. CHANNEL 10 — 88 KHZ

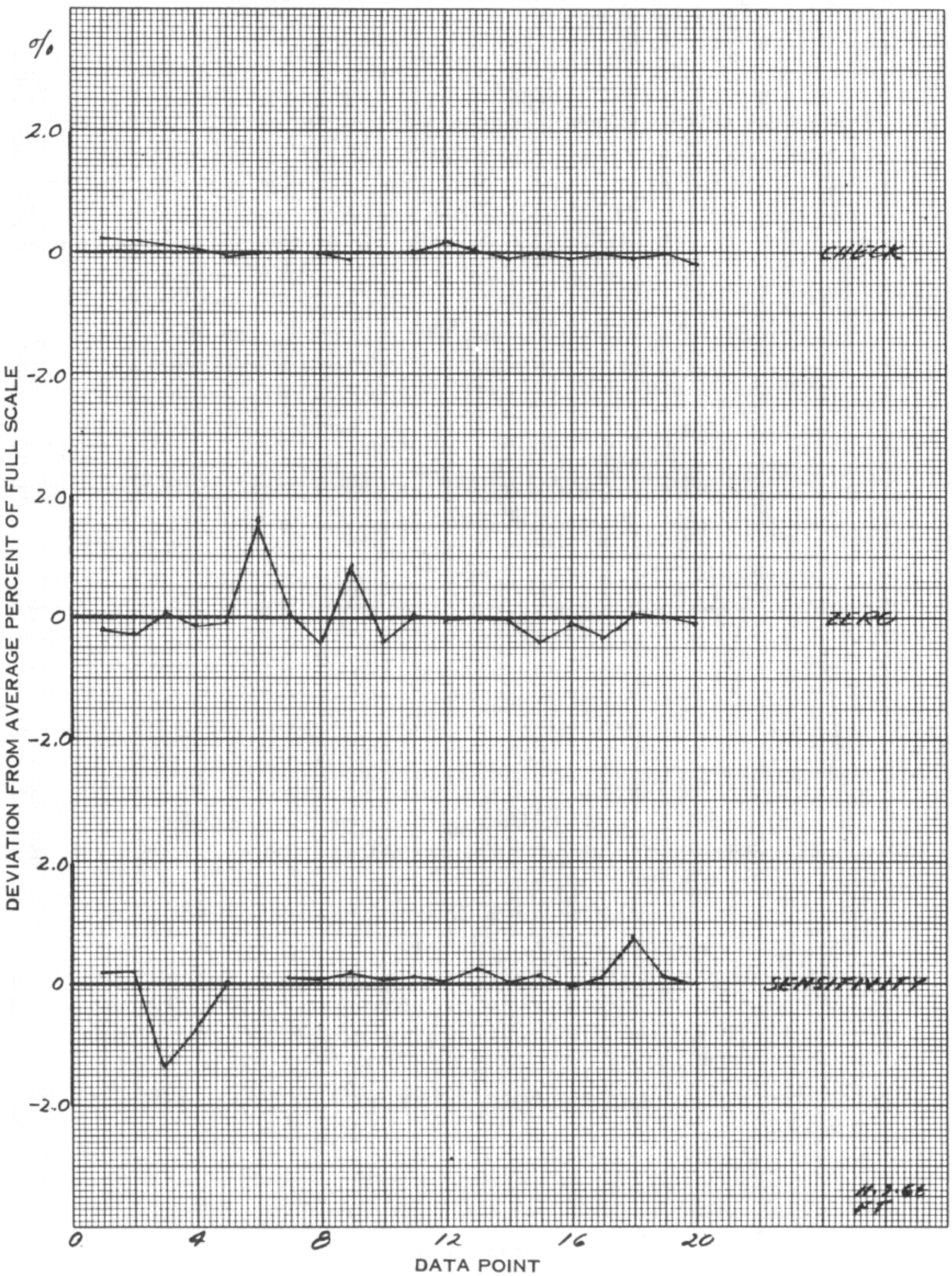


FIGURE 41. CHANNEL 11 — 96 KHZ

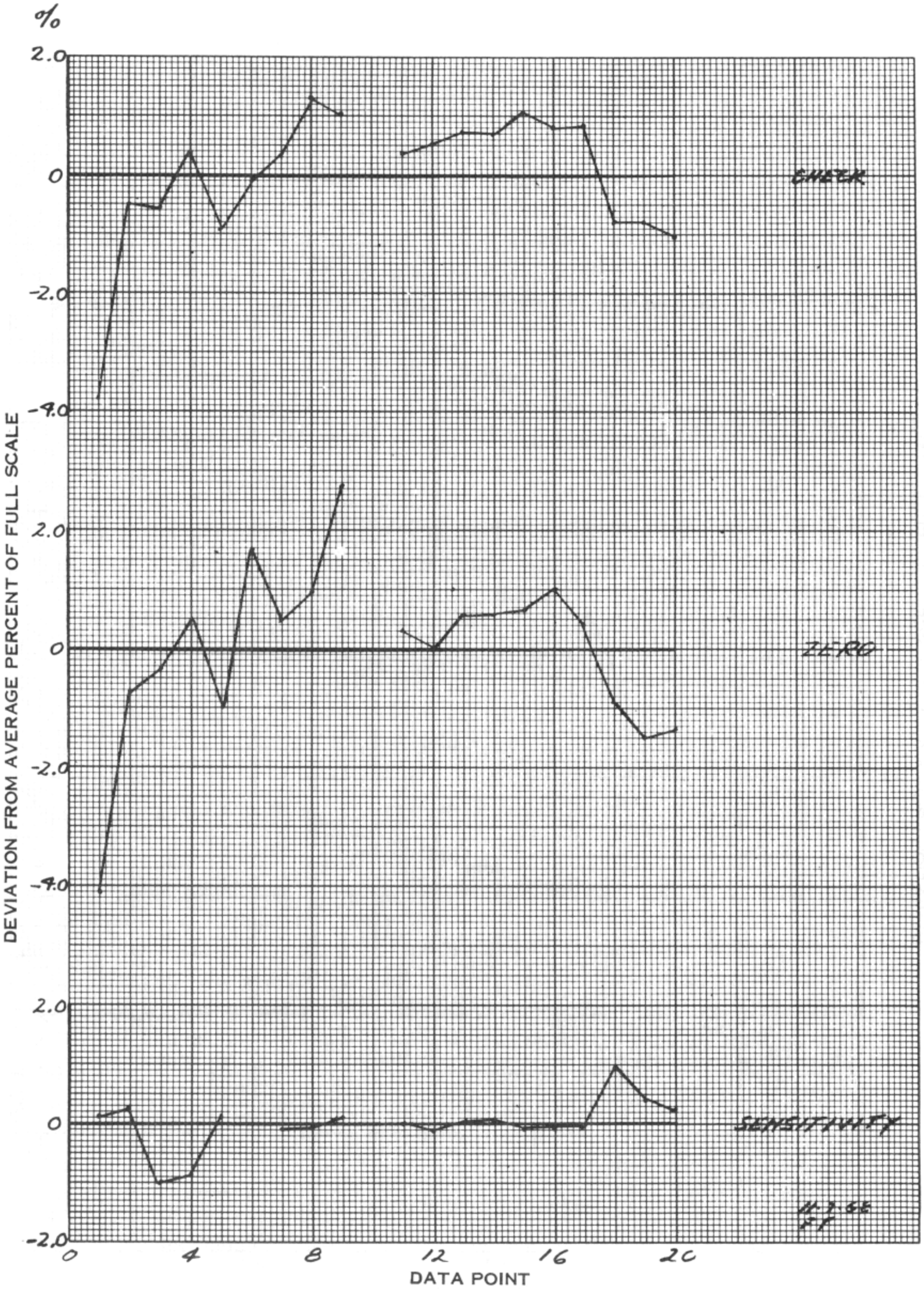


FIGURE 42. CHANNEL 12 — 104 KHZ

able for those channels indicated similar channel stability.

The above data were obtained for the following conditions of the Calibration Unit:

(A) Check - The system gage circuits are connected to the data system but excitation voltage is not applied to the gages. This serves as a zero signal input to the data system.

(B) Zero Standardize - The strain gage circuits are connected to the data system and excitation is applied to the strain gages. This provides a zero strain input to the data system.

(B) Full Scale Standardize - The strain gage circuits are connected to the data system, excitation voltage is applied to the strain gages, and each bridge circuit is shunted with 110 kilohms to provide a signal in the direction of tension strain.

The data presented in Figures 31 through 42 show the changes in percent of full scale from the average value for each recorded data point. That is, the average value for all data points was obtained, then the deviation from the average was calculated and plotted for each data point.

The significance of the three curves for each channel can be explained as follows:

(A) Check - This curve demonstrates the long term stability of the Preamplifier, VCO, and Translator zero since the equivalent system input is zero with the input circuits terminated by the unexcited strain gage bridges.

(B) Zero - This plot adds the effect of the strain gage circuit stability to the electronics zero stability since the strain gages are excited for these data points. Therefore, long term creep and electrical leakage resistance changes will be demonstrated by these data points.

(C) Sensitivity - This plot displays the change from average value of the difference between the Full Scale Std. and Zero Std. values. Therefore, the system sensitivity deviations are depicted by these data points.

In general, the plotted data, which includes 240 data points (12 channels, 20 points each), demonstrated excellent stability. The check plots, which show the electronic system zero stability, exhibited changes from the average on the order of one-quarter to one percent of full scale except for two data points in the 88 kHz and 104 kHz channels. However, these points are so far from the norm (approximately 4% of full scale) that the validity of the data appears questionable.

The Zero plots which include zero effects of the strain gage installation indicated a larger variation from average than the check data as should be expected. This is probably due to the effects of electrical leakage, which would be influenced somewhat by changes in relative humidity experienced by operating over a two month summertime period, and by creep in the strain gage installation. Electrical leakage in the strain gage installation of 12 megohms produces a change in zero equivalent to one percent of full scale. Likewise only 30 microstrain of equivalent creep will result in approximately a one percent change. The plotted data indicate Zero changes on the order of one-half to two percent of full scale except for the two data points previously mentioned in the 88 kHz and 104 kHz channels.

The Sensitivity plots, which include effects of both the strain gage installation and the electronics, exhibit long term changes in the range of one-half to one and one-half percent of full scale.

An analytical assessment of the system accuracy requires consideration of a number of error-contributing elements. The following list includes the various factors of significance and the attendent inaccuracy that must be included. Factors that contribute second order effects have not been included in this tabulation.

(A) Strain Gage - Micro Measurements WK-13-250BG-350

(1) Gage factor accuracy ± 1%.

(2) Gage factor temp. coefficient (-50° F to +150° F) ±1%.

(3) Gage and bridge completion resistor combined apparent strain (-50° F to + 150° F) ± 2% of full scale.

(B) Strain Gage Power Supply

(1) Temperature stability ± 0.08%.

(2) Regulation ± 0.005%.

(C) Voltage-Controlled Oscillator

(1) Linearity ± 0.5%.

(2) Zero stability.

(a) ± 0.5% of full scale for center frequencies below 100 kHz.

(b) ± 1.0% of full scale for center frequencies above 100 kHz.

(3) Temperature Stability.

(a) ± 2% of full scale for center frequencies below 100 kHz.

(b) ± 3% of full scale for center frequencies above 100 kHz.

(4) Acceleration sensitivity ± 1.0%

(D) Translator

(1) Frequency stability -4° F to + 185° F ± 0.01%.

(a) Worst case 152 kHz (highest frequency group of channels) ± 0.38% of full scale.

(b) Best case (lowest frequency group of channels) zero error.

(2) Vibration ± 0.005%.

(a) Worst case ± 0.19% of full scale.

(b) Best case - zero error.

(3) Shock ± 0.005%.

(a) Worst case ± 0.19% of full scale.

(b) Best case - zero error.

(E) Error summation

(1) Worst case (highest frequency group of channels - 112 kHz, 120 kHz, 128 kHz, 136 kHz) - ± 4.18% rms.

(2) Best case (lowest frequency group of channels 16 kHz, 24 kHz, 32 kHz, 40 kHz) - ± 3.4% rms.

CONCLUSIONS

It is concluded that the design concept employed in the Aircraft Propeller Vibration Measurement System is sound. Miniature telemetry components have been successfully used in a propeller environment in conjunction with an alternator power source and a capacitor coupling to provide a 16-channel strain gage measurement system. In addition, the airborne frequency translation technique is particularly useful from the standpoint of reducing the total recording system bandwidth from approximately 150 kHz to 50 kHz.

The overall system provides the frequency response, stability, and signal-to-noise ratio required for the handling of propeller blade strain signals so that a proper assessment of structural integrity can be obtained.

RECOMMENDATIONS

Several comments should be made in regard to future application of the Aircraft Propeller Vibration Measurement System. These recommendations deal with strain gage installations, mechanical adaptation of the system to new installations, and analysis of data.

Strain Gage Installation

The following statements summarize our present thoughts in regard to personnel, techniques, and materials which must be used to obtain a satisfactory propeller strain gage installation.

(A) Experience has clearly demonstrated that a strain gage installation as described in this report should be attempted only by personnel experienced in proper strain gaging techniques. In addition, extreme care and attention to detail is necessary to ensure an adequate installation.

(B) Propeller strain gage installations depend upon adequate adhesive bonding which must operate under high "g" loads. Many uncured epoxy and urethane systems are adversely affected by high humidity and performance may be quite unpredictable when applied in an uncontrolled environment. Therefore, installations should be attempted only in a controlled laboratory environment.

(C) At this time significant improvements do not appear to be available in the areas of strain gages, adhesives or lead wires which can be recommended beyond those used for the test stand installation.

(D) Recent test results obtained in the fields of aircraft and marine propeller protective coating systems indicate that increased strength and erosion resistance may be obtainable with either liquid or cured sheet materials now available.

Further work in this area would be advisable in order to develop the capability to operate strain gaged propellers in highly erosive environments such as blowing sand and heavy precipitation.

Mechanical Adaptation to New Installations

Careful consideration should be given to the structural requirements of the brackets required to adapt the measurement system to various propeller-engine combinations. The primary consideration affecting the rotating components involves the requirement of adequate strength to support the split assembly against centrifugal force. On the other hand, the stationary components are cantilevered from the engine, which makes the stiffness of the brackets a prime consideration. The following is a list of the vibratory acceleration levels and excitation frequencies that are typically used for design of propeller-mounted components.

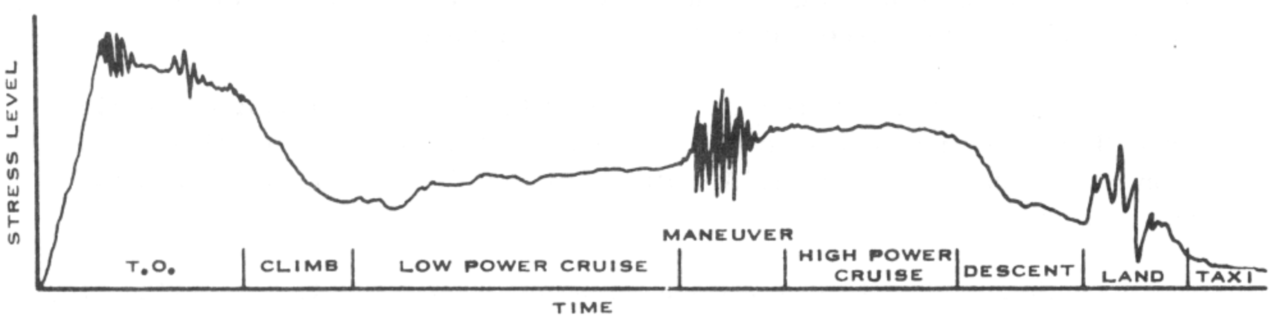
Fore and Aft	±10 g (5-2000 Hz)
Lateral	±10 g (5-2000 Hz)
Torsional	±1000 rad/sec^2 (5-2000 Hz)
Pitching	±1000 rad/sec^2 (5-2000 Hz)
Gyroscopic	±55 rad/sec^2 (5-50 Hz)

In addition, adequate provision must be made for securing rotating cables, static and dynamic balance, and the prevention of stress corrosion by the use of corrosion-resistant fasteners.

Data Analysis

The Propeller Vibration Data System provides the capability for accurate determination of steady and vibratory response of a propeller blade of the aircraft environment. This capability, 16 data channels per propeller with frequency response from dc to 1000 Hz, depending upon the tape recorder used, can provide continuous records up to approximately six and one-half hours.

The aircraft propeller stress history, which is obtainable with this data system, will normally be a complex combination of steady and vibratory loading. It may be possible for the blade material to accumulate both high and low cycle fatigue damage. The illustration below shows a typical propeller blade stress flight profile. Low cycle fatigue may be encountered due to maneuver loading and ground-flight-ground cycles and high cycle fatigue wil be caused by the blades vibrating in resonant modes.



TYPICAL FLIGHT PROFILE - PROPELLER BLADE STRESS

The availability of many hours of data from magnetic tape for 16 strain gage channels provides information for a detailed analysis of propeller loading and vibratory mode shapes under many aircraft operating conditions. However, in order to use this information, several fundamental decisions must be made. That is, from the many available approaches to fatigue determination, a technique must be selected that is most appropriate to the propeller loading problem and then an electronic data handling system should be devised which can reflect the theory against material test data which depicts the endurance limits for the propeller blade material.

Therefore, it is recommended that further study be given to the general problem of using in-flight propeller vibration data in order to assess the structural integrity of propeller installations.

APPENDIX A

Strain Gage Installation Procedure

(A) Surface Preparation - Blades were cleaned with MEK (methyl ethyl ketone) to remove dirt and oil. All bond areas were sanded with 280-320 grit silicon carbide paper to remove anodize and surface-embedded contaminants. These areas were then recleaned with methyl alcohol. Alodine 1200 solution was swabbed onto prepared surfaces, kept wet with additional applications for 5 minutes, then washed off with tap water.

(B) Gage Bonding - Gage locations were marked and these areas were cleaned with methyl alcohol. Gages, terminals, and bonding areas were coated with BR-600 adhesive and allowed to dry five minutes for solvent evaporation. Gages and terminals were then taped into position on the blade. Previously prepared polyethylene vacuum bags were placed over the blades and sealed. A vacuum of 25-28 inches Hg was drawn giving a pressure on the strain gages of approximately 12 psi. Adhesive curing was accomplished with the propeller in a large oven, where 150° F blade temperature was maintained for four hours. Blade temperature was monitored with a thermocouple taped to a blade near the hub. This gage bonding procedure required two technicians and close coordination between the time adhesive was applied and curing started, in order to accomplish the task within the time specified by the adhesive manufacturer.

(C) Wiring - The standard three-wire lead system was employed. The dual strain gage leads were soldered to the appropriate terminals, and flux was removed with methyl alcohol. All gages were then checked for resistance, leakage and bonding voids.

No. 32 Durad wires were soldered at the gage terminals, flux was removed as above, and the wires were taped back. These wires were attached at this stage of the installation in deference to the eight hours time limit between primer and coating application specified for optimum bonding between the two materials.

(D) Priming and Wire Bonding - Areas to be primed were cleaned with methyl alcohol, and Military Specification P-23377B primer was applied in a thin layer over all areas to be coated except the gages and unsoldered shank terminals. Following a one hour drying period, the Durad wires were coated with Bostik 7070 adhesive and tacked into position along the trailing edge of each blade. They were then cut to length, soldered at the shank terminals, and flux was carefully removed as above. Care was exercised to be sure that the Durad insulation carried well up onto the terminal backing. Previous humidity tests had indicated this as a critical requirement.

(E) Protective Coating - The Vorite-63 and Polycin-12 were first stirred in their own containers, then mixed in the ratio and sequence that follows:

Polycin-12 - 35.4 gms
Add Nuocure-28 - one drop, and mix
Add Vorite-63 - 60 gms and mix

This mixture was degassed in a vacuum chamber and then flowed onto the areas to be coated in a layer 0.020 to 0.030 inch thick. Some running occurred, particularly in the shank areas. On removing these runs, wiping along all edges of the urethane with a clean gauze pad helped to produce a smooth feathered edge. Air bubbles introduced during application were removed by the discreet use of a heat gun, being careful to use just enough heat to expand and break the bubbles.

The urethane was cured at room temperature for twenty-four hours, at which time the electronic components of the system were assembled on the propeller hub. Gages and wiring were inspected for resistance, electrical leakage and coating flaws.

(F) Harness Installation - Harness bonding areas of the propeller hub were cleaned with MEK, lightly sanded with 280-320 grit silicon carbide paper, and recleaned with methyl alcohol. Care was exercised to avoid breaking through the cadmium plating. These areas were then primed, coated thinly and cured using the procedures discussed previously.

The Teflon insulation on the harness wires was etched to enhance bonding. The harnesses were connected at the electronics, and tied in position with cleaned, nylon straps. The wires were then cut and soldered to the appropriate terminals and flux was removed. A thick coating of the Vorite/Polycin was applied as above to encapsulate the terminals, wires, straps and harness insulation. A seventy-two hour final cure at room temperature allowed the urethane to reach full strength, and completed the installation.

APPENDIX B

Calculation of Equivalent Full Scale Standardize Values - As noted previously, calibration of the data system is accomplished by use of the Calibration Unit and Battery Power Supply. System Zero is obtained with the strain gages excited and zero strain input. Full Scale Std is obtained by shunting each strain gage with 110 kilohms. The equivalent strain for this shunt can be determined with the following relationships.

Bending Gage - Single Active Arm

(A) The equation for a single active arm strain gage in bending is

$$\frac{e_o}{E_{exc}} = \frac{GF}{4} \times \epsilon$$

where e_o = bridge output volts

E_{exc} = strain gage excitation volts

GF = strain gage factor

ϵ = strain

(B) $$\epsilon = \frac{\Delta R/R}{GF}$$

where ΔR = the incremental strain gage resistance which is a result of a strain input to the bridge.

R = strain gage resistance

(C) For the case of a 110 kilohm shunt in a 350 ohm bridge

where $$\Delta R = R - \frac{R \times R_{shunt}}{R + R_{shunt}}$$

$$\Delta R = 350 - \frac{350 \times 110 \times 10^3}{350 + 110 \times 10^3}$$

$$\Delta R = 1.110 \text{ ohm}$$

(D) Therefore the Full Scale Std strain for a single active bending gage:

$$\epsilon \text{ std} = \frac{\Delta R/R}{GF} = \frac{1.110/350}{2.12} = 1496 \text{ microstrain peak}$$

(E) Or the Full Scale Std Stress

$$S_{std} = \epsilon_{std} \times E$$

where E = Young's Modulus for blade material

S_{std} = 1496 $\times 10^{-6}$ x 10 x 10^6

S_{std} = 14,960 psi peak

Shear or "Vee" Gage - Two Active Arms - In the case of the shear gage, two gages each placed at an angle of 45° from the blade center line, a similar procedure is used except that Young's Modulus can be considered to be modified as follows:

(A) $$G = \frac{E}{2(1 + \mu)}$$

where G = shear modulus

μ = Poisson's Ratio (Approx. 0.3 for steel and aluminum

E = Young's Modulus for blade material

(B) Then $G = 3.85 \times 10^6$

(C) Therefore

τ std = standardize shear stress = ϵ x G

τ std = 1496 x 10^{-6} x 3.85 x 10^6

τ std = 5760 psi peak

APPENDIX C

Assembly Instructions

(A) With the propeller in the horizontal position, locate the rotor bracket assembly so that the split at the alternator lead wires is 15° clockwise from the vertical axis at the top. Install four 1/4-28 bolts, two in each rotor half. Install bus strap under heads of two adjacent capacitor mounting screws to connect the capacitor rotor halves together electrically. The strap should be clamped between the screw heads and the top spring washer. There should be five spring washers under each end of the strap. Tighten screws per table C-1.

(B) Mount stator brackets to engine, tightening bolts only slightly more than finger tight so that the brackets may be adjusted by light tapping.

(C) Mount stator assembly to brackets. Tighten bolts as above. Fasten stator halves together with the two bar straps (Figure 6 in the text). Insure that the front surfaces of the two stator halves are in line within 0.005 inch. Install bus strap under the heads of 2 adjacent capacitor mounting screws as in item 1 above. Torque bar strap bolts per table C-1 and lock wire bolts.

(D) Adjust stator assembly to be centered within 0.005 inch [1] and set a clearance of 0.070 ± 0.003 inch at the rear capacitor gap. Tighten all stator bracket mounting bolts per table C-1. Lock wire as necessary.

(E) Install mounting plates (items 16 and 17, Figure C-1) feeding the alternator wires through the holes in the power supply mounting plate. Some of the No. 10-32 hex head bolts that secure the mounting plates are located under the propeller barrel. Instructions for installing these will be covered in the next step. For now, install those where possible and tighten per table C-1. Washers should be used under the heads of the bolts. Lock wire.

(F) Remove the four 1/4-28 bolts holding the rotor bracket to the flywheel and rotate the rotor assembly relative to the propeller sufficiently to expose the No. 10-32 bolt locations which were previously under the propeller barrel (step 5 above). Install the No. 10-32 hex head bolts and washers. Tighten per table C-1. Lock wire.

---

(1) The generator rotor was fabricated and wound as a continuous ring. When the ring was cut, the ends sprang inward slightly and the assembly is now not perfectly round. The rotor should be centered by setting the gap equal at the two splits and again at the center of the half rings.

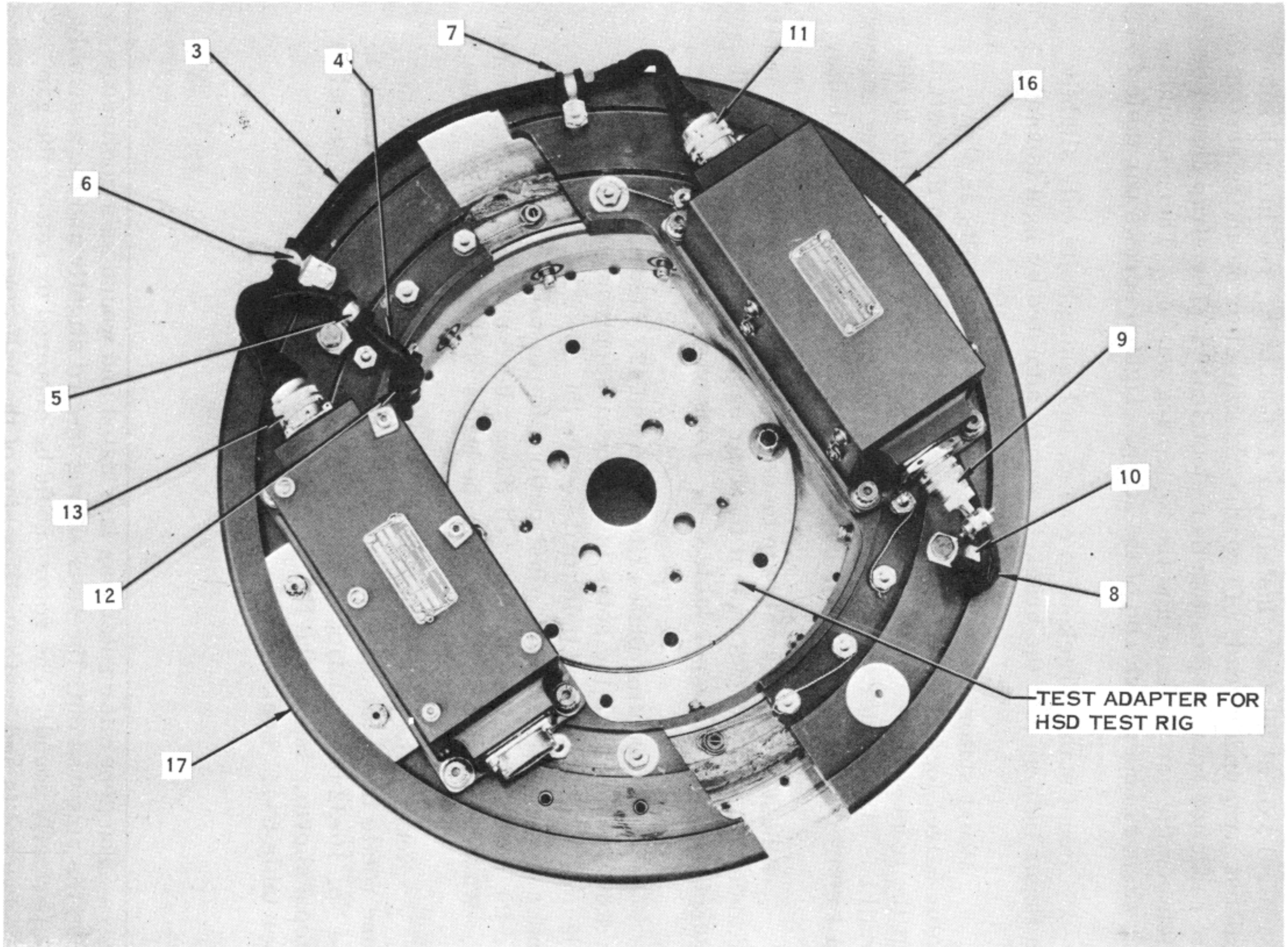


FIGURE C–1. ROTOR ASSEMBLY, FRONT VIEW

(G) Rotate the rotor assembly back to the original position as installed in step A. Secure with four 1/4-28 bolts finger tight. Install balancing washers under the 1/4-28 bolt heads as follows: Facing the propeller, install 14.9 grams under the first bolt clockwise from the split in the rotor bracket on the power supply side, 22.6 grams under the first bolt clockwise from the split and 25 grams under the second bolt also in the clockwise direction. Install the remaining 1/4-28 bolts and torque per table C-1.

(H) Install the aluminum counterweight/spacer (1) and the heavy counterweight/spacer (2) of Figures C-2 and C-1 respectively. Use three NAS620-10 washers under the head of each bolt holding down the aluminum counterweight/spacer to insure proper thread engagement. Do not tighten bolts. Install the electronic boxes in their appropriate locations taking care to route the alternator wires in the grooves provided for them.

(I) Push the boxes radially outward to take up slack between the counterweight/spacers and the plate locating shoulder, then tighten box and counterweight/spacer bolts per table C-1. Lock wire.

(J) Install capacitor rotor cable (4) Figure C-1, connector (14) Figure C-3 and secure with clamps (5) and (12) Figure C-1. Remove the appropriate socket head screw from the capacitor rotor and reinstall, clamping the cable lug between the screw head and the first spring washer. Ensure that five spring washers are between the lug and the large flat washer. Tighten per table C-1.

(K) Install cable (3) to connectors (11) and (13) Figure C-1. Secure cable with clamps (6) and (7) installing the stepped balancing washer under clamp (7).

(L) Install pins of the alternator wires (8) into connector (9) per connector manufacturers instructions. Clamp wires with connector clamp. Mate connector and install clamp (10).

(M) Mate connector (15) Figure C-3 and secure cable with appropriate clamps and brackets.

(N) Install capacitor stator cable under head of a lower capacitor stator mounting screw as in item 10 above. Secure and connect cable to Line Driver.

(O) Check torque on all fasteners per table C-1 and ensure that all screws are lock wired with the exception of the capacitor rotor attaching screws.

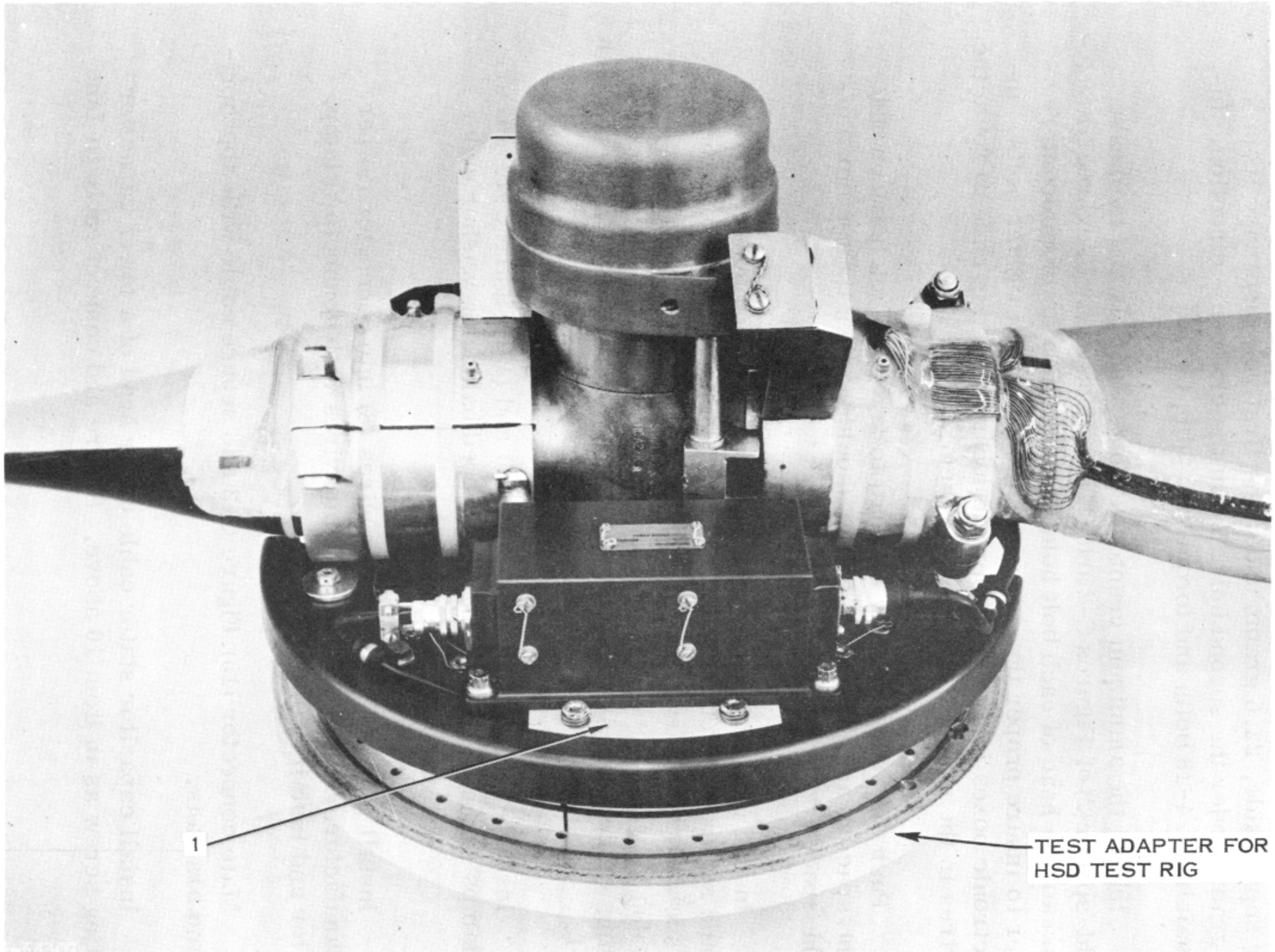


FIGURE C-2. ROTOR ASSEMBLY, POWER SUPPLY SIDE

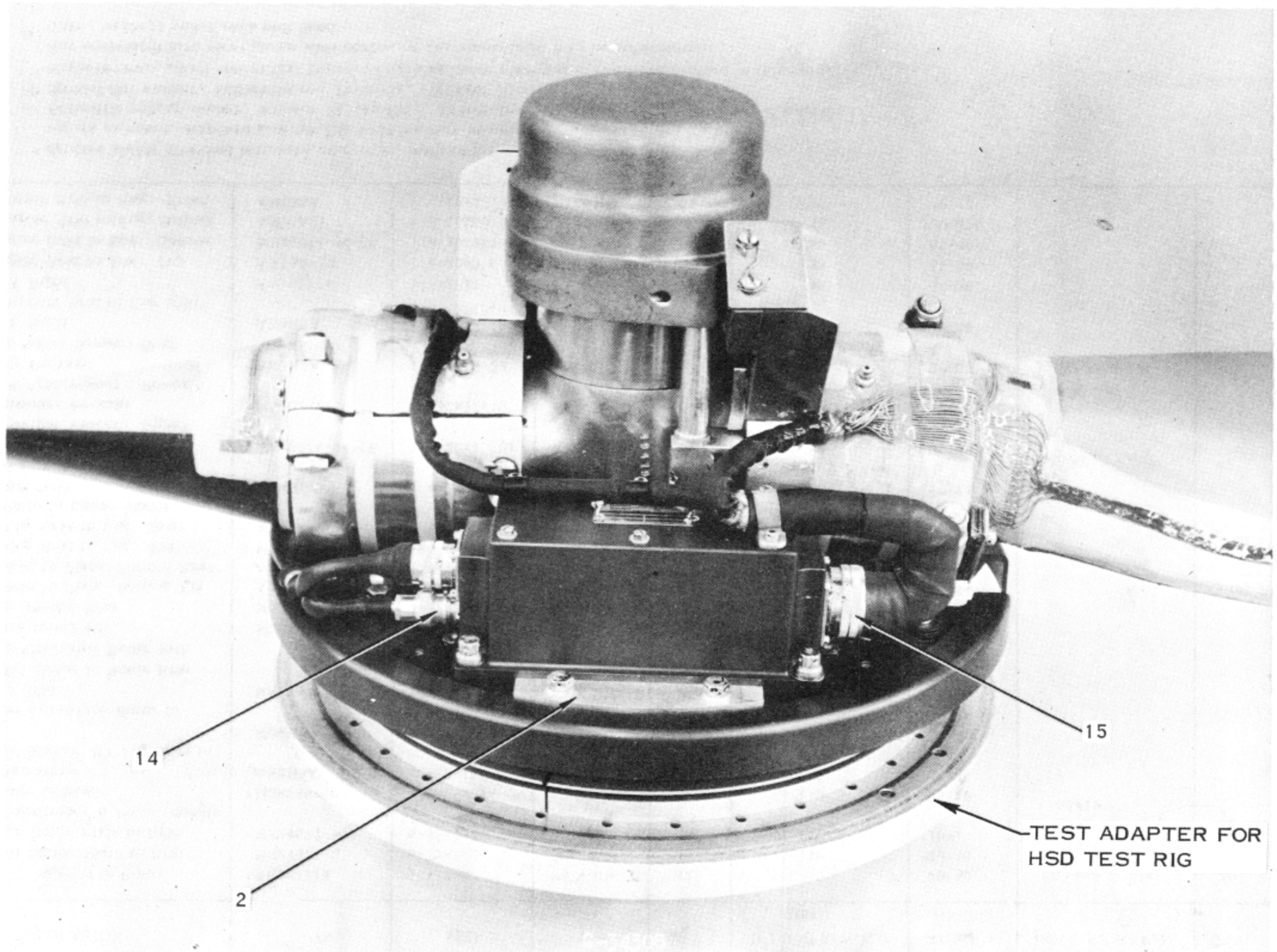


FIGURE C–3. ROTOR ASSEMBLY, SIGNAL CONDITIONER SIDE

TABLE C-1 FASTENERS(3)

LOCATION	P/N	SIZE	TYPE	QTY	MAT'L MIN YIELD STRENGTH (ksi)	TORQUE (IN-LB)	WASHER UNDER BOLT HEAD P/N	QTY
Ring Gear Support to Rotor	*AN101114	1/4-28x1	HEX HD	12	95	75-80	B0312-017(1)	70
Capacitor Stator Plate to Brkt	MS24677-8	6-32x1/2	SOC HD	14	140	*10-13	97419[2]	14
Capacitor Rotor Plate to Brkt	MS24677-10	6-32x3/4	SOC HD	14	140	*10-13	B0312-017(1)	
Signal Conditioner & Power Supply Package to Base	*MS9089-10	1/2-28x3/4	12 PT HD	8	110	*65-70	97419(2)	14
Stator Bar Strap	AN3H3A	10-32x15/32	HEX HD	8	86	20-25		
Threaded Spacer: RT Eng Brkt to Eng	SK68795	3/8-16	HEX HD	2	110	240-260		
Plate and Alternator Rotor to Rotor Brkt	*NAS1303-13H	10-32x1.15	HEX HD	20	140	*40-42		
Alternator Rotor to Rotor Brkt (Hold Alternator Rotor with Plates Removed)	MS24678-12	10-32x3/4	SOC HD	2	140	*40-42		
Magnetic Pickup Brkt	MS24677-10	6-32x3/4	SOC HD	3	140	12-15		
Stator Brkt to Plate: Bottom Frt	AN4H5A	1/4-28x21/32	HEX HD	1	86	70-74		
Stator Brkt to Plate: Bottom Rear	AN101114	1/4-28x1	HEX HD	2	95	75-80		
Lower Eng Brkt to Eng: Frt	MS20074-04-16	1/4-20x1.781	HEX HD	2	84	55-60		
Lower Eng Brkt to Eng: Rear	AN74A-30	1/4-20x3	HEX HD	1	85	55-60		
Stator Plate to Lower Stator Support Brkt	AN4H5A	1/4-28x21/32	HEX HD	3	86	70-74		
Lower Stator Support Brkt to Lower Eng Brkt	MS20074-04-16	1/4-20x1.781	HEX HD	4	84	55-60		
Counterweight/spacer: Signal Conditioner Package	MS102811	10-32x11/16	HEX HD	2	95	30-35		
Counterweight/spacer: Power Supply Package	AN3H3A	10-32x15/32	HEX HD	2	86	20-25	NAS620-10	6(4)
Stator to Stator Support Brkt: Left & Right	AN4H5A	1/4-28x21/32	HEX HD	6	86	70-74		
Stator Support Brkt to Eng Brkt: Left & Right	AN101114	1/4-28x1	HEX HD	8	95	75-80		
Left Engine Brkt to Eng: Top	AN74A-30	1/4-20x3 1/32	HEX HD	2	85	55-60		
Left Engine Brkt to Eng: Bottom	MS20074-04-06	1/4-20x1.781	HEX HD	2	85	55-60		
Right Engine Brkt to Eng: Bottom	AN7CA-7	3/8-16x59/64	HEX HD	2	86	200-220		
Right Engine Brkt to Eng: Front	AN4H6A	1/4-28x25/32	HEX HD	2	86	70-74		

* denotes highly stressed fasteners or critical preload torque
except as noted, standard aircraft flat washers may be used

(1) Belleville spring washer, Wallace Barnes Div., Associated Spring Corporation, Bristol, Connecticut
(2) Special flat washer, Federal Screw Products, Chicago, Illinois
(3) Miscellaneous small noncritical fasteners such as cable clamping screws are omitted in this table. Any equivalent size steel screw with corrosion resistant finish may be substituted.
(4) Three washers under each bolt head.

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PARTS LIST NO. SK67881

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PARTS LIST FOR LINE DRIVER

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR PARTS LIST NO.
SK67881								LAYOUT, LINE DRIVER	
SK67882		1						HOUSING	
SK67883		1						PLATE, MTG.	
SK67883		1						BRACKET, COMPONENT MTG.	
69327A1		1						NAMEPLATE	
MS35265-2		4						MACH. SCREW, STL, FIL. HD. S.W. HOLES	
MS35265-17		8						MACH. SCREW, STL, FIL. HD. S.W. HOLES	
6-32 x 3/8		4						MACH. SCREW, STL., BINDING HD (BLK)	
4-40 x 1/4		6						MACH. SCREW, STL. FIL. HD	
		ELECTRONIC COMPONENTS							
311A	A1	1						AMPLIFIER, MIXER	EMR
C10A823K	C1,C2	2						CAPACITOR, CERAMIC .082 MFD 100V	USCC
PT02A-8-2S	J1	1						CONNECTOR, 2 CONTACTS, SOCKET INSERT	BENDIX
PT02A-8-4P	J2	1						CONNECTOR, 4 CONTACTS, PIN INSERT	BENDIX
2N930	Q1	1						TRANSISTOR, SILICON	MOTOROLA
	R1	1						RESISTOR, CARBON COMP. 536K ±5% 1/2W	ALLEN-BRADLEY
	R2	1						RESISTOR, CARBON COMP. 482K ±5% 1/2W	ALLEN-BRADLEY
	R3	1						RESISTOR, CARBON COMP. 10K ±5% 1/2W	ALLEN-BRADLEY
	R4	1						RESISTOR, CARBON COMP. 20K ±5% 1/2W	ALLEN-BRADLEY
SK67889		SCHEMATIC DIAGRAM - REF. DWG.							

800-1394 4/67 **Hamilton Standard** WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. SK67887

PAGE 1 OF 2

PARTS LIST FOR TRANSLATOR & A/C PARAMETER UNIT

FNA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR
SK67887								TRANSLATOR & A/C PARAMETER UNIT LAYOUT	
AID		1						CASE, ATR, LARGE	CHURCHILL
310A-02-28		1						CHASSIS, MTG., WIRED PER SK68754	LIGHTING ELECTRO-MECH. RESEARCH
304B-02-6-28.0-28.2M		1						FILTER, BAND PASS, 28KHZ ± 14KHZ	EMR
304B-02-6-60.0-28.0M		1						FILTER, BAND PASS, 60KHZ ± 14KHZ	EMR
304B-02-6-92.0-28.0M		1						FILTER, BAND PASS, 92KHZ ± 14KHZ	EMR
304B-02-6-124.0-28.0M		1						FILTER, BAND PASS, 124KHZ ± 14KHZ	EMR
316B-02-M		1						DELAY UNIT FOR 16-40KHZ CHAN.	EMR
311A-02-2		6						AMPLIFIER, MIXING	EMR
313A-01-50.0		1						OSCILLATOR, REF.	EMR
316Y-01-M		1						DETRANSLATOR, FREQUENCY	EMR
316Y-02-M		1						DETRANSLATOR, FREQUENCY	EMR
316Y-03-M		1						DETRANSLATOR, FREQUENCY	EMR
307A-01		4						VCO	EMR
306A-01		3						MVCO	EMR
SK68799		1						FILTER, LO PASS	
341-CR-3A	S1	1						SWITCH, ROTARY, 3 POS., 6 POLE	DAVEN
CMP-5.0-1.5	PS1	1						POWER SUPPLY, 28VDC - 5VDC	TECHNIPOWER
RN60	R1-R10	10						RESISTOR, CARBON FILM, 150Ω ± 1%, ¼W	AEROVOX
PT02A-8-4S	J31-J36	6						CONNECTOR, 4 CONTACTS, SOCKET INSERT	BENDIX
PT02A-10-6S	J37	1						CONNECTOR, 6 CONTACTS, SOCKET INSERT	BENDIX
PT02A-8-4P	J38	1						CONNECTOR, 4 CONTACTS, PIN INSERT	BENDIX
PT02A-8-2S	J39	1						CONNECTOR, 2 CONTACTS, SOCKET INSERT	BENDIX
DE-9S	J40	1						CONNECTOR, 9 CONTACTS, SOCKET INSERT	CANNON
UG-290/U	JAN50	10						CONNECTOR, COAX	AMPHENOL

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PARTS LIST NO. SK67887

PARTS LIST FOR TRANSLATOR & A/C PARAMETER UNIT — PAGE 2 OF 2

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR
DC-37S	P101 P102	2						CONNECTOR, 37 CONTACTS, SOCKET INSERT	CANNON
DE-9P	P103 P104	2						CONNECTOR, 9 CONTACTS, PIN INSERT	CANNON
SK67891								SCHEMATIC DIAGRAM - REF. DWG.	

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PARTS LIST FOR SIGNAL CONDITIONING PACKAGE

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F.A.A. PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR
SK68757								SIGNAL CONDITIONING PACKAGE LAYOUT	
SK68779		1						HOUSING & INSERT, (MAKE FROM SK68768)	
SK68776		1						COVER, HOUSING	
SK68772		2						RAIL, MTG. VCO	
SK68773		1						RAIL, MTG. VCO, CENTER	
SK68774		1						PLATE, END	
SK68775		1						PLATE, MTG. (BRIDGE COMP. RES.)	
SK68764		1						MODULE, PLUG-IN (BRIDGE BAL. RES.)	
3935-9		6						STANDOFFS	CAMBION
10-101949-10		1						GASKET, BUNA-N	BENDIX
10-101949-16		1						GASKET, BUNA-N	BENDIX
MS35265-17		8						MACH. SCREW, STL, FIL. HD., S.W. HOLES	
69327A1		1						NAMEPLATE	
MS35265-2		4						MACH. SCREW, STL, FIL. HD., S.W. HOLES	
MS35265-26		6						MACH. SCREW, STL, FIL. HD. S.W. HOLES	
69915-1		6						WASHER, SEALING	
								ELECTRONIC COMPONENTS	
MMO-35	A1	1						VCO - AMP, 16KC	NORDEN
MMO-35	A2	1						VCO - AMP, 24KC	NORDEN
MMO-35	A3	1						VCO - AMP, 32KC	NORDEN
MMO-35	A4	1						VCO - AMP, 40KC	NORDEN
MMO-35	A5	1						VCO - AMP, 48KC	NORDEN

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PARTS LIST NO. SK 68757
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PARTS LIST FOR SIGNAL CONDITIONING PACKAGE
FAA PROPELLER MEASUREMENT SYS MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR
MMO-35	A6	1						VCO-AMP, 56KC	NORDEN
MMO-35	A7	1						VCO-AMP 64KC	NORDEN
MMO-35	A8	1						VCO-AMP. 72KC	NORDEN
MMO-35	A9	1						VCO-AMP. 80KC	NORDEN
MMO-35	A10	1						VCO-AMP 88KC	NORDEN
MMO-35	A11	1						VCO-AMP. 96KC	NORDEN
MMO-35	A12	1						VCO-AMP 104KC	NORDEN
MMO-35	A13	1						VCO-AMP 112 KC	NORDEN
MMO-35	A14	1						VCO-AMP 120KC	NORDEN
MMO-35	A15	1						VCO-AMP 128 KC	NORDEN
MMO-35	A16	1						VCO-AMP 136KC	NORDEN
MMA-12	A17	1						MIXING AMP.	NORDEN
	J1-J18	18						CONNECTORS, MATE FOR ABOVE VCO-AMP	NORDEN
MDE1-25SL1	J19	1						CONNECTOR, MICRO-D, ENVIRONMENTAL	CANNON
MDE1-25PL1	J20	1						CONNECTOR, MICRO-D, ENVIRONMENTAL	CANNON
JT02RE-16-55S	J21	1						CONNECTOR, 55 CONTACTS, SOCKET INSERT	BENDIX
JT02RE-10-13P	J22	1						CONNECTOR, 13 CONTACTS, PIN INSERT	BENDIX
8174-1	J23	1						CONNECTOR, COAX, TNC, WITH INSULATED GROUND	DAGE
5102	R1-R46	46						RESISTOR, PRECISION, 350 Ω ± 0.1% T.C. 1 PPM/°C	VISHAY
PME55-T2	R(B)							RESISTOR, METAL FILM, SELECTED VALUES BETWEEN ± 1.0% 1/8 WATT @125°C (FOR BALANCING)	PYROFILM
SK68755								SCHEMATIC DIAGRAM - REF. DWG.	

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WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. SK68758

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PARTS LIST FOR POWER SUPPLIES & REGULATORS

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR [redacted]
SK68758								POWER SUPPLIES & REGULATORS LAYOUT	
SK68777		1						HOUSING, MAKE FROM SK68768	
SK68776		1						COVER	
SK68762		1						CHASSIS, COMPONENT MTG.	
SK68761		1						BOARD, MTG. CAPACITOR	
SK68759		1						BOARD, TERMINAL, BOTTOM	
SK68760		1						BOARD, TERMINAL, TOP	
10-101949-10		1						GASKET, BUNA-N	BENDIX
9729-A-0440-2		3						STANDOFF	AMATOM
9725-A-0440-2		3						STANDOFF	AMATOM
4-40 x .25		3						MACH. SCREW, STL. BINDING HD (BLK)	
4-40 x .38		4						MACH. SCREW, NYLON, FLT. HD.	
2-56 x .25		4						MACH. SCREW, STL., FLT. HD. (BLK)	
MS35265-17		4						MACH. SCREW, STL, FIL. HD. S.W. HOLE	
2-56 x .25		4						MACH. SCREW, STL, FIL. HD. (BLK)	
3223-4-1		6						TERMINAL, NURL-LOC	EMC
2764-4-1		4						TERMINAL, NURL-LOC	EMC
2042-2		100						TERMINAL, TURRET TYPE	CAMBION
69915-1		8						WASHER, SEALING	
69327A1		1						NAMEPLATE	
MS35265-2		4						MACH. SCREW, STL, FIL. HD. S.W. HOLES	
MS35265-26		8						MACH. SCREW, STL, FIL. HD. S.W. HOLE	

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WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. SK68758

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PARTS LIST FOR POWER SUPPLIES & REGULATORS

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR [redacted]
								ELECTRONIC COMPONENTS	
LM101	A1	1						AMPLIFIER, OPERATIONAL, -55°C TO +125°C	NAT. SEMICOND. CORP.
302D208C7030D1	C1	1						CAPACITOR, TANTALUM, 2000 MFD. 30V	SPRAGUE
CK13AX	C2	1						CAPACITOR, CERAMIC, .002 MFD.	GULTON
8025	C3	1						CAPACITOR, CERAMIC, 750 PFD.	ERIE
8003	C4	1						CAPACITOR, CERAMIC, 30 PFD.	ERIE
140D247C7018OT3	C5	1						CAPACITOR, TANTALUM, 240 MFD. 18V	SPRAGUE
302D817C5050D1	C6	1						CAPACITOR, TANTALUM, 810 MFD. 50V	SPRAGUE
140D806C7060T3	C7	1						CAPACITOR, TANTALUM, 80 MFD. 60V	SPRAGUE
C10A823K	C8, C9	2						CAPACITOR, CERAMIC, .08 MFD. 100V	USCC
UT5110	CR1-CR6, CR16	7						DIODE, RECTIFIER, WITH INSULATING H.W.	UNITRODE
UT261	CR7, CR12-CR15, CR19-CR22	9						DIODE, RECTIFIER	UNITRODE
80TF-15	CR8	1						DIODE, ZENER, SUPEREG	TRIO LABS
1N757	CR9	1						DIODE, ZENER	MOTOROLA
1N827A	CR10	1						DIODE, ZENER	MOTOROLA
1N754	CR11	1						DIODE, ZENER	MOTOROLA
80TF-27	CR16	1						DIODE, ZENER, SUPEREG	TRIO LABS
1N3324B	CR18	1						DIODE, ZENER,	MOTOROLA
JT07RE-8-44P	J1	1						CONNECTOR, RECEPTACLE, JAM NUT	BENDIX
JT02RE-10-13S	J2	1						CONNECTOR, RECEPTACLE, BOX MTG	BENDIX
2N2222	Q1, Q2	2						TRANSISTOR	MOTOROLA
2N2697	Q3, Q4	2						TRANSISTOR	SOLITRON
HG-5	R1	1						RESISTOR, WIREWOUND, 3.3 Ω ± 3% 15W	DALE

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WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. SK68758

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PARTS LIST FOR POWER SUPPLIES & REGULATORS

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR [redacted]
PME55-T2	R2, R3	2						RESISTOR, METAL FILM, 100 Ω ± 1.0%, 1/8 WATT	PYROFILM
AGS-5	R4	1						RESISTOR, WIREWOUND, .75 Ω ± 1%, 4 WATT	DALE
AGS-1	R5, R6	2						RESISTOR, WIREWOUND, 0.5 Ω ± 1%, 1 WATT	DALE
PME55-T2	R7	1						RESISTOR, METAL FILM, 511 Ω ± 1% 1/8 WATT	PYROFILM
PME55-T2	R8	1						RESISTOR, METAL FILM, 4.75K ± 1% 1/8 WATT	PYROFILM
PME55-T2	R9	1						RESISTOR, METAL FILM, 500K ± 1%	PYROFILM
PME60-T2	R10	1						RESISTOR, METAL FILM, 681 Ω ± 1%, 1/4 WATT	PYROFILM
PME55-T2	R11	1						RESISTOR, METAL FILM, 221 Ω ± 1% 1/8 WATT	PYROFILM
	R12	1						RESISTOR, METAL FILM, SELECTED	PYROFILM
PME60-T2	R13	1						RESISTOR, METAL FILM, 619 Ω ± 1%, 1/4 WATT	PYROFILM
AGS-1	R14	1						RESISTOR, WIREWOUND, 1K ± 1%, 1 WATT	DALE
PME60-T2	R15	1						RESISTOR, METAL FILM, 909 Ω ± 1%, 1/4 W	PYROFILM
PME65-T2	R16	1						RESISTOR, METAL FILM, 1K ± 1%, 1/2 W	PYROFILM
HG-5	R17	1						RESISTOR, WIREWOUND, 13 Ω ± 3%, 15 WATT	DALE
	R18	1						RESISTOR, METAL FILM, SELECTED	PYROFILM
	R19	1						RESISTOR, METAL FILM, SELECTED	PYROFILM
PME60-T2	R20	1						RESISTOR, METAL FILM, 1K ± 1%, 1/4 WATT	PYROFILM
PME60-T2	R21	1						RESISTOR, METAL FILM, 6.49K ± 1%, 1/4 WATT	PYROFILM
PME60-T2	R22	1						RESISTOR, METAL FILM, 26.1K ± 1%, 1/4 WATT	PYROFILM
SK68752								REF. DWG. - SCHEMATIC DIAGRAM	

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PARTS LIST NO. SK68796

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PARTS LIST FOR CALIBRATION UNIT

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR PARTS LIST NO
SK68796								CALIBRATION UNIT LAYOUT	
ZC-7090		1						INSTRUMENT CASE	ZERO MFG.
SK67879		1						PANEL, FRONT	
SK67885		1						BRACKET, CABLE	
1839730-372		2						PILOT LIGHT	DIALCO
90-8WL-2		2						KNOBS, DIAL, SKIRTED, BAR	RAYTHEON
								ELECTRONIC COMPONENTS	
1N940	CR1							DIODE, ZENER	MOTOROLA
382	DS1, DS2	2						PILOT BULB	G.E.
JT02RE-16-55S	J31	1						CONNECTOR, 55 CONTACTS, SOCKET INSERT	BENDIX
JT02RE-16-55P	J32	1						CONNECTOR, 55 CONTACTS, PIN INSERT	BENDIX
JT02RE-10-13S	J33	1						CONNECTOR, 13 CONTACTS, SOCKET INSERT	BENDIX
JT02RE-10-13P	J34	1						CONNECTOR, 13 CONTACTS PIN INSERT	BENDIX
WK-4-32S	J35	1						CONNECTOR, 4 CONTACTS, PIN INSERT	CANNON
DF 31 RC	J36	2						BINDING POST, RED	SUPERIOR ELECT.
DF 31 BC	J36	1						BINDING POST, BLK	SUPERIOR ELECT.
HS22	M1	1						METER, MICROAMMETER, 0-20, WITH SPECIAL SCALE PER HS DWG BLACK LETTERING, WHITE BACKGROUND	HONEYWELL
TP-154	K1	1						RELAY, DPDT, 28V, HIGH RES. COIL	ALLIED
PME 60-T2	R1, R8, R9	3						RESISTOR, METAL FILM, 10K, ±1%, 1/4W	PYROFILM
PME65-T2	R2	1						RESISTOR, METAL FILM, 1M ±1%, 1/2W	PYROFILM
PME55-T2	R3	1						RESISTOR, METAL FILM, 20K ±1%, 1/8W	PYROFILM
PME75-T2	R4	1						RESISTOR, METAL FILM, 1.4K ±1%, 1W	PYROFILM

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PARTS LIST NO. SK68796

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PARTS LIST FOR CALIBRATION UNIT

FAA PROPELLER MEASUREMENT SYS MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR PARTS LIST NO.
PME60-T2	R5	1						RESISTOR, METAL FILM, 383 Ω ±1%, 1/4W	PYROFILM
PME60-T2	R6	1						RESISTOR, METAL FILM, 301K ±1%, 1/4W	PYROFILM
PME65-T2	R7	1						RESISTOR, METAL FILM, 3.74K ±1%, 1/2W	PYROFILM
PME60-T2	R10	1						RESISTOR, METAL FILM, 604Ω ±1%, 1/4W	PYROFILM
PME60-T2	R11	1						RESISTOR, METAL FILM, 47 K ±1%, 1/4W	PYROFILM
PME60-T2	R12-R27	16						RESISTOR, METAL FILM, 110K ±1% 1/4W	PYROFILM
2H50A16-3-DK	S1	1						SWITCH, ROTARY, 3 POLE, 16 POS., GOLD CONTACTS, WITH DUST COVER	SHALLCROSS
TC-3-M	S2	1						SWITCH, TOGGLE, SPDT	A.H.&H
2J6BA3-5-DK	S3	1						SWITCH, ROTARY, 20 POLE, 3 POS., GOLD CONTACTS, WITH DUST COVER	SHALLCROSS
2J56A4-2DK	S4	1						SWITCH, ROTARY, 4 POLE, 4 POS., GOLD CONTACTS, WITH DUST COVER	SHALLCROSS
SK68756								SCHEMATIC DIAGRAM - REF. DWG.	

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WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. SK68798

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PARTS LIST FOR BATTERY CHARGER

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR
SK68798								BATTERY CHARGER LAYOUT	
ZC-7100		1						INSTRUMENT CASE	ZERO MFG.
SK67880		1						PANEL, FRONT	
SK68800		1						BRACKET, PWR. SUPPLY MTG.	
SK67885		1						BRACKET, CABLE MTG.	
137-8836-931		1						PILOT LIGHT	DIALCO
342004		1						FUSEHOLDER	LITTELFUSE
								ELECTRONIC COMPONENTS	
NE-2J	DS1	1						PILOT LAMP	G.E.
3AG	F1	1						FUSE, 1.5A SLO-BLO	LITTELFUSE
MM 1T	M1, M2	2						MILLIAMMETER, 0-500	HONEYWELL
	P1	1						CONNECTOR, PLUG, 115V TWIST-LOCK	H. HUBBEL
PT06A-8-4S	P2	1						CONNECTOR, PLUG, SOCKET INSERT	BENDIX
NP-110.0-0.750	PS1	1						POWER SUPPLY, 110 VDC @ 750 ma	TECHNIPOWER
	R1	1						RESISTOR, CARBON COMP., 56K ±5% 1/2W	ALLEN-BRADLEY
	R2	1						RESISTOR, WIREWOUND, 250 Ω 50W	ALLEN-BRADLEY
	R3	1						RESISTOR, CARBON COMP., 68K, ±5% 1/2W	ALLEN-BRADLEY
	R4	1						RESISTOR, WIREWOUND, 220 Ω 50W	ALLEN-BRADLEY
8381K21C	S1,S2,S3	3						SWITCH, TOGGLE SPST	CUTLER-HAMMER
SK67888								SCHEMATIC DIAGRAM REF. DWG.	

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Hamilton Standard DIVISION OF UNITED AIRCRAFT CORPORATION
WINDSOR LOCKS, CONNECTICUT

PARTS LIST NO. 5K68799

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PARTS LIST FOR LO PASS FILTER / Translator Package

FAA PROPELLER MEASUREMENT SYS. MODEL

PART NO.	REF. NO.	NO. REQ.	1	2	3	4	5	NAME OF PART	VENDOR [redacted]
5K68799								LO PASS FILTER LAYOUT	
11X3824		1						PLATE-BASE	
11X3861		2						MACH. SCREW MODIFIED	
11X3829		1						COVER	
								ELECTRONIK COMPONENTS	
96P-10491	C1	1						CAPACITOR, PALER, .1 MFD, 100 VDC	SPRAGUE
MG51W-24	L1	1						INDUCTOR, 60 MH	TOROTEL
DE-9P	J1	1						CONNECTOR, 9 CONTACTS, PIN INSERT	CANNON
	R1	1						RESISTOR, CARBON COMP, 960 Ω ±5% 1/2 WATT	ALLEN-BRADLEY
	R2	1						RESISTOR, CARBON COMP, 47K ±5% 1/2 WATT	ALLEN-BRADLEY

Hamilton Standard Division, Windsor Locks, Conn. AIRCRAFT PROPELLER VIBRATION MEASUREMENT SYSTEM by R. C. Dorshimer, Final Report, September 1969, 85 pp, incl. illus. (Contract No. FA67NF-257, Project No. 520-004-06X, Report No. NA-69-23)

Unclassified Report

A slip ringless propeller-mounted data systems has been designed, fabricated and tested for the measurement of propeller blade strain during flight and ground operation of an instrumented aircraft. This data system is self-powered through the rotary motion of the test propeller, employs a 16 channel constant bandwidth Frequency Modulated (FM) Multiplex and signals are capacitively coupled from the propeller to the aircraft. The FM Multiplex consists of 17 channels of information including propeller rpm and 16 strain gage channels containing information from dc to 1 kHz. An environmentally protected strain gage installation has also been a consideration of this program.

The FM Multiplex is split into four groups of signals with a frequency translation process in order to conserve bandwidth and/or recording time on an airborne tape recorder. Seven additional data channels are provided on board the aircraft for inclusion of parameters needed to define the aircraft
over

UNCLASSIFIED

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operating condition.

The data system was demonstrated for a period of 50 hours on an engine test stand during which the demodulated signals were observed and additional data was obtained relative to the system stability.

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A slip ringless propeller-mounted data systems has been designed, fabricated and tested for the measurement of propeller blade strain during flight and ground operation of an instrumented aircraft. This data system is self-powered through the rotary motion of the test propeller, employs a 16 channel constant bandwidth Frequency Modulated (FM) Multiplex and signals are capacitively coupled from the propeller to the aircraft. The FM Multiplex consists of 17 channels of information including propeller rpm and 16 strain gage channels containing information from dc to 1 kHz. An environmentally protected strain gage installation has also been a consideration of this program.

The FM Multiplex is split into four groups of signals with a frequency translation process in order to conserve bandwidth and/or recording time on an airborne tape recorder. Seven additional data channels are provided on board the aircraft for inclusion of parameters needed to define the aircraft

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Hamilton Standard Division, Windsor Locks, Conn. AIRCRAFT PROPELLER VIBRATION MEASUREMENT SYSTEM by R. C. Dorshimer, Final Report, September 1969, 85 pp, incl. illus. (Contract No. FA67NF-257, Project No. 520-004-06X, Report No. NA-69-23)

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operating condition.

The data system was demonstrated for a period of 50 hours on an engine test stand during which the demodulated signals were observed and additional data was obtained relative to the system stability.

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